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Tel: +603 78770637 Fax: +603 78779636 Email: mip@mip.org.my
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# A COMPARATIVE STUDY OF GREEN SPACES AND THE URBAN HEAT ISLAND (UHI) EFFECT IN GEORGE TOWN, PENANG.

**Cheah Wei Chee[1] & Mohd Ismail Isa[2]**

[1,2] *School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

This study investigates the influence of green space on environmental quality and its role in mitigating the Urban Heat Island (UHI) effect, with a specific focus on George Town, Penang. By conducting a comparative analysis of two sites- Sia Boey Archaeological Park (Site A) and Little India (Site B)- within the urban setting, the research assesses variations in the Normalised Difference Vegetation Index (NDVI), land surface temperature (LST), and the Urban Thermal Field Variance Index (UTFVI) to evaluate their respective UHI impacts. Site A, characterised by integrated green areas, shows NDVI values ranging from 0 to 0.9, indicating dense, diverse vegetation. In contrast, Site B, which lacks substantial green space, exhibits a more limited NDVI range of 0 to 0.3. The LST analysis indicates that Site A experiences a broader temperature range (36°C to 51°C) than Site B (44°C to 50°C), suggesting that shaded regions within Site A mitigate surface temperatures. Although both sites exhibit similar UTFVI values (0- 0.02), the allocation of green spaces in Site A is associated with greater carbon sequestration and lower overall surface temperatures, emphasising the role of vegetation in reducing UHI intensity. These findings underscore the potential benefits of integrating green spaces within George Town's urban planning framework to substantially mitigate UHI effects, thereby advancing sustainable environmental management and enhancing urban climate resilience.

***Keywords****:* Urban Heat Island (UHI), Urban Thermal Field Variance Index (UTFVI), Land Surface Temperature (LST), Normalised Difference Vegetation Index (NDVI)

[2] Corresponding author. Email: mohdismail.isa@usm.my

## INTRODUCTION

This study aims to analyse and quantify the effectiveness of various green spaces in moderating urban temperatures and reducing UHI intensity in George Town. By mapping green coverage and correlating it with temperature data, researchers (Liu & Wang, 2023) seek to identify UHI hotspots and assess how green areas influence local climate conditions. This approach provides evidence-based insights for urban planning and policy decisions, emphasising the integration of green spaces as a core component of sustainable urban development. The study also highlights the broader socioeconomic benefits of green spaces, including enhanced quality of life, improved public health outcomes, and increased resilience to climate change. Future research should explore innovative green infrastructure solutions suited to George Town's urban context, utilising advanced remote sensing technologies to map green cover and temperature patterns accurately, and to evaluate long-term UHI mitigation strategies. By deepening our understanding of the relationship between green areas and urban heat dynamics, George Town can serve as a model for resilient, liveable cities that prioritise sustainability and community well-being amid ongoing urbanisation and climate change.

The comparative study of green areas and the UHI effect in George Town, Penang, addresses pressing issues related to urbanisation, climate change, and public health. Like many rapidly growing cities, George Town faces an intensifying UHI effect, in which urban areas are significantly warmer than their surrounding rural areas (Chan, 2014). The proliferation of heat-absorbing materials, such as concrete and asphalt, coupled with the reduction of green spaces, such as parks and urban forests, exacerbates this problem. Firstly, the UHI effect intensifies heat stress and public health risks, particularly for vulnerable populations such as the elderly, children, and outdoor workers (Braun et al., 2024). It also affects motivational and constraint factors that influence participation in outdoor recreation (Hasnizam et al., 2023). Prolonged exposure to elevated temperatures can lead to heat-related illnesses, reduced well-being, and diminished productivity. Secondly, the UHI effect places additional strain on urban infrastructure and increases cooling energy demand. Rising temperatures increase the use of air conditioning and refrigeration systems, leading to peak electricity demand that strains urban power grids. This situation elevates operational costs and contributes to higher greenhouse gas emissions, thereby aggravating climate change. These challenges in rapidly urbanising cities like George Town (Othman et al., 2021) underscore the importance of sustainable urban planning and resilient infrastructure investments.

Furthermore, the loss of green spaces accelerates environmental degradation and diminishes ecosystem resilience. As urban areas expand, natural landscapes such as forests and wetlands, which are crucial for biodiversity and

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vital ecological services, are frequently cleared. Decreased vegetation cover hampers urban regions' capacity to mitigate air pollution, sequester carbon, and regulate local climates through evapotranspiration (Piracha & Chaudhary, 2022). Environmental harm from reduced greenery undermines biodiversity and diminishes the efficacy of green infrastructure in mitigating Urban Heat Island (UHI) effects and supporting climate change adaptation. Additionally, social and economic inequalities in access to green spaces and cooling resources (Sha & Cheng, 2024) exacerbate disparities in health outcomes and quality of life. Marginalised communities, often located in neighbourhoods with limited green spaces, bear a disproportionate share of the burden of heat-related risks and environmental hazards. This unequal distribution of amenities perpetuates social injustice and heightens vulnerability to climate change. The significance of this study resides in its potential to provide practical insights for urban planners and policymakers. The development of exemplary public spaces should involve the engagement of various stakeholders (Isa & Shan, 2024). As a UNESCO World Heritage site, George Town presents unique challenges in balancing heritage preservation with sustainable urban development. The findings from this research will assist planners in integrating green infrastructure into urban strategies while safeguarding the city's historical and cultural identity. Moreover, understanding the socio-economic benefits of green spaces, such as improved quality of life, enhanced public health, and reduced energy consumption, will establish a foundation for more resilient and sustainable urban development.

## LITERATURE REVIEW

### Assessing the variables of UHI phenomena

The UHI effect has become a focal point in urban climatology due to its profound impact on cities' sustainability, public health, and energy use. UHI (Figure 1) refers to the temperature disparity between urban and rural areas, primarily driven by human activities and by heat-absorbing materials such as concrete, asphalt, and dense buildings. These materials, with high thermal mass and low reflectivity (albedo), absorb and store heat during the day, gradually releasing it at night and resulting in elevated temperatures. Research on UHI has examined factors such as urban structure, land use, and vegetation distribution. Studies by Fadhil et al. (2012) have shown that urban geometry and surface materials significantly shape heat distribution across cities. Recent research has employed remote sensing and GIS to map temperature variations, highlighting the cooling effects of green spaces and water bodies. For example, Taylor et al. (2024) found that urban parks and tree-lined streets noticeably lower local temperatures through shading and evapotranspiration. Using NDVI in these studies has been essential for assessing vegetation cover and its relationship to surface temperatures.


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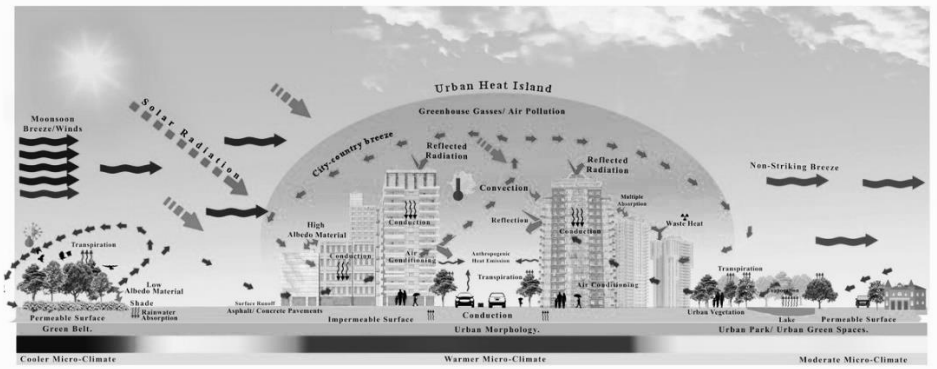



**Figure 1:** Conceptual framework for explaining the UHI phenomenon in city canyons.
*Source: Siddique et al., 2020*

Urban green spaces, including parks and street trees, are vital in mitigating the adverse effects of urbanisation, particularly the Urban Heat Island (UHI) effect. These areas provide cooling through shading, facilitate evapotranspiration, and reduce heat-absorbing surfaces, thereby effectively lowering urban temperatures (Raihan, 2024). Metrics such as NDVI indicate that regions with denser, healthier vegetation exhibit lower surface temperatures, underscoring the importance of dense green spaces (Rahaman et al., 2022). When strategically positioned, green spaces maximise cooling efficacy, diminish UHI intensity, reduce energy consumption, and enhance air quality. The effectiveness of green spaces depends on factors such as vegetation type, maintenance practices, and climate, with native species and broad-canopy trees providing optimal cooling benefits.

The Urban Thermal Field Variance Index (UTFVI) is a valuable metric in urban climatology that assesses the spatial variability of UHI by quantifying the variance in Land Surface Temperature (LST) across urban areas (Degerli & Cetin, 2023). The Urban Thermal Field Variance Index (UTFVI) is an extensively utilised indicator for evaluating ecological and environmental thermal conditions within urban environments. UTFVI measures thermal stress by comparing the land surface temperature (LST) at a specific location with the average LST of the designated study area. Elevated UTFVI values indicate greater thermal discomfort and a more pronounced Urban Heat Island (UHI) effect. In contrast, lower or negative values denote thermally comfortable conditions characterised by improved ecological quality. Accordingly, UTFVI is an effective tool for pinpointing urban thermal hotspots and assessing the environmental benefits of urban vegetation and green infrastructure. This index helps identify thermally intensive zones, providing insights into how urban features such as building density, vegetation, and surface materials influence UHI intensity. Research indicates that areas with high building density and limited

vegetation are associated with elevated UTFVI values, indicating more intense UHI effects, whereas regions with green spaces and water bodies tend to exhibit lower values due to their cooling effects (Jumari et al., 2023; Siddique et al., 2020). Despite its utility, the UTFVI is subject to seasonal and temporal variability, and ongoing research aims to refine the index and integrate it with other environmental metrics to provide a more comprehensive approach to UHI assessment.

Understanding the dynamics of Land Surface Temperature (LST) in George Town, Penang, is essential for evaluating the Urban Heat Island (UHI) effect and advancing urban climate resilience initiatives. Empirical research indicates that densely built urban regions with impervious surfaces, such as asphalt and concrete, tend to exhibit elevated LSTs due to their heat-retaining capacity. Conversely, green spaces help cool through shading and evapotranspiration, thereby reducing surface temperatures and enhancing thermal comfort (Cetin et al., 2024; Kandel et al., 2022; Mishra et al., 2019). The spatial variability of LST influences local microclimates, air quality, and public health outcomes. To measure LST, scholars employ satellite platforms equipped with thermal infrared sensors, such as Landsat, and analyse the data using Geographic Information Systems (GIS) software to generate temperature distribution maps, evaluate urban heat exposure, and validate results through ground truthing. This methodological approach supports the development of evidence-based strategies to mitigate LST, including augmenting green infrastructure and implementing sustainable land-use practices, thereby bolstering climate resilience in George Town and other urban areas.

Carbon sequestration is vital in George Town to mitigate the Urban Heat Island (UHI) effect and enhance climate resilience. The city actively captures atmospheric carbon dioxide through green spaces such as parks, urban forests, and gardens, thereby storing carbon in vegetation and soils and offsetting emissions from urban activities (Rahaman et al., 2022; Shadman et al., 2022; Taylor et al., 2024). These green areas also help lower surface temperatures through shading and evaporative cooling, particularly during heat waves, thereby mitigating UHI impacts. The calculation of carbon sequestration employs remote sensing techniques and field data to estimate carbon stocks in urban green spaces, supplemented by methodologies adapted from IPCC guidelines. These estimates are instrumental in informing sustainable urban planning, biodiversity conservation, and public health initiatives. In summary, research concerning environmental indicators such as UTFVI, NDVI, spatial distribution, and Land Surface Temperature (LST) has been conducted across various countries, including Turkey, China, Malaysia, Nigeria, Nepal, Indonesia, and the United States. Consistent findings highlight the significant influence of urban morphology, vegetation cover, and land use on local climate conditions and the


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intensity of the urban heat island. NDVI, in particular, serves as a tool to quantify vegetation density and its cooling effects across different landscapes.

## MATERIAL AND METHODS

The George Town, Penang, Sia Boey Archaeological Park, and Little India serve as valuable case study sites for examining the Urban Heat Island (UHI) effect within metropolitan environments abundant in cultural heritage. Both sites are located within the George Town UNESCO World Heritage Site and exhibit unique architectural and spatial characteristics that influence local microclimates, making them pertinent to UHI research. Sia Boey Archaeological Park (see Figure 2), a green space surrounded by historic structures and dense urban development, offers an opportunity to analyse how vegetated areas in a heritage context can mitigate UHI effects. Its design, which integrates open spaces and greenery amid preserved colonial buildings, contrasts with the surrounding urban environment, which is composed of heat-retentive surfaces such as concrete and asphalt. Conversely, Little India (see Figure 3), characterised by a compact layout, narrow streets, and historic shophouses, offers a contrasting environment for UHI studies. The densely built environment, combined with the extensive utilisation of heat-absorbing materials, creates conditions conducive to heat retention and limited air circulation. Analysing UHI patterns in Little India can provide insights into how densely developed heritage zones with limited vegetation respond to increasing urban temperatures.

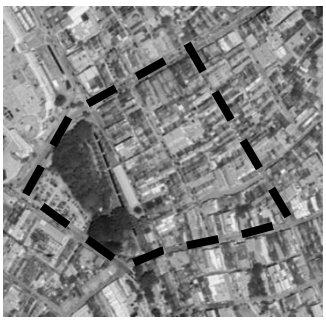


**Figure 2**: Study Site A.

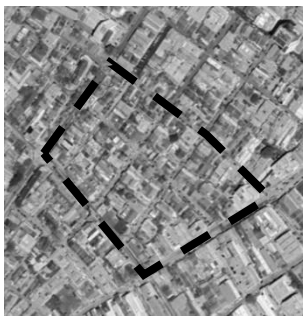


**Figure 3**: Study Site B.

An advanced Geographic Information System (GIS) based analysis is employed to effectively examine the Urban Heat Island (UHI) effect in George Town, Penang, utilising key environmental variables extracted from Landsat 8 satellite data via Google Earth Engine (GEE). The study incorporates explicitly the Normalised Difference Vegetation Index (NDVI), Land Surface Temperature (LST), and Universal Thermal Climate Index (UTFVI), each serving a distinct function in understanding urban heat dynamics. Each dataset is processed in

GEE, with NDVI calculated from Landsat 8's red and near-infrared bands, and LST derived from the thermal infrared band. UTFVI values are computed by correlating LST and NDVI data to map variability in the thermal field.

These datasets are exported as GeoTIFF files for high-resolution spatial analysis in ArcMap. The layers are overlaid and reprojected to align with George Town's coordinate system, ensuring spatial accuracy and precise visualization. The Raster Interpolation Analysis tool generates continuous surface maps from point data, interpolating across gaps for comprehensive spatial insights. This tool estimates values at unsampled locations from known data points, enabling the visualisation of gradients and spatial patterns, which is particularly advantageous when working with environmental datasets such as NDVI, LST, and UTFVI. During raster interpolation for the UHI study in George Town, Penang, the tool uses temperature data points to generate a smooth temperature surface across the city. Data points with known LST are interpolated to estimate LST values at intermediate locations. The resulting output is a continuous raster surface map that highlights temperature variations across the study area, facilitating high-precision identification of UHI intensity and hotspots.

Interpolation creates a surface map of Land Surface Temperature (LST) that can be layered with datasets like NDVI and UTFVI. This helps analysts study relationships between vegetation, urban growth, and temperature, offering key insights for urban planning to reduce Urban Heat Island (UHI) effects. The tool highlights spatial patterns visually and quantitatively, guiding urban cooling and greening policies to promote resilient development. In 2014, the land surface temperature at Site A (Figure 4) ranged from 45°C to 51°C, with an average temperature higher than that recorded in 2024. This rise is ascribed to the completion of the Sia Boey Archaeological Park in 2019, which has demonstrated the efficacy of green spaces in alleviating urban heat island (UHI) effects. Conversely, the 2014 findings for Site B (Figure 5) show slight differences due to the absence of designated green areas. Moreover, this is corroborated by a comparison of NDVI values. The NDVI values for Site A (Figure 6) in 2014 were markedly lower than those in 2024, whereas the NDVI values for Site B (Figure 7) remained unchanged over the ten years.

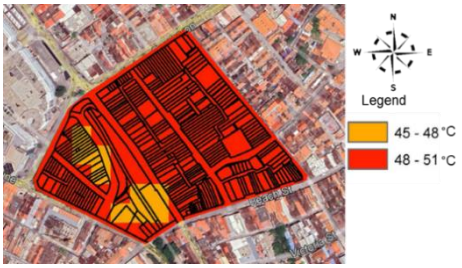



**Figure 4:** LST of Site A in 2014.

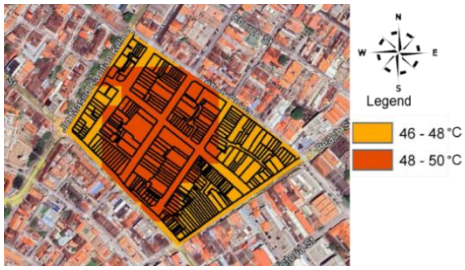



**Figure 5:** LST of Site B in 2014.


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**Figure 6:** NDVI of Site A in 2014.

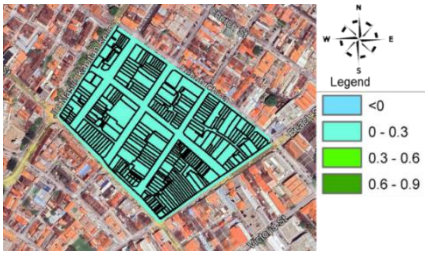



**Figure 7:** NDVI of Site B in 2014.

Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) imagery was obtained through Google Earth Engine (GEE) to evaluate temporal changes in vegetation cover and land surface temperature. Two cloud-free scenes representing conditions before and after the development of Sia Boey Archaeological Park were selected. The Landsat imagery has a spatial resolution of 30 m for multispectral bands and 100 m for thermal bands, with the thermal bands resampled to 30 m.

The selected images were acquired with cloud cover below 10% to minimise atmospheric interference. Standard preprocessing procedures, including radiometric calibration, atmospheric correction, and cloud masking, were performed in GEE prior to further analysis.

The Normalised Difference Vegetation Index (NDVI) was calculated using Equation (1):

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Where NIR represents Landsat Band 5 and Red represents Landsat Band 4.

Land Surface Temperature (LST) was derived from Landsat 8 thermal Band 10 using a multi-step procedure involving conversion of Digital Number (DN) values to spectral radiance, calculation of brightness temperature, emissivity correction, and final temperature conversion. Surface emissivity (ε) was estimated using the NDVI Threshold Method based on the proportion of vegetation cover.

The Urban Thermal Field Variance Index (UTFVI) was subsequently computed using:

$$UTFVI = \frac{LST - LST_{mean}}{LST_{mean}}$$

Where LST denotes the land surface temperature of each pixel, and LSTmean represents the average temperature of the study area. The resulting UTFVI values were classified into six environmental quality classes ranging from "Excellent" to "Worst" ecological conditions.

## RESULTS AND DISCUSSION

At Site A (refer to Figure 8), the dominant land use is commercial, occupying 9.55 acres, constituting 61% of the total 15.54-acre area. Green spaces are the subsequent most prevalent land use, covering 2.34 acres (15%), followed by development land at 2.25 acres (14%), facilities spanning 1.01 acres (6%), with smaller allocations for parking (0.08 acres, 1%), water bodies (0.25 acres, 2%), and a minimal mixed-use area at 0.06 acres. Conversely, Site B (refer to Figure 9) primarily consists of commercial land use, with 9.63 acres (96%) allocated to this purpose and facilities covering only 0.42 acres (4%) of the 10.15-acre site.




**Figure 8:** Land Use Activities of Site A in 2019.
*Source: Majlis Bandaraya Pulau Pinang, 2019*

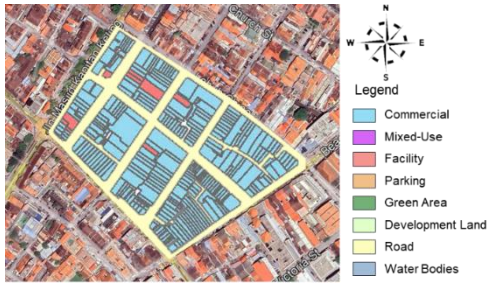



**Figure 9:** Land Use Activities of Site B in 2019.
*Source: Majlis Bandaraya Pulau Pinang, 2019*

The analysis of NDVI values reveals notable disparities among sites, indicating differences in vegetation cover. Site A (see Figure 10) exhibits a broad NDVI range from 0 to 0.9, with higher values in green spaces, indicative of vigorous vegetation, and lower values in commercial zones, suggesting sparse or absent vegetation. In contrast, Site B (see Figure 11) displays a consistently narrow NDVI range of 0 to 0.3, reflecting a deficiency of green spaces and an area predominantly characterised by impervious surfaces underpinned by commercial land use.


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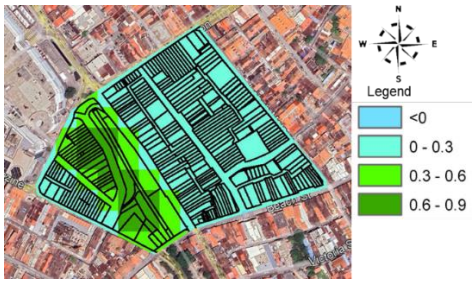



**Figure 10**: NDVI of Site A in 2014.

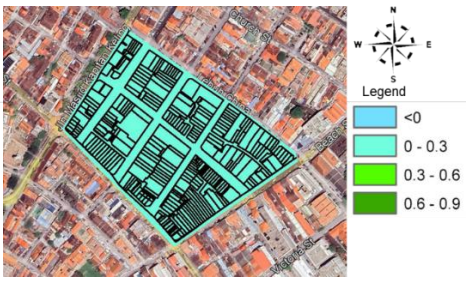



**Figure 11**: NDVI of Site B in 2024.

The analysis of Land Surface Temperature (LST) further delineates the distinctions between the two sites. The LST at Site A (see Figure 12) exhibits considerable fluctuations, ranging from 36°C to 51°C, reflecting a mixture of shaded and sun-exposed surfaces, potentially moderated by green spaces that aid in heat management. In contrast, Site B (see Figure 13) exhibits a narrower LST range of 44°C to 50°C, indicating more uniform and possibly elevated surface temperatures, likely due to the presence of a commercial hardscape landscape with minimal vegetation. The Urban Thermal Field Variance Index (UTFVI) analysis highlights significant differences in environmental thermal quality between these two locations. Although both sites show UTFVI values spanning from 0 to above 0.02, their spatial distributions vary considerably. Site A features larger areas within advantageous UTFVI categories, especially in regions proximate to vegetation, open spaces, and water features. These zones suggest reduced thermal stress and enhanced ecological conditions.

In contrast, Site B exhibits a markedly higher proportion of pixels classified in the “Poor”, “Bad”, and “Worst” environmental quality categories, indicating increased thermal discomfort and intensified Urban Heat Island (UHI) effects. The predominance of impervious surfaces, densely constructed buildings, limited sky-view factors, and scarce vegetation contribute to the sustained elevation of thermal conditions across the site. The findings underscore that the mere presence of green space is inadequate; rather, its spatial configuration, connectivity, canopy density, and integration with surrounding urban land uses are equally critical. Moreover, the results demonstrate that even relatively small urban green spaces can provide measurable cooling benefits when strategically situated within densely developed heritage districts. Site A (Figure 14) is likely situated within more favourable categories due to its green spaces, which mitigate heat and result in lower Urban Tree Vegetation Index (UTFVI) values. Conversely, Site B (Figure 15), characterised predominantly by commercial land use, is likely to fall within lower UTFVI categories.

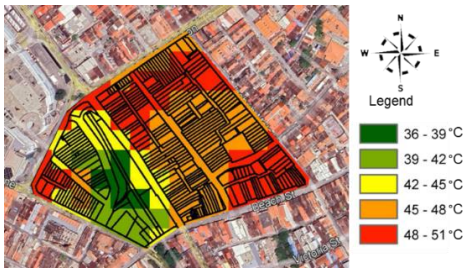



Figure 1: LST of Site A in 2024.




Figure 2: LST of Site B in 2024.

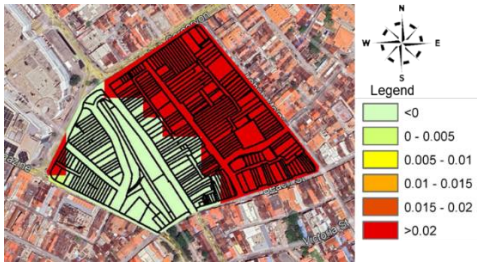



**Figure 14:** UTFVI of Site A.

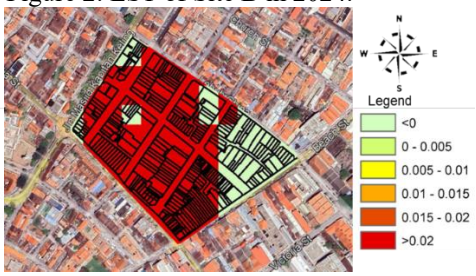



**Figure 15**: UTFVI of Site B.

Validation using ground-based measurements (Figures 16 and 17) supports the findings, demonstrating a strong correlation between remote-sensing data and actual surface conditions. To verify the accuracy of remotely sensed LST values, we conducted field measurements at representative locations within both study sites during daytime observations. Surface temperatures were recorded using a handheld infrared thermometer at selected points representing vegetated surfaces, paved areas, building surfaces, and open spaces. The geographic coordinates of each measurement point were recorded using a GPS-enabled mobile device. The field observations were subsequently compared with corresponding Landsat-derived LST values. The comparison revealed a strong consistency between satellite-derived temperatures and observed field conditions, confirming the reliability of the remote sensing approach for evaluating thermal variations in George Town. Although slight deviations were observed due to differences in measurement scale and acquisition timing, the overall temperature distribution patterns were highly comparable.


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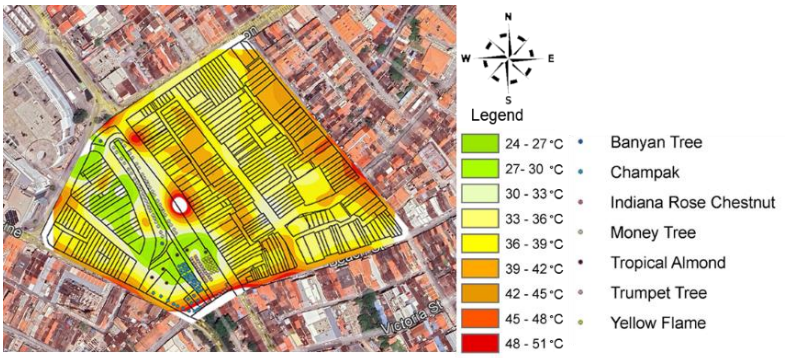



**Figure 16**: Surface Temperature in Site A captured by on-ground survey.

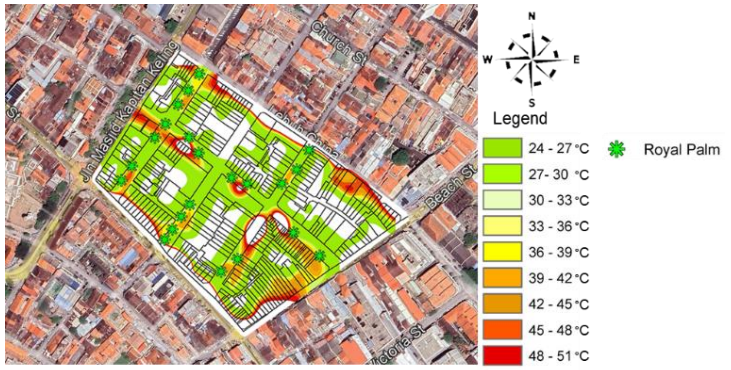



**Figure 17**: Surface Temperature in Site B captured by on-ground survey.

**Table 1:** Summary of the findings.

| No. | Variable | Findings | |
|---|---|---|---|
| | | **Site A** | **Site B** |
| 1. | NDVI | Varies from 0 to 0.9 | Varies from 0 to 0.3 |
| 2. | LST | Varies from 36°C to 51°C | Varies from 44°C to 50°C |
| 3. | UTFVI | Varies from 0 to 0.02 | Varies from 0 to 0.02 |
| 4. | Spatial Distribution | The green area is allocated | No green area |

*Source: Authors, 2024*

This validation process ensures reliability by confirming that remote sensing accurately captures on-the-ground variations in vegetation cover, surface temperature, and urban thermal stress, emphasising the impact of land-use composition on environmental quality across these sites. Table 1 summarises the findings and data interpretation. The results from land-use, NDVI, LST, and

UTFVI analyses directly support key development strategies, environmental policies, and climate-responsive design principles. Site A, with a balanced mix of commercial zones, green spaces, and supporting facilities, aligns with planning standards that promote diverse land use, sufficient open spaces, and the integration of green infrastructure. Conversely, Site B's predominantly commercial character and scarce vegetation conflict with sustainable development policies that advocate urban greenery, heat mitigation, and public amenities. NDVI results show healthier vegetation at Site A, supporting green infrastructure and low-carbon city goals, while Site B's low vegetation indicates non-compliance with urban greening standards. LST patterns reveal cooling effects from greenery at Site A, in line with climate-responsive urban design, whereas higher temperatures at Site B highlight the impact of excessive hard surfaces. UTFVI analysis further confirms these differences, with Site A closer to favourable environmental quality categories and Site B showing signs of thermal stress, highlighting the importance of adhering to planning and environmental guidelines. Overall, these findings illustrate how land-use composition significantly affects environmental quality, aligning with the goals and requirements of contemporary urban planning.

**Study Limitations**

Although the comparative analysis offers valuable insights into the influence of green spaces on urban thermal conditions, the study is restricted by its focus on only two sites within George Town. Sia Boey Archaeological Park and Little India exemplify contrasting urban environments; however, they may not fully encompass the diversity of land-use types and urban morphological characteristics present throughout the city. Accordingly, the findings should be regarded as case-specific rather than universally representative of George Town. Future research should incorporate a greater number of sites, including residential neighbourhoods, waterfront areas, industrial districts, and mixed-use zones, to enhance the generalizability of results and facilitate a more comprehensive understanding of UHI dynamics.

**Planning and Design Implications**

The findings are of considerable significance for climate-responsive urban planning in George Town and other cities characterised by high-density heritage precincts. Primarily, the development of additional pocket parks in underutilised urban areas can increase vegetation cover and establish localised cooling islands in densely built-up zones such as Little India. Small-scale green spaces, tactically positioned throughout the urban landscape, often achieve greater efficacy in enhancing pedestrian thermal comfort than a single large park at a distance. Furthermore, the implementation of a comprehensive street tree planting


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programme along principal pedestrian thoroughfares and commercial streets is recommended. Indigenous and broad-canopy tree species can provide shade, diminish pavement temperatures, enhance walkability, and promote urban biodiversity.

Thirdly, local authorities should promote the utilisation of cool materials, including high-albedo pavements, reflective roofing materials, and permeable surfaces. These measures can substantially diminish heat absorption and decrease surface temperatures in densely urbanised areas. Fourthly, the development of shaded pedestrian corridors should be prioritised, especially within heritage tourism zones. Continuous shade provision through tree canopies, covered walkways, and arcades can markedly enhance outdoor thermal comfort, minimise heat exposure, and foster active mobility. Lastly, urban planners should establish a network of interconnected green corridors linking major parks, riverfronts, open spaces, and heritage districts. Green corridors facilitate airflow, improve ecological connectivity, aid urban cooling, and bolster climate resilience at the metropolitan level. Such measures are particularly pertinent for George Town, where balancing heritage preservation with climate adaptation has become an increasingly significant planning challenge.

## CONCLUSION

This study investigates the Urban Heat Island (UHI) phenomenon in George Town, Penang, with particular focus on the influence of green spaces on UHI intensity and spatial distribution within two primary areas: Sia Boey Archaeological Park (Site A) and Little India (Site B). Employing advanced remote sensing techniques and high-resolution spatial data, the research's initial objective is to map and analyse the distribution of green areas, thereby revealing notable disparities in vegetation cover between the two sites. Site A, characterised by extensive green spaces, exhibits a broad range of NDVI values (0-0.9), indicative of diverse and vigorous vegetation. Conversely, Site B's NDVI values are confined to a narrow range of 0-0.3, indicating sparse vegetation and limited green infrastructure. These distinctions highlight the critical importance of urban planning that prioritises the allocation of green space, as areas with denser vegetation directly contribute to cooling effects and mitigate the adverse consequences of urbanisation.

LST analyses further emphasise the cooling benefits of greenery, with Site A exhibiting greater LST variation (36°C to 51°C) than Site B (44°C to 50 °C). This wider range indicates that Site A's vegetation and shaded areas help to regulate surface temperatures, fostering a more favourable microclimate. Using UTFVI, the study classifies environmental conditions and corroborates remote sensing data with on-the-ground measurements. Site A's UTFVI values indicate a healthier environment, attributable to higher vegetation density and strategically

placed green spaces, which directly enhance carbon sequestration and provide essential thermal regulation. Combining remote sensing, ground truthing, and ArcGIS spatial analysis ensures data precision and deepens understanding of UHI patterns across George Town's diverse urban landscape.

In conclusion, the study, utilising spatial analysis and visualisations in ArcGIS, demonstrates that green spaces are instrumental in alleviating Urban Heat Island (UHI) effects. Site A exemplifies effective urban planning. The findings indicate that areas with allocated green spaces exhibit lower land-surface temperatures, reduced UHI intensity, and higher carbon sequestration rates, suggesting that expanding urban greenery could substantially improve George Town's sustainability. For policymakers and urban planners, this evidence-based analysis underscores the importance of incorporating additional green infrastructure in densely developed areas such as Little India. The comprehensive methodology employed in this study provides a strategic framework for addressing the UHI challenge, integrating academic insights with practical recommendations to augment the livability and environmental resilience of George Town through targeted urban greening initiatives.

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# REVEALING THE SPACE CHALLENGES VS INDOOR AIR QUALITY IN ADAPTIVE-REUSED PRESHOOLS

**Naziah Muhamad Salleh[1], Anisah Ahmad Nahar[2], Mohd Rodzi Ismail[3], Siti Hamidah Husain[4], Emma Marinie Ahmad Zawawie[5]**

[1,2,3,4]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[5]*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA (UITM)

## Abstract

The number of preschools has significantly enhanced in recent years, even though numerous preschools are housed in facilities that are not initially intended for such use. Space and indoor Air Quality (IAQ), specifically Carbon Dioxide (CO2) is regarded as a crucial element influencing the physical growth of children. Therefore, it is crucial to assess the indoor environments of the preschool located in premises that have been renovated and modified from their initial use. Elevated carbon dioxide (CO2) concentrations in indoor environments may adversely affect children's health and cognitive function. Preschool environments, characterised by high occupancy rates and limited ventilation, are particularly susceptible to poor air quality, which can consequently lead to respiratory issues and diminished learning performance. This study investigates the impact of spaces and ventilation strategies on $CO_2$ concentration levels in preschool classrooms by examining the occupants activities towards IAQ. The results demonstrated that the CO2 concentration in the classroom exceeded the recommended 1000 ppm threshold during lesson and group activities but the levels decreased during low-occupancy periods, such as breaks and outdoor activities. Factors such as room size, and occupancy density influenced the increase of CO2 concentrations. The implementation of exemplary design practices, implementation of hybrid ventilation systems, coupled with thoughtful renovation and ongoing maintenance of preschool facilities, is essential for fostering a high-quality indoor environment within classroom space.

***Keywords:*** Adaptive-reused building, Carbon dioxide, Indoor air quality, Preschool, Classroom, Children

[2] Corresponding author. Email: anisahahmadnahar@gmail.com

## INTRODUCTION

Indoor air quality (IAQ) in educational environments has increasingly been recognised as a crucial determinant of children's physical health, cognitive performance, and academic achievement. Previous studies have highlighted air pollution as a significant environmental concern, demonstrating its adverse effects on both outdoor and indoor air quality in surrounding neighbourhoods (Abdullah et al., 2024; Rashid & Sipahi, 2021). Poor indoor air quality, characterised by inadequate ventilation and elevated carbon dioxide ($CO_2$) concentrations, may contribute to a range of health problems, including headaches, fatigue, respiratory discomfort, and exacerbated asthma symptoms (Settimo et al., 2024). Since preschool children typically spend approximately eight hours per day in educational facilities (Salleh et al., 2015), maintaining acceptable IAQ levels within classrooms is essential for ensuring their comfort, health, well-being, and learning performance.

In Malaysia, most IAQ studies have been conducted in public schools, where buildings and facilities are generally planned, constructed, and maintained according to standards established by government authorities (Kamaruzzaman & Rasitah, 2011; Hussin, 2011). In contrast, private preschools are often operated by individuals or non-governmental organisations (NGOs), with facilities commonly housed in adaptively reused residential buildings (Kuala Lumpur City Hall, 2010). These buildings were not originally designed for educational purposes, and residential spaces such as bedrooms are frequently converted into classrooms. Consequently, providing an indoor environment that adequately supports children's health and learning remains a significant challenge (Salleh et al., 2016).

Previous research reported that approximately 90% of adaptively reused preschool classrooms accommodated more than 15 occupants per classroom (Salleh et al., 2016). Such occupancy levels may contribute to overcrowding and inadequate ventilation, thereby increasing indoor $CO_2$ concentrations and potentially compromising classroom air quality. Despite the widespread use of adaptively reused buildings for private preschools, limited studies have examined the relationship between classroom spatial characteristics, occupancy density, ventilation strategies, and indoor $CO_2$ concentrations. Therefore, this study aims to quantify the spatial characteristics and environmental conditions of adaptively reused private preschool classrooms and to evaluate the effects of different ventilation strategies on classroom $CO_2$ concentrations.


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## LITERATURE REVIEW

### *Adaptive-Reused Preschool in Malaysia*

Overall, the enrolment of preschool children aged 4 to 6 years in Malaysia increased substantially from 539,469 in 2000 to 729,043 in 2013 (EPRD, 2001; EPRD, 2014). This rapid growth has placed considerable pressure on the capacity of public preschool facilities provided by the government. Concurrently, preschool education coverage has expanded significantly as part of national efforts to enhance access to early childhood education and strengthen the foundation of compulsory education (MOE, 2001). Consequently, the private preschool sector has emerged as an important provider of early childhood education services. Most private preschools are established and operated by private individuals or organisations and are regulated under the Child Care Centres Act 1984 and its Amendment 2007 (Act 308).

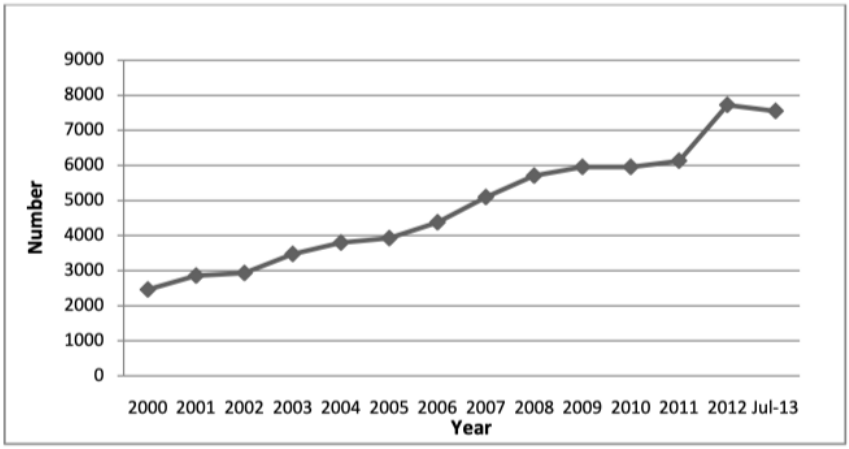



**Figure 1:** Trends of Private Pre-school in Malaysia from 2000-January 2013
*(Source: EPRD MOE, 2013)*

In the Malaysian context, the number of private preschools registered with the Ministry of Education more than doubled between 2000 and January 2013. During the same period, preschool enrolment among children aged 4+ to 5+ years increased from 67% in 2010 to 87% in 2013. This significant growth in enrolment has stimulated the expansion of the private preschool sector despite the concurrent increase in preschool classes provided by public schools under the Tenth Malaysia Plan (2010).

Figure 1 illustrates the rapid growth in the number of private preschools in Malaysia between 2000 and 2013. This upward trend has contributed to the increasing adaptation and reuse of existing premises to accommodate preschool

operations. As demand for preschool education continues to grow, the enrolment capacity of private preschools has expanded in parallel with the availability of suitable educational facilities.

Private preschools play an important role in meeting the growing demand for early childhood education among children aged 4 to 6 years. Many registered private preschools operate in buildings that have undergone adaptive reuse, including residential properties, commercial premises, and institutional buildings. Figure 2 presents the types of buildings occupied by private preschools in Kuala Lumpur following adaptive reuse. The findings indicate that residential buildings within housing developments constitute the most common type of adaptively reused preschool premises.

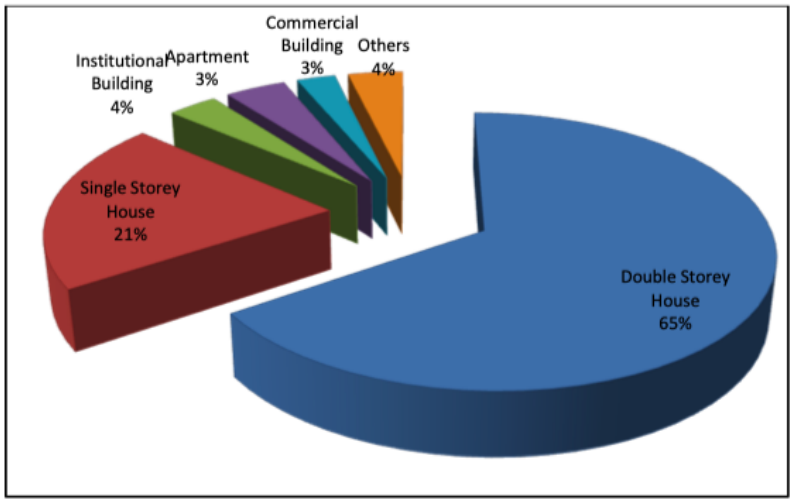



**Figure 2:** Types of Private Pre-school Premises in Kuala Lumpur
*(Source: KL City Council, 2021)*

### *Space Requirements of Preschool Classrooms*

The physical environment of educational facilities is an important component of sustainable learning environments; however, its role in supporting sustainability remains underexplored. Recent studies have highlighted that institutional physical environments, particularly classroom space requirements, constitute a major challenge in implementing sustainable preschool ecosystems within the framework of Malaysia's National Preschool Curriculum Standards and broader national sustainability goals (Hashim et al., 2025). In many cases, spatial comfort is compromised in favour of safety requirements and other functional priorities associated with preschool operations (Mansour, 2025).


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In addition to building design, the geographical location of preschool facilities can significantly influence indoor air quality (IAQ) conditions (Sarijuddin et al., 2018). In Malaysia, a large proportion of private preschools operate in adaptively reused residential buildings that were originally designed as family dwellings rather than educational facilities. As a result, these buildings often provide limited spatial capacity and inadequate classroom layouts, which may adversely affect children's learning experiences and overall environmental quality (Yoo & Ito, 2022). Preschool environments are of particular concern because children spend a substantial proportion of their time indoors, second only to their homes. Studies have reported that individuals in educational settings may spend up to one-third of their day in enclosed indoor environments (Rahman et al., 2019).

Occupancy density is another important factor influencing IAQ in preschool classrooms. Naziah et al. (2016) reported that approximately 90% of surveyed adaptively reused preschool classrooms accommodated more than 15 occupants per classroom, exceeding the recommended capacity limits for preschool facilities. High occupancy levels can increase the accumulation of indoor pollutants, particularly carbon dioxide ($CO_2$), as pollutant generation is closely related to the number of occupants within an enclosed space (Horr et al., 2016). Consequently, overcrowded classrooms may experience reduced air quality and diminished thermal comfort, potentially affecting children's health and learning performance.

Several standards and guidelines have established minimum space requirements for educational facilities. The Uniform Building By-Laws (UBBL, 2016) specify a minimum floor area of 2 $m^2$ per person, which permits approximately seven students in a typical classroom of the size examined in this study. In addition, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends a maximum occupancy of 50 persons per 100 $m^2$ for classroom environments. International standards provide even more stringent requirements. For example, Serbian regulations stipulate that preschool facilities should allocate between 6 and 9 $m^2$ per child, depending on the facility's overall capacity. For children aged 3 to 7 years, indoor activity spaces should provide between 2.5 and 3.75 $m^2$ per child, while facilities for children aged 1 to 3 years should allocate between 3.3 and 5.0 $m^2$ per child (Lee & Chang, 1999). Furthermore, classroom spaces should be sufficiently flexible to accommodate a range of educational activities and future adjustments in response to changing childcare demands. Such flexibility is essential to ensure that preschool environments remain functional, adaptable, and supportive of children's developmental needs (Lee & Chang, 1999).

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### *Carbon Dioxide Concentration in Classroom*

Although numerous studies have investigated indoor air quality (IAQ) in institutional buildings, relatively few have focused on preschool environments (Nahar & Salleh, 2019; Almeida et al., 2016; Kapalo et al., 2018). Maintaining good IAQ is particularly important because individuals spend most of their time indoors, and children are more vulnerable to air pollution due to their higher respiratory rates and developing physiological systems (Settimo et al., 2024; Nahar & Salleh, 2019).

Carbon dioxide ($CO_2$) is commonly used as an indicator of ventilation adequacy because human respiration is the primary indoor source of $CO_2$ in occupied spaces. Although $CO_2$ itself is not considered a major indoor pollutant, elevated concentrations may indicate inadequate ventilation and have been associated with reduced cognitive performance and adverse respiratory effects (Mainka et al., 2018). According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and Malaysia's Industry Code of Practice (ICOP), indoor $CO_2$ concentrations below 1,000 ppm generally indicate acceptable ventilation conditions.

Previous studies have reported elevated $CO_2$ concentrations in educational settings, particularly in densely occupied classrooms. Kapalo et al. (2018) found that classroom $CO_2$ levels frequently exceeded recommended standards during teaching activities, especially in rooms with high occupancy rates. Similarly, Zawawi et al. (2019) demonstrated that ventilation performance significantly influenced IAQ in air-conditioned classrooms equipped with mechanical ventilation systems. These findings highlight the importance of effective ventilation strategies in maintaining acceptable indoor air quality and providing a healthy learning environment for preschool children.

### *Adaptive Reuse Policy Implications for Sustainable Preschool Development*

Adaptive reuse has emerged as an important planning strategy for optimising existing building stock, reducing urban development pressures, and supporting sustainable community development. In Malaysia, the increasing demand for preschool education has encouraged the conversion of residential and commercial buildings into educational facilities, particularly within urban areas where land availability is limited. The National Physical Plan Fourth Edition (NPP-4) promotes sustainable spatial development through the efficient utilisation of existing built environments and community facilities, while the Garis Panduan Perancangan Tadika dan Taska provides planning guidance on the location, accessibility, and physical requirements of preschool facilities (Department of Town and Country Planning Peninsular Malaysia [PLANMalaysia], 2021, 2017). These policy initiatives support adaptive reuse as a practical approach to expanding preschool provision. However, existing planning guidelines primarily


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focus on land use compatibility, accessibility, safety, and service provision, with limited emphasis on indoor environmental quality (IEQ) performance, ventilation adequacy, and occupant health.

The need to strengthen environmental performance criteria is further reinforced by the aspirations of the Thirteenth Malaysia Plan (RMK13) 2026–2030, which prioritises environmental sustainability, public health, and quality of life (Ministry of Economy, 2025). These objectives are also aligned with Sustainable Development Goal (SDG) 3 (Good Health and Well-being), SDG 4 (Quality Education), and SDG 11 (Sustainable Cities and Communities) (United Nations, 2015). Nevertheless, literature addressing adaptive reuse in educational settings suggests that buildings originally designed for residential occupancy may not adequately support the ventilation and spatial requirements associated with preschool activities. Consequently, there is a need for greater integration of indoor environmental performance standards within adaptive reuse policies and preschool planning guidelines to ensure that educational accessibility is achieved without compromising children's health and learning outcomes.

## RESEARCH METHODOLOGY

The study was carried out in four classrooms located in the Penang area, due to the progress development and density of enrolments. All the preschools are private preschools and are entirely managed by the owner. The selection of preschools is based on the number of children per year, population density, and number of seats and applications.

The study continuously refers to schools by labeling them with the development scheme and the road where the buildings are situated. Table 1 indicates the case studies labeled for each classroom are tagged with numbers and Figure 4(a) and 4 (b) the photo of the case studies. Figure 5 indicates the dense indoor environment in case study P2-R2

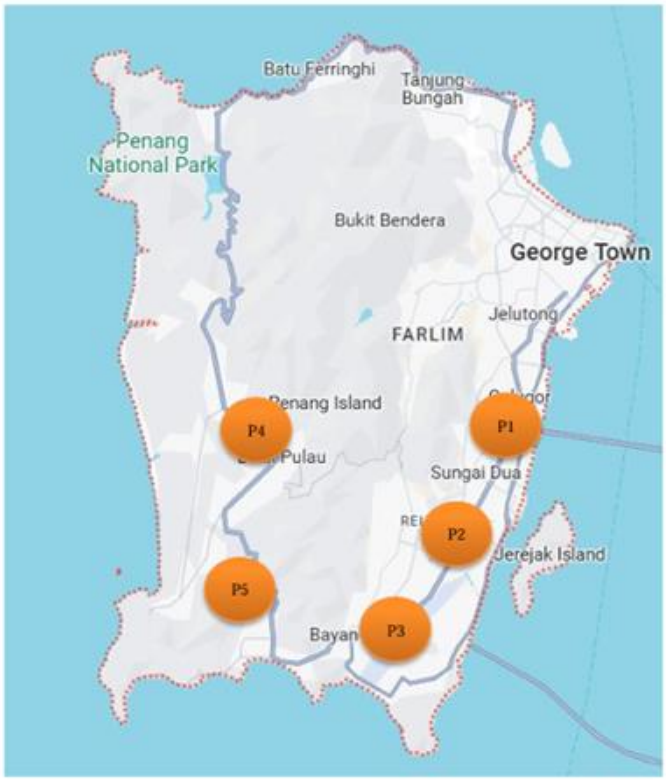



**Figure 3:** The Location of preschools involved in a field study

**Table 1:** Case studies for this research

| ***Pre-schools*** | **P1** | | **P2** | | **P3** | | **P4** | |
|---|---|---|---|---|---|---|---|---|
| ***Classroom/case study*** | **R1** | **R2** | **R1** | **R2** | **R1** | **R2** | **R1** | **R2** |
| ***Type of building*** | Double-storey detached house | | | | | | | |
| ***Age of the building*** | 20 years | | 25 years | | 12 years | | 20 years | |
| ***Location*** | Roadside with less traffic | | Roadside with less traffic | | Roadside with less traffic | | Roadside with heavy traffic | |
| ***Surrounding details*** | Urban, residential, commercial area | | Urban, Residential (rock quarry about 1 km from the location) | | Urban, residential, commercial area | | Urban, residential, commercial area | |
| ***Constructional activity*** | No | | No | | No | | No | No |


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| ***Distance from main road*** | 20m | | 300m | | 100m | | 100m | 100m |
|---|---|---|---|---|---|---|---|---|
| ***Operation Hour*** | 8am-5pm | | 7am-3pm | | 8am-5am | | 8am-5am | |
| ***Maximum pupils' capacity per classroom*** | 16 | 19 | 17 | 16 | 16 | 19 | 19 | 20 |
| ***Monitoring Period*** | 4 days | 4 days | 4 days | 4 days | 4 days | | 4 days | 4 days |
| ***Ventilation status*** | Natural ventilation with ceiling fan, windows open | | Natural ventilation with ceiling fan, windows open | | Air conditional with ceiling fan, door open | | Air-conditional | Air-conditional |
| ***Number of ceiling fan*** | 1 | 1 | 1 | 1 | 1 | | 1 | 1 |
| ***Classroom area($m^2$)*** | 22.1 | 14.00 | 17.08 | 13.06 | 23.65 | | 15.47 | 15.57 |
| ***Classroom volume ($m^3$)*** | 66.3 | 36.4 | 44.41 | 33.96 | 66.22 | | 39.70 | 40.48 |
| ***Window Size($m^2$)*** | 2.88 | 2.88 | 2.88 | 2.16 | 2.88 | | 2.88 | 2.88 |
| ***Door*** | 1 (exit) | | 2 (exit) | 1 (exit) | 1 (exit)<br>1 (washroom)<br>2 (panel sliding door) | | 1 (exit) | 1 (exit) |



(a) (b)

**Figure 4:** Case study building (a) Case study P1 and (b) Case Study P2



**Figure 5:** Indoor Environment Case Study P2-R2

***Sampling Method***

The monitoring study aimed to identify $CO_2$ concentration levels in preschools. The measurements were taken for $CO_2$ concentration, RH, T, and airflow to enhance the understanding of classroom conditions. The equipment used in the field measurement is BABUC A, TSI IAQ model 7525, Hot Wire CFM Thermo-Anemometer, measuring tape, and laser distance. All equipment used for measurement must ensure it works in good condition. Due to limited instruments, TSI IAQ model 7525 was used to measure only indoor carbon dioxide, humidity, and temperature. The log interval of the concentration data was set at every 60 seconds. Then, the recorded data were downloaded to a PC via USB and opened in Microsoft window to specific software provided along with TSI IAQ model 7525.

The optimal sampling point was typically at the center of the classroom or next to a chair, provided it was away from windows or ventilation and heating systems. the same point was used for measuring $CO_2$ levels, humidity, temperature, and airflow. To ensure consistency, the same sampling points were used across all classrooms in the 4 schools. The samplers were positioned at a height of approximately 1meter.

***The Measurement protocols***

The measurement was done for three days in each classroom for a few reasons :

1) Three as the optimal sample size, which allows us to verify the mean and frequency of the data to determine the valid minimum and maximum results


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2) Sampling could be repeated if the instrument fails to measure, as the measurement logging should occur at every one-minute interval during the measurement for at least eight hours per day.
3) The measurement devices should be placed at least one meter away from any wall, half a meter from bookshelves, out of reach of children, and 0.5 meters away from the air supply, which is not directly beneath it.
4) The measurement devices are consistently positioned at the height equivalent to the children's breathing zone, roughly one meter from the floor, since the pre-school's activities are usually energetic, causing children to move around frequently.

***Analysis Indicator Occupancy Density and Ventilation Performance Indicators***

To evaluate the adequacy of classroom space and its potential influence on indoor air quality, three spatial indicators were calculated: occupancy density (pupils/m²), floor area per child (m²/pupil), and air volume per child (m³/pupil). These indicators were benchmarked against established space standards and ventilation-related literature. The Uniform Building By-Laws (UBBL) recommend a minimum allocation of 2 m² per occupant, while the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends a maximum occupancy density of 50 persons per 100 m², equivalent to 2 m² per person. In preschool settings, Lee and Chang (1999) further suggest a provision of 2.5–3.75 m² per child for indoor activity spaces. Classrooms providing less than 2 m² per pupil and exhibiting air volumes below 3 m³ per pupil were considered more susceptible to elevated $CO_2$ accumulation due to limited dilution capacity and reduced ventilation effectiveness. Therefore, occupancy density and air volume per child were employed as proxy indicators of ventilation performance and indoor environmental adequacy within the adaptively reused preschool classrooms, enabling a comparative assessment of the relationship between spatial constraints and indoor $CO_2$ concentrations.

**Table 2**: Ventilation Adequacy Classification Based on Available Air Volume per Child

| Air Volume per Child (m³/pupil) | Ventilation Adequacy |
|---|---|
| **> 4.0** | **Good** |
| **3.0 – 4.0** | **Moderate** |
| **2.0 – 3.0** | **Poor** |
| **< 2.0** | **Critical** |

To facilitate comparison among classrooms, an indicative ventilation adequacy classification was developed based on the calculated air volume available per child (Table 2). The classification was derived from the distribution

of observed classroom volumes and occupancy densities within the present study and is intended as a comparative indicator rather than a regulatory benchmark.

## ANALYSIS AND DISCUSSION

$CO_2$ concentration measurements were conducted continuously during classroom activities and break periods to evaluate indoor air quality under different ventilation strategies. The investigated classrooms employed either split-unit air conditioning (AC) or natural ventilation (NV). Figure 6 illustrates the fluctuation of indoor $CO_2$ concentrations over time, enabling a comparison of ventilation performance between the two classroom conditions.

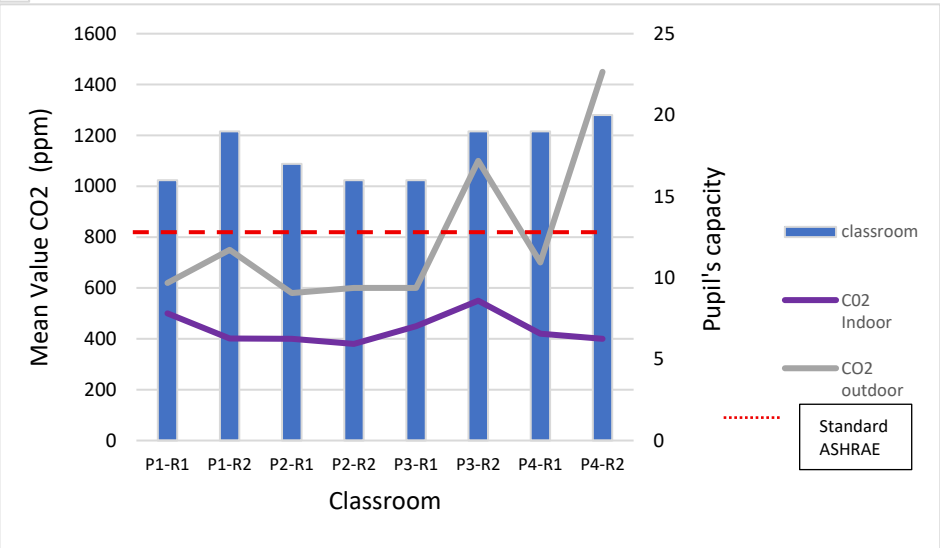



**Figure 6:** Mean Carbon Dioxide, $CO_2$ Concentration, and Occupants between Preschool Classroom

Figure 6 compares indoor and outdoor $CO_2$ concentrations across classrooms P1-R1 to P4-R2 and relates these measurements to maximum occupancy levels. Indoor $CO_2$ concentration, outdoor $CO_2$ concentration, and occupant density are presented to evaluate ventilation performance. The ASHRAE and ICOP recommended $CO_2$ limit is included as a reference benchmark for assessing indoor air quality conditions within the classrooms.

### *$CO_2$ Concentrations Exceeding Recommended Limits*

As shown in Figure 6, indoor $CO_2$ concentrations varied considerably across the sampled classrooms and frequently exceeded the ASHRAE and ICOP recommended limit of 1,000 ppm. The highest concentration was recorded in


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classroom P2-R1, reaching approximately 1,200 ppm, indicating inadequate ventilation during occupancy periods. Elevated $CO_2$ levels were generally associated with higher classroom occupancy, particularly in P2-R1 and P3-R1, suggesting that increased occupant density contributed to the accumulation of indoor $CO_2$.

In contrast, outdoor $CO_2$ concentrations remained relatively stable throughout the monitoring period, ranging between 400 and 500 ppm. These values were substantially lower than the corresponding indoor concentrations and exhibited minimal variation. The findings indicate that fluctuations in indoor $CO_2$ levels were primarily influenced by internal factors, particularly occupant density and ventilation effectiveness, rather than changes in outdoor environmental conditions.

***Occupancy Density and Indoor $CO_2$ Concentration***

Classroom occupancy was found to be a key factor influencing indoor $CO_2$ concentrations. The highest $CO_2$ levels were recorded in classrooms P2-R1 and P3-R1, which accommodated 22 and 20 pupils, respectively. This finding suggests that increased occupant density contributed to the accumulation of indoor $CO_2$, indicating that the existing ventilation systems were insufficient to maintain acceptable air quality under high-occupancy conditions. Overcrowded classrooms may therefore experience reduced ventilation effectiveness, leading to poorer indoor air quality, occupant discomfort, and potential adverse effects on health and learning performance, consistent with previous studies.

***Occupancy Density and Ventilation Performance Indicators of Adaptive-Reused Preschool Classrooms***

Table 3 indicates the occupancy density and ventilation performance indicators of adaptive-reused preschool classrooms for this study. Occupancy density varied considerably among the investigated classrooms, ranging from 0.68 to 1.36 pupils/m². Classrooms P1-R2, P4-R2, P2-R2, and P4-R1 recorded the highest occupancy densities, all exceeding 1.20 pupils/m². The floor area available per child ranged from only 0.74 to 1.48 m²/pupil, which is substantially lower than the 2 m²/person minimum requirement recommended by the Uniform Building By-Laws (UBBL).

Similarly, air volume per child ranged from 1.92 to 4.14 m³/pupil. Classrooms P1-R2, P4-R2, P4-R1, and P2-R2 exhibited the lowest air volume per occupant, indicating a higher likelihood of rapid $CO_2$ accumulation. Although several classrooms had relatively high window-to-floor area ratios (16–21%), elevated occupancy densities reduced the effectiveness of natural ventilation. The findings suggest that classroom volume and occupancy density were more influential than window provision alone in determining ventilation performance

and indoor $CO_2$ concentrations. These results support the observed exceedance of the 1,000 ppm $CO_2$ threshold in several classrooms and confirm that adaptively reused preschool classrooms often experience inadequate ventilation under high-occupancy conditions. These findings suggest that inadequate space allocation and limited air volume per occupant contributed to reduced ventilation effectiveness.

**Table 3:** Occupancy Density and Ventilation Performance Indicators of Adaptive-Reused Preschool Classrooms

| Classroo | Area ($m^2$) | Volume ($m^3$) | Maximum Occupancy (Pupils) | Occupancy Density (Pupils/$m^2$) | Floor Area per Child ($m^2$/pupil) | Air Volume per Child ($m^3$/pupil) | Window-to-Floor Ratio (%) | Ventilation Type |
|---|---|---|---|---|---|---|---|---|
| **P1-R1** | 22.10 | 66.30 | 16 | 0.72 | 1.38 | 4.14 | 13.03 | Natural Ventilation |
| **P1-R2** | 14.00 | 36.40 | 19 | 1.36 | 0.74 | 1.92 | 20.57 | Natural Ventilation |
| **P2-R1** | 17.08 | 44.41 | 17 | 1.00 | 1.00 | 2.61 | 16.86 | Natural Ventilation |
| **P2-R2** | 13.06 | 33.96 | 16 | 1.23 | 0.82 | 2.12 | 16.54 | Natural Ventilation |
| **P3-R1** | 23.65 | 66.22 | 16 | 0.68 | 1.48 | 4.14 | 12.18 | Air-Conditioned |
| **P3-R2** | 23.65 | 66.22 | 19 | 0.80 | 1.24 | 3.49 | 12.18 | Air-Conditioned |
| **P4-R1** | 15.47 | 39.70 | 19 | 1.23 | 0.81 | 2.09 | 18.62 | Air-Conditioned |
| **P4-R2** | 15.57 | 40.48 | 20 | 1.28 | 0.78 | 2.02 | 18.50 | Air-Conditioned |

### *Influence of Ventilation on $CO_2$ Concentration*

The observed variations in $CO_2$ concentrations highlight the influence of ventilation effectiveness on classroom air quality. Natural ventilation, which relies on airflow through windows, doors, and other openings, can adequately dilute indoor pollutants in classrooms with lower occupancy levels. However, its performance is highly dependent on occupancy density and outdoor environmental conditions.

In contrast, mechanical ventilation systems, including air-conditioning and air-handling units, are designed to provide more consistent indoor air quality control. Nevertheless, elevated $CO_2$ concentrations may still occur when such systems are inadequately sized, poorly maintained, or unable to meet ventilation demands in highly occupied classrooms. These findings suggest that both occupancy density and ventilation effectiveness are critical factors in maintaining acceptable indoor $CO_2$ levels in preschool classrooms. Figure 7 illustrates the variation in indoor $CO_2$ concentrations throughout the school day. The x-axis represents the monitoring intervals, while the y-axis indicates $CO_2$ concentration


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(ppm). The dashed reference line denotes the ASHRAE recommended limit of 1,000 ppm.

The results show substantial fluctuations in $CO_2$ concentration during classroom activities, with levels exceeding the recommended threshold at several intervals. The highest concentration was recorded at C5 (10:30 a.m.), reaching approximately 2,700 ppm, nearly three times the recommended limit. This peak coincided with periods of intensive classroom activities and high occupancy, suggesting that the natural ventilation system was unable to provide sufficient fresh air to offset the increased $CO_2$ generated by occupants.

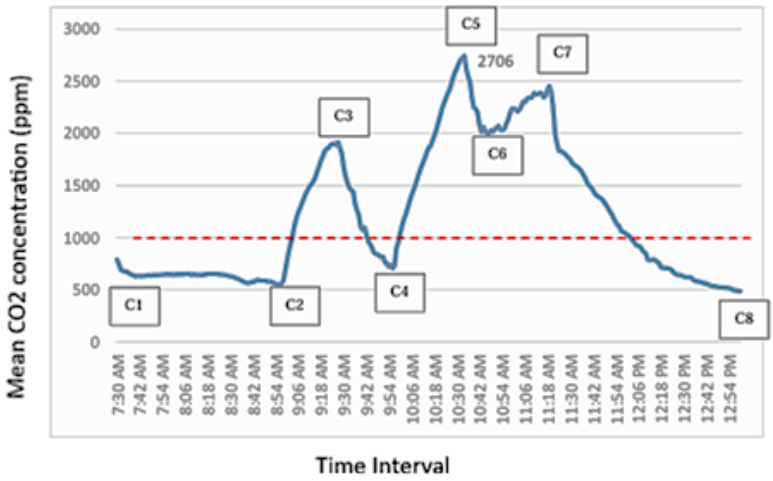



**Figure 7**: $CO_2$ Concentration Level and Occupant Density in Naturally Ventilated Classroom (P2-R1)

Following the peak period, $CO_2$ concentrations declined from C5 to C6, likely due to reduced occupancy and increased air exchange. A gradual decrease was subsequently observed from C6 to C8, indicating an improvement in ventilation effectiveness and indoor air quality. These findings suggest that naturally ventilated classrooms may experience inadequate ventilation during periods of high occupancy and intensive activities, resulting in elevated indoor $CO_2$ concentrations.

## CONCLUSION

The results demonstrate a clear relationship between classroom occupancy, spatial constraints, and indoor $CO_2$ concentrations, highlighting the limitations of natural ventilation in maintaining acceptable indoor air quality during periods of high occupancy and intensive classroom activities. $CO_2$ concentrations frequently

exceeded the recommended ASHRAE and ICOP threshold of 1,000 ppm, particularly during lessons and group activities when occupancy levels were highest. In contrast, $CO_2$ concentrations declined during breaks and outdoor activities, indicating that natural ventilation was more effective when occupancy density was reduced. These findings suggest that natural ventilation alone may be insufficient to provide adequate air exchange under high-occupancy conditions, resulting in suboptimal indoor air quality. Classrooms providing less than 2 $m^2$ per pupil and exhibiting air volumes below 3 $m^3$ per pupil demonstrated higher susceptibility to elevated $CO_2$ concentrations.

Preschool classrooms located in adaptively reused buildings face additional challenges in maintaining acceptable IAQ. Many of these facilities operate in former residential buildings that were not originally designed for educational purposes, resulting in limited classroom space and high occupancy density. Compared with typical office environments, preschool classrooms often accommodate substantially higher occupant densities, leading to the rapid accumulation of $CO_2$ and other indoor pollutants. Furthermore, activity-based learning environments require designated functional zones, such as reading, art, and science areas, which may increase furniture density and obstruct airflow, creating poorly ventilated areas within the classroom.

Based on the findings, several key observations can be made:

1. Indoor $CO_2$ concentration is strongly influenced by classroom volume and occupancy density.
2. Ventilation through the opening of windows and doors significantly reduces indoor $CO_2$ concentrations during breaks and after classroom sessions.
3. Many preschool classrooms exceeded the recommended $CO_2$ threshold (>1,000 ppm) during occupied periods, indicating that existing classroom space and occupancy levels may not adequately support acceptable indoor air quality.
4. Elevated $CO_2$ concentrations were associated with inadequate ventilation and high occupant density.
5. Natural ventilation alone was insufficient to maintain acceptable IAQ during periods of high occupancy and intensive classroom activities.

To improve indoor air quality in adaptively reused preschool classrooms, several measures should be considered. Hybrid ventilation strategies that combine natural and mechanical ventilation could provide more effective air exchange and maintain $CO_2$ concentrations within acceptable limits during peak occupancy periods. Additionally, classroom occupancy limits should be aligned


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with available floor area and ventilation capacity. Regular monitoring of $CO_2$ concentrations is also recommended to support evidence-based ventilation management and ensure a healthier learning environment. Implementing these measures would enhance indoor environmental quality, improve occupant comfort, and support the health and learning performance of preschool children.
The paper reveal an important policy gap in the regulation of adaptively reused preschool buildings in Malaysia. While adaptive reuse is recognised as a sustainable planning approach that supports efficient land use and the provision of community facilities, current planning and approval mechanisms largely focus on land-use compatibility, building safety, and operational licensing, with limited emphasis on indoor environmental performance. Existing planning frameworks, including National Physical Plan Fourth Edition (NPP-4) and Garis Panduan Perancangan Tadika dan Taska, provide guidance on preschool location, accessibility, and physical planning requirements but offer limited provisions relating to indoor air quality, ventilation effectiveness, occupancy density, and post-occupancy environmental monitoring. Furthermore, the aspirations of Thirteenth Malaysia Plan (RMK13) 2026–2030 emphasise environmental sustainability, public health, and quality of life but do not explicitly address IAQ performance in adaptively reused educational facilities.

Given that many classrooms in this study exceeded the recommended $CO_2$ threshold despite complying with existing planning and operational requirements, greater attention should be given to performance-based environmental assessment in adaptive reuse projects. Future planning approvals should incorporate minimum ventilation requirements, occupancy-space standards, and periodic IAQ monitoring, particularly for preschool facilities converted from residential buildings. Strengthening coordination between planning authorities, local governments, public health agencies, and educational regulators would also improve regulatory enforcement and post-occupancy compliance. Such measures would support the objectives of RMK13 and contribute to the achievement of Sustainable Development Goal (SDG) 3: Good Health and Well-being, SDG 4: Quality Education, and SDG 11: Sustainable Cities and Communities by ensuring that adaptive reuse practices promote both educational accessibility and healthy learning environments.

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# BEYOND ACCESS: EXPLAINING THE INTENTION-BEHAVIOUR GAP IN LIGHT RAIL TRANSIT USE WITHIN TRANSIT-ORIENTED DEVELOPMENTS

**Naomi Nathalia[1], I Dewa Made Frendika Septanaya[2]***

[1,2]*Department of Urban and Regional Planning,*
INSTITUT TEKNOLOGI SEPULUH NOPEMBER

## Abstract

Despite the proximity of apartment complexes to Jabodebek Light Rail Transit (LRT) stations, ridership within Jakarta's Transit-Oriented Development (TOD) areas remains below expectations. This study applies the Theory of Planned Behaviour (TPB) and Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine factors associated with Behavioural Reluctance to Use LRT among TOD apartment residents. The results show that Attitude and Subjective Norm are significantly associated with Intention, while Perceived Behavioural Control is negatively associated with Intention, contrary to the hypothesised direction. Both Intention and Perceived Behavioural Control are significantly associated with Behavioural Reluctance to Use LRT, with Perceived Behavioural Control emerging as the strongest predictor. Environmental Norm is not significantly associated with Intention. The model explains 58.3% of the variance in Intention, 49.5% in Habit, and 35.9% in Behavioural Reluctance to Use LRT. However, relationships involving Attitude, Subjective Norm, Intention, and Habit should be regarded as provisional because discriminant validity was not fully established. By contrast, the association between Perceived Behavioural Control and behavioural reluctance represents the most consistently supported relationship in the estimated model.

***Keywords***: Transit-Oriented Development, Theory of Planned Behaviour, PLS-SEM, public transport behaviour, Jakarta, Light Rail Transit

[2] Corresponding author. Email: septanaya@its.ac.id

## INTRODUCTION

Urban mobility in the Jabodetabek metropolitan region faces persistent challenges amid rapid urbanisation and a population exceeding 30 million (Silver, 2024). High population density and fragmented public transport services have weakened the competitiveness of mass transit, reinforcing dependence on private vehicles and contributing to environmental pressures (Camagni et al., 2002). In response, Transit-Oriented Development (TOD) has been promoted as an approach to reduce car dependency by integrating dense urban development with mass transit within walkable catchment areas, aligning land use and transport planning to encourage public transport use (Zhang, 2025).

In Indonesia, TOD has been operationalised through the Jabodebek LRT, which commenced operations in August 2023 to support sustainable mobility across Jakarta, Bekasi, and Depok (Hasibuan & Mulyani, 2022). In March 2024, average daily ridership was reported at approximately 60,000-61,000 passengers, below the target of more than 65,000 passengers per day, leading operators to postpone planned increases in service frequency (Rahayu & Djumena, 2024). Subsequent operational data indicate that average daily ridership reached approximately 54,640 passengers on weekdays and 30,842 passengers on weekends, representing only about 40% of the first-year target of 137,000 passengers per day (Maruf, 2025; Utami & Ananda, 2023).

In contrast, both emerging and mature rail systems demonstrate that substantially higher ridership levels are achievable. Relatively young networks such as the Delhi Metro have surpassed previous ridership records, while Singapore's MRT recorded its highest average daily ridership in 2024. These comparisons highlight the comparatively weaker performance of the Jabodebek LRT, which has achieved only around one-third of its intended first-year demand (Chen et al., 2019; Kormos et al., 2021).

This situation challenges the assumption that proximity and accessibility alone are sufficient to encourage public transport use. Although TOD has traditionally emphasised physical factors such as density, mixed land use, and transit accessibility, growing evidence suggests that these conditions may be necessary but not sufficient to induce modal shift (Zhang, 2025). In high-access environments, behavioural and psychological factors may also be associated with whether residents choose public transport or continue to rely on private modes.

Behavioural perspectives provide a useful framework for understanding these dynamics, with the Theory of Planned Behaviour (TPB) widely applied to explain public transport use through attitudes, subjective norms, and perceived behavioural control. Previous studies have highlighted an intention-behaviour gap, whereby favourable intentions do not always translate into actual public transport use, particularly in contexts characterised by execution barriers such as


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service reliability, multimodal integration, and perceived convenience (Murray & Davis, 2001).

Despite growing attention to the intention-behaviour gap, behavioural responses to public transport in TOD settings, particularly in rapidly urbanising megacities, remain underexplored. TOD research has largely focused on spatial outcomes, whereas behavioural studies have generally examined broader urban populations rather than TOD residents. As a result, limited evidence exists regarding how TPB mechanisms operate in environments where accessibility is high but public transport uptake remains relatively low (Murray et al., 1998).

This study examines behavioural barriers associated with LRT use among TOD apartment residents living within walking distance of Jabodebek LRT stations. Using the Theory of Planned Behaviour and PLS-SEM, the study focuses on Behavioural Reluctance to Use LRT despite physical access and evaluates the roles of Attitude, Subjective Norm, Perceived Behavioural Control, Habit, and Environmental Norm in shaping Intention and Behavioural Reluctance to Use LRT.

## RESEARCH BACKGROUND

In transport planning, access and accessibility are related but conceptually distinct. Access refers to the physical and economic ability to enter a transit system, whereas accessibility reflects how effectively the system enables users to reach destinations within acceptable time, effort, and reliability constraints (Cascetta et al., 2015; Ewing & Cervero, 2001). While access ensures availability, accessibility determines the usefulness of public transport in daily travel.

Transit-Oriented Development (TOD) is explicitly designed to strengthen both dimensions. By concentrating high-density residential development and mixed land uses within walkable distances of mass transit stations, TOD aims to minimise barriers and reduce generalised travel costs (Zhang, 2025). Empirical evidence consistently shows that residents living in dense, mixed-use neighbourhoods with convenient transit access are more likely to rely on public transport than those in car-oriented environments (Cervero, 2002; Evans IV et al., 2007; Ghosh et al., 2025).

Physical proximity remains a core benchmark of TOD effectiveness. International planning standards and Indonesian spatial regulations (*Peraturan Menteri ATR/BPN No.16/2017*) commonly adopt an 800-metre walking radius as the threshold for effective station catchment areas. This study adheres to that benchmark by focusing on apartment developments located within 800 metres of Jabodebek LRT stations.

Additionally, economic access is a key pull factor in megacities where fare sensitivity is high, and affordability strongly shapes ridership (Sogbe et al., 2025). In the Jakarta metropolitan region, where the minimum monthly wage is

approximately IDR 5.7 million (BPS, 2026), assuming an LRT fare of IDR 20,000 per trip and 20 commuting days per month, round-trip commuting costs would amount to approximately IDR 800,000 per month, equivalent to 14.0% of the DKI Jakarta Provincial Minimum Wage. In response, Jabodebek LRT operators have introduced peak-hour discounts and off-peak fare reductions, signalling policy efforts to strengthen economic access and enhance the system's pull factors.

Taken together, physical and economic access, along with network accessibility, create the structural conditions necessary for public transport adoption in TOD areas. However, their effectiveness depends on complementary factors related to ease of use. This limitation of access-based explanations highlights the need for planning approaches that move beyond physical design (Cervero, 2002; Zhang, 2025).

While pull factors create opportunities for public transport use, behavioural factors often determine whether these opportunities translate into adoption. Behavioural constraints such as attitudes, habits, perceived behavioural control, and intention, interact with accessibility and the built environment to shape mode choice, particularly among individuals reluctant to shift from private vehicles (Donald et al., 2014; Ghosh et al., 2025).

One of the most widely applied frameworks for analysing such behavioural determinants is the Theory of Planned Behaviour (TPB) (Yuda Bakti et al., 2020). TPB posits that behaviour is primarily guided by behavioural intention, which in turn is shaped by three core components: attitude toward the behaviour, subjective norms, and perceived behavioural control. Attitude reflects an individual's evaluation of the desirability of a behaviour, subjective norms capture perceived social pressure, and perceived behavioural control represents beliefs about one's ability to perform the behaviour given existing constraints (Ali et al., 2023). In transport contexts, TPB has been extended to incorporate habit and environmental or moral norms, acknowledging that behavioural and value-based considerations can be associated with travel choices alongside rational evaluation (Yuda Bakti et al., 2020).

Empirical applications of TPB have demonstrated its explanatory power across diverse transport contexts. Studies in developing countries show that attitudes, social influence, and control perceptions significantly shape intentions to use public transport, particularly rail-based systems in urban areas (Donald et al., 2014). Similar findings have been reported in developed-country contexts, where TPB-based models successfully explain intentions to use transit and other sustainable modes (Hu et al., 2021).


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## THEORETICAL FRAMEWORK

This study is grounded in the Theory of Planned Behaviour (TPB), which posits that human behaviour is primarily associated with intention, which is shaped by attitude, subjective norms, and perceived behavioural control (Ajzen, 1991). TPB has been widely applied in transport behaviour research to explain individuals' decisions to adopt or avoid public transport, particularly in urban contexts where multiple alternatives are available.

In transport studies, TPB is frequently extended to incorporate additional constructs such as habit and environmental norms. Habit reflects the routinised nature of travel behaviour, which can either reinforce existing mode choices or constrain behavioural change. Environmental norms represent individuals' moral considerations regarding sustainability and environmental impact. Prior studies suggest that while these factors may be associated with stated preferences, their ability to be associated with actual behaviour depends strongly on contextual constraints.

However, a recurring insight from this literature is the presence of an intention-behaviour gap (Limtanakool et al., 2006). Even with favourable attitudes and strong intentions, public transport use may not materialise under operational constraints or strong competition from private modes, as perceived behavioural control may be associated with behaviour, while habits reinforce existing travel routines (Murray et al., 1998). Environmental norms, although salient in stated preferences, may remain secondary when instrumental barriers dominate everyday travel decisions.

In TOD settings, this gap becomes particularly salient. Residents living near transit stations typically face fewer spatial barriers, yet adoption rates may still lag expectations. This suggests that behavioural factors, such as control perceptions, social influence, and entrenched habits, may be associated with actual behavioural outcomes. Despite this, behavioural mechanisms within TOD contexts have received limited empirical attention, as much of the literature continues to prioritise spatial metrics and accessibility indicators.

Building on prior work, this study applies an extended Theory of Planned Behaviour framework to examine Behavioural Reluctance to Use LRT among TOD apartment residents, defined as non-use despite physical access. This study examines behaviour, operationalised as Behavioural Reluctance to Use LRT, among residents of TOD apartments. Higher Y scores indicate greater Behavioural Reluctance to Use LRT.

The model incorporates attitude, subjective norms, perceived behavioural control, habit, and environmental norms to capture both motivational and execution-related dimensions of travel behaviour. While the primary hypotheses focus on Intention and Behavioural Reluctance to Use LRT, the paths involving Habit are retained as exploratory relationships based on prior TPB

extensions and transport behaviour literature. These paths are intended to provide additional insight into potential behavioural mechanisms rather than constitute the primary focus of hypothesis testing. The constructs and initial indicators are summarised in Table 1.

**Table 1**: Constructs and Initial Indicators Included in the Model

| Construct | Indicators | Code |
|---|---|---|
| Behaviour/Dependent Variable | Behavioural Reluctance to use LRT | Y |
| Habit | Public Transport Usage | H1 |
| | Spontaneity | H2 |
| | Dependency | H3 |
| Intention | Time Intention | I1 |
| | Cost Intention | I2 |
| | Accessibility Intention | I3 |
| Attitude | Security | S1 |
| | Pedestrian Quality | S2 |
| | Passenger Density | S3 |
| | Cost-Benefit | S4 |
| | Facilities | S5 |
| | Route | S6 |
| | Trip Purpose | S7 |
| Subjective Norm | Recommendation | NS1 |
| | Time Efficiency | NS2 |
| | Cost | NS3 |
| | Social Influence | NS4 |
| | Environment | NS5 |
| | Media Influence | NS6 |
| | Social Pressure | NS7 |
| Perceived Behavioural Control | Parking Availability | PKP1 |
| | Feeder Connectivity | PKP2 |
| | Headway | PKP3 |
| | Transit Difficulty | PKP4 |
| | Payment Method | PKP5 |
| | Real-time Info | PKP6 |
| | Punctuality | PKP7 |
| | Alternative Public Options | PKP8 |
| | Private Options | PKP9 |
| Environmental Norm | Air Pollution | NL1 |
| | Traffic Congestion | NL2 |
| | Environmental Protection | NL3 |

*Source: Authors' analysis (2025)*


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The model is centred on Behavioural Reluctance to Use LRT as the focal dependent construct. This construct is operationalised as a single-item measure, as it represents a specific behavioural outcome that can be directly and unambiguously assessed through a single indicator. Intention and Habit are included as intermediate endogenous constructs within the extended Theory of Planned Behaviour (TPB) framework. The primary hypotheses focus on the determinants of Intention and Behavioural Reluctance to Use LRT, whilst the additional paths involving Habit are retained as theoretically informed supplementary relationships that provide further insight into the behavioural mechanisms underlying reluctance to use LRT.

## METHODOLOGY

This study adopts a quantitative, explanatory-exploratory design grounded in the Theory of Planned Behaviour to examine Behavioural Reluctance to Use LRT among residents of TOD apartments. The hypothesised relationships were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM), which is well suited for examining complex relationships among latent constructs (Hair et al., 2019, 2022) and has been widely applied in transport behaviour research (Ali et al., 2023; Yuda Bakti et al., 2020). Based on the TPB framework and prior transport behaviour research, six hypotheses were formulated:

H1: A less favourable attitude towards LRT use is associated with a weaker Intention to use the LRT.

H2: Weaker subjective norms supporting LRT use are associated with a weaker Intention to use the LRT.

H3: Lower perceived behavioural control is associated with a weaker Intention to use the LRT.

H4: Weaker environmental norms are associated with a weaker Intention to use the LRT.

H5: A weaker intention to use the LRT is associated with greater Behavioural Reluctance to Use LRT.

H6: Lower perceived behavioural control is associated with greater Behavioural Reluctance to Use LRT.

These hypotheses reflect the proposition that public transport behaviour in TOD contexts is associated not only with physical access, but also with

attitude, social influence, environmental considerations, intention, and perceived behavioural control. The structural model follows the theoretical relationships proposed in the extended TPB framework. However, the primary hypotheses focus on the determinants of intention and behavioural reluctance to use LRT, while additional paths involving habit are retained to preserve the theoretical structure and improve model explanatory power.

Although Habit is included in the structural model, no formal hypotheses were developed for the Habit-related paths. These relationships are retained as exploratory paths based on previous transport behaviour studies that suggest Habit may influence behavioural outcomes and related TPB constructs. The path model used to examine these relationships is presented in Figure 1.

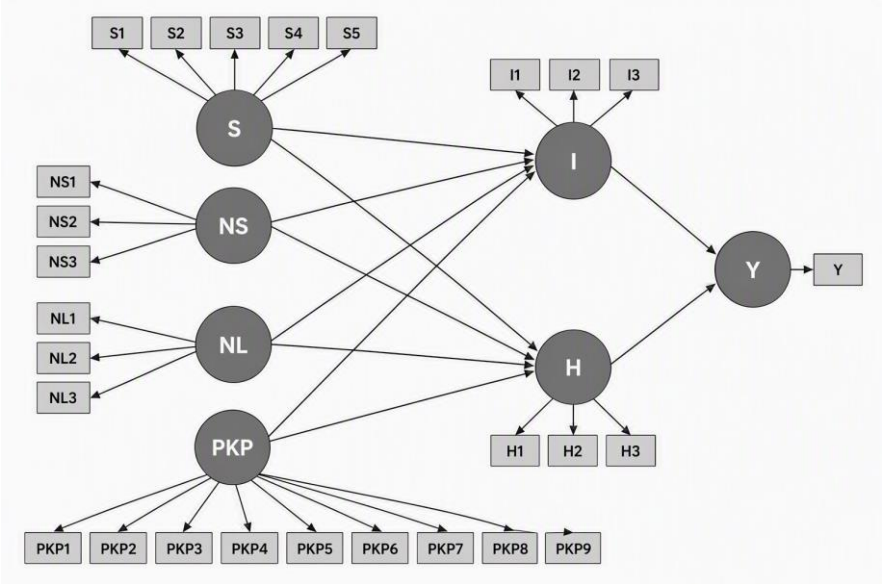



**Figure 1**: PLS-SEM Path Model
*Source: Authors' analysis (2025)*

To complement the quantitative findings, supplementary stakeholder interviews were conducted with representatives of PT Adhi Karya (Persero) Tbk., PT Adhi Commuter Properti Tbk., and ITDP Indonesia. These consultations were undertaken to obtain contextual insights regarding the operational and institutional conditions surrounding LRT implementation and TOD development. The stakeholder perspectives were used to support the interpretation of findings and the development of practical recommendations and were not included as part of the PLS-SEM analysis.


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## SAMPLING AND PARTICIPANTS

The study population consisted of residents of occupied TOD apartments surrounding Jabodebek LRT stations, comprising approximately 5,493 residential units across eight apartment developments.

Respondents were recruited through an intercept-based purposive sampling approach across eight occupied apartment developments located within 800 metres of Jabodebek LRT stations. Eligibility was limited to individuals residing in the selected apartment developments. Eligible residents encountered within the apartment premises were invited to participate, without additional selection based on age or occupation.

**Table 2**: Distribution of Respondents Across TOD Apartment Developments

| Apartment Development | Nearest LRT Station | TOD Zone | Respondents (%) |
|---|---|---|---|
| Grand Dhika City | Jatimulya Station | Core TOD Area (< 400 m) | 22% |
| The Hive Tamansari | Cawang Station | Supporting TOD Area (400-800 m) | 16% |
| Signature Park Grande | Cawang Station | Supporting TOD Area (400-800 m) | 14% |
| LRT City Ciracas | Ciracas Station | Core TOD Area (< 400 m) | 10% |
| LRT City Bekasi | Bekasi Barat Station | Supporting TOD Area (400-800 m) | 10% |
| The Conexio | Cikunir 1 Station | Core TOD Area (< 400 m) | 10% |
| Sakura Garden City | Ciracas Station | Supporting TOD Area (400-800 m) | 9% |
| LRT City Jatibening | Jatibening Baru Station | Core TOD Area (< 400 m) | 9% |

*Source: Authors' analysis (2025)*

Following current best practices in Partial Least Squares Structural Equation Modelling (PLS-SEM), sample size adequacy was determined using a statistical power analysis approach, which is recommended over heuristic rules such as the "10-times rule" (Hair et al., 2022). Assuming a significance level (α) of 0.05, as suggested by Cohen (1992), the minimum required sample size was estimated at 155 respondents.

Due to questionnaire length considerations, respondent profiling was limited to age and occupation characteristics. Future research could incorporate income, vehicle ownership, residential tenure, primary travel mode, and frequency of LRT use to provide a more detailed assessment of sample composition and behavioural heterogeneity. The age and occupation profiles of the respondents are presented below.

**Table 3**: Age Distribution of Respondents

| Generation | Age Range | Frequency | Percentage |
|---|---|---|---|
| Gen Z | 13-28 | 42 | 26% |
| Millennial | 29-44 | 114 | 70% |
| Gen X | 45-60 | 8 | 4% |

*Source: Authors' analysis (2025)*

**Table 4**: Occupational Distribution of Respondents

| Occupation | Frequency | Percentage |
|---|---|---|
| Employee | 60 | 37% |
| Homemakers | 45 | 27% |
| Student | 33 | 20% |
| Self-employed | 26 | 16% |

*Source: Authors' analysis (2025)*

The respondent profile was dominated by Millennials (70%), followed by Generation Z (26%) and Generation X (4%). With regard to occupation, Employees represented the largest proportion of respondents (37%), followed by Homemakers (27%), Students (20%), and Self-employed respondents (16%). Overall, the sample reflects a predominantly working-age population residing within TOD apartment developments surrounding Jabodebek LRT stations.

The final dataset comprised 164 valid and complete responses from a total of 177 collected responses, exceeding the minimum sample size requirement. Thirteen responses were excluded due to incomplete information. Consequently, the final sample exceeded the estimated minimum sample requirement and was considered adequate for the PLS-SEM analysis.

## DATA COLLECTION METHODS

Primary data were collected through a structured questionnaire administered to residents of TOD apartments located within the defined study area. All items were measured using a four-point Likert scale (1-4) to eliminate the neutral midpoint and encourage respondents to take a clear evaluative stance, thereby reducing central tendency bias and non-committal responses (Chyung et al., 2017; Garland, 1991; Thomander & Krosnick, 2024).

All questionnaire items were phrased in the direction of barriers. For example, "*I have not yet used the Jabodebek LRT for my daily activities*." Responses ranged from 1, "strongly disagree", to 4, "strongly agree". Accordingly, higher construct scores indicate stronger negative evaluations, weaker perceived behavioural control, weaker intention to use the LRT, and greater Behavioural Reluctance to Use LRT, depending on the construct. The interpretation of each path coefficient therefore follows the substantive direction


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of the corresponding items rather than assuming that higher scores represent stronger willingness to use the LRT.

Respondents were recruited through an intercept-based purposive sampling approach across eight occupied apartment developments located within 800 metres of Jabodebek LRT stations. Eligibility was limited to individuals residing in the selected apartment developments. Eligible residents encountered within the apartment premises were invited to participate, without additional selection based on age or occupation.

Questionnaires were administered through both paper-based and online formats covering all study variables. Data collection was conducted between 9 and 25 February 2025 from 09:00 to 21:00 across the selected apartment developments. Eligibility was restricted to residents living within TOD apartment developments located within 800 metres walking distance of a Jabodebek LRT station.

## DATA ANALYSIS

The hypothesised relationships were analysed using PLS-SEM implemented in SmartPLS 4 through the following steps:

1. Measurement Model Evaluation
   The reflective measurement model was evaluated using outer loadings, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE), applying thresholds of 0.70 and 0.50 to assess reliability, internal consistency, and convergent validity (Hair et al., 2019, 2022).
2. Structural Model Evaluation
   The structural model was evaluated using bootstrapping procedures to examine the hypothesised relationships among constructs. Model performance was assessed using path coefficients, confidence intervals, $R^2$, $Q^2$, and $f^2$ values. Collinearity was assessed using Variance Inflation Factor (VIF) values below 5.0 (Cohen, 1992; Hair et al., 2019, 2022).
3. Validity and Reliability Testing
   The reliability and validity of the measurement model were assessed using Cronbach's Alpha, Composite Reliability (ρA and ρC), and Average Variance Extracted (AVE). Composite Reliability values above 0.70 indicate adequate internal consistency reliability, while AVE values above 0.50 demonstrate convergent validity (Hair et al., 2019, 2022).
4. Omitted Variable Bias Test
   Omitted variable bias was assessed by introducing age as an additional predictor of intention, with results showing no substantive change in estimated relationships and indicating model stability (Pearl, 2009; Wooldridge, 2002).

## ANALYSIS AND DISCUSSION

This section presents the empirical results of the PLS-SEM analysis, beginning with an assessment of the measurement model to establish construct reliability and validity before evaluating the structural relationships. Consistent with the analytical procedure described in the Methodology section, indicator reliability was first assessed using outer loadings and their statistical significance.

1. Measurement Model

In the measurement model, most indicators exhibited significant loadings above the recommended threshold of 0.70. Constructs including Habit, Environmental Norm, and Perceived Behavioural Control demonstrated acceptable measurement properties. However, indicators with low loadings for Subjective Norm (NS4-NS7) and Attitude (S6-S7) were removed in accordance with PLS-SEM best practices. The initial measurement model, prior to indicator removal, is presented in Table 5.

**Table 5**: Initial Measurement Model Before Indicator Removal

| Factor | Variable | Loading Value |
|---|---|---|
| Habit | H1 | 0.780 |
| | H2 | 0.826 |
| | H3 | 0.778 |
| Intention | I1 | 0.811 |
| | I2 | 0.785 |
| | I3 | 0.772 |
| Attitude | S1 | 0.782 |
| | S2 | 0.756 |
| | S3 | 0.831 |
| | S4 | 0.824 |
| | S5 | 0.776 |
| | S6 | 0.618 |
| | S7 | 0.640 |
| Subjective Norm | NS1 | 0.827 |
| | NS2 | 0.790 |
| | NS3 | 0.820 |
| | NS4 | -0.200 |
| | NS5 | 0.061 |
| | NS6 | 0.060 |
| | NS7 | 0.046 |
| Perceived Behavioural Control | PKP1 | 0.732 |
| | PKP2 | 0.710 |
| | PKP3 | 0.763 |
| | PKP4 | 0.796 |
| | PKP5 | 0.705 |
| | PKP6 | 0.796 |


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| Factor | Variable | Loading Value |
|---|---|---|
| | PKP7 | 0.770 |
| | PKP8 | 0.677 |
| | PKP9 | 0.743 |
| Environmental Norm | NL1 | 0.890 |
| | NL2 | 0.881 |
| | NL3 | 0.910 |

*Source: Authors' analysis (2025)*

Following the initial measurement model assessment presented in Table 5, indicators S6, S7, and NS4-NS7 were removed due to low or non-significant outer loadings. After refinement, PKP8 and PKP2 recorded outer loadings of 0.682 and 0.685, respectively, slightly below the recommended threshold of 0.70. However, both indicators were retained because of their theoretical importance and because their removal did not improve the reliability, convergent validity, or overall quality of the measurement model. Reliability and validity were subsequently reassessed using the refined measurement model. The results are presented in Table 6.

**Table 6:** Measurement Model After Indicator Removal

| Factor | Variable | Loading Value |
|---|---|---|
| Habit | H1 | 0.770 |
| | H2 | 0.825 |
| | H3 | 0.789 |
| Intention | I1 | 0.812 |
| | I2 | 0.789 |
| | I3 | 0.767 |
| Attitude | S1 | 0.854 |
| | S2 | 0.823 |
| | S3 | 0.853 |
| | S4 | 0.832 |
| | S5 | 0.811 |
| | S6 | *removed* |
| | S7 | *removed* |
| Subjective Norm | NS1 | 0.834 |
| | NS2 | 0.790 |
| | NS3 | 0.834 |
| | NS4 | *removed* |
| | NS5 | *removed* |
| | NS6 | *removed* |
| | NS7 | *removed* |
| Perceived Behavioural Control | PKP1 | 0.754 |
| | PKP2 | 0.685 |
| | PKP3 | 0.767 |
| | PKP4 | 0.797 |

| Factor | Variable | Loading Value |
|---|---|---|
| | PKP5 | 0.734 |
| | PKP6 | 0.822 |
| | PKP7 | 0.791 |
| | PKP8 | 0.682 |
| | PKP9 | 0.797 |
| Environmental Norm | NL1 | 0.890 |
| | NL2 | 0.881 |
| | NL3 | 0.909 |

*Source: Authors' analysis (2025)*

2. Reliability & Validity Testing

Following indicator refinement, Composite Reliability (CR), Average Variance Extracted (AVE), and Cronbach's Alpha were recalculated for all constructs. Composite Reliability (ρc) values exceeded 0.70 and AVE values exceeded 0.50 for all constructs. Although the Cronbach's Alpha and rho_A values for Intention (0.698) were marginally below the recommended threshold, the construct remained acceptable given its Composite Reliability (ρc = 0.832).

**Table 7:** Reliability & Convergent Validity Assessment

| Construct | Cronbach's Alpha | Composite Reliability (rho_a) | Composite Reliability (rho_c) | Average Variance Extracted (AVE) |
|---|---|---|---|---|
| Intention | 0.698 | 0.698 | 0.832 | 0.624 |
| Habit | 0.709 | 0.710 | 0.837 | 0.632 |
| Environmental Norm | 0.874 | 0.878 | 0.922 | 0.798 |
| Subjective Norm | 0.756 | 0.758 | 0.860 | 0.672 |
| Perceived Behavioural Control | 0.899 | 0.902 | 0.918 | 0.585 |
| Attitude | 0.891 | 0.892 | 0.920 | 0.697 |

*Source: Authors' analysis (2025)*

Predictive relevance was assessed using the $Q^2$ criterion. All endogenous constructs recorded $Q^2$ values greater than zero, indicating satisfactory predictive relevance. Intention exhibited the highest predictive relevance ($Q^2$ = 0.528), followed by Habit ($Q^2$ = 0.459) and Behavioural Reluctance to Use LRT ($Q^2$ = 0.349). These findings suggest that the model demonstrates adequate predictive capability for the endogenous constructs included in the study.

**Table 8:** Predictive Relevance


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| Construct | $Q^2$ |
|---|---|
| Intention | 0.528 |
| Habit | 0.459 |
| Behavioural Reluctance to Use LRT | 0.349 |

*Source: Authors' analysis (2025)*

3. Measurement Model Evaluation

The HTMT assessment identified potential discriminant validity concerns among Intention, Habit, Subjective Norm, and Attitude, as several HTMT values exceeded the conservative threshold of 0.90. These results suggest a degree of conceptual overlap among the constructs.

Most retained indicators exceeded the recommended outer loading threshold of 0.70, while PKP2 and PKP8 recorded slightly lower values of 0.685 and 0.682, respectively. As shown in Table 9, all retained indicators loaded more strongly on their assigned constructs than on any alternative construct, thereby satisfying the cross-loading criterion. Although the cross-loading criterion was satisfied, this result does not override the HTMT assessment. Discriminant validity therefore remains inconclusive for the affected constructs.

**Table 9:** Cross-loading Assessment

| Indicator | Intended Construct | Own Loading | Highest Cross-Loading | Cross-Loading Value | Gap |
|---|---|---|---|---|---|
| H1 | Habit | 0.770 | Intention | 0.688 | 0.082 |
| H2 | | 0.825 | | 0.715 | 0.110 |
| H3 | | 0.789 | Attitude | 0.683 | 0.106 |
| I1 | Intention | 0.812 | | 0.717 | 0.095 |
| I2 | | 0.789 | | 0.720 | 0.069 |
| I3 | | 0.767 | | 0.728 | 0.039 |
| NL1 | Environmental Norm | 0.890 | Perceived Behavioural Control | 0.759 | 0.131 |
| NL2 | | 0.881 | | 0.714 | 0.167 |
| NL3 | | 0.909 | | 0.756 | 0.153 |
| NS1 | Subjective Norm | 0.834 | Attitude | 0.661 | 0.173 |
| NS2 | | 0.790 | | 0.743 | 0.047 |
| NS3 | | 0.834 | | 0.735 | 0.099 |
| PKP1 | Perceived Behavioural Control | 0.754 | Environmental Norm | 0.734 | 0.020 |
| PKP2 | | 0.685 | | 0.662 | 0.023 |
| PKP3 | | 0.767 | | 0.706 | 0.061 |
| PKP4 | | 0.797 | | 0.676 | 0.121 |

| Indicator | Intended Construct | Own Loading | Highest Cross-Loading | Cross-Loading Value | Gap |
|---|---|---|---|---|---|
| PKP5 | | 0.734 | | 0.725 | 0.009 |
| PKP6 | | 0.822 | | 0.702 | 0.120 |
| PKP7 | | 0.791 | | 0.741 | 0.050 |
| PKP8 | | 0.682 | | 0.606 | 0.076 |
| PKP9 | | 0.797 | | 0.704 | 0.093 |
| S1 | | 0.854 | | 0.692 | 0.162 |
| S2 | | 0.823 | | 0.677 | 0.146 |
| S3 | Attitude | 0.853 | Intention | 0.708 | 0.145 |
| S4 | | 0.832 | | 0.735 | 0.097 |
| S5 | | 0.811 | | 0.703 | 0.108 |

*Source: Authors' analysis (2025)*

The HTMT assessment indicated that discriminant validity was not fully established, particularly among Attitude, Subjective Norm, Intention, and Habit. However, all retained indicators loaded more strongly on their intended constructs than on alternative constructs, while internal consistency reliability and convergent validity remained acceptable. Because indicator removal reduced construct reliability and weakened the theoretical representation of the core TPB constructs, the original constructs were retained. Consequently, structural relationships involving the affected constructs are interpreted as provisional and should not be regarded as definitive evidence of empirically distinct effects.

**Table 10:** HTMT Matrix

| Construct | Intention | Habit | Behavioural Reluctance to Use LRT | Environmental Norm | Subjective Norm | Perceived Behavioural Control | Attitude |
|---|---|---|---|---|---|---|---|
| Intention | | | | | | | |
| Habit | 0.950 | | | | | | |
| Behavioural Reluctance to Use LRT | 0.412 | 0.346 | | | | | |
| Environmental Norm | 0.262 | 0.167 | 0.564 | | | | |
| Subjective Norm | 0.974 | 0.914 | 0.328 | 0.341 | | | |
| Perceived Behavioural Control | 0.144 | 0.144 | 0.472 | 0.537 | 0.136 | | |
| Attitude | 0.881 | 0.781 | 0.249 | 0.354 | 1.016 | 0.141 | |

*Source: Authors' analysis (2025)*

4. Structural Model Evaluation


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All predictor constructs exhibited VIF values below 2.170, which is well below the commonly accepted threshold of 5.0. These results indicate that multicollinearity is unlikely to affect the estimated structural relationships.

5. Path Coefficient & Hypothesis Testing

The bootstrapping results indicate that Attitude and Subjective Norm are positively and significantly associated with Intention, supporting H1 and H2. Perceived Behavioural Control exhibits a significant negative association with Intention, contrary to the hypothesised direction; therefore, H3 is not supported. Environmental Norm is not significantly associated with Intention and therefore does not support H4. Furthermore, both Intention and Perceived Behavioural Control are significantly associated with Behavioural Reluctance to Use LRT, supporting H5 and H6. Among the structural relationships examined, Perceived Behavioural Control exhibits the strongest association with Behavioural Reluctance to Use LRT. The detailed bootstrapping results are presented in Table 13.

6. Explanatory Power ($R^2$)

Explanatory power was assessed using the coefficient of determination. The model explained 58.3% of the variance in Intention, 49.5% in Habit, and 35.9% in Behavioural Reluctance to Use LRT.

**Table 11:** R-squared ($R^2$) Assessment

| R Square | Value |
|---|---|
| Intention | 0.583 |
| Habit | 0.495 |
| Behavioural Reluctance to Use LRT | 0.359 |

*Source: Authors' analysis (2025)*

7. Effect Size ($f^2$)

The $f^2$ analysis indicates that Perceived Behavioural Control had the largest substantive association with Behavioural Reluctance to Use LRT ($f^2 = 0.365$), representing a large effect size. Subjective Norm demonstrated a medium effect on Habit ($f^2 = 0.160$). All other relationships exhibited small effects ($f^2 = 0.039$–$0.142$), while the effect of Habit on Behavioural Reluctance to Use LRT was negligible ($f^2 = 0.009$).

The inclusion of Habit served an exploratory purpose. Although the model explained 49.5% of the variance in Habit, the effect of Habit on Behavioural Reluctance to Use LRT was negligible ($f^2 = 0.009$), suggesting that habitual tendencies were less strongly associated with the dependent variable than perceived behavioural control and intention. These results suggest that

perceptions of behavioural control are more strongly associated with Behavioural Reluctance to Use LRT than attitudinal, normative, or habitual factors.

**Table 12:** Effect Size Assessment ($f^2$)

| Path | $f^2$ | Interpretation |
|---|---|---|
| Intention towards Behavioural Reluctance to Use LRT | 0.083 | Small |
| Habit towards Behavioural Reluctance to Use LRT | 0.009 | Negligible |
| Environmental Norm towards Intention | 0.070 | Small |
| Environmental Norm towards Habit | 0.041 | Small |
| Subjective Norm towards Intention | 0.142 | Small |
| Subjective Norm towards Habit | 0.160 | Medium |
| Perceived Behavioural Control towards Intention | 0.085 | Small |
| Perceived Behavioural Control towards Habit | 0.045 | Small |
| Perceived Behavioural Control towards Behavioural Reluctance to Use LRT | 0.365 | Large |
| Attitude towards Intention | 0.113 | Small |
| Attitude towards Habit | 0.039 | Small |

*Source: Authors' analysis (2025)*

8. Robustness Check: Omitted Variable Bias (OVB)

To assess model robustness, age was incorporated as a control variable. The inclusion of this variable produced no substantial changes in the estimated path coefficients or $R^2$ values, and no significant associations were observed between age and the endogenous constructs. These findings provide evidence of the stability of the estimated relationships, although they should be interpreted as a sensitivity assessment rather than conclusive proof of the absence of omitted variable bias.

9. Hypothesis Testing Summary

The bootstrapping results indicate that Attitude and Subjective Norm are positively and significantly associated with Intention, supporting H1 and H2. Perceived Behavioural Control exhibits a significant negative relationship with Intention ($\beta$ = -0.198, 95% CI [-0.362, -0.011], p = 0.024), contrary to the hypothesised direction; therefore, H3 is not supported. Because higher scores represent weaker perceived behavioural control and weaker intention, the negative coefficient indicates a relationship opposite to the hypothesised direction. H3 is therefore not supported despite being statistically significant.

Environmental Norm is not significantly associated with Intention, as the confidence interval includes zero ($\beta$ = 0.209, 95% CI [-0.029, 0.422], p =


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0.069). Therefore, H4 is not supported. Intention is positively and significantly associated with Behavioural Reluctance to Use LRT (β = 0.283, 95% CI [0.036, 0.564], p = 0.040), supporting H5. Perceived Behavioural Control also demonstrates a significant positive association with Behavioural Reluctance to Use LRT (β = 0.526, 95% CI [0.440, 0.641], p < 0.001), supporting H6. Given the barrier-oriented coding of the questionnaire, the positive coefficient indicates that weaker perceived behavioural control, or stronger perceived constraints, is associated with greater Behavioural Reluctance to Use LRT.

**Table 13:** Structural Path Coefficients and Hypothesis-Testing Results

| Hypothesis | Path | β (O) | M | STDEV | t | 95% CI | p | Decision |
|---|---|---|---|---|---|---|---|---|
| H1 | Attitude towards Intention | 0.391 | 0.404 | 0.115 | 3.403 | [0.173, 0.629] | 0.001 | Supported |
| H2 | Subjective Norm towards Intention | 0.442 | 0.433 | 0.096 | 4.598 | [0.238, 0.616] | <0.001 | Supported |
| H3 | Perceived Behavioural Control towards Intention | -0.198 | -0.185 | 0.088 | 2.262 | [-0.362, -0.011] | 0.024 | Not Supported |
| H4 | Environmental Norm towards Intention | 0.209 | 0.197 | 0.115 | 1.821 | [-0.029, 0.422] | 0.069 | Not Supported |
| H5 | Intention towards Behavioural Reluctance to Use LRT | 0.283 | 0.292 | 0.138 | 2.052 | [0.036, 0.564] | 0.040 | Supported |
| H6 | Perceived Behavioural Control towards Behavioural Reluctance to Use LRT | 0.526 | 0.541 | 0.051 | 10.286 | [0.440, 0.641] | <0.001 | Supported |

*Source: Authors' analysis (2025)*

This study examines factors associated with Behavioural Reluctance to Use LRT among residents of TOD apartment developments located within walking distance (<800 m) of Jabodebek LRT stations. The results indicate that Attitude and Subjective Norm are significantly associated with Intention, while Perceived Behavioural Control exhibits a significant negative association with Intention. Furthermore, both Intention and Perceived Behavioural Control are significantly associated with Behavioural Reluctance to Use LRT, with Perceived Behavioural Control emerging as the strongest statistical predictor. These findings suggest that physical access alone may be insufficient to explain Behavioural Reluctance to Use LRT among TOD residents (Donald et al., 2014; Hu et al., 2021; Yuda Bakti et al., 2020).

The strong role of subjective norms highlights the salience of social influence in dense residential settings, consistent with prior evidence that intention is shaped by shared social and peer environments (Ismael & Duleba, 2021; Mayo & Taboada, 2020). Perceived Behavioural Control exhibits a significant negative association with Intention and a strong positive association

with Behavioural Reluctance to Use LRT, suggesting that perceived constraints may be associated with both behavioural motivation and behavioural outcomes. These findings are consistent with previous studies emphasising the importance of operational factors such as reliability, connectivity, and convenience in public transport decision-making (Ali et al., 2023; Frank et al., 2005; Prayogi & Lissimia, 2021; Schlossberg & Brown, 2004; Yuda Bakti et al., 2020).

The negligible effect of Habit on Behavioural Reluctance to Use LRT, together with the non-significant association between Environmental Norm and Intention, suggests that behavioural reluctance in TOD contexts may be more strongly associated with practical considerations than with habitual or value-based motivations (De Oña et al., 2015; Frank et al., 2005; Gomez et al., 2019; Hu et al., 2021; Uddin et al., 2023).

These findings are also consistent with the TOD and built-environment literature, which suggests that density, land-use mix, and proximity increase opportunities for public transport use but do not necessarily correspond with lower Behavioural Reluctance to Use LRT (Murray et al., 1998; Shi & Zeng, 2025; Zhang, 2025). Behavioural Reluctance to Use LRT appears to be associated with perceptions of convenience, accessibility, and ease of use (Frank et al., 2005; Prayogi & Lissimia, 2021; Schlossberg & Brown, 2004).

In the Indonesian context, particularly within the Jabodebek LRT corridor, these findings suggest a shift in emphasis from TOD as a spatial planning concept towards TOD as a performance-oriented transport system. Efforts to improve perceived behavioural control may include improvements in service reliability, headway consistency, and first- and last-mile connectivity, as these factors are likely to be associated with users' perceptions of convenience and feasibility (Frank et al., 2005; Prayogi & Lissimia, 2021; Schlossberg & Brown, 2004).

**Table 14:** Descriptive Statistics

| Variable | Mean | Std. Dev | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|
| | | | **Statistics** | **Std. Error** | **Statistics** | **Std. Error** |
| Pedestrian Quality | 2.39 | 0.757 | -0.048 | 0.184 | -0.389 | 0.366 |
| Feeder Connectivity | 2.49 | 0.758 | 0.120 | | -0.316 | |
| Punctuality | 2.45 | 0.701 | -0.068 | | -0.237 | |
| Headway | 2.45 | 0.685 | -0.105 | | -0.229 | |
| Real-time Information | 2.49 | 0.695 | -0.189 | | -0.211 | |

*Source: Authors' analysis (2025)*


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Several limitations should be noted. The cross-sectional design limits analysis of behavioural change over time, and self-reported data may introduce response bias. Although key TPB constructs are included, additional operational and institutional factors may also be associated with Behavioural Reluctance to Use LRT and were not included in the present model.

Additionally, the significant associations of Attitude and Subjective Norm with Intention should be interpreted cautiously because the HTMT results indicate substantial empirical overlap among these constructs. These findings may reflect closely related dimensions of respondents' overall evaluation of LRT use rather than fully distinct construct-specific effects. By contrast, Perceived Behavioural Control demonstrated adequate empirical distinction from behavioural reluctance and emerged as the strongest statistical predictor in the estimated model. The policy discussion therefore places greater emphasis on perceived feasibility and operational constraints.

**Table 15:** Recommended Actions to Improve LRT Accessibility and Use

| Priority Issue | Recommended Action | Primary Actors | Relationship to Findings |
|---|---|---|---|
| **Waiting time and service frequency** | Optimize the deployment of available rolling stock and establish a measurable service-frequency target during peak periods. Publish actual headway performance to help users assess waiting time reliability. | LRT operator, central government, infrastructure and operating partners | Responds to the strong association between Perceived Behavioral Control and Behavioral Reluctance to Use LRT |
| **Punctuality communication** | Regularly publish punctuality performance through stations, official applications, social media, and apartment communication channels. Reported operational performance should be communicated in a clear and verifiable format. | LRT operator and apartment property managers | May strengthen perceptions of service reliability and reduce uncertainty |
| **Real-time passenger information** | Improve the visibility and accuracy of arrival, disruption, and interchange information at stations and through digital platforms. Existing external applications may be retained while an integrated internal information system is developed. | LRT operator, JakLingko, relevant government agencies | Addresses informational barriers associated with Perceived Behavioral Control |
| **Travel-time efficiency** | Use operational monitoring, automated systems, and preventive maintenance to identify and reduce avoidable | LRT operator and infrastructure partners | May improve perceptions of efficiency and feasibility |

| Priority Issue | Recommended Action | Primary Actors | Relationship to Findings |
|---|---|---|---|
| | delays across the passenger journey. Performance indicators should include total journey time rather than in-vehicle time alone. | | |
| **Fare affordability** | Evaluate targeted fare packages for frequent users, apartment residents, and eligible groups rather than relying solely on general discounts. Information regarding existing discounts should also be communicated more actively within TOD apartment developments. | Central government, LRT operator, apartment property managers | Supports the financial dimension of perceived control and Intention |
| **Payment and top-up methods** | Improve the reliability of existing ticketing machines and expand functional payment channels, including interoperable cards, QR-based payments, mobile banking, and electronic wallets. | LRT operator, payment providers, and government agencies | May reduce transaction-related barriers associated with Behavioral Reluctance to Use LRT |
| **Apartment-to-station access** | Improve pedestrian routes, crossings, lighting, weather protection, wayfinding, and safe pick-up and drop-off points between apartment developments and stations. | Local government, apartment developers, property managers, and LRT operator | Supports the accessibility and convenience dimensions of Perceived Behavioral Control |
| **Parking management** | Prioritise integrated access and mobility management rather than automatically expanding parking capacity. Where park-and-ride facilities are necessary, their design and pricing should support public transport use without encouraging additional private-vehicle dependence. | Local government, property managers, developers, and transport authorities | Addresses competing incentives between private-vehicle convenience and LRT use |
| **Feeder services** | Coordinate feeder routes, schedules, pick-up points, and service information with LRT operating hours. Internal apartment feeders should be connected to a wider area-based network where operationally feasible. | Local government, LRT operator, bus and feeder operators, property managers | Responds to connectivity barriers associated with Perceived Behavioral Control |
| **Intermodal integration** | Establish clearer institutional responsibility for physical, operational, informational, and | Central and local governments, JakLingko, | Addresses fragmented responsibility |


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| Priority Issue | Recommended Action | Primary Actors | Relationship to Findings |
|---|---|---|---|
| | payment of integration between the LRT and other public transport services. | transport operators | identified in stakeholder consultations |
| **Private-vehicle dependence** | Consider progressive parking charges, maximum parking standards, public transport incentives, and the reallocation of street space towards walking, cycling, feeder services, and public transport access. | Central and local governments, developers, and property managers | May reduce the relative convenience of private vehicles while improving LRT accessibility |
| **Institutional coordination** | Create a formal coordination mechanism with defined responsibilities, service indicators, reporting requirements, and funding arrangements for station access and intermodal integration. | Central government, local governments, transport operators, developers, and property managers | Addresses institutional fragmentation across the identified interventions |

## CONCLUSION

This study examined factors associated with behavioural reluctance to use the Jabodebek LRT among residents of apartment developments located within 800 metres of LRT stations. The results indicate that physical proximity alone does not necessarily correspond with lower reluctance to use the LRT. Attitude and Subjective Norm were positively associated with Intention, whereas Perceived Behavioural Control was negatively associated with Intention, contrary to the hypothesised direction. Environmental Norm was not significantly associated with Intention. Both Intention and Perceived Behavioural Control were significantly associated with behavioural reluctance, with Perceived Behavioural Control showing the strongest relationship in the estimated model.

The model explained 58.3% of the variance in Intention, 49.5% in Habit, and 35.9% in behavioural reluctance. The association between Perceived Behavioural Control and behavioural reluctance represents the most consistently supported relationship in the estimated model. This finding suggests that perceived operational and practical constraints, including service reliability, feeder connectivity, waiting time, payment methods, real-time information, and first- and last-mile access, warrant particular attention when examining LRT use in high-access TOD settings.

The findings involving Attitude, Subjective Norm, Intention, and Habit should nevertheless be interpreted cautiously. Although the retained indicators satisfied the cross-loading criterion, several HTMT values exceeded 0.90, indicating that discriminant validity was not fully established for these constructs.

The corresponding coefficients should therefore be regarded as provisional associations rather than distinct construct-specific effects. The cross-sectional design, purposive intercept sampling, limited respondent profile, and single-item measurement of behavioural reluctance further constrain causal interpretation and generalisability. In this study, behavioural reluctance refers specifically to self-reported non-use of the LRT for daily activities despite residential proximity to a station; it does not measure psychological resistance or observed travel frequency.

For TOD implementation, the findings support greater attention to the operational conditions that affect residents' perceived ability to use the LRT. Potential priorities include improving service frequency and punctuality, coordinating feeder services, strengthening pedestrian connections between apartments and stations, expanding integrated payment and real-time information systems, and clarifying institutional responsibilities for intermodal integration. These measures should be treated as priorities for implementation and evaluation rather than as definitive causal solutions. Future research should refine the overlapping TPB measures, incorporate more detailed socioeconomic and travel-behaviour characteristics, use observed ridership or travel-frequency data, and validate the model using longitudinal or independent samples.

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# AN EXAMINATION OF SPATIAL FACTORS AND ENVIRONMENTAL CONFIGURATION ON SOCIAL VULNERABILITY IN URBAN KAMPUNG

**Dewi Septanti[1], Dian Inayah Zahrah Pombo[2], Iftekhar Ahmed[3], Tisya Surya Narida[4], Nugraha Miftahul Bahri[5]**

[1,2,4]*Department of Architecture,*
INSITUT TEKNOLOGI SEPULUH NOPEMBER, INDONESIA
[3] *School of Architecture and Built Environment,*
UNIVERSITY OF NEWCASTLE, AUSTRALIA
[5] *Department of Business Digital,*
TELKOM UNIVERSITY, INDONESIA

## Abstract

An urban kampung represents a distinctive form of Indonesian urban settlement that functions as a complex socio-spatial environment. Despite its vibrancy, high density, limited public space, and infrastructural constraints contribute to latent social risks that are often underrepresented in formal crime statistics but are experienced through everyday spatial perceptions. This study examines gendered perceptions of social risk in Kampung Ketandan–Kebangsren, Surabaya, and evaluates the role of participatory mapping in capturing women's experiential spatial knowledge. A qualitative participatory approach was employed, combining participatory mapping, semi-structured interviews, field observation, and visual documentation. Data were analysed using thematic analysis and visualized through social risk heatmaps. The findings reveal that social risk perception is gendered and intersectional. Women tend to perceive risk as interpersonal threats in spaces characterized by low visibility, inadequate lighting, and limited natural surveillance, whereas men associate risk with social conflict and conventional crime. Although only a small proportion of respondents identified high-impact, high-probability risks, these were prioritized and predominantly reported by women. This study argues that safety in urban kampung is a relational construct shaped by spatial configuration, temporal dynamics, and embodied experiences, highlighting the need for participatory and gender-sensitive planning approaches.

***Keywords***: Urban *Kampung*, Social Risk, Spatial Safety Perception, Gender, Participatory Mapping

[1] Corresponding author. Email: dewi_septanti@its.ac.id

## INTRODUCTION

Urban kampung represents one of the most distinctive forms of urban settlement in Indonesia, shaped through long-term socio-spatial adaptation and the community's capacity to continuously negotiate spatial and resource constraints within rapidly urbanizing contexts. Unlike formally planned housing developments, urban kampung operate as complex socio-spatial systems in which residential, economic, and cultural functions are deeply interwoven into everyday life. Existing studies have emphasized their resilience and adaptive capacity in responding to urbanization pressures despite limited integration into formal planning and governance systems (Budiharjo, 1991; Anggraeni, 2010).

Kampung Ketandan–Kebangsren in Surabaya exemplifies this condition. Located within the historic Tunjungan Quadrangle, the area is characterized by extreme building density, organically formed narrow circulation networks, and a significant lack of public open space. These spatial characteristics are not the result of planned design, but rather of long-term incremental densification processes that have progressively intensified land use and spatial occupation. Consequently, the physical environment is highly constrained, producing not only environmental limitations but also shaping complex patterns of social interaction, territorial negotiation, and everyday spatial behaviour (Anggraeni, 2010). Within such densely built environments, risk cannot be reduced to a narrow interpretation of physical hazards or statistically recorded crime incidents. Contemporary risk scholarship instead conceptualizes risk as socially constructed, context-dependent, and embedded in everyday spatial practices and lived experiences (Wisner et al., 2004).

Empirical studies reinforce this shift: in informal settlements such as Kibera, Kenya, perceived insecurity shapes spatial behaviour more strongly than actual crime rates, with poor lighting, limited visual permeability, and weak natural surveillance heightening fear and avoidance (De Filippi et al., 2020). Comparable patterns emerge in Surabaya kampung, where residents may perceive high severity for risks that occur relatively infrequently (Septanti et al., 2026). Yet despite this progress, many studies still treat kampung residents as a homogeneous user group (Mohamed Saniff et al., 2026), masking differentiated vulnerabilities; gender in particular remains critically underexplored in empirical analyses of social risk in informal urban environments.

Feminist urban scholarship challenges the notion of spatial neutrality, arguing that women experience urban space through heightened vigilance that shapes their mobility, route choices, and use of time (Valentine, 1989; Koskela, 1997) pressures intensified in kampung settings by overlapping domestic, economic, and caregiving demands, and by spatial configurations that combine poor lighting with limited visual permeability (Yahya et al., 2026). Despite growing attention to participatory planning, empirical research that

systematically integrates gendered perceptions of social risk in Southeast Asian urban kampung remains scarce (Ismail et al., 2026), limiting understanding of how vulnerability is spatially produced and negotiated at the micro-scale, and how participatory methods can surface differentiated experiential knowledge (Mohamed Saniff et al., 2026).

Addressing this gap, the study positions gender not as a supplementary variable, but as a central analytical lens in understanding social risk. Specifically, this research aims to examine how women and men differently perceive social risk in Kampung Ketandan–Kebangsren, and to investigate how participatory mapping can function as a methodological instrument to surface and represent women's experiential spatial knowledge. By doing so, the study contributes to two key scholarly advancements: first, the refinement of Community-Based Participatory Risk Analysis (CBPRA) approach through the incorporation of gendered spatial experience; and second, the development of a more nuanced, empirically grounded framework for understanding social vulnerability in dense urban kampung environments.

## LITERATURE REVIEW

### Urban Kampung as Living Urban Heritage

Urban kampung in Indonesia represent a distinctive form of settlement shaped through long-term socio-spatial adaptation to economic pressures, limited land availability, and dynamic urban transformation (Anggraeni et al., 2010). Rather than being formally planned, these settlements evolve incrementally, resulting in highly compact environments where residential, economic, and social functions overlap. This multifunctional character positions urban kampung not merely as residential areas, but as complex socio-spatial systems embedded within the broader urban fabric.

The notion of living urban heritage highlights that urban kampung are not static relics, but continuously evolving environments that retain their social identity through everyday practices and collective memory (Pendlebury et al., 2015). Importantly, this perspective shifts the understanding of urban kampung from marginal or informal spaces to integral components of the city. It also implies that planning interventions should not focus solely on physical upgrading, but must consider lived experiences, spatial practices, and perceived safety among residents. These dimensions are particularly relevant when addressing vulnerable groups whose spatial experiences are often overlooked in conventional planning approaches.

### Social Risk in Dense Residential Environments

In dense residential environments, social risk often manifests in subtle and context-dependent ways that are not fully captured by formal crime statistics.


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Rather than being defined solely by measurable incidents, risk is increasingly understood as a socially constructed and experiential phenomenon shaped by spatial, social, and individual factors (Wisner et al., 2004).

In the context of urban kampung, these conditions are especially pronounced. Narrow alleys, overlapping functions, and fluctuating activity patterns create spatial environments where perceptions of safety vary across time and users. As a result, social risk becomes highly contextual, emerging from the interaction between physical configuration and everyday social practices. Moreover, risk perception is not uniform across populations. This highlights the need for analytical approaches that move beyond generalized assumptions of safety toward a more differentiated understanding of vulnerability.

**Spatial Factors and Environmental Configuration Affecting Safety**

The relationship between spatial configuration and perceived safety has been extensively explored in urban design and environmental criminology. Jacobs (1961) introduced the concept of eyes on the street, emphasizing the role of active street life and natural surveillance in creating safe environments. Newman (1972) further developed this idea through the theory of defensible space, highlighting the importance of territoriality and clear spatial boundaries in reducing crime risk.

These principles were later integrated into Crime Prevention Through Environmental Design (CPTED), which identifies key design elements such as lighting, visibility, access control, and maintenance as critical factors influencing safety (Jeffery, 1971). Complementing these approaches, space syntax theory (Hillier & Hanson, 1984; Hillier, 2004) provides a quantitative framework for analyzing spatial configuration, linking integration and connectivity to movement patterns and surveillance potential. Empirical studies suggest that spaces with low visibility, weak connectivity, and limited activity tend to be perceived as less safe, particularly by women (Hillier & Sahbaz, 2009).

Building on these theoretical perspectives, this study identifies seven key spatial parameters that influence social risk and safety perception in urban kampung: integration, lighting, vitality and diversity, active frontages, visibility, territoriality, and image and maintenance. These parameters are understood as interconnected elements that support natural surveillance, sustain social activity, and reinforce informal control mechanisms (Jacobs, 1961; Newman, 1972; Kelling & Wilson, 1982). In this research, each parameter is operationalized into observable indicators to examine their relationship with social risk hotspots in Kampung Ketandan–Kebangsren.

## METHODOLOGY

This study employs a mixed-methods approach with a participatory qualitative dominance, selected to capture social risk perception as a subjective, contextual

phenomenon tied to the bodily experiences of space users (Creswell & Plano Clark, 2018). This approach allows the integration of residents' experiential narratives with spatial representations of risk in the form of perception maps, as recommended in community-based participatory environmental safety studies (De Filippi et al., 2020).

This study involved a total of 128 participants purposively selected from residents of Kampung Ketandan–Kebangsren. The sample comprised 67 women and 61 men, distributed across three age categories: youth (age range 15-24, n = 30), adults (age range 25-59, n = 77), and elderly (>60 years, n = 21). All participants were long-term residents of the kampung (minimum 5 years of residency and holding local identity card such as KTP-KK), reflecting the study's focus on embedded, everyday spatial knowledge. Participants were recruited through purposive sampling, initiated through introductions from the local neighborhood unit (RT/RW) leadership and subsequently expanded through participant referrals to ensure adequate representation across gender and age groups. Of this total, five residents (three women, two men, spanning youth to elderly categories) took part in the participatory mapping exercise, while the remaining participants contributed through semi-structured interviews and field observation.

Data collection was conducted through several complementary techniques. Participatory mapping served as the primary method to identify locations perceived as socially risky, involving five participants, consistent with risk mapping practices in dense settlements (Chambers, 1994). This process was supplemented by semi-structured interviews to explore narratives of experience, avoidance strategies, and the meaning of safety in the daily lives of women and other groups. Additionally, observations were carried out to record actual spatial conditions such as lighting, visibility, spatial activity, and alley configurations, which have been shown to influence safety perceptions in CPTED studies (Hillier & Sahbaz, 2009; Jeffery, 1971). Visual documentation in the form of photographs was used to strengthen the linkage between subjective narratives and the physical environmental conditions.

Data analysis followed the six-phase thematic analysis procedure of Braun and Clarke (2006), moving from familiarization and initial open coding (e.g., “fear at night,” “avoidance of unlit alleys”) through candidate sub-themes (temporal risk shift, embodied physical risk, interpersonal threat, spatial ambiguity) to the three final themes reported below: gendered interpersonal threat perception, age-related embodied risk, and temporal-spatial ambiguity. Coding was conducted independently by three researchers, with discrepancies resolved through discussion to strengthen analytic reliability.

The participatory mapping results were then transformed into a social risk heatmap, serving as a visualization tool for the concentration of risk


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perceptions within the kampung, as applied in participatory safety mapping studies in informal settlements (De Filippi et al., 2020). Participatory mapping was conducted in a facilitated group session using a base map of Kampung Ketandan–Kebangsren printed at scale 1 : 500. Each of the five participants was asked to mark locations they perceived as socially risky and to annotate each point with the type of risk, the time of day it was most salient, and a brief narrative justification. These annotations were digitized as point data and imported into manual overlay for spatial aggregation. Point density was calculated using overlay-count method, producing a heatmap in which color intensity corresponds to the number of participants who independently identified a given area as risky. Hotspots reported in this paper (Hotspot 1 and 2) were selected as the two locations with the highest convergence of independent risk markings, subsequently triangulated against interview narratives and field observation. Subsequently, a more inclusive reading of social risk was performed. The entire research process adhered to the principles of participatory research ethics, including informed consent, anonymity, and sensitivity to personal experiences, to avoid reproducing social vulnerabilities in the knowledge production process (Moser, 2012).

The location of this study is Kampung Ketandan–Kebangsren, administratively located in Ketabang Subdistrict, Genteng District, Surabaya City. This area was selected because it represents the typical characteristics of an urban kampung in the city center of a major Indonesian city, characterized by high building density, limited environmental infrastructure, and the presence of relatively strong and active social networks in residents' daily lives. Furthermore, Ketandan–Kebangsren is part of the Tunjungan Square heritage area, a historic district that has developed since the colonial era and to this day maintains both residential functions and local community socio-economic activities, thus holding significant historical and cultural importance within Surabaya's urban structure (Anggraeni et al., 2010). From an urban risk perspective, previous studies have identified that social problems and theft rank highest in the high-impact, high-probability category in this area, indicating the existence of real and relevant social risks for further investigation (Septanti et al., 2026).

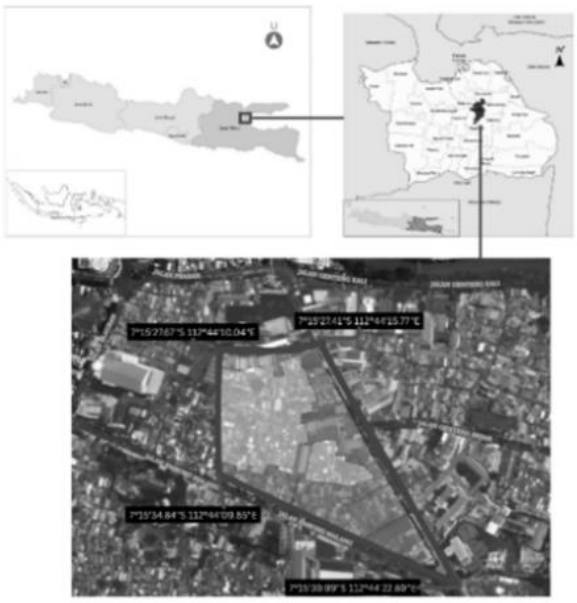


**Figure 1**: Research Location Map of Kampung Ketandan – Kebangsren
*Source: Google Earth, 2025*

## ANALYSIS AND DISCUSSION

### Social Risk Perception Patterns in Kampung Ketandan–Kebangsren

The results of the analysis show significant differences in how gender and age groups perceive social risk. Adult women tend to assess risk based on the potential for interpersonal threats, such as harassment or intimidation, especially in spaces with low visibility. In contrast, male participants more frequently associate risk with potential social conflict or conventional criminality. This perception is spatially translated into a heightened concern for locations where group interactions and territorial tensions are more likely to occur, such as busy intersections, informal gathering spots, street corners, and areas with a history of disputes or criminal incidents. These spaces are not necessarily characterized by low visibility, but rather by the presence of unfamiliar groups, competitive social dynamics, or weak social control. Thus, while women's risk perception is closely tied to spatial enclosure and visibility, men's perceptions are more strongly linked to the social function and interactional intensity of space. This difference is consistent with the findings of Koskela (1999) and Valentine (1989) regarding the gender construction of fear in public spaces.

The elderly group shows a different risk orientation, with their main focus on the physical aspects of the environment, such as uneven road surfaces, poor lighting, and the risk of falling. This finding indicates that social risk cannot


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be separated from the bodily condition of space users, as emphasized in the embodied perception approach (Pain, 2001). Thus, social risk in urban kampung is intersectional that influenced by gender, age, and physical capacity.

These differences in perception have a direct impact on patterns of space use. Women report strategies of restricting time and routes, while the elderly tend to reduce the frequency of leaving home at certain hours. These strategies show that social risk not only affects the sense of safety but also shapes mobility patterns and access to public space, as documented in feminist urban geography studies (Kern, 2020). Risk classification followed the Community-Based Participatory Risk Analysis (CBPRA) framework used in earlier studies of Surabaya kampung (Septanti et al., 2026). Each identified hazard was scored by participants on two dimensions: potential impact and likelihood of occurrence, using a 5-point Likert scale, e.g., 1 = very low to 5 = very high]. Scores of [≥3] on a dimension were classified as 'high', and scores below 3 as 'low', yielding the four-category matrix (High Impact–High Probability, High Impact–Low Probability, Low Impact–High Probability, Low Impact–Low Probability) presented in Table 1.

**Table 1:** Results of Social Risk Perception Assessment

| Hazards | High Impact High Probability | High Impact Low Probability | Low Impact High Probability | Low Impact Low Probability | SUM |
|---|---|---|---|---|---|
| **Social Problems** | 16 | 9 | 17 | 86 | 128 |
| **Men** | 6 | 8 | 6 | 41 | 61 |
| **Youth** | 3 | 3 | 3 | 5 | 14 |
| **Adult** | 3 | 3 | 3 | 29 | 38 |
| **Elderly** | 0 | 2 | 0 | 7 | 9 |
| **Women** | 10 | 1 | 11 | 45 | 67 |
| **Youth** | 3 | 0 | 7 | 6 | 16 |
| **Adult** | 5 | 0 | 4 | 30 | 39 |
| **Elderly** | 2 | 1 | 0 | 9 | 12 |

The analysis of social risk perception shows that although quantitatively only 12.5% of respondents (16 out of 128 people) placed social problems in the high impact–high probability category, this category ranked highest compared to other types of hazards, thus relatively becoming the main risk priority in residents' perception. This finding confirms that social risks including theft, social disturbances, and feelings of insecurity are perceived as the most relevant threats in the daily life of the urban kampung (Septanti et al., 2026).

When examined by respondent characteristics, it is evident that women contribute significantly to the assessment of social risk as high impact–high probability; approximately 69% of this category came from women, whether

young, adult, or elderly. This indicates that the perception of social risk is not gender-neutral but is more strongly felt and expressed by women.

This finding shows that women have higher spatial sensitivity to micro-environmental conditions, especially in transitional spaces such as connecting alleys, areas behind houses, and paths leading to public facilities. This result aligns with the research of Pain (2001), which states that women tend to map risk more broadly because their daily mobility experiences are layered and repetitive. Furthermore, the results of this study show that perceived social risk does not always correlate with physically isolated spaces. Some locations with relatively high pedestrian traffic are still perceived as risky due to low natural surveillance and the absence of a sense of spatial ownership (territoriality), as explained in the theory of defensible space (Newman, 1972).

**Local Analysis of Spatial Security in Kampung Ketandan–Kebangsren**

To move beyond a purely descriptive juxtaposition of spatial and narrative data, the two hotspots discussed below were identified through a triangulation process: locations first emerged as high-density points on the participatory heatmap, were then cross-referenced against the thematic codes generated from interview data (particularly codes relating to temporal risk shift and spatial ambiguity), and were finally verified through direct field observation of the seven spatial parameters. This triangulated procedure ensures that each hotspot represents convergence across quantitative spatial pattern, qualitative lived experience, and observed physical configuration, rather than reliance on any single data source.

The social risk heatmap generated from participatory mapping shows a concentration of risk hotspots in the kampung boundary area adjacent to the tourist corridor and the city's main road. Although this area has a high level of activity, the low social engagement of kampung residents and the lack of natural surveillance create a transitional space perceived as unsafe. This pattern supports Jacobs' (1961) argument that the mere presence of people is not enough; the quality of interaction and a sense of ownership of the space are key factors in security. This spatial visualization also reveals differences in the scale of risk perception between participant groups. Women's maps show a broader and more layered scope of risk, while men's maps are more focused on specific points. This finding reinforces Hillier and Sahbaz's (2009) approach that security analysis needs to consider how spatial configurations are interpreted differently by different user groups.


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**Figure 2:** Map of Hot Spot Area Analysis Mapping Results
*Source: Researcher, 2025*

## HOT – SPOT 1

**Location:** Around Jalan Kebangsren Gang II and Gang III



**Figure 3**: Street view of hot-spot 1
*Source: Google Maps Street Views, 2025*

The designation of Hotspot 1 as a risky area is strongly supported by participant narratives emphasizing the drastic change in the sense of safety depending on the time of day. Several adult female respondents described that during the day, this space is still considered relatively safe due to the presence of informal activities, particularly street stalls and resident foot traffic. However, this sense of safety does not continue into the night when social activity disappears and natural surveillance decreases. One adult female participant stated:

> *"During the day, it's still normal because there are stalls and people passing by. But at night, it feels different it becomes quiet and dark. If possible, I only pass through there in the afternoon, not at night."* (P1)

This quote shows that risk is not attached to the spatial form alone, but rather to the loss of continuity in social activity. This perception reinforces the spatial analysis showing that the integration of secondary paths is not sufficient to guarantee a sense of safety without the continuity of activity across time (Jacobs, 1961). Another participant also highlighted the role of inadequate lighting in reinforcing the impression of vulnerability.

> "*The lights exist, but they are dim. At night, it feels like an unmonitored alley that is very vulnerable, even though it's close to the main road."* (P2)

This narrative clarifies that Hotspot 1 is constructed as an ambiguous space: structurally connected and active during the day but experientially felt as unsafe at night. Thus, Hotspot 1 is designated not because of extreme physical isolation, but because of the asynchrony between spatial configuration and the temporal social rhythm. The analysis of each hotspot is further elaborated based on seven spatial safety parameters, namely integration, lighting, vitality and diversity, active frontages, visibility, territoriality, and image and maintenance. Each parameter is used to read the relationship between the physical conditions of space, the dynamics of social activity, and the risk perceptions expressed by participants.

**HOT – SPOT 2**
**Location: Inside Small Alleys around Jalan Ketandan Tengah**



**Figure 4**: Street view of hot-spot 2
*Source: Field Photo by Researcher, 2025*

Unlike Hotspot 1, the designation of Hotspot 2 as a risky area is based on narratives consistently describing the absence of a sense of safety throughout


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the day, not only at certain times. Participants described this narrow alley as a space that is rarely traversed, has minimal activity, and serves no social function other than residential access.

An elderly female respondent stated:

> "*In that alley, people very rarely pass by. Even during the day it's quiet, especially at night. The path is also uneven, and the lights often go out."* (P3)

**Table 2:** Comparative Analysis of Seven Spatial Safety Parameters

| Parameter | Hotspot 1 (Jl. Kebangsren Gg. II–III) | Hotspot 2 (alleys off Jl. Ketandan Tengah) |
|---|---|---|
| **Integration** | Moderately integrated secondary path; busy by day but loses social function and surveillance at night (Hillier, 2004; Brantingham & Brantingham, 1991). | Very low integration; residential-access-only alley with no compensating social control, highly vulnerable to opportunistic acts (Hillier, 2004). |
| **Lighting** | Minimal, uneven lighting weakens perceived social presence during the day-to-night transition (UN-Habitat, 2007; Cho, 2017). | Streetlights often broken; alley nearly dark at night, reinforcing a sense of a hidden, unmonitored space (UN-Habitat, 2011). |
| **Vitality & diversity** | Daytime stalls create temporary vitality that vanishes at night, an asynchrony between activity rhythm and spatial structure (Jacobs, 1961; Hillier & Sahbaz, 2008). | No non-residential activity at any time; near-zero vitality removes potential “eyes on the street” (Brantingham & Brantingham, 1991). |
| **Active facades** | The façade faces a public space, yet the openings are covered by security grilles that are oriented towards the public but remain visually passive. (Newman, 1972). | Facades closed with small, inward-oriented openings that prioritize privacy over street life (Jacobs, 1961). |
| **Visibility** | Narrow alley width and building density create fragmented sightlines, correlating with elevated micro-scale risk (Hillier & Sahbaz, 2008). | Same condition as Hotspot 1: narrow width and density fragment sightlines and correlate with elevated risk (Hillier & Sahbaz, 2008). |
| **Territoriality** | Alley gates mark private claims but narrow shared space — individually defensive rather than collective (Newman, 1972). | No clear territorial markers; semi-private space without control mechanisms is the most vulnerable typology (Newman, 1972). |
| **Image & maintenance** | Ambiguous image — some houses unkempt, signalling weak collective social control (Kelling & Cole, 1997). | Poor maintenance, uneven surfaces, and dim lighting jointly reinforce signals of neglect (Kelling & Cole, 1997). |

## DISCUSSION

**1. Perception of social risk as a spatial and gender construction**

The research findings show that perceived social risk in Kampung Ketandan–Kebangsren is not neutral but constructed through the interaction of spatial configuration, social practices, and users' embodied experience. Women tend to interpret risk as interpersonal threat harassment or intimidation, especially in low-visibility, weakly surveilled spaces, confirming Valentine (1989) and Koskela's (1999) argument that women's fear in public space is shaped by bodily vulnerability and internalized power relations.

**2. Age dimension and the embodied perception approach**

Unlike the adult group, the elderly interpret social risk primarily through the physical conditions of the environment, such as uneven road surfaces, poor lighting, and the potential for falling. This finding reinforces the embodied perception approach, which positions the body as the primary mediator in the experience of space and risk (Pain, 2001). Thus, social risk in urban *kampung* is intersectional, influenced by a combination of gender, age, and physical capacity, and cannot be understood through only one spatial or social dimension.

**3. Relevance of social risk in the daily life of urban *kampung***

This reaffirms the earlier finding that although only 12.5% of respondents classified social risk as high impact–high probability, it remained the top-ranked hazard category, with women accounting for 69% of this classification underscoring that insecurity in the kampung is fundamentally gendered (Pain, 2001; Kern, 2020; Septanti et al., 2025).

**4. The role of lighting, visibility, and maintenance as mediators of safety**

Lighting, visibility, and image and maintenance emerged as key parameters mediating the relationship between physical form and the sense of safety. Inadequate lighting and unkempt buildings reduce environmental legibility and send signals of weak social control, as explained by Nasar and Jones (1997) and Kelling and Cole (1997). This confirms that the safety of urban *kampung* depends not only on spatial morphology but also on the quality of maintenance and the social meaning attached to the space.

## CONCLUSION

This study concludes that spatial safety in urban *kampung* is a relational quality produced through the interaction between space, time, and user experience. The perception of social risk in Kampung Ketandan–Kebangsren is proven to be significantly influenced by gender and age factors, where women and the elderly show higher sensitivity to micro-spatial conditions such as visibility, lighting, and


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spatial legibility. These findings reinforce the critique of feminist urban studies against the assumption of neutral urban space and affirm the importance of the embodied perception approach in understanding social risk in dense settlements (Valentine, 1989; Pain, 2001; Kern, 2020).

Furthermore, this study shows that women's sense of safety can be positioned as a sensitive indicator of the environmental safety quality of urban *kampung*. Therefore, the planning and improvement of urban *kampung* quality need to adopt a participatory and gender-based approach, focusing on micro-interventions based on the seven-parameter spatial analysis of Hotspot 1 and 2, four concrete, site-specific interventions are recommended. First, lighting improvement should prioritize the two identified hotspots with the illuminance level of the urban pedestrian corridor was evaluated based on SNI 7391:2008, supplemented by motion-activated fixtures at the narrowest, least-trafficked segments (Hotspot 2) where continuous lighting may not be economically justified. Second, facade permeability should be improved incrementally by encouraging residents to replace solid security grilles with semi-transparent alternatives (e.g., perforated metal screens or raised window openings) at ground-floor frontages facing the alley, restoring partial visual connection between dwellings and public space without compromising residents' privacy or security concerns. Third, alley maintenance should be organized through a community-based rotating maintenance scheme, addressing uneven surfaces and signs of neglect identified in Hotspot 2, paired with small-scale infrastructure repair funded through kampung improvement program / CSR / local government budget. Fourth, a gender-sensitive safety audit should be institutionalized as a recurring practice, following the women's safety audit method (Whitzman, 2009): periodic (e.g., biannual) walkabouts led by women residents across age groups, using a structured checklist covering the seven spatial parameters identified in this study (integration, lighting, vitality, active frontages, visibility, territoriality, maintenance), with findings reported to the local neighborhood unit (RT/RW) and relevant city agencies to inform incremental kampung improvement planning

While grounded in a case study in Surabaya, these findings have broader applicability to other Indonesian cities where dense kampung settlements exhibit similar spatial characteristics, social structures, and informality. The relational nature of perceived safety identified in this study suggests that comparable patterns may also emerge in other Global South urban contexts characterized by high density, mixed-use environments, and strong community-based spatial practices. Thus, the insights from this research contribute not only to local urban discourse but also to wider discussions on inclusive and gender-responsive urban design in comparable settings beyond Indonesia. Future research is advised to develop comparative studies across urban *kampung* using

an intersectional approach and integrating spatial-quantitative data, to enrich the understanding of urban safety in the context of dense settlements in Indonesia.

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# ASSESSMENT OF CARRYING CAPACITY AND ENVIRONMENTAL CAPACITY IN EAST JAVA PROVINCE

**Ema Umilia[1], Bieby Voijant Tangahu[2], Ary Mazharuddin Shiddiqi[3]**

*[1,2]Department of Environmental Engineering,*
*[3]Department of Informatics Engineering Department,*
SEPULUH NOPEMBER INSTITUTE OF TECHNOLOGY

## Abstract

Assessing carrying capacity and environmental capacity is essential for sustainable development, especially in regions with rapid population growth and economic expansion. East Java faces increasing pressure on biophysical resources, particularly water, requiring evaluation of the balance between environmental provision and human demand. This study assesses water resources carrying capacity (WRCC) using grid-based spatial analysis and the Simple Additive Weighting method to map water availability and demand. Carrying capacity status is determined by comparing both to identify surplus and deficit conditions. However, only 30.2% of studies include water quality parameters, even though pollutant loading is a key constraint. Research in China dominates, accounting for 95.2%, while tropical regions remain underrepresented. China (95.2%), leaving tropical regions underrepresented. The main gap is the lack of integrated WRCC models that combine machine learning with uncertainty analysis. Results show spatial disparities: some areas remain sustainable, while others exceed critical thresholds. Integrating these findings into governance is crucial to prevent resource depletion.

***Keywords***: water carrying capacity; water availability; water demand; spatial analysis

[2] Corresponding author. Email: voijant@its.ac.id

## INTRODUCTION

Ecological sustainability depends on the balance between biophysical thresholds and anthropogenic pressures, particularly in jurisdictions with rapid population growth. The theoretical frameworks of carrying capacity and environmental tolerance have emerged as the primary conduits for regional planning; these structures facilitate the rigorous evaluation of whether extant natural resource bases remain congruent with human demands without precipitating irreversible degradation. In Indonesia's regulatory landscape, this approach is formalized through the Environmental Carrying Capacity and Capacity Assessment, which integrates ecological, social, and spatial dimensions into regional planning.

East Java is often cited as a paradigmatic locus for studying hydrological constraints, where the confluence of demographic density and intensified land use exacerbates strain on vital water reservoirs. Disparities in spatial distribution, coupled with rising demands from domestic and industrial sectors, necessitate a rigorous evaluation of environmental thresholds; water scarcity is thus a direct manifestation of these spatial incongruities. Scarcity remains a spatial artifact.

Environmental carrying capacity is defined through the equilibrium established between biophysical water availability and the consumptive pressures exerted by anthropogenic and economic variables. To this end, a grid-based spatial analytical framework is implemented alongside the Simple Additive Weighting protocol, enabling a granular assessment of water carrying capacity. By systematically comparing resource availability with localized demand, this approach facilitates the identification of surpluses and deficits across the regional landscape.

This investigation primarily examines the overall status of environmental capacity in East Java. To address this core objective, the following sub-queries were established:

**RQ:** *What is the status of carrying capacity and environmental capacity in East Java Province?*
**SRQ1:** *What is the spatial configuration of water availability?*
**SRQ2:** *What are the quantitative dimensions of water demand across the population?*
**SRQ3:** *To what extent does the correlation between water availability and land-use characteristics dictate regional capacity?*

## LITERATURE REVIEW

### Water Resources Carrying Capacity: Concept and Dimensions

Water resources represent a critical component of environmental carrying capacity, as they directly influence both ecological integrity and human well-being. Water Resource Carrying Capacity (WRCC) is thus interpreted as the

threshold at which a localized jurisdiction can meet demographic and fiscal demands without compromising systemic functionality. This framework is bifurcated into two primary vectors: supply-side biophysical capacity and demand-oriented consumption. Equilibrium remains the objective.

Recent studies published in Planning Malaysia: Journal of the Malaysian Institute of Planners emphasize that Water Resources Carrying Capacity (WRCC) is not solely determined by volumetric water availability but is also strongly influenced by environmental quality, spatial characteristics, and risk factors such as hydrometeorological hazards. For instance, Nurul A. Mohd Yassin et al. (2023) highlight that watershed characteristics—including slope, soil, vegetation, and land cover—play a critical role in determining flood potential and hydrological response, thereby affecting the effective carrying capacity of water systems. This indicates that WRCC must incorporate not only supply–demand balance but also landscape vulnerability and hazard exposure.

Furthermore, Bhuiyan et al. (2021) demonstrate that climate-related hazards, particularly flash floods in urban Malaysia, significantly impact socioeconomic systems and water resource stability. This suggests that WRCC should be understood as a dynamic concept influenced by climate variability and extreme events, rather than a static threshold.

In addition, Abdul Malek et al. (2020) underline the importance of integrating GIS-based spatial analysis in assessing water-related risks and carrying capacity. Spatial approaches enable more precise identification of areas with high environmental stress, supporting the argument that WRCC consists of interconnected dimensions: biophysical capacity, socioeconomic demand, environmental quality, and climate risk.

**Methodological Approaches: Spatial Analysis and Simple Additive Weighting**

Evolutionary shifts in spatial analytics and geographic information systems (GIS) have facilitated a more granular stratification of environmental carrying capacity assessments. By adopting spatial methodologies, researchers can identify regional ecological heterogeneities, enabling precise detection of localized disequilibrium between resource inventories and demand. Within the Environmental Carrying Capacity and Capacity Assessment framework (Daya Dukung dan Daya Tampung Lingkungan Hidup – D3TLH), standardized analytical units are established using grid-based spatial constructs; these structures facilitate rigorous comparisons across divergent geographical domains.

To assess environmental service performance, particularly hydrological availability, the Simple Additive Weighting (SAW) protocol is used. This multicriteria decision-making framework synthesizes disparate environmental variables, including geomorphological traits and natural vegetation patterns, into a single composite index that reflects an ecosystem's capacity to sustain water


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supply. Within this methodology, specific weights are assigned to individual parameters and aggregated to formulate an index of service provision; these results are subsequently distributed across the grid-cell architecture. This systemic aggregation rigorously interrogates the multifarious drivers of water availability. Evaluation remains strictly objective.

## RESEARCH METHODOLOGY

### Study Area and Analytical Framework

This study focuses on East Java Province, Indonesia, a region characterized by diverse land use, high population density, and significant economic activity. The analytical framework adopts a supply–demand approach, where water availability represents environmental supply, and water demand represents anthropogenic pressure. The assessment uses a spatially explicit, grid-based system, enabling identification of spatial variations in carrying capacity across the region. The overall process consists of four main phases: (1) data collection and variable identification, (2) calculation of total water demand, (3) analysis of carrying capacity and environmental limits, and (4) determination of status and final classification.

### Data Collection and Variable Identification

The first phase involves identifying key variables representing both water demand and water availability.

Water demand variables include:

1. Population data, used to estimate domestic water demand.
2. Land use/land cover data, particularly agricultural land, used to estimate economic water demand.
3. Water requirement standards, including per capita water demand for a decent living standard and agricultural water requirements based on crop types and cropping intensity.

Water availability variables are derived from environmental characteristics influencing water provisioning services, including:

1. Landscape characteristics (e.g., slope, geomorphology),
2. Natural vegetation cover,
3. Existing land cover conditions.

Water availability is defined as usable water availability, representing the volume of water that can be sustainably utilized within each spatial unit.

**Calculation of Water Demand**
Total water demand is calculated as the sum of domestic and land-based economic water demand.

**Domestic Water Demand (DWD)**
Domestic water demand was calculated based on population and the applicable per-capita water requirement standard:

$$DWD_i = P_i \times q$$

where $DWD_i$is domestic water demand in a grid cell $i$(m³/year), $P_i$is the population in grid cell $i$(persons), and $q$is the per-capita water requirement (m³/person/year).

**Land-Based Economic Water Demand (EWD)**
Land-based economic water demand was calculated according to the area of each land-use category and its corresponding water requirement:

$$EWD_i = \sum_{k=1}^{m} A_{ik} \times q_k$$

where $EWD_i$is economic water demand in grid cell $i$(m³/year), $A_{ik}$is the area of land-use category $k$within the grid cell $i$(ha or m²), and $q_k$is the water requirement coefficient for land-use category $k$(m³/area/year).

**Total Water Demand (TWD)**
Total water demand is calculated as:

$$TWD_i = DWD_i + EWD_i$$

The resulting grid-level values are subsequently aggregated to the regency/city level:

$$TWD_r = \sum_{i=1}^{n} T\,WD_i$$

where $TWD_r$represents total water demand within an administrative unit $r$.

**Estimation of Water Availability**
Water availability is assessed using an environmental service index approach that represents ecosystems' capacity to provide water. The analysis applies the Simple


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Additive Weighting (SAW) method to integrate multiple environmental parameters.

The water availability index was developed using three groups of environmental criteria: landscape characteristics, vegetation cover, and existing land-cover conditions. Each criterion was transformed into a standardized score to allow comparison among spatial units. We selected the criteria because they represent key environmental characteristics that affect an area's capacity to provide and retain water.

We combined the standardized scores for each criterion using the Simple Additive Weighting (SAW) method. The general formulation is:

$$WSI_i = \sum_{j=1}^{n} w_j \, r_{ij}$$

where $WSI_i$is the Water Service Index for grid cell $i$, $w_j$is the weight assigned to criterion $j$, and $r_{ij}$is the standardized score of criterion $j$for grid cell $i$.

The weights and scoring scheme were determined based on the criteria applied in the D3TLH assessment of East Java Province. The weighting procedure ensures that each environmental parameter's contribution is explicitly represented in the resulting index.

**Analysis of Carrying Capacity and Environmental Limits**

**Population Threshold (PT)**

The population threshold represents the maximum population that available water resources can support:

$$PT = \frac{WA}{W_s}$$

where:
$WA$= water availability
$W_s$= per capita water requirement

**Water Utilization Index (WUI)**

The Water Utilization Index reflects the ratio between water demand and availability:

$$WUI_i = \frac{TWD_i}{WA_i}$$

where $WUI_i$is the Water Utilization Index of grid cell $i$, $TWD_i$is total water demand, and $WA_i$is usable water availability.

A WUI value below 1 indicates that water demand remains below the available water supply, whereas a value above 1 indicates that demand exceeds the estimated usable water availability. A value approaching 1 indicates that demand and availability are relatively balanced.

**Determination of Status and Classification**

The final phase determines carrying capacity and environmental capacity by comparing water availability and water demand.

For the final classification, the water balance is calculated as:

$$WB_i = WA_i - TWD_i$$

where $WB_i$is the water balance of the grid cell $i$. Positive values indicate a surplus, while negative values indicate a deficit.

The classification criteria are defined as follows:

1. Surplus: $WA > TWD$(water availability exceeds demand)
2. Critical: $WA \approx TWD$(balanced condition)
3. Exceeded (Overshoot): $WA < TWD$(demand exceeds availability)

We applied the classification consistently to each grid cell and then aggregated it to the administrative level. The classification describes the relationship between estimated water supply and demand. It should therefore be interpreted as a spatial carrying-capacity assessment rather than a direct measurement of physical water scarcity at a specific point in time.

**Spatial Analysis and Mapping**

All variables and calculations are processed using Geographic Information Systems (GIS). The grid-based spatial approach ensures consistent analysis and allows detailed identification of spatial disparities in water availability, water demand, and carrying capacity status. The final outputs include thematic maps of:

1. Water availability
2. Water demand
3. Water utilization index
4. Carrying capacity status


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# ANALYSIS AND DISCUSSION

## Overview of the Included Studies

Previous studies highlight that environmental carrying capacity depends on the balance between water availability and water demand. Many studies use spatial (GIS-based) approaches and multi-criteria methods, such as the Simple Additive Weighting (SAW), to assess environmental capacity.

In Indonesia, the Environmental Carrying Capacity and Capacity Assessment framework (*Daya Dukung dan Daya Tampung Lingkungan Hidup – D3TLH*) is commonly applied to integrate resource supply and demand in a spatial context. However, most studies still analyze these components separately. Therefore, this study integrates both aspects using a grid-based spatial approach to provide a more comprehensive assessment in East Java Province.

## SRQ1: The configuration of water availability is scrutinized through the lens of geographic distribution

Water availability within the East Java administrative domain is quantified using datasets from the Environmental Carrying Capacity and Capacity Assessment (D3TLH) framework; these metrics, disseminated by the Ministry of Environment, establish the baseline for regional resource audits. The province's cumulative annual yield is documented at 32,429,028,339.04 m³. This figure represents the aggregate hydrological endowment distributed across the various regencies and municipalities.

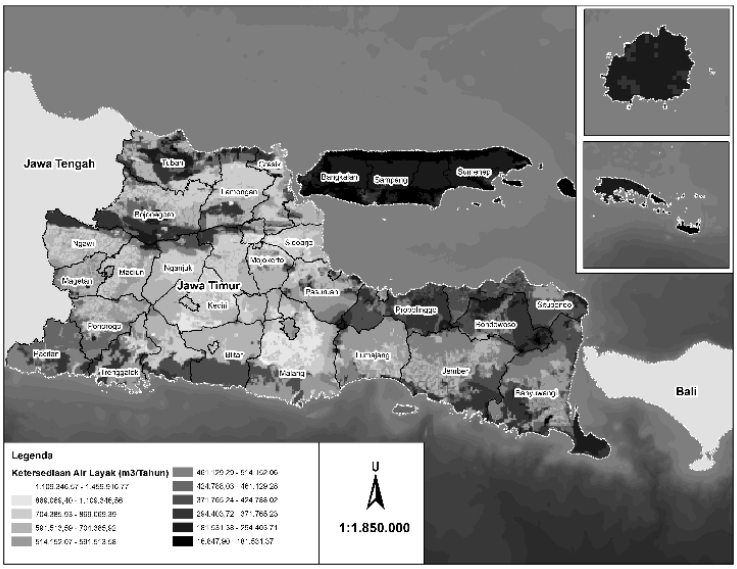



**Figure 3:** Water Availability Map of East Java Province
*Source: Authors (2026)*

**Table 1:** Availability of Usable and Contaminated Water in East Java Province

| Regency/City | Contaminated Water ($m^3$/year) | Usable Water ($m^3$/year) |
|---|---|---|
| **Bangkalan** | 28.673.830,09 | 310.180.224,44 |
| **Banyuwangi** | 96.142.539,30 | 1.906.827.029,53 |
| **Blitar** | 65.205.422,02 | 1.166.479.920,21 |
| **Bojonegoro** | 87.863.351,46 | 1.429.900.536,31 |
| **Bondowoso** | 137.952.625,34 | 677.225.684,30 |
| **Gresik** | 178.196.417,03 | 822.176.440,06 |
| **Jember** | 494.655.720,81 | 1.978.622.883,23 |
| **Jombang** | 91.866.113,15 | 853.842.278,31 |
| **Kediri** | 49.898.685,52 | 1.370.098.056,67 |
| **Batu (City)** | 5.715.761,23 | 161.951.039,31 |
| **Blitar (City)** | 1.010.123,13 | 29.296.601,54 |
| **Kediri (City)** | 2.255.157,92 | 60.896.841,98 |
| **Madiun (City)** | 2.701.042,82 | 26.386.215,65 |
| **Malang (City)** | 10.691.452,68 | 74.840.168,76 |
| **Mojokerto (City)** | 1.702.912,59 | 17.906.859,29 |
| **Pasuruan (City)** | 2.571.416,93 | 23.142.752,35 |
| **Probolinggo (City)** | 4.078.604,64 | 36.707.441,80 |
| **Surabaya (City)** | 43.919.774,97 | 261.290.614,01 |
| **Lamongan** | 91.154.316,84 | 1.300.089.835,18 |
| **Lumajang** | 102.408.479,81 | 1.228.955.012,26 |
| **Madiun** | 34.533.564,25 | 820.681.003,50 |
| **Magetan** | 120.238.605,83 | 480.954.423,32 |
| **Malang** | 71.297.229,56 | 2.780.591.952,90 |
| **Mojokerto** | 72.430.519,68 | 760.487.139,91 |
| **Nganjuk** | 75.671.964,98 | 990.580.888,11 |
| **Ngawi** | 97.761.025,01 | 992.591.696,51 |
| **Pacitan** | 86.155.654,08 | 775.400.886,73 |
| **Pamekasan** | 21.491.554,88 | 193.423.993,88 |
| **Pasuruan** | 82.185.290,05 | 974.452.535,23 |
| **Ponorogo** | 94.423.826,06 | 938.885.717,19 |
| **Probolinggo** | 309.845.904,29 | 762.693.485,41 |
| **Sampang** | 22.307.573,52 | 312.289.299,38 |
| **Sidoarjo** | 70.898.037,04 | 663.112.078,29 |
| **Situbondo** | 15.018.592,24 | 856.129.449,56 |
| **Sumenep** | 66.438.597,09 | 597.947.373,85 |
| **Trenggalek** | 113.305.344,62 | 805.039.157,05 |
| **Tuban** | 97.631.572,19 | 1.126.435.280,78 |
| **Tulungagung** | 101.725.845,05 | 808.491.093,51 |

*Source: Environmental Carrying Capacity and Environmental Capacity of East Java Province (2025)*


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Of this aggregate, the fraction identified as anthropogenically viable totals 29,377,003,890.32 $m^3$ annually. Conversely, an estimated 3,052,024,448.72 $m^3$ is classified as degraded, indicating water resources that remain unsuitable for direct use without intensive remediation. This bifurcation underscores the critical intersection of volumetric abundance and qualitative integrity. Measuring supply alone is insufficient.

Spatial heterogeneity is particularly pronounced when examining regional sub-sectors. Malang Regency sustains the largest reservoir of viable water at 2,780,591,952.90 $m^3$ per year; this surplus aligns with its robust forest density, mountainous topography, and resulting hydrological stability. In stark contrast, Mojokerto City sits at the lower end of this spectrum, recording a mere 17,906,859.29 $m^3$. This limitation largely stems from constricted administrative boundaries and the prevalence of impervious surfaces common in urbanized centers.

Qualitative degradation follows a distinct spatial logic within the dataset. Jember Regency has the largest volume of polluted water, at 494,655,720.81 $m^3$; this concentration suggests intensified environmental stress, likely from agricultural runoff and land-use conversion. Conversely, the minimal polluted volume identified in Blitar City, totaling 1,010,123.13 $m^3$, signals a localized preservation of hydrological standards.

The overarching spatial configuration of these resources demonstrates a clear divergence between ecological strongholds and urbanized interstices. Systems characterized by upland topography and dense vegetative cover maintain superior hydrological solvency. However, these findings vary, so resource management protocols must be spatially differentiated. Ensuring long-term sustainability requires a strategy sensitive to these regional variances. Precise interventions are required.

**SRQ2: The Volumetric Quantification of Consumption Requirements**

Quantifying hydraulic requirements in East Java Province requires synthesizing domestic consumption metrics with land-contingent economic pressures. While domestic demand remains tethered to demographic distribution, economic requirements are extrapolated from land-use typologies and their respective spatial footprints. This estimation is facilitated through a grid-based analytical framework; consequently, data aggregation occurs at the resolution of individual spatial units. Two distinct investigative phases were used: the first focused on domestic consumption, and the second on land-centric economic activities.

The aforementioned grid-cell methodology identified an aggregate volume of 3,687,020,139.60 $m^3$/year as the domestic threshold. These results reflect differences in urban density. Surabaya City shows a maximum requirement of 256,809,123.60 $m^3$/year, directly reflecting its concentrated

population. Conversely, Mojokerto City recorded a domestic nadir of 12,142,498.80 m³/year. This variance aligns with the latter's smaller population.

Substantially greater volumes are attributed to land-centric economic processes; the total was calculated at 43,749,237,022.12 m³/year. Expansive agrarian footprints largely drive this magnitude. Jember Regency, characterized by intensive production systems, registers the peak at 2,758,618,476.60 m³/year. Conversely, the 5,502,928.07 m³/year observed in Trenggalek Regency reflects a truncated land-use intensity.

Consolidation of these vectors yields a province-wide requirement of 47,436,257,161.72 m³/year. Jember Regency sits at the top of this demand hierarchy at 2,988,142,302.60 m³/year. In contrast, Mojokerto City represents the total minimum at 30,220,771.07 m³/year.

Ultimately, the data reveals that hydraulic appropriation in East Java is fundamentally driven by land-based economic production. Agriculture constitutes the primary pressure. These findings underscore a critical spatial stratification: integrating population dynamics and land-use characteristics is mandatory for viable resource governance. Planning must reflect these interstices.

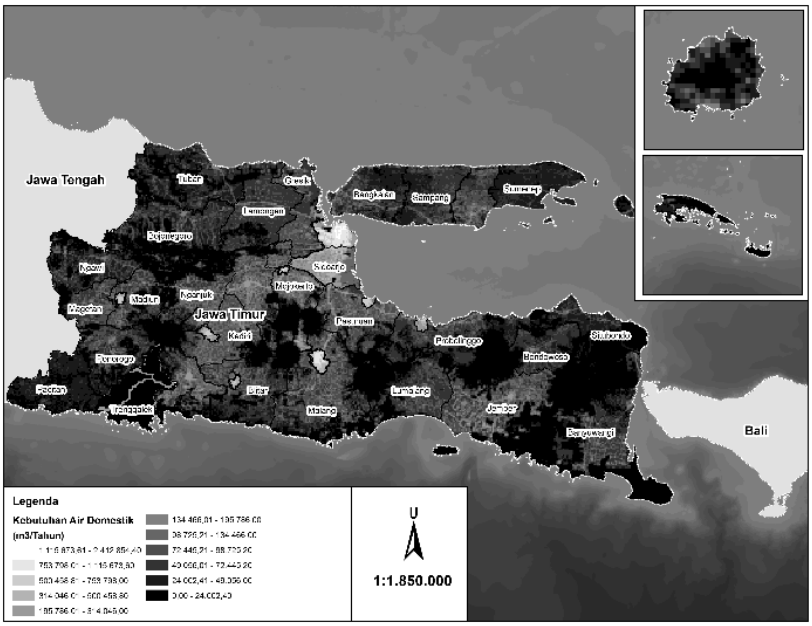



**Figure 2:** Map of Domestic Water Demand in East Java Province
*Source: Authors (2026)*


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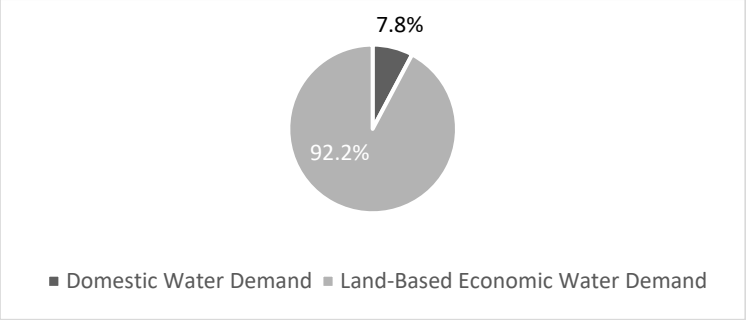



**Figure 3:** Total Water Demand in East Java Province
*Source: Authors (2026)*

The quantitative distribution in the data indicates that water requirements from terrestrial economic activities make up a clear majority in East Java Province; this segment accounts for an estimated 92.2% of the total volume. This disproportionate consumption stems from the extensive allocation of regional topography to agrarian and silvicultural activities, where maintaining irrigation networks requires persistent, high-magnitude hydro-logistic dependence. Domestic requirements remain marginal. This 7.8% allocation is a byproduct of fragmented demographic distribution; moreover, residential consumption patterns inherently lack the volume and intensity characteristic of industrial-scale cultivation. Thus, the hydro-spatial architecture of East Java Province is governed by land-centric economic pressures; consequently, optimizing agrarian water management is the underlying prerequisite for long-term ecological viability.

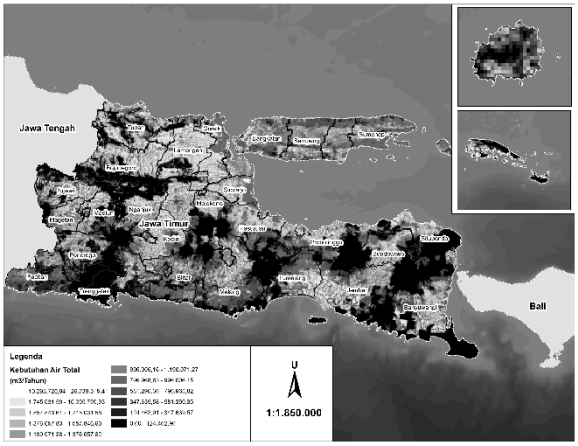



**Figure 4:** Total Water Demand Map of East Java Province
*Source: Authors (2026)*

**SRQ3: The correlation between localized water availability and varied land-use classifications**

The Water Utilization Capacity Index (Indeks Kemampuan Pemanfaatan—IKP) indicates the balance between total water demand—including domestic needs and land-based economic activities—and the availability of usable water resources. This index shows the extent to which a region can supply adequate water to support its population and economic activities without stressing or depleting water resources.

In East Java Province, the Water Utilization Capacity Index is classified as very low, with a value of 1.61. This result indicates that the province has a very limited capacity to provide sufficient, usable water to meet domestic and economic demands without leading to water scarcity.

Comparing total water availability with total water demand reveals the carrying capacity and environmental capacity of water resources. This study assesses the gap between water availability and total water demand, allowing identification of water balance conditions at both provincial and regency/city levels.

The analysis shows that East Java Province's water resources carrying capacity and environmental capacity were exceeded in 2025. Total water availability is estimated at 32,429,028,339.04 $m^3$/year, which is significantly lower than total water demand of 47,436,257,161.72 $m^3$/year. This results in a deficit (gap) of –18,059,253,271.40 $m^3$/year, indicating that water resources are insufficient to meet existing needs. This condition reflects an overall water deficit, where available resources can no longer adequately support both domestic consumption and land-based economic activities.

From a population threshold perspective, East Java Province can support the water needs of only about 38,641,727 people, while the current population has reached 42,089,271. This indicates a shortfall of 3,447,544 people, further emphasizing that existing water resources are under significant pressure and cannot sustainably meet current population demands.

Overall, these findings confirm that East Java Province is experiencing a critical imbalance between water availability and demand, highlighting the urgent need for more sustainable water resource management and policy interventions.


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**Table 2:** Water Carrying Capacity Status of East Java Province

| Regency/City | Population (inhabitants) | Water Availability ($m^3$/year) | Total Water Demand ($m^3$/year) | Status |
|---|---|---|---|---|
| **Bangkalan** | 1.112.956 | 338.854.054,53 | 1.567.247.960,91 | Exceeded |
| **Banyuwangi** | 1.764.540 | 2.002.969.568,83 | 2.646.627.309,00 | Exceeded |
| **Blitar** | 1.273.451 | 1.231.685.342,22 | 1.600.823.916,47 | Exceeded |
| **Bojonegoro** | 1.330.516 | 1.517.763.887,77 | 2.250.826.148,23 | Exceeded |
| **Bondowoso** | 796.300 | 815.178.309,64 | 1.323.451.510,36 | Exceeded |
| **Gresik** | 1.377.287 | 1.000.372.857,10 | 1.731.212.386,92 | Exceeded |
| **Jember** | 2.620.135 | 2.473.278.604,03 | 2.988.142.302,60 | Exceeded |
| **Jombang** | 1.373.793 | 945.708.391,46 | 1.364.002.279,52 | Exceeded |
| **Kediri** | 1.702.262 | 1.419.996.742,19 | 2.016.306.918,23 | Exceeded |
| **Batu (City)** | 225.120 | 167.666.800,54 | 128.698.560,17 | Not Exceeded |
| **Blitar (City)** | 156.330 | 30.306.724,68 | 39.951.880,41 | Exceeded |
| **Kediri (City)** | 301.202 | 63.151.999,90 | 93.065.620,94 | Exceeded |
| **Madiun (City)** | 203.552 | 29.087.258,47 | 45.891.485,36 | Exceeded |
| **Malang (City)** | 879.873 | 85.531.621,44 | 157.080.902,21 | Exceeded |
| **Mojokerto (City)** | 138.613 | 19.609.771,88 | 30.220.771,07 | Exceeded |
| **Pasuruan (City)** | 222.334 | 25.714.169,28 | 57.144.232,52 | Exceeded |
| **Probolinggo (City)** | 252.085 | 40.786.046,45 | 85.996.074,15 | Exceeded |
| **Surabaya (City)** | 2.931.611 | 305.210.388,98 | 507.821.825,40 | Exceeded |
| **Lamongan** | 1.386.390 | 1.391.244.152,03 | 2.561.344.969,38 | Exceeded |
| **Lumajang** | 1.152.264 | 1.331.363.492,06 | 1.566.675.363,96 | Exceeded |
| **Madiun** | 760.948 | 855.214.567,75 | 932.973.014,58 | Exceeded |
| **Magetan** | 689.209 | 601.193.029,16 | 982.273.885,13 | Exceeded |
| **Malang** | 2.755.438 | 2.851.889.182,46 | 2.894.359.051,04 | Exceeded |
| **Mojokerto** | 1.162.696 | 832.917.659,59 | 1.107.912.537,33 | Exceeded |
| **Nganjuk** | 1.138.604 | 1.066.252.853,10 | 1.300.039.722,89 | Exceeded |
| **Ngawi** | 887.172 | 1.090.352.721,52 | 1.440.412.207,03 | Exceeded |
| **Pacitan** | 589.034 | 861.556.540,81 | 1.159.216.139,68 | Exceeded |
| **Pamekasan** | 893.327 | 214.915.548,76 | 975.817.269,06 | Exceeded |
| **Pasuruan** | 1.669.400 | 1.056.637.825,28 | 1.762.470.994,79 | Exceeded |
| **Ponorogo** | 966.111 | 1.033.309.543,25 | 1.231.173.636,78 | Exceeded |
| **Probolinggo** | 1.193.272 | 1.072.539.389,71 | 1.608.883.652,67 | Exceeded |

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| | | | | |
|---|---|---|---|---|
| **Sampang** | 1.027.538 | 334.596.872,89 | 1.509.622.876,52 | Exceeded |
| **Sidoarjo** | 2.193.692 | 734.010.115,32 | 1.343.964.195,05 | Exceeded |
| **Situbondo** | 704.243 | 871.148.041,80 | 1.165.816.143,76 | Exceeded |
| **Sumenep** | 1.159.397 | 664.385.970,95 | 1.970.710.893,85 | Exceeded |
| **Trenggalek** | 747.614 | 918.344.501,67 | 70.993.914,47 | Not Exceeded |
| **Tuban** | 1.231.374 | 1.224.066.852,97 | 2.289.020.761,74 | Exceeded |
| **Tulungagung** | 1.119.588 | 910.216.938,57 | 928.063.847,49 | Exceeded |
| **Jawa Timur** | **42.089.271** | **32.429.028.339,04** | **47.436.257.161,72** | **Exceeded** |

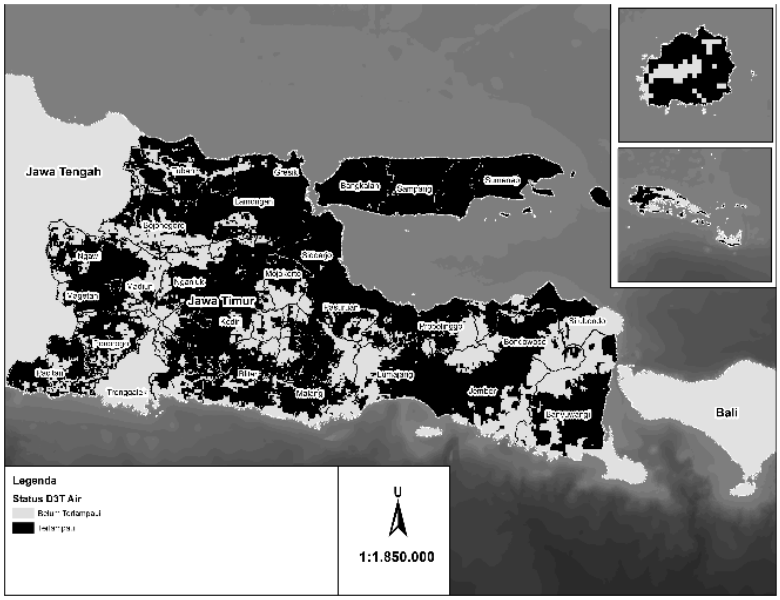



**Figure 5:** Water Carrying Capacity Status of East Java Province
*Source: Authors (2026)*

Interpret the results with several sources of uncertainty in mind. First, water availability is represented through an environmental service index and therefore reflects a spatial estimation rather than direct continuous measurements of streamflow, groundwater storage, or actual water withdrawals. Second, domestic water demand depends on population estimates and per-capita water-requirement standards. In contrast, land-based economic water demand depends on land-use classification and the corresponding water-requirement coefficients.

Third, the spatial aggregation process may influence the magnitude and distribution of estimated availability and demand. Differences in the spatial resolution of input datasets may introduce uncertainty when variables are


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standardized into a common grid. Fourth, the SAW method requires assigning criteria weights and scores, which may affect the resulting spatial index. Consequently, the carrying-capacity classification should be interpreted as an assessment based on the selected datasets, assumptions, and methodological framework for the 2025 assessment period.

Future research should incorporate temporal variability in rainfall and hydrological flows, observed water quality, actual water abstraction, climate-change scenarios, and uncertainty or sensitivity analysis to evaluate the robustness of the carrying-capacity classification.

## CONCLUSION

This study assessed total service quality and environmental challenges in East Java Province's hydrological resources using a high-resolution, grid-based spatial analysis approach. Spatial heterogeneity in water resource availability was observed: high densities in ecological preserves, while a dramatic decline occurred in highly urbanized areas. The supply-demand balance is largely determined by land-based economic productivity, with the agricultural sector being the main water consumer.

By systematically comparing resource availability to volumetric demand, the province-wide hydrological deficit is uncovered. Exceeding ecological thresholds indicates a clear excess of carrying capacity. Similar discrepancies appear in the underperforming utilization indices, as the current resource base fails to sustain the present demographic density.

This signals an urgent need for better management of water resources, carrying capacity, and land use planning to make the environment more sustainable.

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# BUILDING SURVEYORS' COMPETENCIES IN SUPPORTING SUSTAINABLE CONSTRUCTION ACROSS DEVELOPMENT PHASES: EVIDENCE FROM MALAYSIAN PRACTICE

**Siti Hamidah Husain[1], Naziah Muhamad Salleh[2*], Adi Irfan Che Ani[3], Vivian Wong Shao Yun[4]**

[1,2,4]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[3]*Faculty of Engineering and Built Environment,*
UNIVERSITI KEBANGSAAN MALAYSIA

## Abstract

Gaps in building compliance and maintenance planning often lead to performance issues after project completion. This study examines the competencies required of building surveyors in supporting sustainable construction across development phases in Malaysia. A structured questionnaire survey was administered to construction professionals from various disciplines. The data were then analysed using the Rasch Measurement Model to establish item reliability, dimensionality and competency domains. The findings indicate that building surveyors' competencies can be categorised into technical and non-technical domains. Technical domains related to building pathology, condition assessment, and maintenance management received strong endorsement, reflecting the increasing importance of life-cycle performance. Non-technical domains, including ethics and professionalism, communication, and analytical thinking, were also strongly emphasised as enabling effective coordination and decision-making. The study highlights that building surveyors' roles extend beyond technical execution to encompass sustainable construction across development phases, providing practical insights for industry, professional training, and education providers in supporting integrated sustainable development in Malaysia.

***Keywords***: Building Surveyor, Competency, Building Life Cycle, Sustainable Development, Construction Industry

[2] Corresponding author. Email: naziahmsalleh@usm.my

## INTRODUCTION

The construction industry is undergoing continuous transformation driven by sustainability requirements, regulatory expectations, and increasing demand for performance across the building life cycle. Construction project success is no longer evaluated solely in terms of time, cost and quality, but also through a broader understanding of project performance that includes the competencies of built environment professionals involved across the development process (Kiani Mavi et al. 2024). In this context, the effectiveness of construction outcomes depends not only on planning and design, but also on the competencies of professionals involved in translating planning intent into built reality. In addition, sustainable construction practices do not inherently guarantee improved environmental performance, as their effectiveness is highly dependent on how they are applied in practice (Onubi et al., 2020).

Within this context, building surveyors represent an important professional group whose roles intersect construction development, quality control, building performance, and end-users' satisfaction through inspection, assessment and technical advisory services. Their roles extend from pre-construction advisory and compliance review to construction stage inspection and post-construction performance management. This broad involvement positions building surveyors as an important link between planning, construction execution and building operation. Their responsibility includes regulatory compliance, defects management, certification processes, maintenance management, building conservation, repair, restoration, and the assessment of both new and existing buildings (Li et al., 2026). These responsibilities also position building surveyors as important contributors to sustainable construction planning, particularly in supporting continuity between planning approval, construction execution and post-occupancy building performance.

Despite this strategic role, existing competency frameworks do not fully capture the integration of technical, cognitive, and professional competencies required across development phases. As a result, the role of building surveyors in supporting sustainable construction management remains underexplored. Existing studies on professional competencies have largely focused on educational outcomes and employability, with less attention given to how such competencies contribute to planning implementation, construction control and post-construction building performance across the building life cycle. Employers and industry stakeholders have also raised concerns regarding the preparedness of building surveying practitioners and the extent to which their competencies align with evolving industry demands, particularly in relation to sustainability, regulatory compliance and life-cycle-based building management.

Many building surveying firms continue to face difficulties in recruiting suitably skilled graduate building surveyors, as the competency level of new


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entrants does not always meet industry expectations (Zaheer et al., 2021). These conditions underscore the need for clearer competency requirements that respond to sustainability, regulatory compliance, life-cycle-based building management, and employer expectations. Given the limited research in this area, this study seeks to bridge the gap by analysing the competencies of building surveyors across different stages of the construction life cycle.

## LITERATURE REVIEW

### Recent Gaps in Competencies Across Building Surveying

Employers increasingly value graduates who possess not only academic knowledge but also strong non-technical skills, including communication, adaptability, and professional behaviour. Aliu and Aigbavboa (2021) highlight that industry employers are seeking graduates with a broader range of generic competencies beyond disciplinary knowledge alone. In Malaysia, concerns over insufficient skills and competency gaps among building surveying graduates continue to affect professional readiness and performance in meeting evolving industry expectations. This issue is not limited to the Malaysian context, as growing demands within the building sector have also put pressure on global employers to recruit competent graduate building surveyors (Zaheer et al., 2021). These conditions indicate the need for further research to clarify the competencies required in building surveying practice and to strengthen the profession's capacity to respond to contemporary industry demands in Malaysia.

### A Guiding Framework for Building Surveyors' Competencies Across Construction Stages

Competencies in the construction industry are generally classified into technical and non-technical domains. Technical competencies relate to discipline-specific knowledge and functional expertise, whereas non-technical competencies refer to interpersonal, communication, behavioural and cognitive capabilities that support effective project delivery (Hasim et al., 2024). Additionally, technical competencies refer to competencies relating to specific areas of expertise and are generally acquired through formal education, training and professional experience. Non-technical competencies, also known as generic or soft skills, refer to abilities and personal attributes that are generally not specific to a particular industry or functional area (Shermon, 2004).

Boyatzis (1982) defined competency as capability or ability, while Shermon (2004) described competence as an ability based on a work task for a job output. Spencer and Spencer (1993) proposed two significant types of competency levels, which are visible and hidden. The knowledge and skill competencies tend to be visible and relative on the surface characteristics of

people, whereas self-concept, trait, and motive competencies are more hidden, and central to personality (Spencer and Spencer, 1993).

The visible competency (knowledge and skills) is referred to as technical competency required by an individual to deliver superior performance in handling tasks. The personal attributes located within the hidden layer consist of motives, traits, and self-concept, including a person's attitudes, values and self-image. These attributes may indicate an employee's probable behaviour and are generally more difficult to alter and develop. These visible and hidden competencies are also known as technical and non-technical or generic skills. Technical competency is a set of competencies relating to a specific area of expertise, which generally is acquired through some form of training, while non-technical competency which is also known as generic and soft skills, usually described as a set of abilities and personal attributes, which generally are not specific to an industry or functional area (Shermon, 2004).

In building surveying practice, both domains are essential because professional effectiveness depends not only on technical knowledge, but also on the ability to communicate, coordinate, and respond to complex project conditions. However, due to unclear competency boundaries, the industry's demand will not be met as there is no clear guideline for universities or colleges to design a curriculum that suits the industry's demands. This highlights the need to identify the current skills and competencies that are highly valued by employers in the building surveying industry in responding to industry demands.

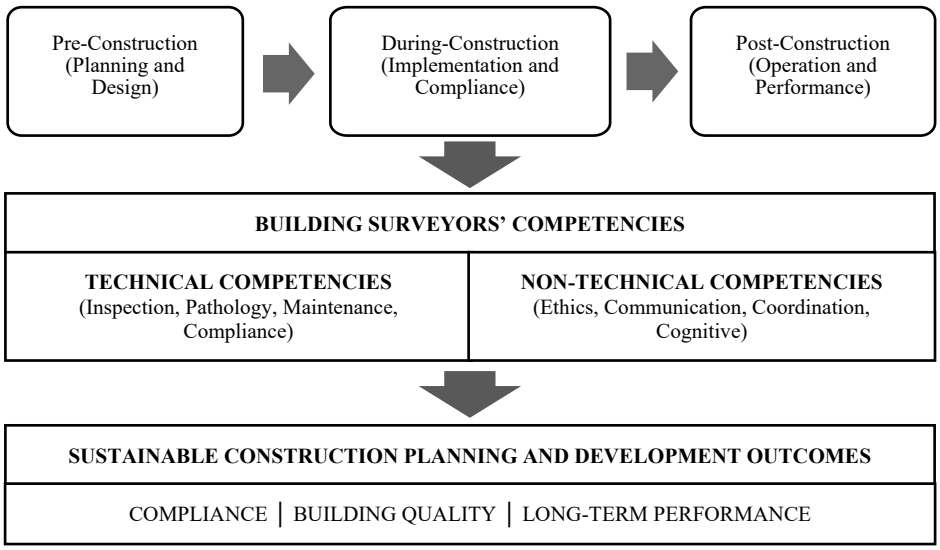



**Figure 1:** Conceptual Framework of Building Surveyors' Competencies in Sustainable Construction Planning and Development Across Construction Phases
*Source: Author's Work*


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In defining the roles and responsibilities of building surveyors across the pre-construction, construction and post-construction phases, this study proposes a conceptual framework (Figure 1) that positions building surveyors' competencies as a form of planning implementation capacity within sustainable construction planning. The framework recognises that planning effectiveness is not achieved solely through statutory approval or policy formulation, but through the continuous application of professional competencies across the development life cycle. In this sense, the framework provides a structured basis for understanding how building surveyors' competencies contribute to sustainable construction planning and development outcomes.

## RESEARCH METHODOLOGY

This study adopted a quantitative approach using a structured questionnaire survey to examine the competencies expected of building surveyors in supporting sustainable development across construction stages. A quantitative research design enables the systematic analysis of numerical data to describe, explain, predict or control variables or phenomena of interest (Creswell, 2012). The data were analysed using the Rasch Measurement Model in Winsteps. The diagnostic assessment covered person and item reliability, person and item separation, item measure quality, item polarity using point-measure correlation (PTMEA Corr), dimensionality using principal component analysis (PCA) of standardised residuals, and item fit using INFIT and OUTFIT statistics. However, differential item functioning (DIF) was not included in the present analysis because several respondent subgroups were small and unevenly distributed, which would limit stable item-level comparisons. Accordingly, the Rasch findings are interpreted at the aggregate-sample level, while future validation using larger and more balanced professional subgroups should examine item invariance through DIF analysis.

The questionnaire consisted of closed-ended items rated on a four-point Likert scale ranging from 1 (not important) to 4 (very important). A four-point Likert scale was selected to encourage clearer judgement and to avoid neutral midpoint responses, which is considered acceptable in survey-based measurement studies (Tsang, 2012; Garland, 1991). The target population comprised building surveying practitioners and built environment professionals involved in the Malaysian construction and built environment industry. A probability sampling approach was adopted to obtain industry-based responses from relevant professional groups. A total of 138 valid responses were included in the Rasch analysis. This sample exceeded the 100 respondents considered adequate for most purposes and fell within the recommended range of 64–144 respondents for item calibration precision of ±0.5 logit at a 95% confidence level, based on the Rasch sample-size guideline adopted in this study (Aziz et al., 2013).

## ANALYSIS AND DISCUSSION

### Respondent Profile

A total of 138 valid responses were obtained from professionals working in Malaysia's construction and built environment sector. The largest proportion of respondents was from private-sector organisations (58.7%), followed by higher education institutions (21.7%) and public-sector organisations (19.6%). Building surveyors formed the largest professional group (34.8%), followed by lecturers (29.7%) and construction project managers (16.7%). In terms of professional experience, 94.2% of respondents had more than three years of experience, including 32.6% with more than 12 years of experience. The profile demonstrates that the sample comprised respondents from varied organisational, professional and experience backgrounds relevant to building surveying and the built environment. Table 1 summarises the respondent profile.

**Table 1:** Profile of Respondents ($n$ = 138)

| Characteristic | Category | Frequency ($n$) | Percentage (%) |
|---|---|---|---|
| Organisation | Public sector | 27 | 19.6 |
| | Private sector | 81 | 58.7 |
| | Higher education institution | 30 | 21.7 |
| Position | Building manager | 10 | 7.2 |
| | Building surveyor | 48 | 34.8 |
| | Construction project manager | 23 | 16.7 |
| | Facilities manager | 8 | 5.8 |
| | Lecturer | 41 | 29.7 |
| | Other | 8 | 5.8 |
| Experience | Less than 3 years | 8 | 5.8 |
| | More than 3-6 years | 28 | 20.3 |
| | More than 6-9 years | 38 | 27.5 |
| | More than 9-12 | 19 | 13.8 |
| | More than 12 years | 45 | 32.6 |

*Source: Author's Calculation*

### Reliability and Validity of the Instrument

Principal component analysis (PCA) of residuals was used to examine the unidimensionality of the instrument (Figure 2). The raw variance explained by the Rasch measures was 35.9%, which exceeded the minimum acceptable threshold of 20%. The unexplained variance in the first contrast was 4.6%, indicating acceptable unidimensionality (Aziz et al., 2013; Sumintono and Widhiarso, 2013). The ratio between explained variance and unexplained variance was approximately 8:1 (35.9/4.6), surpassing the minimum 3:1 criterion for unidimensionality (McCreary et al., 2013). These PCA results were interpreted together with the reliability, separation, polarity, local dependence and item-fit diagnostics rather than as a stand-alone indication of measurement


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quality. As suggested by Árnadóttir and Fisher (2008), when the items demonstrate statistical goodness of fit with the Rasch model, the instrument can be said to be unidimensional.

Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)

| | | -- Empirical -- | | | Modeled |
|---|---|---|---|---|---|
| Total raw variance in observations | = | 316.8 | 100.0% | | 100.0% |
| Raw variance explained by measures | = | 113.8 | 35.9% | | 35.8% |
| Raw variance explained by persons | = | 61.4 | 19.4% | | 19.3% |
| Raw Variance explained by items | = | 52.3 | 16.5% | | 16.4% |
| Raw unexplained variance (total) | = | 203.0 | 64.1% | 100.0% | 64.2% |
| Unexplned variance in 1st contrast | = | 14.7 | 4.6% | 7.3% | |
| Unexplned variance in 2nd contrast | = | 11.6 | 3.6% | 5.7% | |
| Unexplned variance in 3rd contrast | = | 11.3 | 3.6% | 5.6% | |
| Unexplned variance in 4th contrast | = | 10.3 | 3.2% | 5.1% | |
| Unexplned variance in 5th contrast | = | 9.7 | 3.1% | 4.8% | |

**Figure 2:** PCA of Standardized Residual Variance (in Eigenvalue units)
*Source: Author's analysis using Winsteps*

The Rasch analysis demonstrated strong internal consistency and reliability. Cronbach's alpha (α) was 0.99 (Figure 3), which indicates that the variables and research instrument are reliable (LoBiondo-Wood and Haber, 2014). The person reliability was 0.95 (excellent), indicating that 95% of the results of the person responses would be repeated if the same respondents answered questions using an equivalent instrument (Aziz et al., 2013). In addition, the item reliability was 0.89 (good), which shows the instrument demonstrates good reliability in measuring what needs to be measured and there are sufficient items to measure an accurate reading.

Subsequently, Linacre (2006) and Fisher (2007) suggested that the accepted strata separation value for both person and item should exceed 2.0. Ariffin et al. (2010) mention that the person strata separation is used to classify people while item separation indicates the separation of item difficulty level. The person separation index was 4.45 (rounded to 4.0) (Figure 3), indicating clear differentiation among respondents along the measured continuum (Fisher, 2007; Linacre, 2006). Meanwhile, the item separation index was 2.91 (rounded to 3.0), indicating adequate differentiation among competency items.

SUMMARY OF 138 MEASURED (EXTREME AND NON-EXTREME) PERSON

| | TOTAL SCORE | COUNT | MEASURE | MODEL ERROR | INFIT MNSQ | INFIT ZSTD | OUTFIT MNSQ | OUTFIT ZSTD |
|---|---|---|---|---|---|---|---|---|
| MEAN | 709.9 | 203.0 | 3.76 | .28 | | | | |
| S.D. | 66.4 | .0 | 2.24 | .40 | | | | |
| MAX. | 812.0 | 203.0 | 9.97 | 1.82 | | | | |
| MIN. | 550.0 | 203.0 | .09 | .13 | .09 | -9.9 | .08 | -9.9 |
| REAL RMSE | .49 | TRUE SD | 2.19 | SEPARATION | 4.45 | PERSON RELIABILITY | | .95 |
| MODEL RMSE | .49 | TRUE SD | 2.19 | SEPARATION | 4.48 | PERSON RELIABILITY | | .95 |
| S.E. OF PERSON MEAN = .19 | | | | | | | | |

PERSON RAW SCORE-TO-MEASURE CORRELATION = .90
CRONBACH ALPHA (KR-20) PERSON RAW SCORE "TEST" RELIABILITY = .99

SUMMARY OF 203 MEASURED (NON-EXTREME) ITEM

| | TOTAL SCORE | COUNT | MEASURE | MODEL ERROR | INFIT MNSQ | INFIT ZSTD | OUTFIT MNSQ | OUTFIT ZSTD |
|---|---|---|---|---|---|---|---|---|
| MEAN | 482.6 | 138.0 | .00 | .19 | 1.00 | .0 | 1.02 | .0 |
| S.D. | 16.6 | .0 | .62 | .01 | .18 | 1.4 | .34 | 1.2 |
| MAX. | 519.0 | 138.0 | 1.50 | .23 | 1.48 | 3.6 | 2.90 | 5.2 |
| MIN. | 439.0 | 138.0 | -1.52 | .18 | .60 | -3.5 | .55 | -2.9 |
| REAL RMSE | .20 | TRUE SD | .58 | SEPARATION | 2.91 | ITEM RELIABILITY | | .89 |
| MODEL RMSE | .19 | TRUE SD | .59 | SEPARATION | 3.02 | ITEM RELIABILITY | | .90 |
| S.E. OF ITEM MEAN = .04 | | | | | | | | |

**Figure 3:** Summary of Statistics Results
*Source: Author's analysis using Winsteps*

## Item Fit and Item Polarity

Following the item-measure analysis, item-fit assessment was conducted on the 100 competency items with negative logit measures to determine their conformity with the Rasch model. Item fit was evaluated using point-measure correlation (PTMEA Corr), INFIT and OUTFIT mean-square (MNSQ), and standardised Z (ZSTD) statistics. The adopted acceptable ranges were $0.5 < \text{MNSQ} < 1.5$ and $-2.0 < \text{ZSTD} < +2.0$. Twenty-one (21) items initially exhibited at least one statistic outside the specified ranges. Following consideration of the item-fit diagnostics, five (5) items were identified as misfitting and excluded, while the remaining 95 items were retained as the competency set for subsequent interpretation.

Item polarity was further examined using PTMEA Corr to determine whether each competency item operated in the same direction as the underlying construct. Positive PTMEA Corr values indicate that an item is aligned with the construct being measured, whereas negative or zero values may indicate inconsistency with the intended construct. All analysed competency items recorded positive PTMEA Corr values, ranging from 0.39 to 0.65, which fell within the adopted acceptable range of 0.20 to 0.79 (Linacre, 2006; Bond & Fox,


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2007). The positive correlations therefore provided further evidence that the retained items operated consistently in measuring the intended competency construct. Table 2 summarises the Rasch measurement diagnostics.

**Table 2:** Summary of Rasch Measurement Diagnostics and Item-Retention Results

| Diagnostic | Result | Reference/Criterion Use | Interpretation |
|---|---|---|---|
| Cronbach's alpha | 0.99 | Closer to 1.0 | Excellent internal consistency |
| Person reliability | 0.95 | Rasch reliability analysis | High person reliability |
| Item reliability | 0.89 | Rasch reliability analysis | Good item reliability |
| Person separation | 4.45 | > 2.0 | Strong person differentiation |
| Item separation | 2.91 | > 2.0 | Adequate item differentiation |
| Mean item INFIT MNSQ | 1.00 | 0.5–1.5 | Acceptable aggregate item fit |
| Mean item OUTFIT MNSQ | 1.02 | 0.5–1.5 | Acceptable aggregate item fit |
| PTMEA Corr | 0.39–0.65 | 0.20-0.79: positive values | All items positively aligned with the intended construct |
| Raw variance explained | 35.9% | ≥ 20% criterion adopted | Acceptable evidence of unidimensionality |
| Initial competency items | 203 | — | Items entering the initial Rasch analysis |
| Initial competency constructs | 21 | — | Constructs represented in the initial competency skills set |
| Items with negative logit measures | 100 | Item measure < 0.00 logits | Items subjected to subsequent item-fit assessment |
| Constructs represented after item-measure screening | 18 | Representation within the negative-logit item set | Constructs represented in the retained item set after item-measure screening |
| Items initially outside specified fit ranges | 21 | MNSQ 0.5-1.5 and ZSTD -2.0 to +2.0 | Items requiring further evaluation |
| Misfitting items removed | 5 | Overall evaluation of INFIT/OUTFIT MNSQ and ZSTD | Items excluded following item-fit evaluation |
| Final retained competency items | 95 | — | Competency items retained across 18 constructs for subsequent interpretation |

*Source: Author's analysis using Winsteps*

## Key Competencies Identified by Industry

The item measure analysis was used to identify whether items within the same construct reflected similar difficulty levels or calibration values to detect any

redundant items (Aziz et al., 2013) and thus to interpret the relative level of respondents' endorsement of the competency items. Rasch item measures are expressed in logits on an interval scale, with the item mean centred at 0.00 logits as the reference point. As suggested by Bond and Fox (2007), higher or positive (+) logit values indicate competencies that were comparatively more difficult to endorse, whereas lower or negative (-) logit values indicate competencies that were comparatively easier for respondents to endorse. In this context, the logit measure reflects the relative difficulty of endorsing a competency item rather than the difficulty of performing the competency in practice.

For example, BP01 - Building Pathology recorded an item measure of -1.52 logits, indicating comparatively stronger endorsement among respondents. In contrast, BIM05 - Building Information Modelling Management (BIM) recorded +1.50 logits, indicating comparatively lower endorsement. These values are interpreted relative to the 0.00-logit reference point and are used in this study to support the identification of competencies relevant to building surveyors' contribution to sustainable construction across the development phases.

The item-measure analysis first identified 100 competency items with negative (−) logit values that were more readily endorsed by respondents, while 103 competency items with positive (+) logit values were excluded from the retained set. Three constructs represented only by positive (+) logit items were consequently excluded, namely Managerial and Entrepreneurial Skills (MES) from the non-technical domain, and BIM and Conflict Avoidance, Management, and Dispute Resolution Procedures (CAMD) from the technical domain. The subsequent item-fit assessment identified five misfitting items among the 100 negative-logit items, resulting in a final set of 95 retained competencies. A summary of selected high-priority competencies is provided in Table 3. The findings suggest that, in addressing evolving employer demands and industry challenges, the professional competency requirements for building surveyors encompass a balanced integration of both non-technical and technical competencies.

**Table 3:** Selected Competency Domains and High-Priority Items Identified by Industry

| Competency Domain | Selected High-Priority Items | Item Measure |
|---|---|---|
| **Non-technical Competency** | | |
| BSCOMP 1: Value, Ethics, and Professionalism | VEP01: Demonstrate a clear understanding of the roles, functions and professional significance of building surveyors | -1.42 |
| BSCOMP 2: Communication Skills | CS02: Present ideas clearly and confidently in both oral and written forms | -1.32 |
| BSCOMP 3: Thinking Skills | TS01: Apply critical, analytical, creative and innovative thinking in problem-solving | -1.03 |
| BSCOMP 5: Teamwork Skills | TwS01: Understand team dynamics, roles and | -.77 |


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| Competency Domain | Selected High-Priority Items | Item Measure |
|---|---|---|
| | collaboration working principles | |
| BSCOMP 4: Information Management and Lifelong Learning Skills | IMLSS03: Source, evaluate and manage relevant information from multiple sources | -.64 |
| **Technical Competency** | | |
| BSCOMP 15: Building Pathology | BP01: Apply knowledge to diagnose building defects and failure mechanisms | -1.52 |
| BSCOMP 9: Building Control Administration | BCA01: Demonstrate knowledge of regulatory requirements and building legislation, especially the Uniform Building Bylaws 1984, the Street, Drainage, and Building Act 1974, and the Local Government Act 1976 | -1.37 |
| BSCOMP 8: Building Maintenance and Management | BMM01: Demonstrate knowledge of building maintenance principles and management practices | -1.32 |
| BSCOMP 7: Building Inspection | BI01: Apply knowledge of construction, pathology, and inspection techniques in site assessments | -1.27 |
| BSCOMP 10: Risk Management and Building Audit | RMB02: Conduct and prepare a report on building conditions assessment, post-occupancy evaluation, and risk analysis | -.86 |
| BSCOMP 16: Fire Safety | FS01: Apply fire safety principles to minimise risk of fire to personal injury or death, physical loss, and adverse environmental impact | -.81 |
| BSCOMP 11: Building Works and Quality Management | BWQM10: Diagnose building defects and recommend appropriate remedial measures including structural survey | -.77 |
| BSCOMP 17: Health and Safety | HS01: Understand health and safety regulations and compliance requirements, including fire safety and workplace regulations | -.73 |
| BSCOMP 14: Conservation and Restoration | CR04: Conduct inspections to identify factors affecting conservation and restoration works | -.64 |
| BSCOMP 18: Sustainability | SuS02: Identify sustainability criteria in construction and building performance | -.44 |

Among the technical domains, competencies related to building pathology, building inspection, and building maintenance and management recorded the lowest logit values, indicating strong agreement among industry respondents. This suggests that employers place particular importance on competencies associated with defect diagnosis, understanding building failure mechanisms, preparing technical reports, and managing building performance over time. The high ranking of maintenance management competency further reflects the growing expectation for professionals to consider maintainability and operational performance from the earlier stages of planning and construction. In this regard, Sh Said et al. (2025) noted that continuous investment in training and the adoption of emerging technologies can strengthen maintenance competencies,

improve operational efficiency, and enhance overall user experience. Other technical competencies, including building control administration, risk management and building audit, fire safety, health and safety, conservation and restoration, and sustainability, were also rated as important, reinforcing the role of building surveyors in regulatory compliance, quality assurance, building safety, and strategic performance monitoring.

Non-technical competencies were similarly emphasised by respondents. Competencies related to value, ethics and professionalism, communication skills, and thinking skills were among the most readily agreed upon, indicating that industry expectations extend beyond technical execution alone. In contemporary construction and built environment practice, building surveyors frequently operate in multidisciplinary environments involving planners, consultants, contractors, regulatory authorities, and clients. As such, effective communication, sound judgement, and professional conduct are essential in ensuring that technical advice is translated into practical decisions, coordinated action, and responsible professional practice.

**Competencies Across Construction Development Phases**

Competencies should be viewed as critical resources that enable professionals to perform effectively, coordinate stakeholders, and drive development initiatives towards achieving desired outcomes (Md Rami et al., 2023). When examined across the construction development process, the findings indicate that different competency domains become more prominent at different stages of the building life cycle. Figure 4 illustrates the integration of building surveyors' roles across the construction development phases.

At the pre-construction phase, building surveyors' competencies are primarily associated with planning, regulatory compliance and early technical advice. Relevant technical competencies include Pre-Construction Building Inspection (BSCOMP 7), Building Control Administration (BSCOMP 9), Fire Safety Compliance (BSCOMP 16), Health and Safety Regulatory Knowledge (BSCOMP 17) and Sustainability Planning and Life-Cycle Cost Consideration (BSCOMP 18). These competencies enable building surveyors to contribute to early decisions concerning building condition, statutory requirements, safety, maintainability and sustainability before construction proceeds. Non-technical competencies such as communication, analytical thinking and information management also support coordination between planners, consultants, and approving authorities.

During the construction phase, the competency emphasis shifts towards implementation, inspection, quality assurance and compliance monitoring. Key technical competencies include Building Control Administration (BSCOMP 9), Building Works and Quality Management (BSCOMP 11), emerging defect diagnosis through Building Pathology (BSCOMP 15), Fire Safety Inspection and Compliance


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(BSCOMP 16) and Site Health and Safety Supervision (BSCOMP 17). Through these competencies, building surveyors support the translation of approved plans and statutory requirements into compliant construction works while identifying defects, quality deficiencies and safety issues during implementation. At this stage, teamwork, leadership, and professional communication support coordination among contractors, consultants, and regulatory bodies. Effective leadership in the construction industry requires context-sensitive capabilities that address the complexity, fragmentation and uncertainty inherent in project environments (Yang et al., 2026). The effectiveness of such sustainable leadership is also shaped by critical thinking, ethical judgement and stakeholder engagement (Abdullah et al., 2025).

At the post-construction phase, competencies become increasingly oriented towards building operation, performance, and long-term asset sustainability. Relevant technical competencies include Maintenance and Facilities Management (BSCOMP 8), Building Audit and Risk Assessment (BSCOMP 10), Building Insurance Evaluation and Damage Assessment (BSCOMP 13), Conservation and Restoration (BSCOMP 14), Advanced Building Pathology and Defect Analysis (BSCOMP 15), and Operational Sustainability Advisory (BSCOMP 18). These competencies support building performance monitoring, maintenance planning, defect diagnosis, risk assessment, conservation and sustainability-related advice throughout the operational life of the building. As highlighted by Ayob et al. (2025), building maintenance plays a fundamental role in ensuring that facilities continue to function as intended and support operational needs throughout their service life. This phase therefore highlights the continuing role of building surveyors in safeguarding asset value, user safety, and operational sustainability.

Across all three phases, Value, Ethics and Professionalism (BSCOMP 1), Communication Skills (BSCOMP 2), Thinking Skills (BSCOMP 3) and Information Management and Lifelong Learning (BSCOMP 4) operate as cross-cutting professional competencies. Rather than being confined to a particular development phase, these competencies support professional judgement, stakeholder coordination, information-based decision-making and continuous professional practice throughout the development life cycle. Figure 4 therefore illustrates building surveyors' competencies as an integrated life-cycle mechanism across pre-construction, construction and post-construction rather than isolated skill sets applied at discrete project milestones.

Taken together, the identified competencies support sustainable construction through three interrelated outcomes: regulatory compliance, building quality and long-term building performance. At the pre-construction phase, competencies in building inspection, building control, fire and health and safety requirements, and sustainability planning support informed decision-making, statutory compliance and consideration of maintainability before construction begins.

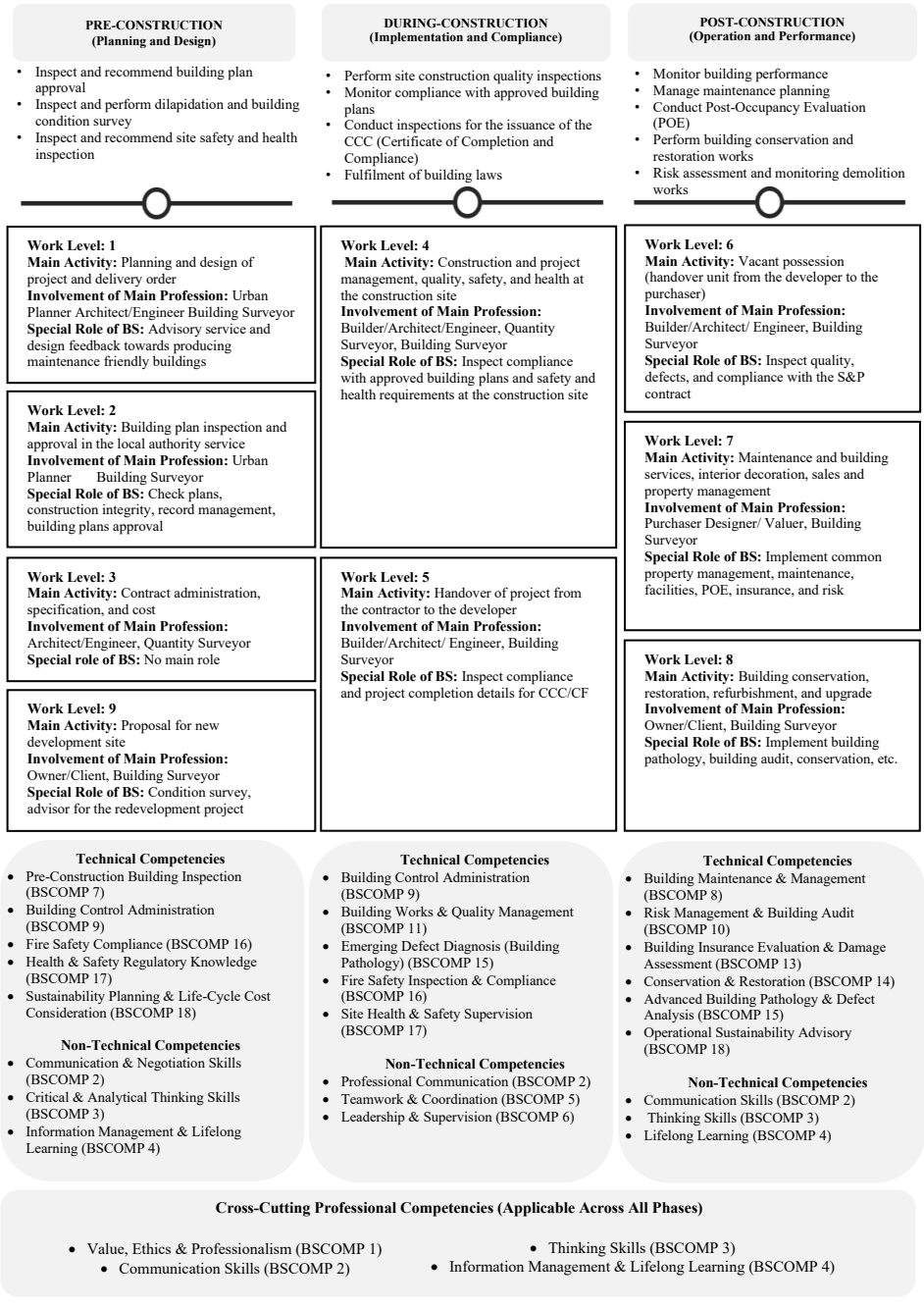



**Figure 4:** The integration of building surveyors' roles across the construction development phases
*Source: Author's Work*


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During construction, competencies in quality management, compliance monitoring, defect diagnosis and safety inspection contribute to the delivery of building works in accordance with approved requirements and acceptable performance standards. At the post-construction phase, competencies in maintenance management, building audit, risk assessment, building pathology, conservation and sustainability advisory support continued building functionality, asset performance and service-life considerations. Sustainable construction is therefore supported not by a single sustainability-specific competency, but through the combined application of technical and non-technical competencies across the building life cycle.

From a sustainability perspective, the competency framework provides a life-cycle basis for understanding how building surveyors can contribute to construction outcomes beyond project completion. Competencies associated with compliance and inspection can contribute to addressing the risk of non-compliant or deficient work, while building pathology and quality-management competencies support the identification and resolution of defects. Maintenance, audit, risk-management and sustainability competencies subsequently support the continued performance and maintainability of buildings during operation. Cross-cutting competencies in ethics, communication, analytical thinking and information management enable these technical functions to be coordinated effectively among clients, consultants, contractors, regulatory authorities and building users.

## CONCLUSION AND RECOMMENDATIONS

The findings suggest that building surveyors' competencies are not confined to a single stage of construction, but extend across the entire development life cycle, namely the pre-construction, construction, and post-construction phases. This indicates that the role of building surveyors goes beyond inspection or post-completion functions, involving broader and more continuous professional contributions throughout the development process. At the pre-construction stage, the importance of regulatory knowledge, inspection capability, and sustainability-related competencies highlights the strategic value of early professional input, particularly in shaping long-term building performance, compliance, and maintainability. During construction, competencies such as defect diagnosis, fire safety inspection, and statutory enforcement remain critical in ensuring that regulatory and design requirements are effectively upheld.

The findings also reinforce the view that sustainable construction is not achieved solely through design innovation, but through continuous monitoring, evaluation, and enforcement during implementation and beyond project completion. In the post-construction phase, competencies related to maintenance management, risk assessment, building audit, building insurance, pathology, conservation, and sustainability become increasingly significant, reflecting the

reality that building performance continues long after handover. At the same time, non-technical competencies such as ethics, communication, and professional judgement remain relevant across all phases, supporting the view that technical practice is strengthened by strong professional conduct and effective stakeholder engagement.

The identified competency set is aligned with current industry expectations and contributes a structured framework that is valuable for both professional practice and higher education. For practitioners, it offers a benchmark for competency development and professional growth throughout their careers. For universities, it provides a useful reference for curriculum design, review, and accreditation, while also supporting more consistent approaches to graduate training and assessment. Although the competency set was empirically derived from the responses of building surveying and built environment professionals and subsequently examined using the Rasch Measurement Model, the resulting phase-based competency framework was not subjected to a separate post-analysis validation by a dedicated panel of subject matter experts. This represents a limitation of the present study.

Future research should further validate the proposed framework with experienced practitioners, professional bodies, and relevant industry experts (subject matter experts) to assess the relevance, clarity and practical applicability of the identified competencies across the pre-construction, construction and post-construction phases. Such validation may further refine the framework before its wider application in professional practice, training and competency-based education. The contribution of these competencies to sustainable construction is therefore understood through their collective support for regulatory compliance, construction quality, maintainability and long-term building performance across the development life cycle. The findings do not imply that competency alone determines sustainability outcomes; rather, they demonstrate the professional capabilities through which building surveyors can contribute to achieving such outcomes.

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## DISCLOSURE STATEMENT

The authors declare that there are no conflicts of interest.

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# PRACTICES, CHALLENGES AND STRATEGIES FOR INTEGRATING GREEN BUILDING ELEMENTS INTO HERITAGE CONSERVATION: EVIDENCE FROM THE GEORGE TOWN WORLD HERITAGE SITE

**Tan Wei Ze[1], Izyan Yahaya[2*]**

[1,2]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

Heritage buildings hold significant architectural, historical and cultural values, yet their conservation increasingly demands alignment with sustainability goals. This study explores the integration of green building elements within heritage conservation, focusing on George Town, Penang, a UNESCO World Heritage Site. Using a qualitative research design, data were collected through semi-structured interviews with five purposively selected experts with relevant professional experience in heritage conservation and green building practices. Interview data were examined using narrative analysis supporting by thematic coding. The findings identified thirteen distinct green building elements currently incorporated into conservation efforts, ten major challenges hindering their integration and nine key strategies supporting successful implementation. By providing evidence-based insights, this study contributes to policy development and industry best practices, guiding practitioners toward more environmentally responsible heritage conservation. It also highlights the need to align green interventions with conservation requirements, sustainability criteria and relevant heritage approval processes while safeguarding heritage authenticity.

***Keywords***: green building element, heritage conservation, challenges, strategies, George Town, Malaysia

[2] Corresponding author. Email: izyanyahaya@usm.my

## INTRODUCTION

George Town, Penang, was designated a UNESCO World Heritage Site in 2008 and is a home to nearly 5000 heritage buildings. Beyond its historical significance, the city has embraced sustainability initiatives that align with global trends in heritage conservation and environmental stewardship (Alauddin et al., 2022; Bagheri et al., 2022). This aligns with the Penang 2030 vision, which emphasises environmental sustainability in heritage conservation. Heritage buildings in George Town, are important legacies of the past, embodying architectural, historical and cultural values that are vital to community identify and should be persevered for future generation (Abdullah et al., 2024; Husa & Harun, 2023). Numerous studies highlight the importance of maintaining the authenticity of heritage sites to retain their historical, cultural and architectural characteristics (Mohd Rahil et. al, 2020; Abdul Aziz, 2021; Al-Sakkaf et al., 2020; Husa & Harun, 2023; Mat Hasan et al., 2022).

In striving for a balanced approach to heritage site management, emphasis has also been placed on ensuring that heritage conservation activities comply with sustainable and environmentally responsible practices (Teoh, 2021; Adib et. al, 2025). However, while the integration of sustainable principles has gained traction in new development projects, their adoption in heritage conservation remains comparatively limited. This is evident from the small number of heritage buildings formally certified under Malaysia's Green Building Index (GBI). Yet there are cases where green features have been incorporated without receiving formal environmental rating recognition (Green Building Index, 2025). The lack of acknowledgment and promotion of sustainable efforts in heritage conservation raises concerns about missed opportunities for environmental benefits (Alauddin et al., 2022; Pedersen et al., 2024). Globally, researchers have highlighted similar challenges in balancing heritage preservation with sustainability. Pedersen et. al (2024) highlight the development and evaluation of advanced energy-efficient technologies to improve building performance, while also identifying challenges and solutions associated with energy upgrading and preservation. Similarly, Panakaduwa et. al (2024), examine advanced energy-efficient technologies for retrofitting buildings, addressing challenges and proposing solutions to balance sustainability and architectural integrity. These studies provide important insight into balancing sustainability and cultural heritage, offering perspectives that are highly relevant to the Malaysian context. Without a clear understanding of how green elements can be integrated into heritage conservation and what challenges hinder the process, achieving a balance between heritage preservation and sustainability remains difficult (Abdul Aziz, 2021; Alauddin et al., 2022; Lidelöw et al., 2019).

Against this backdrop, this study seeks to investigate heritage conservation with the George Town World Heritage Site as the focal area.


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Specifically, this study pursues three objectives: to identify green building elements, challenges and important strategies for integrating green building elements into heritage building conservation.

## LITERATURE REVIEW

### Conservation of Heritage buildings

Heritage buildings encompass structures, artifacts and areas of historical and architectural significance. They serve as tangible links to the past and reflects community cultural identity (Al-Sakkaf et al., 2020). Norazman et. al (2023) define heritage in terms of its architectural, aesthetic, historical and cultural significance and emphasise the importance of preserving local identity and history. Therefore, many scholars agree that heritage buildings require delicate conservation strategies to preserve their historical, cultural and architectural characteristics (Alauddin et al., 2022; Husa & Harun, 2023; Norazman et al., 2023). Conservation strategies can be divided into four types: restoration and repair, adaptive reuse, maintenance, and retrofitting or rehabilitation. Heritage conservation today is seen not just as protecting old buildings but as a process of balancing historical authenticity with modern social, economic and environmental needs (Alauddin et al., 2022; Husa & Harun, 2023; Vafaie et al., 2023). It also involves adapting heritage assets to contemporary urban life while retaining their meaning and functionality.

### George Town World Heritage Site and Green Heritage Conservation

George Town World Heritage Site (GTWHS), is a thriving living heritage site that combines modern urban life with historical and cultural preservation. Conservation measures include stringent rules, adaptive reuse of heritage structures, and community involvement. George Town World Heritage Incorporated (GTWHI) has been actively involved in conservation projects, community engagement, and educational programs to address challenges such as urbanisation and development. Scholars agree that sustaining the vitality of George Town requires not only protective regulations but also collaborative governance involving communities, stakeholders and international organisation.
Green buildings are defined as those that use eco-friendly technologies, such as renewable energy and low-carbon systems, to reduce their adverse environmental impacts while remaining safe, functional and reliable (Yin et al., 2024). While maintaining historical and cultural features, green heritage conservation seeks to promote ecosystem protection, reduce carbon footprints and encourage sustainable practices (Shehata et al., 2024). In Malaysia, policy frameworks have been introduced to align heritage conservation with sustainability. The Green Technology Master Plan (2017-2030) sets out a roadmap towards a resource-efficient, low carbon economy including the construction sector (Ministry of

Energy, Green Technology and Water (KeTTHA), 2017). Complementing this, the Green Building Index (GBI) serves as a national benchmark for sustainable building practices and has been extended to cover heritage projects. However, while these frameworks demonstrate Malaysia's commitment, their application in the heritage context remain selective and uneven, revealing a gap between policy and implementation. The integration of green building elements into heritage conservation can promote environmental sustainability and reduce carbon emission, contributing to a more sustainable built environment (Shehata et al., 2024). However, such integration must balance modernisation with authenticity to preserve heritage value.

**Principles of Green Building Element Heritage Conservation**

Green building elements are commonly structured around the following interrelated principles; energy efficiency, indoor environmental quality, sustainable site planning and management and material and resources. *Energy efficiency* emphasises on reducing energy consumption through resources optimization while maintaining comfortable indoor conditions (Gupta & Chakraborty, 2021; Lidelöw et al., 2019; Min et al., 2022). *Indoor environmental quality* encompasses factors such as air quality, lighting, thermal comfort, and ergonomics, which affect occupants' health, comfort and well-being (Kang et al., 2024). It can be improved through natural ventilation, appropriate mechanical ventilation, indoor temperature control and humidity and moisture management. *Sustainable site planning and management* aims to minimise the environmental impact of development while maximising social and economic benefits This idea can be implemented through facility evaluations (such as examining roofs, windows, HVAC systems, and plumbing), energy and erosion management, and the use of renewable energy sources for heating and cooling (Alauddin et al., 2022). *Material and resources*, focusses on materials with appropriate performance, durability, low maintenance requirements and low embodied energy (Tazmeen & Mir, 2024). Green Heritage conservation also depends on sustainable materials that minimise environmental impacts while providing long term durability effect (Tam & Hao, 2019).

**Challenge in Maintaining Authenticity and Green Value in Heritage Conservation**

Scholars acknowledge that integrating green building elements into heritage conservation is a complex process primarily due to regulatory, technical and structural limitations. Heritage conservation is governed by national and international regulations, which often priorities the protection of the original form and character (Azizan et al., 2020; Conejos et al., 2019). Adherence to heritage protection requirements is important but impede the implementation of energy-


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efficient renovations because alterations to original features can affect heritage value. The lack of explicit guidelines for integrating green building elements within conservation constraints can discourage their adoption in heritage buildings (Conejos et al., 2019). Another key barrier is the lack of professionals with expertise in both heritage conservation and green building approaches (Azizan et al., 2020; Harun, 2011), making implementation more difficult. The structural condition of heritage building presents additional challenge to green integration.

***Strategies for incorporating green element in heritage conservation***

Researchers have identified several strategies to address the challenges of incorporating green building elements into heritage conservation. One of the key approaches is stakeholder involvement and awareness. Awareness programs are used to inform stakeholders of the benefits of integrating green technologies in conservation efforts. Such initiatives can also mitigate concerns about regulatory implications and promote wider acceptance of sustainable practices (Harun, 2011). Another recurring strategy is the establishment of adaptable regulatory frameworks that enable energy-efficient improvement without undermining conservation principles. Conejos et. al (2019) argue that updating existing guidelines to provide clearer pathways for green technologies is essential for ensuring compliance and heritage integrity. In addition, scholars emphasise training and education to equip architects, engineers and artisans with the skills required to integrate sustainability into historic structures. Leijonhufvud et al (2024) highlight that such capability-building effort are critical for developing practical solutions that respect cultural heritage. Adaptive reuse is also widely recognised as a means of introducing contemporary sustainable technologies into existing buildings. Shehata et al (2024) show that adaptive reuse not only preserves the historical significance of structures but also improves their functionality and environmental performance. Finally, collaboration with conservation experts (Hassan & Abdul Nasir, 2017) during planning and implementation stages is considered vital to ensure that modification align with conservation principles. Involving specialist helps to identify potential conflict between modern technologies and historical features, enabling better-informed decision making. Overall, these strategies demonstrate that green integration requires a multidimensional approach that combines technical solutions with the governance mechanism while balancing sustainability and authenticity.

## RESEARCH METHODOLOGY

This research employed a qualitative research design using purposive sampling. Participants were selected due to their professional roles and project experience to heritage conservation and integration of green building elements. George

Town was selected as the case study due to its significance as a UNESCO World Heritage Site. Between February and April 2025, five (5) eligible experts, including conservation architects, heritage managers and related professionals were interviewed to gain in-depth insight into green heritage elements, implementation challenges and effective strategies. As shown in Table 1, all participants had approximately five to ten years professional experience, while the majority had been involved in several green building projects, with two reporting extensive experience in heritage building conservation, indicating sufficient relevant expertise to provide credible insights for the study. Data were analysed using narrative analysis supported by systematic coding to identify recurring patterns and categories across respondents. Similar statements were coded and grouped into related domains and patterns were compared across respondents and with the literature. This method helped develop a clearer understanding of the complex issues involved in green heritage conservation (Creswell & Poth, 2024).

**Table 1:** Demographic Information

| | **Position** | **Experience in Construction Industry** | **Green project involvement** | **Heritage conservation project involvement** |
|---|---|---|---|---|
| R1 | Director | > 5 years | < 5 projects | < 5 projects |
| R2 | Conservation Architect | > 5 years | < 5 projects | >10 projects |
| R3 | Heritage Operation Manager | > 5 years | >10 projects | >10 projects |
| R4 | Assistance Curator for Building Conservation | > 5 years | < 5 projects | < 5 projects |
| R5 | Assistance Manager Architect | > 5 years | < 5 projects | < 5 projects |

## ANALYSIS AND DISCUSSION

The interview findings were organised into three thematic domains corresponding to the research objectives (i) green building elements, (ii) challenges to integration and (iii) implementation strategies. Table 1 shows all respondents had relevant experience in both green building and heritage project making them suitable for this study.


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**Table 2:** Green Building Elements in GTWHS

| Category | | Green Building Element |
|---|---|---|
| Energy Efficiency (EE) | i | Installation of Solar Panel |
| | ii | Installation of Low-Carbon Air Conditioning |
| | iii | Reduce the number of Air-Conditional |
| | iv | Installation LED Lighting |
| | v | Passive Design |
| Indoor Environment Quality (IEQ) | i | Natural Ventilation |
| | ii | Natural Lighting |
| Sustainable Site Planning and Management (SM) | i | Vegetation |
| | ii | Restore Drainage System |
| | iii | Rainwater Harvesting System |
| Materials and Resources (MR) | i | Original Material |
| | ii | Low-Carbon Material |
| Water Efficiency (WE) | i | Rainwater Harvesting System |
| | ii | Low-Flush Toilet System |

As shown in Table 2, the findings identified thirteen green building elements integrated in the GTWHS across five categories: energy efficiency (EE), indoor environmental quality (IEQ), sustainable site planning and management (SM) and materials and resources (MR) and water efficiency (WE). These elements also correspond to relevant GBI criteria. Rainwater harvesting contributes to both SM and WE but is counted once. For EE, most respondents generally (R1, R2, R3 and R4) acknowledged that solar panels can be integrated, provided that installation remain visually unobtrusive and comply with relevant regulations. This reflects conditional acceptance of renewable technologies within the heritage context, particularly due to concerns regarding safety and regulatory compliance. The findings reflect previous research which argues that renewable energy technologies can contribute meaningfully to conservation areas if interventions are unobtrusive and their application remains sensitive to regulatory and structural limitations (Conejos et al., 2019). In the George Town heritage context, such external services require careful assessment against the UNESCO-related authenticity considerations. This is consistent with Abdullah et. al (2024) who emphasise the importance of maintaining external appearance without compromising authenticity. IEQ findings emphasised natural ventilation and lighting through features such as air wells, timber shutters and high ceilings. This confirms earlier studies that highlight these features as both functional and environmentally responsive (Alauddin et al., 2022; Bay et al., 2022). SM measures, including vegetation, drainage restoration and rainwater harvesting were viewed as relatively non-intrusive ways to improve environmental performance. More importantly, these measures are generally less intrusive and can be incorporated with limited disturbance to the heritage fabric. These findings align with Amaka-Anolue et al. (2024) and Hoyle and Sant'Anna (2023), who

emphasise the role of site interventions in reducing environmental risks. For MR, all respondents prioritised the original materials such as lime plaster and timber, while low-carbon alternatives were considered acceptable only when compatible with the original materials. The findings reflect the ongoing debate in the literature which point out both the advantages and risks of replacing traditional materials with modern ecological ones (Abd Elgawad et al.,2025; Alauddin et al., 2022; Tazmeen & Mir, 2024). Finally, WE measures revealed both opportunities and constraints. Rainwater harvesting was widely accepted (R1-R5) as practical and non-intrusive, complementing the broader site management strategies. However, the use of low-flush toilets was less accepted due to higher costs. Hence, these findings illustrate how economic considerations strongly influence the adoption of sustainable practices, consistent with earlier research by Amaka-Anolue et al., (2024).

**Table 3** Challenges of Green Building Integration in Heritage Conservation

| Challenges | Representative interview evidence |
|---|---|
| Regulatory Constraint | R2: "The first point is regulation, as you know regulation for heritage building is very tight. So, anything that we want to develop, installation and repair, we need to refer to the guideline, 'special area plan for George Town'." |
| Lack of Skilled Worker | R4: "In Malaysia, our worker involved in the heritage conservation is less, they are more like to join the other type building which is fast finish and easy job." |
| Structural and Appearance Restrictions | R2: "We need to maintain the exterior look, if we integrate more of green features, then we need to install something to maintain the exterior look." |
| Cost Constraints | R3: "Many heritage building owners are individuals or small businesses that may not have the budget to invest in green technology that also meets heritage standards." |
| Material Availability and Authenticity | R5: "Because the heritage building material is already old... maybe in Malaysia didn't have this kind of original material, but in heritage conservation, we want to try to maintain the original material." |
| Stakeholder Awareness and Understanding | R4: "I think is the awareness of the public. This is because not so many people interesting involved in heritage conservation." |
| Enforcement and Expertise Gaps | R1: Some conservation work is "renovated in a hurry" without following the heritage conservation guideline, while there are too few green-heritage specialists to evaluate the integration accurately. |
| Conflicting Requirements | R1: "They want us to maintain the wood thing... But the Bomba say cannot... so want to accept both requirements, we do RC and cover with wood." |


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| Challenges | Representative interview evidence |
|---|---|
| Balancing Aesthetics and Functionality | R5: "It's required careful planning in-order to balance modern technologies with historical aesthetics, energy efficiency vs functionality and cost constraints." |
| Time and Process Constraints | R4: "The heritage conservation building takes a lot time to done the project... they like to do fast project and get fast money, so this is a challenge." |

Based on Table 3, the interview findings revealed ten (10) key challenges in integrating green building elements into heritage conservation. The most recurrent concerns were regulatory constraints, shortages of skilled workers, cost, material availability and the need to protect structural and visual authenticity. The policy gap creates uncertainty among practitioners regarding the appropriate application of green standards in conservation projects. This is supported by Conejos et al., (2019) who underscore that misaligned regulatory frameworks can hinder would hinder effective implementation. In addition, all respondents emphasised the shortage of skilled workers emerged as key constraint, as heritage conservation requires specialized expertise that remains limited within the current industry. This is also highlighted by Abdullah et. al (2024). Economic barriers were another recurring theme, with all respondents indicating that many clients were unwilling to invest beyond minimum requirements. Abdullah et. al (2024) further noted that sourcing materials can be challenging, thereby increasing overall project costs. Limited material availability compounds this problem as the difficulty of sourcing authentic materials raises both procurement challenges and project expenditure. Similar to Halim and Tambi (2021), several respondents also indicated that limited stakeholder awareness further complicates progress, as contractors often prioritise cost efficiency over sustainability goals. All respondents also highlighted the difficulty of balancing aesthetic integrity with modern functionality, noting that such decisions require careful negotiation to avoid undermining heritage values. Collectively, these challenges illustrate the complex trade-offs that must be managed in aligning environmental objectives with heritage preservation priorities.

**Table 4:** Strategies for integrating green building elements

| Strategies | Representative interview evidence |
|---|---|
| Stakeholder Education and Awareness | R3: "When building owners and local people understand the environmental value of traditional design, they are more likely to support green conservation practices." |
| Financial Incentives | R4: "Government can give some incentive to the contractor if they interested in green heritage conservation." |

| Strategies | Representative interview evidence |
|---|---|
| Expert Knowledge | R1: "This is good, this activity should be more practice. But the experts from outside country need look careful because the habit is different." |
| Integrated Guideline | R1: "Since we didn't have specific guideline on how green building element can integrate into the heritage conservation, so have a specific guideline as reference is good." |
| Material Sourcing and Innovation | R4: "If say the wood didn't have, then one way we practice is replace to more quality wood or high grad material." |
| Skilled Workforce Development | R4: "But I think most important is training, like we train ourselves worker have this knowledge, which increase their awareness." |
| Adaptive Reuse Strategies | R3: "Heritage buildings are given new functions while keeping their original form." |
| Research and Documentation | R2: It is essential to understand the history of a heritage building before intervention; this can include speaking with an elderly person or owner to learn the building's history, purpose and ownership. |
| Leveraging Traditional Design | R3: "Many traditional structures in Penang, such as old shophouses, already include green features like air wells, high ceilings, and timber windows that support natural ventilation and cooling." |

Findings in Table 4 revealed nine (9) key strategies that can support the integration of green building elements into heritage conservation. Most respondents emphasised stakeholder education and awareness as the foundation for progress with respondents noting that training programs and stakeholder engagement can enhance understanding and foster long-term commitment to sustainable heritage practices (Harun, 2011; Leijonhufvud et al., 2024). This aligns with earlier literature that stresses the role of knowledge as the driver for behavioural change and informed decision-making in conservation. In addition, several respondents (R1, R2) highlighted expert collaboration and knowledge sharing were also viewed as essential for ensuring technical quality and consistency, as they promote interdisciplinary cooperation that enhances both energy efficiency and the preservation of heritage value (Shehata et al., 2024). The development of updated and comprehensive guidelines also emerges as major priority. Majority respondents (R1, R2, R3, R4) emphasized that Malaysia requires a regulatory framework specifically tailored to harmonies heritage conservation and sustainability goals, supporting Conejos et al., (2019), who argue that clear policy direction is critical for effective implementation. Adaptive reuse was further identified by several respondents (R2, R3, R5) as a practical strategy, demonstrating how existing buildings can be repurposed while maintaining authenticity, as exemplified by the Penang Hill Gallery @ Edgecliff


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(Shehata et al., 2024). Meanwhile most respondents (R1, R2, R4) highlighted financial incentives and funding mechanism, including grant and tax reduction as key enablers to encourage client participation and offset the higher cost associated with sustainable materials and technologies. Developing a skilled workforce through continuous professional was considered equally important to ensure that conservation practitioners are equipped to manage both heritage requirement and sustainability standards. All respondents (R1-R5) also highlighted the importance of research and documentation in understanding a building's history, materials and condition before any intervention. Such preparation helps reduce risks and improve conservation outcomes. Finally, leveraging traditional methods such as passive design and the use of local materials was seen as one of the most authentic and sustainable approaches. These methods not only retain cultural identity but also provide environmental benefits without major alterations to the building structure. Collectively, these strategies suggest that achieving sustainable heritage requires an integrated approach, combining education, collaboration, financial support and traditional wisdom to balance the authenticity with environmental responsibility.

## CONCLUSION

In an effort to understand the integration of green building elements into heritage conservation, this study focuses on George Town Penang, a UNESCO World Heritage Site and highlights the importance of aligning conservation efforts with environmental responsibility. The study also identifies significant challenges that emerge when integrating modern sustainability practices with heritage conservation. These findings underscore the need to reconcile environmental responsibility with heritage conservation, ensuring that sustainability improvements are introduced without compromising the authenticity and significant fabric of heritage building in line with Penang 2030 goals. These insights provide practical references for policymakers and practitioners toward environmentally responsible heritage preservation. Future research should further explore scalable solutions and policy frameworks to accelerate the integration of green building principles within heritage conservation practices.

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# TOWARDS SUSTAINABLE PRIVATE FINANCE INITIATIVE (PFI) PROJECT DELIVERY: STRATEGIES FOR MITIGATING INCOMPLETE CONTRACT IMPLICATIONS

**Nur Syaimasyaza Mansor[1], Faraziera Mohd Raslim[2*]**

[1]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA, 11800 PENANG
[2] *Fakulti Kejuruteraan,*
UNIVERSITI MALAYSIA SABAH, 88450 KOTA KINABALU, SABAH

## Abstract

Incomplete contract (IC) is defined as a contract that fails to clearly spell out ex-ante the parties' requirements, duties and obligations for every realised contingency and it has gaps, missing provisions, and ambiguities in its terms. Past studies have found that PFI contracts in Malaysia are incomplete and consequently caused positive and negative implications. Addressing these implications is crucial to achieving not only project efficiency but also long-term sustainability in PFI project delivery. The methodology adopted combines an intensive review of literature on IC and PFI, and two (2) rounds of Modified Delphi. A total of 55 strategies were identified for the 12 clauses deemed incomplete in PFI contracts. Some of the strategies are to ensure that both public and private representatives involved are technically knowledgeable, to develop a complete database on the service level and standard for the purpose of determining the KPI, and to provide a clear statement of needs. By mitigating the implications of incomplete contracts, these strategies contribute towards more transparent governance, efficient resource utilisation, and sustainable outcomes in future PFI projects. The findings of this research can serve as a reference for key PFI stakeholders, policy makers and contract drafters in their future endeavour in developing and managing PFI contracts that support sustainable project delivery.

***Keywords***: incomplete contract, Private Finance Initiative, strategy, concession contract

[2] Corresponding author. Email: faraziera@ums.edu.my

## INTRODUCTION

The concept of incomplete contract (IC) in this study concerns the substance of a contract. In principle, every uncertain condition that might happen during the contract duration must be identified and addressed in the contract. However, the contracting parties are not able to do so since the potential future contingencies might be too great and/or too difficult to foresee. This makes the contract incomplete (Domingues & Sarmento, 2016).

Theoretically, a complete contract could not be attained, and nearly all contracts are inescapably incomplete (Domingues & Sarmento, 2016). When there is IC, there is potential for inefficiency (Garvin, 2009) and dispute (Grant et al., 2012). Despite that, IC also has potential for efficiency as it enables a contract to be executed promptly with provisions for future negotiations. In Malaysia, PFI is among the key alternatives in procuring public infrastructure (Samer Shahedza & Khairuddin, 2016). However, the use of IC in PFI projects caused positive and negative implications to the project's success. Addressing these implications is crucial to achieving not only project efficiency but also long-term sustainability in PFI project delivery.

The strategies identified serve to achieve two purposes i.e. to enhance or maintain the status-quo of the positive implications and to eliminate or reduce the inefficiencies arising from the negative implications. The methodology for the study combines an intensive review of literature on IC and PFI, and two (2) rounds of Modified Delphi involving 18 PFI experts (Round 1) and 13 PFI experts (Round 2).

## LITERATURE REVIEW

### Incomplete Contract (IC)

Incomplete contract (IC) is a contract that fails to clearly spell out ex-ante the parties' requirements, duties and obligations for every realised contingency and it has gaps, missing provisions, and ambiguities in its terms. IC can be identified when the contract has a gap or loophole, the clause is vague or ambiguous, there are additional works or changes to the contract, and the contract has to be renegotiated. It is hard to attain a complete contract as the parties to the contract often meet with uncertainties (Grant et al., 2012). They are then expected to renegotiate, breach or litigate. A complete contract is therefore just a theoretical concept used to describe one endpoint of completeness. Previous research identified high transaction cost, long project duration, high risk or uncertainty, bounded rationality, signalling trust and asymmetric information to be the factors that cause the contract to be incomplete. Having an IC does not mean that the ensuing transaction is incomplete or unsuccessful. When IC is used, the success of the project could be positively or negatively affected. The flexibility to cope with uncertainty and change is one of the positive implications of IC (Miller et


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al., 2013). On the contrary, the contracting parties will be exposed to the possibility of opportunistic behaviour, haggling, conflicts and others (Bajari et al., 2014; Robinson & Scott, 2009).

**Private Finance Initiative (PFI)**

The United Kingdom launched the Private Finance Initiative in 1992 and since then it has been widely implemented around the world including Malaysia. This approach allows for more flexibility in meeting the increasing demand and supply of infrastructure as it reduces the requirement for public funds through the innovative project finance route (Dolla & Laishram, 2020; Mat Aron et al., 2024). PFI incorporates resources or skills from the public and private sectors to provide more effective public services (Robert et al., 2014). It allows the private sector, through concession contracts, to conduct some construction of public infrastructure and facilities on behalf of the public sector (Samer Shahedza & Khairuddin, 2016). In PFI, the contract for design, construct, finance, operate and maintain the properties (until the concession period expired) is packaged into one contract (Abdullah Habib et al., 2020). Thus, synergies between the various stages of the project can be utilized, where innovative and cost-effective designs can be produced (Bennett & Iossa, n.d.). In a common PFI project, the principal contract, which is known as the concession contract, is signed between the government and the private concessionaire (i.e. a special purpose vehicle, SPV).

**IC in PFI**

Typically, a PFI concession contract spans between 20 and 30 years or longer. Therefore, the risk and uncertainty associated with the project are greater than a simple contract for a construction project (X. Jin & Doloi, 2008; Van Den Hurk & Verhoest, 2016). Although the government would usually predetermine the terms in the concession agreements before the bidding stage, the uncertain market surroundings will cause the contracting parties to have post-contractual renegotiations (H. Jin et al., 2020). According to Keenan & Mccabe (2010), it is unlikely that the contracting parties can specify all potential future risks and contingencies which could happen during concession contract period. Furthermore, changes such as in financial, legislation, politics, organisations, technological and technical, are most likely to happen throughout the contract duration (Demirel et al., 2017; H. Jin et al., 2020). Thus, PFI contracts are inevitably incomplete.

In a study carried out by previous researchers, PFI contracts in Malaysia have been found to be incomplete and had positive and negative implications as a result. Eight PFI concession contracts were analysed and the results found 12 clauses (in a standard PFI contract) that are considered incomplete. The clauses are: 1) Condition precedent; 2) Concession charges; 3) Design and construction

of the project; 4) Delay of the construction works; 5) Asset management services; 6) Service levels; 7) Additional works; 8) The concession company; 9) Force majeure; 10) Project monitoring committee; 11) Dispute resolution committee; and 12) Occupational safety and health requirements. From the study, it was found that IC in PFI projects in Malaysia causes negative implications such as delay, disputes, and the risk of opportunistic behaviour, along with positive implications such as flexibility to deal with future uncertainties and changes as it offers the parties opportunity to renegotiate. Thus, strategies are required to reduce or mitigate the negative implications and maintain or enhance the status quo of the positive implications. The discussion onward will present the development of the said strategies.

**Strategy to deal with IC**

In the case of strategies suggested by previous scholar, there are two contradicting opinions. Some scholars held that a contract must be structured 'as complete as possible' because it governs ex-ante expected potential changes that create a kind of built-in flexibility that diminishes the need for contractual changes and is not subject to any of the renegotiation downsides. The renegotiation procedure can be tedious, costly and the high rate of ex-post renegotiation would undermine the credibility of the initial bids, thus, encouraging corruption and opportunistic behaviour (H. Jin et al., 2020; Senanu et al., 2021). Contrarily, others prefer to provide a flexible contract because it may provide a structured approach to dealing with IC, allow the parties the ability to review the scope and change the clauses for the mutual good of all parties (Demirel et al., 2017; Domingues & Zlatkovic, 2015). The establishment of a good working relationship or a 'spirit of partnership' could also minimise the IC's negative effects where compromises could be encouraged, difficulties in the negotiating process minimised and conflicts prevented (Domingues & Zlatkovic, 2015; Robinson & Scott, 2009). Trust, ethics and cooperation between the contracting parties should be integrated in order to solve the problem of opportunism and asymmetric information and thereby achieve efficiency in contracting (Abdallah et al., 2013).

## RESEARCH METHODOLOGY

The methodology adopted to achieve the objective of the research is literature review (LR) and two rounds of Modified Delphi (MD) (Figure 1).


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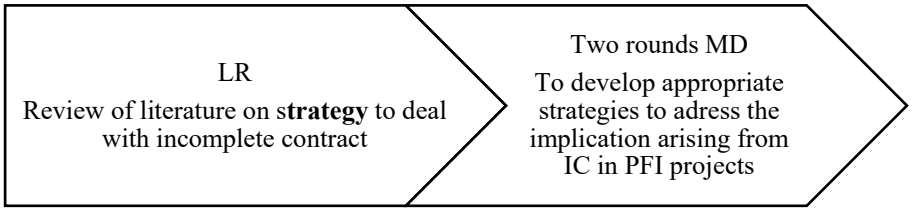



**Figure 1:** Outline methodology for the study

LR was conducted to identify strategies to deal with the implication of IC in PFI projects. Data from LR was used as an input for the development of MD questionnaire. The second method used was Modified Delphi. Delphi is a commonly used method in attaining consensus of experts' opinions concerning real-world knowledge on a specific area of studies. The techniques may be carried out in several styles. MD is a variation of the Delphi approach, which traditionally involved an open-ended questionnaire and pen-and-paper methods using traditional mail (see discussion on MD in Mohd Fairullazi, 2014). Semi-structured questionnaires and face-to-face interviews were carried out in this study. MD interviews were carried out to validate the findings from LR and to obtain expert inputs regarding the strategies. Since the data needed for this study requires in-depth knowledge and sound experience about PFI contracts, a purposive approach and snowball method were used to identify suitable experts who possess the criteria as presented in Table 1. Letters of invitation were sent to 23 selected experts and 18 panellists agreed to participate.

**Table 1**: Panellist criteria and sample size for MD technique

| | Description |
|---|---|
| Panellist criteria | • Knowledge wise - have at least a Degree in the field of PFI practice for construction works, e.g. engineer, architect, quantity surveyor, banker, etc.<br>• Skills - ability to make sound decision based on: 1) knowledge and experience in the execution of PFI and contracts by participating in PFI projects e.g. in the context of policy, planning implementation, supervision etc.; or 2) proof of expertise such as prior research, publications, and positions.<br>• Working experience with PFI projects in Malaysia. |
| Sample size | • Round 1, 18 participated (78.2% response rate)<br>• Round 2, 13 participated (72.2% response rate). |

In Round 1 MD, the panellists were given a semi-structured questionnaire consisting of a 5-point Likert-type scale (i.e. 1. Strongly disagree - 5. Strongly agree) to rate their degree of agreement with the strategies mentioned. The panellists were also given the opportunity to propose other strategies. The

data collected was analysed and the mode score was calculated to assess the value in the data set that has the highest frequency, and the standard deviation (SD) score was calculated to measure the response variability in the data set and the degree of consensus achieved. The data was presented in Round 2 and the panellists were given the opportunity to re-rate their Round 1 scores and provide reason(s) if they decided to do so. Additional strategies obtained from Round 1 were consolidated and presented in a 5-point Likert type scale (i.e. 1. Strongly disagree - 5. Strongly agree). The panellists rated their level of agreement with each item response and the scores were then analysed using the Relative Importance Index (RII) technique to ascertain the ranking of the item responses (Mohd Fairullazi, 2014). Higher RII score means higher ranking or more significant. On the 5-point Likert scale, a 'cut-off' relative index of 0.60 was applied (Muhwezi et al., 2014) and items with a RII of 0.80 and above are categorized as 'Very significant' (Hamimah & Morledge, 2003; Mohd Fairullazi, 2014), whereas items with a score between 0.79 and 0.60 are categorized as 'Significant'. Items that achieved SD score less than 1.5 (reasonable level of consensus) and 1.00 (high level of consensus) are considered items that achieved consensus (Mohd Fairullazi, 2014).

Referring to Table 2, all panellists had professional backgrounds and work experience related to PFI projects. More than half (55.6%) had over six years of experience. Based on their profiles and experience, all panellists in the two rounds of the Modified Delphi study met the criteria for the expert panel. Five panellists from Round 1 did not participate in Round 2 due to non-response despite follow-up reminders and scheduling unavailability. This attrition rate (27.8%) is within the range commonly reported in Delphi studies and is unlikely to have introduced systematic bias, as the remaining 13 panellists still represented the full range of expertise and sectors captured in Round 1.

**Table 2**: Demographic of the expert panel in the modified Delphi study

| No. | Description | Round 1 | Round 2 |
|---|---|---|---|
| 1. | Professional background: | | |
| | i. Construction contractor | 1 (5.6%) | 0 (0%) |
| | ii. Architect | 1 (5.6%) | 0 (0%) |
| | iii. Engineer | 9 (50%) | 8 (61.5%) |
| | iv. Facilities management operator | 1 (5.6%) | 1 (7.7%) |
| | v. Contract administrator | 1 (5.6%) | 1 (7.7%) |
| | vi. Financier | 2 (11.1%) | 0 (0%) |
| | vii. Academician | 3 (16.7%) | 3 (23.1%) |
| | viii. Lawyer | 2 (11.1%) | 2 (15.4%) |
| | ix. Accountant | 2 (11.1%) | 1 (7.7%) |
| 2. | Current organization: | | |
| | Public sector: | | |
| | i. Unit Kerjasama Awam Swasta (UKAS) | 3 (16.7%) | 2 (15.4%) |
| | ii. Kementerian Kerja Raya Malaysia (KKR) | 1 (5.6%) | 1 (7.7%) |


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| No. | Description | Round 1 | Round 2 |
|---|---|---|---|
| | iii. Public Higher Educational Institution | 5 (27.8%) | 5 (38.5%) |
| | Private sector: | | |
| | i. Concession company | 3 (16.7%) | 2 (15.4%) |
| | ii. Consultancy firm | 1 (5.6%) | 1 (7.7%) |
| | iii. Contractor firm | 1 (5.6%) | 0 (0%) |
| | iv. Facilities management firm | 2 (11.1%) | 2 (15.4%) |
| | v. Financial institution | 2 (11.1%) | 0 (0%) |
| 3. | Work experience in PFI projects: | | |
| | i. ≤ 1 years | 1 (5.6%) | 1 (7.7%) |
| | ii. 2-3 years | 1 (5.6%) | 1 (7.7%) |
| | iii. 4-5 years | 6 (33.3%) | 4 (30.8%) |
| | iv. ≥ 6 years | 10 (55.6%) | 7 (53.8%) |
| 4. | Sector of PFI projects that the panellist had involved: | | |
| | i. Highway, Rail & Town Services | 6 (33.3%) | 5 (38.5%) |
| | ii. Infrastructure Section | 4 (22.2%) | 2 (15.4%) |
| | iii. Security, Housing, Local Government & Land Development Section | 4 (22.2%) | 3 (23.1%) |
| | iv. Education, Energy & Utility Section | 13 (72.2%) | 9 (69.2%) |
| | v. Health, Social, Science, Technology & Services Industry Section | 9 (50%) | 6 (46.2%) |

## DATA ANALYSIS AND RESULTS

### Modified Delphi Approach

26 strategies were presented and one strategy (Item: 90) achieved mode score '2' suggesting that the panellists 'Disagree' with the strategy, while the remaining strategies achieved mode score '4' or 'Agree' (Table 3). All items reached 'high level' to 'reasonable' level of consensus with SD score between 0.00 and 1.13.

**Table 3**: Descriptive statistic for Round 1 and Round 2 MD

| Code[1] | Strategies | 1st round | | 2nd round | |
|---|---|---|---|---|---|
| | | Mode | SD | Mode | SD |
| 10 | **Clause B - Concession Charges**<br>1) Appropriate action to ensure deflation/inflation and other price-related variables are taken into account. | 4 | 0.00 | 4 | 0.00 |
| 20 | 2) Freeze potential occurrence in the future so that it will not be taken into account as a component for negotiation. Consequently, the contractor must make a prediction failing which it will revert to renegotiation as it happen. | `4 | 0.97 | 4 | 1.13 |
| 30 | 3) Introduce mixed-price structure in the contract where, the public authority sets the quantities of service to be delivered per person and the fees would be covered by the government. The cost is | 4 | 1.06 | 4 | 1.11 |

| | | | | | |
|---|---|---|---|---|---|
| | charged to the users when they require extra service that is above the specified level. | | | | |
| 40 | 4) Include provision for renegotiation so that the parties could prepare when new information becomes available. | 4 | 0.00 | 4 | 0.00 |
| 50 | **Clause C - Design and Construction of the Project**<br>Sustainable element<br>a) Ensure that sustainability objectives are established early on. For example, objectives could be waste reduction, carbon management, sustainable design, sustainable materials | 4 | 0.00 | 4 | 0.00 |
| 60 | b) Ensure that sustainability objectives are clear | 4 | 0.00 | 4 | 0.00 |
| 70 | c) Ensure that there is a well-developed change mechanism in the contract to facilitate the adoption of new developments that deliver improved sustainability or new legislation | 4 | 0.47 | 4 | 0.38 |
| 80 | d) Link payment to the achievement of agreed measurable sustainability outputs | 4 | 0.57 | 4 | 0.58 |
| 90 | **Clause D - Delay of the Construction Works**<br>Incorporate Liquidated ascertained damages (LAD) in the contract to provide incentives for the private sector to invest and perform. | 2/4 | 1.15 | 2 | 1.15 |
| 100 | **Clause E - Asset Management Services**<br>Improve output specifications to reduce subjectivity. The action that could be taken is by simplifying performance metrics so that they are more transparent | 4 | 0.54 | 4 | 0.35 |
| 110 | **Clause F - Service Levels**<br>1) Include adjustment mechanism in the contract to allow for changing circumstances to be dealt within the contract. The adjustment mechanism can be in the form of changes to service requirements | 4 | 0.83 | 4 | 0.71 |
| 120 | 2) Appropriate measures to deal with change in service should be included in the contract. The measure could be in the form of periodic review mechanisms | 4 | 0.67 | 4 | 0.89 |
| 130 | **Clause G - Additional Works**<br>1) Ensure value for money by paying a reasonable price to implement the change by including provisions within the project agreement as follows:<br>a) The project company has the duty to mitigate the costs; | 4 | 0.63 | 4 | 0.76 |
| 140 | b) Transparency of information on costing; | 4 | 0.57 | 4 | 0.69 |
| 150 | c) If the change is to be implemented by a sub-contractor, competitive quotes should be obtained and, if possible, competitive tendering | 4 | 0.63 | 4 | 0.76 |


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| | | | | | |
|---|---|---|---|---|---|
| | should be sought in respect of any capital works required to implement the relevant change in service. | | | | |
| 160 | d) If the change is to be implemented by the project company, the cost is benchmarked against prevailing market rates. | 4 | 0.00 | 4 | 0.00 |
| 170 | 2) Use effective validation mechanisms to challenge costs when necessary by comparing with:<br>a) industry-wide benchmark prices; | 4 | 0.00 | 4 | 0.00 |
| 180 | b) the experience of other PFI projects | 4 | 0.84 | 4 | 0.98 |
| 190 | 3) Adopt a strategic approach to change, for instance:<br>a) bundling similar changes together to reduce costs; or | 4 | 0.32 | 4 | 0.00 |
| 200 | b) Planning a change programme based on anticipated needs. | 4 | 0.32 | 4 | 0.00 |
| 210 | **Clause J - Project Monitoring Committee**<br>1) Identify the resources required to carry out the PPP monitoring in the bidding documents | 4 | 0.00 | 4 | 0.00 |
| 220 | 2) Specify in the contract on how the monitoring will be performed, including:<br>a) All reporting procedures; | 4 | 0.49 | 4 | 0.52 |
| 230 | b) The amount and circumstances under which sanctions can be applied; | 4 | 0.49 | 4 | 0.52 |
| 240 | c) Procedures in the event of renegotiation; and | 4 | 0.79 | 4 | 0.52 |
| 250 | d) Quality of service supervision and, particularly, the handling of complaints | 4 | 0.49 | 4 | 0.52 |
| 260 | **Clause K - Dispute Resolution**<br>Incorporate an Alternative Dispute Resolution (ADR) which include negotiation, mediation, adjudication, expert determination and arbitration, to provide a more comprehensive approach to dispute resolution | 4 | 0.00 | 4 | 0.00 |

Additional strategies proposed by the panellists in Round 1 were consolidated into 31 strategies and they were presented in Round 2 to be rated (Table 4). Scores obtained were then transformed into Relative Importance Index (RII) values using the RII formula. As shown in Table 4, 11 strategies are considered 'Very significant' as the RII score is 0.80 and above. Only one item (510) did not achieve the 'cut-off' relative index of 0.60. Other strategies achieved RII score 0.60 to 0.79 and they are considered 'Significant'.

**Table 4**: Ranking of new additional strategies obtained from Round 1 MD

| Code | Suggested strategies | RII | Rank | Significant |
|---|---|---|---|---|
| | **Clause A - Condition precedent** | | | |
| 270 | Detail out all the documents required | 0.80 | 1 | Very significant |
| 280 | Ensure that the government's representative that involve for the whole contract period is technically knowledgeable | 0.80 | 1 | Very significant |
| 290 | Provide a more detailed clause about what the SPV could do and cannot do before signing the contract | 0.72 | 3 | Significant |
| 300 | Remained the existing clause (depending on the nature of the project, the document required for condition precedent will be varies) | 0.71 | 4 | Significant |
| | **Clause B - Concession Charges** | | | |
| 310 | Develop a complete database on the service level and standard for the purpose of determining the KPI | 0.82 | 1 | Very significant |
| 320 | Allow renegotiation for inflation/deflation, but only within the specified range of increase or decrease | 0.78 | 2 | Significant |
| 330 | Make deduction to Availability Charges or Asset Maintenance Charges if the work or services did not comply with Key Performance Indicator (KPI) | 0.71 | 3 | Significant |
| | **Clause C - Design and Construction of the Project** | | | |
| 340 | Discuss the output requirement in detail during the Value Management meeting | 0.86 | 1 | Very significant |
| 350 | Provide a clear statement of needs (by the end-user) | 0.85 | 2 | Very significant |
| 360 | Allow changes to some degree and the changes should comply certain criteria e.g. no change in the square feet, no increase in the construction charges/availability charges | 0.82 | 3 | Very significant |
| 370 | Specify all details in the contract to prevent any changes during construction | 0.78 | 4 | Significant |
| | **Clause D - Delay of the Construction Works** | | | |
| 380 | Maintain the current practice (The inclusion of Liquidated Ascertained Damages (LAD) or the Concession Company to provide and bear the cost of temporary facility, should be determined according to the nature of the project) | 0.75 | 1 | Significant |
| 390 | Ensure the uniformity of the clause, e.g. to provide temporary facility or to impose LAD | 0.66 | 2 | Significant |
| | **Clause E - Asset Management Services** | | | |
| 400 | Defined a clear objective, including a well-developed change mechanism that consist the process for approval, recommendation, record and etc. | 0.85 | 1 | Very significant |
| 410 | Ensure that the endorsement of material by the end-user is performed early and any changes later on will give the rights to concession company for variation (cost and time) | 0.82 | 2 | Very significant |


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| | | | | |
|---|---|---|---|---|
| 420 | Define more on facility management scope rather than only maintenance | 0.78 | 3 | Significant |
| 430 | Thoroughly checked the contract and it must be acknowledged by the end-user | 0.74 | 4 | Significant |
| 440 | Allow more involvement from end-user, i.e. put more consideration to the practitioner/end-users point of view (currently, even though there is end-user involvement, however, they did not have enough say in the decision making) | 0.66 | 5 | Significant |
| | **Clause F - Service Levels** | | | |
| 450 | Apply the true Asset Facility Management process (not only focusing on maintenance, but also other core competencies such as quality, health and safety, security, etc.) | 0.77 | 1 | Significant |
| | **Clause G - Additional Works** | | | |
| 460 | Consider the change that is categorized as crucial and important only | 0.80 | 1 | Very significant |
| 470 | Include a pre-agreed schedule of rates in the contract | 0.71 | 2 | Significant |
| | **Clause H - The Concession Company** | | | |
| 480 | Determine upfront the basis and method of calculation for Refinancing Gain | 0.83 | 1 | Very significant |
| 490 | Ensure that the new shareholder are from a competent company | 0.82 | 2 | Very significant |
| 500 | To be specific on what of the terms to be changed (in case that the parties decide to renegotiate the terms and conditions of the Agreement due to changes in shareholder) | 0.75 | 3 | Significant |
| 510 | Changes in the shareholding structure should not be allowed | 0.57 | 4 | |
| | **Clause I - Force Majeure** | | | |
| 520 | Provide a platform/mechanism for the parties to mutually agree on the definition of 'substantial cost' | 0.78 | 1 | Significant |
| 530 | Define the term ‘substantial cost’ e.g. specify the percentage of cost that can be entitled to an extension of time, for example, substantial cost is defined as 5% of the cost of completed construction works | 0.77 | 2 | Significant |
| | **Clause J - Project Monitoring Committee** | | | |
| 540 | Provide a framework or standard operating procedure (SOP) to conduct the Project Monitoring Committee | 0.77 | 1 | Significant |
| | **Clause K - Dispute Resolution** | | | |
| 550 | Provide a framework or standard operating procedure (SOP) to conduct the Dispute Resolution Committee e.g. adopts KL Arbitration procedure | 0.77 | 1 | Significant |
| | **Clause L – Occupational Safety and Health** | | | |
| 560 | Need for standardization of clause | 0.77 | 1 | Significant |
| 570 | Specify the Occupational Safety & Health Requirement in the contract | 0.74 | 2 | Significant |

## DISCUSSION OF RESEARCH FINDINGS

A total of 55 strategies have been identified from the two rounds of MD. From the list of strategies, it seems that flexibility is preferred in some areas of the contract for example as proposed in item 40, 110, 320, 360, 520. Cruz & Marques (2013) and Miller et al. (2013) in their research mentioned that a flexible contract could provide a structured approach to IC management, giving the parties the opportunity to review the scope and amend the clauses for the mutual benefit of both parties. On the other hand, other strategies emphasize the details of the contract, for example item 100, 220, 260, 270, 370, 400 and others. This is consistent with Iossa et al. (2007). A contract designed 'as complete as possible' or it regulates ex-ante all anticipated future changes creates a kind of built-in flexibility that minimizes the need for contractual changes and avoids the renegotiation downside such as opportunism and haggling. This is corroborated by research by Muhammuddin et al., (2023) where they reported that one of the strategies to minimize disputes is to prepare a clear and comprehensive contract document.

To support practical application of the findings, the 55 validated strategies were further classified according to five dimensions: project phase (pre-contract, design, construction, or operation), the actor primarily responsible for implementation (public sector, private/SPV, or joint action), the type of risk each strategy addresses, urgency (derived from the consensus level and RII score obtained in the Modified Delphi rounds), and feasibility of implementation (Table 5). This classification allows stakeholders to identify which strategies require immediate versus longer-term action, and which party holds primary responsibility for implementation. The classification reveals that the majority of strategies (26 of 55, 47%) are targeted at the operation/concession period, reflecting the long duration of PFI contracts and the corresponding need for mechanisms to manage change after the contract is signed. A further 12 strategies (22%) apply at the pre-contract stage, underscoring the importance of getting contract terms and processes right before signing. In terms of responsibility, most strategies (33 of 55, 60%) require joint action from both public and private parties, indicating that mitigating the implications of incomplete contracts is largely a shared, collaborative responsibility rather than one that can be addressed unilaterally. Financial risk was the most frequently addressed risk category (11 strategies), followed by operational and governance-related risks, reflecting the centrality of cost certainty and service performance management in PFI concession arrangements. Overall, 36 strategies (65%) were classified as high urgency based on their consensus level and RII score, while 33 strategies (60%) were assessed as highly feasible to implement, requiring primarily contractual or procedural adjustments rather than significant institutional change.


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The 55 strategies were further classified according to the Environmental, Social, and Governance (ESG) framework, with an additional Economic dimension incorporated to reflect the centrality of financial and value-for-money considerations in PFI contracts. Using this framework, each strategy was mapped to the pillar(s) it most directly addresses (Table 5). The classification shows that governance-related strategies are the most prevalent (20 of 55, 36%), followed by economic strategies (15 of 55, 27%), reflecting the centrality of contract clarity, accountability, and cost certainty to sustainable PFI delivery. Social strategies account for 9 of 55 (16%), covering end-user involvement, service quality, and occupational safety. A smaller but explicit cluster of strategies (Clause C, items 50–80) directly targets environmental sustainability objectives.

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**Table 5**: Strategy prioritisation and sustainability matrix

| Code | Clause | Strategy | Project Phase | Responsible Actor | Risk Addressed | Sustainability Pillar | Urgency Priority | Consensus / RII Basis | Feasibility |
|---|---|---|---|---|---|---|---|---|---|
| 270 | Clause A - Condition precedent | Detail out all the documents required | Pre-contract | Public & Private (joint) | Legal/Contractual | Governance | High | 0.80 (Very significant) | High |
| 280 | Clause A - Condition precedent | Ensure the government's representative is technically knowledgeable | Pre-contract & Operation | Public | Governance/Capacity | Governance | High | 0.80 (Very significant) | Medium |
| 290 | Clause A - Condition precedent | Provide a more detailed clause on what the SPV could/cannot do before signing | Pre-contract | Private (SPV) | Legal/Contractual | Governance | Medium | 0.72 (Significant) | High |
| 300 | Clause A - Condition precedent | Retain existing clause (varies by project nature) | Pre-contract | Public & Private (joint) | Legal/Contractual | Governance | Medium | 0.71 (Significant) | High |
| 10 | Clause B - Concession Charges | Appropriate action to account for deflation/inflation and price-related variables | Operation | Public & Private (joint) | Financial | Economic | High | Mode 4, SD 0.00 (high consensus) | Medium |
| 20 | Clause B - Concession Charges | Freeze potential future occurrence so it is not a negotiation component | Operation | Private | Financial | Economic | High | Mode 4, SD 0.97-1.13 (reasonable consensus) | Medium |
| 30 | Clause B - Concession Charges | Introduce mixed-price structure (public sets quantities, users pay for extra) | Operation | Public & Private (joint) | Financial | Economic & Social | High | Mode 4, SD 1.06-1.11 (reasonable consensus) | Medium |
| 40 | Clause B - Concession Charges | Include provision for renegotiation when new information becomes available | Operation | Public & Private (joint) | Financial/Legal | Economic & Governance | High | Mode 4, SD 0.00 (high consensus) | High |
| 310 | Clause B - Concession Charges | Develop a complete database on service level/standard for determining KPI | Pre-contract & Operation | Public | Operational/Governance | Governance | High | 0.82 (Very significant) | Medium |
| 320 | Clause B - Concession Charges | Allow renegotiation for inflation/deflation within a specified range | Operation | Public & Private (joint) | Financial | Economic | Medium | 0.78 (Significant) | High |
| 330 | Clause B - Concession Charges | Deduct Availability/Asset Maintenance Charges for KPI non-compliance | Operation | Public | Financial/Operational | Economic & Governance | Medium | 0.71 (Significant) | High |
| 50 | Clause C - Design and Construction | Ensure sustainability objectives are established early | Pre-contract/Design | Public & Private (joint) | Design/Environmental | Environmental | High | Mode 4, SD 0.00 (high consensus) | High |
| 60 | Clause C - Design and Construction | Ensure sustainability objectives are clear | Design | Public & Private (joint) | Design/Environmental | Environmental | High | Mode 4, SD 0.00 (high consensus) | High |
| 70 | Clause C - Design and Construction | Well-developed change mechanism for new developments/legislation | Design/Construction | Public & Private (joint) | Legal/Technical | Environmental & Governance | High | Mode 4, SD 0.38-0.47 (high consensus) | Medium |



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|---|---|---|---|---|---|---|---|---|---|
| 80 | Clause C - Design and Construction | Link payment to achievement of agreed sustainability outputs | Operation | Public | Financial/Environmental | Economic & Environmental | High | Mode 4, SD 0.57-0.58 (high consensus) | Medium |
| 340 | Clause C - Design and Construction | Discuss output requirement in detail during Value Management meeting | Pre-contract/Design | Public & Private (joint) | Design | Economic | High | 0.86 (Very significant) | High |
| 350 | Clause C - Design and Construction | Provide a clear statement of needs (by the end-user) | Pre-contract | Public/End-user | Design | Social | High | 0.85 (Very significant) | High |
| 360 | Clause C - Design and Construction | Allow changes to some degree, with defined criteria | Design/Constructio n | Public & Private (joint) | Design/Financial | Economic & Environmental | High | 0.82 (Very significant) | Medium |
| 370 | Clause C - Design and Construction | Specify all details in contract to prevent changes during construction | Pre-contract | Public & Private (joint) | Legal/Design | Governance | Medium | 0.78 (Significant) | Medium |
| 380 | Clause D - Delay of Construction Works | Maintain current practice (LAD or temp facility, per project nature) | Construction | Private | Operational/Financial | Economic | Medium | 0.75 (Significant) | High |
| 390 | Clause D - Delay of Construction Works | Ensure uniformity of the clause (LAD or temporary facility provision) | Construction | Public & Private (joint) | Legal | Governance | Medium | 0.66 (Significant) | High |
| 100 | Clause E - Asset Management Services | Improve output specifications to reduce subjectivity | Operation | Public | Operational | Governance | High | Mode 4, SD 0.35-0.54 (high consensus) | Medium |
| 400 | Clause E - Asset Management Services | Define a clear objective incl. a well-developed change mechanism | Operation | Public & Private (joint) | Operational/Legal | Governance | High | 0.85 (Very significant) | Medium |
| 410 | Clause E - Asset Management Services | Ensure early endorsement of material by end-user; variation rights if changed later | Construction/Opera tion | Public/End-user | Operational | Social | High | 0.82 (Very significant) | High |
| 420 | Clause E - Asset Management Services | Define facility management scope beyond maintenance | Operation | Private | Operational | Social | Medium | 0.78 (Significant) | Medium |
| 430 | Clause E - Asset Management Services | Thoroughly check contract; acknowledged by end-user | Pre-contract | Public/End-user | Legal | Governance | Medium | 0.74 (Significant) | High |
| 440 | Clause E - Asset Management Services | Allow more end-user involvement in decision making | Operation | Public/End-user | Governance | Social | Medium | 0.66 (Significant) | Medium |
| 110 | Clause F - Service Levels | Include adjustment mechanism for changing service requirements | Operation | Public & Private (joint) | Operational | Social | High | Mode 4, SD 0.71-0.83 (reasonable consensus) | Medium |
| 120 | Clause F - Service Levels | Appropriate periodic review mechanisms for change in service | Operation | Public & Private (joint) | Operational/Governance | Governance | High | Mode 4, SD 0.67-0.89 (reasonable consensus) | High |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 450 | Clause F - Service Levels | Apply true Asset Facility Management (quality, H&S, security, not just maintenance) | Operation | Private | Operational/Safety | Social | Medium | 0.77 (Significant) | Medium |
| 130 | Clause G - Additional Works | Ensure value for money; project company duty to mitigate costs | Construction/Operation | Private | Financial | Economic | High | Mode 4, SD 0.63-0.76 (reasonable consensus) | High |
| 140 | Clause G - Additional Works | Transparency of information on costing | Construction/Operation | Public & Private (joint) | Financial/Governance | Governance | High | Mode 4, SD 0.57-0.69 (high consensus) | High |
| 150 | Clause G - Additional Works | Competitive quotes/tendering for sub-contracted capital works | Construction | Private | Financial | Economic | High | Mode 4, SD 0.63-0.76 (reasonable consensus) | Medium |
| 160 | Clause G - Additional Works | Cost benchmarked against prevailing market rates | Construction/Operation | Public & Private (joint) | Financial | Economic | High | Mode 4, SD 0.00 (high consensus) | High |
| 170 | Clause G - Additional Works | Use validation mechanisms - compare with industry-wide benchmark prices | Construction/Operation | Public & Private (joint) | Financial | Economic | High | Mode 4, SD 0.00 (high consensus) | High |
| 180 | Clause G - Additional Works | Compare costs with experience of other PFI projects | Construction/Operation | Public | Financial | Economic | High | Mode 4, SD 0.84-0.98 (reasonable consensus) | Medium |
| 190 | Clause G - Additional Works | Adopt strategic approach - bundle similar changes to reduce costs | Operation | Public & Private (joint) | Financial/Operational | Economic | High | Mode 4, SD 0.00-0.32 (high consensus) | High |
| | | | | | | | | | |
| 200 | Clause G - Additional Works | Plan a change programme based on anticipated needs | Operation | Public & Private (joint) | Operational | Economic & Governance | High | Mode 4, SD 0.00-0.32 (high consensus) | Medium |
| 460 | Clause G - Additional Works | Consider only changes categorized as crucial and important | Operation | Public | Financial | Economic | High | 0.80 (Very significant) | High |
| 470 | Clause G - Additional Works | Include a pre-agreed schedule of rates in the contract | Pre-contract | Public & Private (joint) | Financial | Economic | Medium | 0.71 (Significant) | High |
| 480 | Clause H - The Concession Company | Determine upfront the basis/method of calculation for Refinancing Gain | Pre-contract | Public & Private (joint) | Financial/Legal | Economic | High | 0.83 (Very significant) | High |
| 490 | Clause H - The Concession Company | Ensure new shareholder is from a competent company | Operation | Public | Governance/Financial | Governance | High | 0.82 (Very significant) | Medium |
| 500 | Clause H - The Concession Company | Be specific on terms to be changed if renegotiating due to shareholder change | Operation | Public & Private (joint) | Legal | Governance | Medium | 0.75 (Significant) | High |
| 520 | Clause I - Force Majeure | Provide a platform/mechanism to mutually agree the definition of 'substantial cost' | Operation | Public & Private (joint) | Legal/Financial | Economic & Governance | Medium | 0.78 (Significant) | Medium |



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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 530 | Clause I - Force Majeure | Define 'substantial cost' quantitatively (e.g. % of completed works cost) | Pre-contract | Public & Private (joint) | Legal/Financial | Economic | Medium | 0.77 (Significant) | High |
| 210 | Clause J - Project Monitoring Committee | Identify resources required for PPP monitoring in bidding documents | Pre-contract | Public | Governance | Governance | High | Mode 4, SD 0.00 (high consensus) | High |
| 220 | Clause J - Project Monitoring Committee | Specify in contract how monitoring will be performed (reporting procedures) | Operation | Public & Private (joint) | Governance | Governance | High | Mode 4, SD 0.49-0.52 (high consensus) | High |
| 230 | Clause J - Project Monitoring Committee | Specify amount/circumstances under which sanctions can be applied | Operation | Public | Governance/Legal | Governance | High | Mode 4, SD 0.49-0.52 (high consensus) | Medium |
| 240 | Clause J - Project Monitoring Committee | Specify procedures in the event of renegotiation | Operation | Public & Private (joint) | Legal/Governance | Governance | High | Mode 4, SD 0.52-0.79 (reasonable consensus) | Medium |
| 250 | Clause J - Project Monitoring Committee | Specify quality of service supervision and complaint handling | Operation | Public & Private (joint) | Operational/Governance | Social | High | Mode 4, SD 0.49-0.52 (high consensus) | High |
| 540 | Clause J - Project Monitoring Committee | Provide a framework/SOP to conduct the Project Monitoring Committee | Pre-contract/Operation | Public | Governance | Governance | Medium | 0.77 (Significant) | High |
| 260 | Clause K - Dispute Resolution | Incorporate Alternative Dispute Resolution (ADR) | Operation | Public & Private (joint) | Dispute/Legal | Social & Governance | High | Mode 4, SD 0.00 (high consensus) | High |
| 550 | Clause K - Dispute Resolution | Provide a framework/SOP for the Dispute Resolution Committee (e.g. KL Arbitration) | Operation | Public & Private (joint) | Dispute/Legal | Governance | Medium | 0.77 (Significant) | High |
| 560 | Clause L - Occupational Safety and Health | Standardization of the OSH clause | Pre-contract | Public & Private (joint) | Safety/Legal | Social | Medium | 0.77 (Significant) | High |
| 570 | Clause L - Occupational Safety and Health | Specify the Occupational Safety & Health Requirement in the contract | Pre-contract | Public & Private (joint) | Safety | Social | Medium | 0.74 (Significant) | High |

## CONCLUSION

This paper reports the development of proposed strategies to deal with the implications of IC in PFI projects. Some of the strategies proposed are: to ensure that both public and private representatives involved are technically knowledgeable, to develop a complete database on the service level and standard for the purpose of determining the KPI, and to provide a clear statement of needs. The strategies proposed could be used by key PFI stakeholders, policy makers and contract drafters as a reference in their future endeavour in developing and managing PFI contracts. If implemented effectively, the identified strategies can mitigate the implications of IC and consequently enhance the overall performance, transparency, and accountability of PFI projects. Furthermore, by promoting efficient resource management, long-term value creation, and equitable risk allocation, the strategies also support the sustainability of PFI project delivery.

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# BIM COMPETENCY REQUIREMENTS FOR CHINA RAILWAY INFRASTRUCTURE PROJECT

**Dahuai Zhao[1], Nurul Sakina Mokhtar Azizi[2*], Nazirah Zainul Abidin[3], Weiwei Wang[4], Jiasheng Zhou[5]**

[1,2,3,5]*School of Housing Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[1,4]*School of Civil Engineering,*
DEYANG COLLEGE OF URBAN RAIL TRANSIT, CHINA

## Abstract

BIM delivery in railway infrastructure is shaped by dense subsystem interfaces and formal review-and-acceptance gates, which place strong demands on traceable, auditable information. However, BIM competency descriptions in the literature remain largely generic and provide limited guidance for railway-specific delivery governance and role profiling. This study investigates the BIM competencies required for railway infrastructure projects through a qualitative design using a structured interview protocol with open-ended prompts. Ten railway BIM practitioners were interviewed, and transcripts were analysed thematically; themes were developed inductively and reported using Succar's Core-Domain-Execution layers. The findings indicate that competency is primarily judged by the ability to produce review-ready packages under controlled coordination and change, rather than by software proficiency alone. Five competency clusters were identified: data governance and traceability; integration and platform-enabled coordination; compliance and configuration discipline; model and workflow execution for deliverable production; and lifecycle readiness supported by scenario thinking and reality-capture/verification. The study proposes a preliminary railway-contextualised competency structure and links clusters to delivery nodes and verifiable artefacts to support assessment and training design.

***Keywords***: railway infrastructure, BIM, competency requirements, thematic analysis, delivery governance

[2] Corresponding author. Email: sakinamokhtar@usm.my

## INTRODUCTION

Railway infrastructure delivery is inherently information-intensive and interface-dense, involving tightly coupled civil, track, power, signaling, and systems engineering disciplines, multiple organizational actors, and a requirement for information continuity over asset lifespans that commonly extend beyond 30-50 years. These characteristics materialize most clearly at specific delivery nodes rather than at the level of abstract processes. Typical examples include a federated multi-disciplinary model review in which interface clashes are identified, logged as issues, revised across authoring teams, re-submitted, and formally accepted within an assurance regime; or a design change that cascades through model versions, requiring configuration control and traceability to demonstrate compliance with safety and regulatory requirements. At the transition to operations, asset information must further satisfy criteria of completeness, consistency, and auditability to support maintenance, certification, and future renewal decisions. Under railway-specific constraints-most notably safety assurance, regulatory scrutiny, high interface density, and long service life-these delivery nodes transform BIM from a representational or coordination tool into a governance instrument, thereby imposing capability requirements that are more fine-grained, more rigorous, and explicitly verifiable than those typically observed in building projects (Hussain et al., 2024; Grossauer et al., 2022).

While BIM has been increasingly mandated and implemented in rail projects, existing BIM competency frameworks remain predominantly generic and articulated at a macro level, limiting their direct applicability to railway delivery governance, role definition, and training implementation. Two testable gaps emerge from recent literature. First, there is a lack of railway-specific, first-hand empirical evidence capturing how BIM competencies are understood and enacted by practitioners in real delivery contexts; much of the current research emphasizes technologies, standards, or organizational strategies, with limited attention to situated professional practice (Bartoněk et al., 2023; Shi & Guo, 2025). Second, prevailing frameworks rarely establish an explicit connection between competencies, concrete delivery nodes or task situations, and observable evidence of performance. This missing "competency-node-evidence" linkage constrains operability: competencies cannot be readily translated into role-based capability statements, curriculum modules, or auditable governance checkpoints within railway projects (Lee et al., 2023). As a result, competency frameworks risk remaining conceptually sound yet practically under-utilized.

In response, this study aims to identify the BIM competencies required for railway infrastructure projects, addressing the research question: what BIM competencies are perceived by practitioners as essential for managing information-intensive delivery nodes in railway infrastructure projects? Drawing analytically on established BIM competency thinking-particularly the three-level logic distinguishing task, process, and organizational capabilities-this study


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makes three contributions. First, it proposes a preliminary railway-specific BIM competency structure organised along these three levels, explicitly grounded in the delivery characteristics of rail infrastructure. Second, it develops an initial inventory linking competencies to concrete delivery nodes and task situations, providing actionable inputs for subsequent scale development, training modules, and role profiling. Third, it offers insights for delivery governance and capability development, informing how competencies may be embedded in assurance processes, organizational roles, and project controls (Hussain et al., 2024; Laishram & Sood, 2024). The scope of the study is intentionally bounded: the findings are exploratory, reflect practitioner-perceived competencies rather than normative standards, and require further validation before the proposed structure can be treated as a taxonomy or industry framework.

## LITERATURE REVIEW

BIM competency has been discussed in the literature using a range of definitions and levels of abstraction, often reflecting the specific objectives of each study. For the purpose of this research, BIM competency is defined as a context-dependent and integrative ability that is directly related to project delivery requirements, enacted through specific task situations, and observable through task execution and its associated evidence. This working definition emphasizes performance in context rather than possession of isolated skills. Accordingly, a distinction is made between skills as discrete technical or tool-based proficiencies, competencies as the ability to integrate multiple skills to achieve observable outcomes in specific tasks or situations, and capabilities as organizational-level, repeatable system abilities embedded in processes and governance structures. Consistent with the exploratory nature of this study, competency is treated as an analytical construct rather than a normative benchmark. The focus is on identifying competency requirements relevant to railway project delivery, rather than on measuring competency maturity, validating scales, or proposing prescriptive standards.

Existing BIM competency research has predominantly focused on building projects or on the general architecture, engineering, and construction (AEC) domain, with relatively limited attention to infrastructure contexts and even fewer studies explicitly addressing railways. Prior work has commonly adopted high-level competency frameworks, role-based classifications, or maturity models aimed at assessing organizational readiness or professional development needs (Lee et al., 2023; Laishram & Sood, 2024). While these studies provide valuable insights, several operational limitations can be identified when viewed from a railway delivery perspective. First, competencies are frequently articulated in generic terms, with limited linkage to specific delivery nodes or recurring task situations where competencies are enacted and assessed. Second, the mechanisms connecting organizational governance requirements to

frontline execution tasks are often underexplored, leaving the role of competency in mediating this relationship insufficiently explained. Third, the resulting competency descriptions are difficult to translate into actionable outputs such as role profiles, targeted training modules, or auditable governance checkpoints. In this study, delivery nodes are understood as recurring task situations at which BIM-related competencies are enacted, evaluated, or contested within project governance, a clarification that directly addresses these limitations and frames the subsequent review.

**Railway infrastructure context and competency implications**

Railway infrastructure projects exhibit a set of delivery characteristics that intensify the need for context-specific BIM competencies and expose the limitations of generic competency formulations. High levels of system integration and interface density across civil works, track, signaling, power, and communications demand robust competencies in interface management and cross-disciplinary coordination, often enacted through iterative review and resolution cycles. Stringent review, approval, and safety assurance processes place additional emphasis on competencies related to model quality control, regulatory awareness, and the ability to demonstrate compliance through verifiable information (Hussain et al., 2024). Design changes in railway projects frequently propagate across multiple systems and contractual boundaries, thereby elevating the importance of version control, configuration management, and traceability competencies (Grossauer et al., 2022). Moreover, the exceptionally long lifecycle of railway assets, coupled with operation and maintenance dominating whole-life costs, requires competencies in information governance, asset data completeness, and long-term information usability (Bartoněk et al., 2023). Taken together, these characteristics form a mechanism chain through which railway-specific constraints translate into differentiated competency requirements. Consequently, BIM competencies in railway projects need to be explicitly identified, contextualized around delivery nodes, and structured in a way that supports delivery governance and capability development.

**Succar framework as analytical baseline**

To provide a theoretically grounded and internally consistent structure for analysing BIM competencies, this study adopts the BIM competency framework developed by Bilal Succar as its analytical baseline. Within this framework, BIM competency is defined as the personal traits, professional knowledge, and technical abilities required by an individual to perform a BIM-related activity or deliver a BIM-related outcome, where such abilities, activities, or outcomes are measurable against performance standards. This definition explicitly situates competency at the intersection of ability, activity, and observable outcome, rather than framing it as an abstract attribute or a role-based qualification. While not


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intended as a comprehensive theory of professional competence, Succar's framework offers a clear and coherent logic for organising individual BIM competencies through three complementary tiers-core, domain, and execution competencies-which together describe how competencies manifest and combine in practice. In this study, the framework is neither evaluated, adapted, nor extended, nor is it compared against alternative competency models; it is employed solely as a post-analytic structuring and reporting baseline.

For clarity, Table 1 summarises the three BIM competency tiers as defined by Succar, together with their conceptual scope and typical manifestations in BIM-related activities. The table strictly follows the terminology and intent of the original framework and is included to make explicit the analytical structure underpinning this study, rather than to reinterpret or modify the framework.

**Table 1.** BIM competency tiers according to Succar

| BIM competency tier | Definition | Typical manifestation in BIM-related activities |
|---|---|---|
| Core competencies | Personal abilities attributable to an individual that enable the performance of measurable activities or the delivery of outcomes, including inherent traits, qualifications, situational enablers, and experience-related indicators. | Professional attitudes, educational background, experience profiles, and personal attributes conditioning engagement in BIM-enabled work. |
| Domain competencies | Professional abilities that enable individuals to perform multi-task activities and deliver complex outcomes within a BIM context, encompassing managerial, functional, technical, and supportive competencies. | Managing, coordinating, analysing, and facilitating BIM processes across disciplines and project stages. |
| Execution competencies | Abilities to use specific tools, techniques, and equipment to conduct an activity or deliver a measurable outcome. | Use of BIM software applications, data exchange tools, modelling techniques, and related technologies. |

*Source: Succar's BIM Competency (2013)*

In operational terms, the framework is applied through a hybrid analytical approach. BIM competency themes are first identified inductively from empirical material, without using Succar's Core-Domain-Execution structure as an a priori coding framework. These empirically derived competencies are then mapped onto the three-tier structure of core, domain, and execution competencies to support systematic organisation and transparent reporting. Mapping decisions are guided by the dominant nature of each competency-whether it primarily reflects personal attributes, professional abilities, or tool-based execution-while recognising that effective BIM-enabled performance typically draws upon

competencies across all three tiers. This use of Succar's framework enables the identified competencies to be structured and interpreted in a consistent manner, while remaining aligned with the exploratory aim of the study to identify railway-specific BIM competency requirements. Accordingly, Succar's framework does not determine the initial coding or theme generation.

## RESEARCH METHODOLOGY

This study employed a qualitative exploratory design to identify BIM competency requirements as perceived by practitioners involved in railway infrastructure delivery. The design was appropriate because the objective was to elicit context-specific, practice-grounded accounts rather than to test hypotheses or claim statistical generalisability. Data were generated through semi-structured interviews conducted using a structured protocol and open-ended prompts to enhance cross-case comparability while allowing depth and flexibility. Probing followed a consistent logic to capture (i) the delivery node or governance gate in which a competency was required, (ii) the verifiable evidence produced (e.g., model packages, review outputs, issue/closure logs, change records), and (iii) critical incidents involving deviation, failure, and rectification.

The primary analytical sample comprised ten railway BIM practitioners (n = 10) recruited through purposeful sampling with a maximum-variation rationale to achieve heterogeneity in role responsibility, organisational context, lifecycle-stage exposure, and interface scope. The sample covered contractor/O&M and several design-related organisational or functional contexts, including subcontracting, design institutes, design/management, and design/R&D, and included participants whose work spanned design production, construction coordination, formal review/acceptance activities, and handover or O&M-readiness preparation. Interface exposure ranged from discipline-specific work requiring structured hand-offs to interface-dense, multi-system coordination involving civil, track, signalling, and electrification stakeholders. Eligibility was restricted to practitioners with direct involvement in railway BIM delivery within the preceding 12 months to ensure experience-near accounts. Following preliminary analysis, five additional interviews (n = 5) were conducted as a thematic sufficiency check after the initial theme structure had been established. These follow-up interviews used the same protocol and were assessed against the established codebook to test for the emergence of substantively new competency clusters; none were identified, supporting the stability of the thematic structure within the defined scope. Accordingly, the thematic results and participant-coverage summaries reported in this article are based exclusively on the ten primary analytical participants (P01-P10); the five follow-up interviews were used only to assess thematic sufficiency and were not included in the reported coverage counts. All interviews were undertaken with informed consent, audio-recorded, transcribed verbatim, anonymised, and


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focused on experiences from the past 12 months; typical interview durations were approximately 40-60 minutes. The practitioner profiles of the primary analytical sample are summarised in Table 2.

**Table 2.** Practitioner profiles of the primary analytical sample (n = 10)

| Participant | Experience (Professional / Railway BIM) | Position / Principal Role | Organisational / Functional Context | Project-stage Involvement |
|---|---|---|---|---|
| P01 | 6 / 4 years | O&M Engineer / O&M Party | Contractor / O&M | Implementation / O&M |
| P02 | 4 / 2 years | BIM Engineer / Modelling / Consultancy | Design / Subcontractor | Construction Deepening |
| P03 | 5 / 3 years | BIM Engineer / Design Party | Design Institute | Design / Construction |
| P04 | 6 / 4 years | BIM Lead / Design / Management | Design Institute | Full Lifecycle |
| P05 | 11 / 8 years | Deputy Director / Design Party | Design / Management | Full Lifecycle |
| P06 | 5 / 4 years | Software Designer / R&D Party | Design Institute | Design / R&D |
| P07 | 11 / 11 years | Tunnel R&D Lead / R&D Party | Design / R&D | Design / R&D |
| P08 | 7 / 7 years | Roadbed R&D Lead / R&D Party | Design / R&D | Design / R&D |
| P09 | 6 / 6 years | Bridge Design / R&D / R&D Party | Design / R&D | Design / Implementation |
| P10 | 8 / 8 years | Software Developer / R&D Party | Design Institute | R&D / Production |

Note: Experience is reported as total professional experience / railway BIM experience. O&M = operation and maintenance; R&D = research and development.

Data analysis followed a stepwise thematic analysis procedure involving repeated familiarisation with transcripts, coding of meaning units, clustering into candidate themes, and iterative refinement through review and naming. Coding was inductive and grounded in the empirical material, with analytic attention directed to how competencies were described in relation to delivery governance and evidence production, rather than as decontextualised "software skills". As a post-analytic structuring step, finalised themes were mapped onto Succar's core, domain, and execution competency tiers to support

transparent reporting. This mapping was applied as a reporting scaffold rather than as an a priori coding framework; Succar's categories were not used to generate the codes or themes, and the framework itself was not adapted. Decisions were guided by each theme's dominant functional locus and typical context of enactment, and cross-tier relevance was noted where empirically indicated. Trustworthiness was strengthened through maintenance of a codebook, analytic memos, and an audit trail, supplemented by second-researcher review of the codebook and theme assignments using two transcripts (20% of the primary dataset) and representative coded extracts, with discrepancies resolved through discussion. A light form of member checking was conducted by sharing a concise summary of key themes with three participants for confirmation of interpretive accuracy. Ethical safeguards included informed consent, anonymisation, and secure storage with controlled access in line with institutional requirements.

Table 3 provides illustrative examples linking participant extracts, the competency coding used to organise the coded material, the final theme clusters, and the subsequent Succar-layer reporting assignment. The examples are illustrative rather than a complete coding audit trail. The broader clusters were developed through iterative grouping and refinement of related coded material; only after the clusters were finalised were they mapped onto Succar's Core-Domain-Execution structure.

**Table 3.** Illustrative examples of coding and thematic development

| Participant | Illustrative interview extract | Competency coding | Final theme cluster | Succar reporting layer |
|---|---|---|---|---|
| P06 | *"Digital delivery requires each component to contain the necessary information before the model is uploaded to a platform for subsequent operation and maintenance."* | D9 - Lifecycle Information Governance and Continuity Management | Data governance & traceability | Domain |
| P08 | *"Collaborative design involving multidisciplinary data exchange requires the establishment of a shared data centre."* | D4 - Supportive | Integration & platform coordination | Domain / Execution |
| P10 | *"Standards and workflows are interrelated and should be developed together."* | D7 - Implementation | Compliance & configuration discipline | Domain |
| P09 | *"Coordinate points can be extracted from models and exported as data files for direct use in surveying and setting-out."* | E4 - Techniques | Model & workflow execution | Execution |
| P01 | *"Existing assets may be reconstructed through UAV, GIS, and scanning technologies to supplement operation and maintenance information."* | E6 - Integrated GIS-BIM and Digital Surveying Execution | O&M readiness: scenario & reality capture | Execution |


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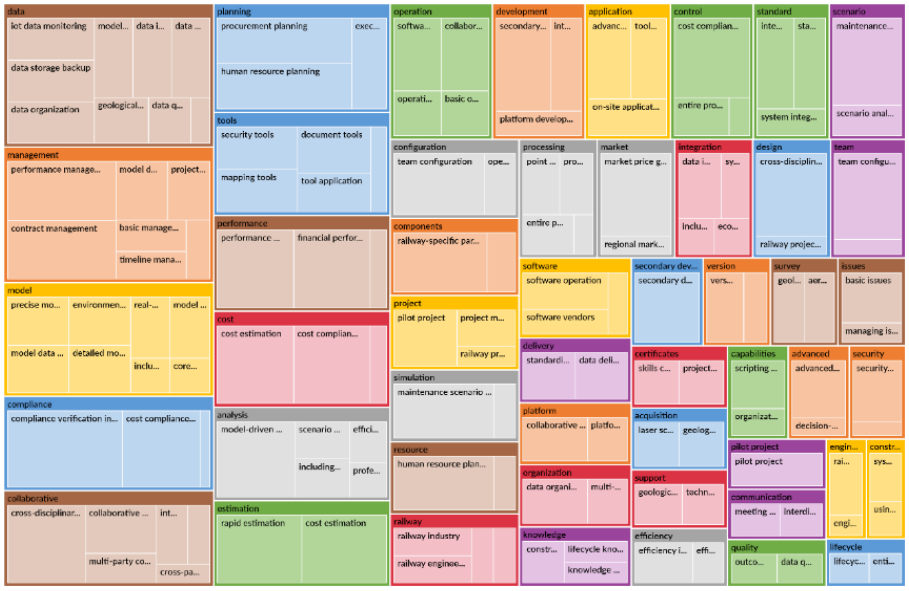



**Figure 1.** NVivo treemap of coded material distribution across competency clusters
*Source: Authors' NVivo output (treemap), generated from coded transcripts*

## ANALYSIS AND DISCUSSION

The analysis indicates that practitioners describe BIM competency requirements for railway infrastructure through an integration- and delivery-oriented lens. The NVivo treemap (Figure 1) provides an overview of where coded material concentrates across the dataset, showing substantial attention to data work, project governance, compliance and control, standards and versioning, collaborative arrangements, and operation-facing concerns. Rather than treating this distribution as evidence of "importance" on its own, the figure is used here to orient the thematic narrative. The substantive results are reported through theme clusters with evidence strength (Table 4) and then translated into delivery-node requirements through verifiable artefacts (Table 5).

Table 4 summarises the theme clusters and their relative strength in the dataset. Two observations matter for how railway BIM competency is best interpreted. First, the clusters are not confined to modelling execution; they consistently span governance, coordination, and gatekeeping functions that determine whether outputs can pass review and acceptance. Second, the distribution captured in Figure 1 aligns with this broader conception: integration- and control-related coding appears alongside technical work, indicating that practitioners often judge competence by the ability to deliver controlled, reviewable outputs rather than by software proficiency alone. This framing is important because it sets up the logic for presenting results as a chain from information governance to integrated delivery and operational usability.

**Table 4.** Theme clusters and NVivo evidence strength

| Theme cluster | Succar layer | Coverage (x/10) | Refs(n) |
|---|---|---|---|
| Data governance & traceability | Domain | 9/10 | 42 |
| Integration & platform coordination | Domain/Execution | 10/10 | 58 |
| Compliance & configuration discipline | Domain | 8/10 | 33 |
| Model & workflow execution | Execution | 9/10 | 49 |
| O&M readiness: scenario & reality capture | Execution | 7/10 | 27 |

A major cluster in Table 4 concerns data governance and traceability, which participants consistently treated as a baseline condition for reliable railway BIM delivery. In Figure 1, data-related nodes occupy a large share, covering routine but consequential work such as storage/backup, organisation, quality checks, and monitoring or domain-specific datasets. In the interviews, these were not framed as general "digitalisation" requirements; instead, they were described as practical competencies required to keep information recoverable, auditable, and trustworthy across stages. In railway delivery, where subsystems are tightly coupled and decisions may need to be revisited long after design, weak traceability becomes a governance risk rather than a simple efficiency problem. This helps explain why data governance appears as a recurring competency requirement and why it is treated as foundational to later integration and acceptance activities.

The theme cluster centred on integration and collaborative coordination emerges as a distinctive organising feature of the dataset. Its prominence in Table 4 is consistent with Figure 1, where integration- and platform-related coding sits adjacent to team configuration and cross-disciplinary design work. Participants framed integration as a practical capability: aligning disciplinary contributions into a shared baseline, managing interface dependencies, and sustaining closure through iterative review cycles. What makes this cluster analytically important is its procedural character. Integration is repeatedly tied to platform-mediated practices-permissions, audit trails, structured exchanges, and issue logs-suggesting that competence is associated with running collaboration as a controlled process rather than relying on informal coordination. This cluster therefore bridges organisational arrangements and task-level routines, and it provides the connective tissue linking upstream information governance to downstream deliverable acceptance.

A further cluster concerns compliance-oriented control and configuration discipline, including version and change management. Table 4 indicates that compliance and control are not peripheral topics in the competency narrative; they are part of what practitioners consider necessary for "successful delivery". Figure 1 reinforces this by showing substantial coding around control/compliance and versioning alongside more technical areas. Participants


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described competence in terms of producing outputs that can withstand review and audit: packaging submissions, applying checks, documenting non-conformities, recording rectification actions, and maintaining approved baselines across milestones. Version discipline is especially consequential in railway projects because changes propagate across interdependent systems and can affect safety-critical interfaces. In this sense, competence is framed not only as the ability to update models, but as the ability to preserve an auditable record of what changed, why it changed, and which baseline is approved for downstream use.

Execution-oriented themes in Table 4 do include modelling and toolchain work, but the interviews tend to evaluate execution through the lens of deliverability and evidence. In Figure 1, model- and tool-related coding is positioned near verification- and process-oriented nodes, which is consistent with how participants described their work: producing models at stage-appropriate detail, ensuring information completeness, running coordination checks, and completing workflows in ways that generate inspectable records. This implies a stricter competence standard than "being proficient" with a tool. Competence is expressed as the ability to deliver review-ready packages repeatedly and reliably-packages that include not only models but also the outputs that make quality and compliance visible (e.g., coordination reports and closure records).

Operation-facing competencies appear as a meaningful component of the dataset, particularly through maintenance-related scenarios and verification-oriented practices. In Figure 1, scenario and operation nodes sit alongside acquisition/survey-related coding, while Table 4 captures this as a distinct theme cluster. Participants did not treat O&M as a distant downstream concern; rather, they associated competence with whether delivered information remains usable for verification and decision-making beyond design and construction. Where reality capture and survey-related practices are discussed, they are typically connected to the credibility of "as-built" states and the reliability of handover information. Similarly, maintenance scenarios and operational viewpoints signal a lifecycle orientation: competence includes anticipating how information will be interrogated in operational contexts, not merely how it is produced during delivery.

**Table 5.** Linking theme clusters to railway delivery nodes and verifiable artefacts

| Theme cluster | Delivery node and competency requirement | Verifiable artefacts |
|---|---|---|
| Data governance & traceability | Review & acceptance: Configure auditable information governance to ensure submission packages are traceable, secure, and review-ready. | Review checklist; rectification/closure log; CDE permission and audit logs; naming/classification rules; structured transmittals. |

| Theme cluster | Delivery node and competency requirement | Verifiable artefacts |
|---|---|---|
| Integration & platform coordination | Handover to O&M: Maintain a reusable, standardised documentation system to support lifecycle continuity and accountability. | Handover package index; asset data dictionary; archival catalogue; metadata completeness check report; long-term storage/backup record. |
| | Interface coordination: Translate cross-disciplinary requirements into coordinated actions and close interface issues with accountable records. | Interface register; coordination minutes; RACI/issue assignment; issue log with closure evidence; clash/coordination report. |
| | Model federation & integration milestone: Operate platforms and interoperability workflows to federate models and stabilise integrated baselines. | Federated model release record; clash detection report; model exchange records (e.g., IFC/NWC); integration acceptance sign-off; platform activity logs. |
| Compliance & configuration discipline | BEP/standards parameterisation: Convert policy/standard requirements into BEP constraints and checking rules governing downstream deliverables. | BEP key-parameter table; checking rule set; standardised delivery protocol; compliance information extraction sheet. |
| | Change/version control gate: Enforce controlled change propagation and baseline discipline under multi-party approvals. | Version register; baseline approval record; change request + approval trail; compliance verification report; delta/diff record of key model outputs. |
| Model & workflow execution | Drawing & data delivery: Produce discipline models and extracted outputs through repeatable workflows supporting formal submission. | Standard drawing set; model-derived schedules/quantities; delivery package (RVT/IFC + drawings); QC checklist; transmittal. |
| | Quantity/cost submission: Execute model-based measurement and cost workflows with traceable inputs and outputs. | QTO sheet; cost estimate summary; change impact comparison; measurement rule documentation; model snapshot/baseline referenced in submission. |
| O&M readiness: scenario & reality capture | As-built verification: Capture reality conditions and validate as-built fidelity to reduce downstream uncertainty for O&M. | Point-cloud dataset; processing report; deviation/comparison report; as-built model release; verification sign-off record. |
| | Scenario-based O&M readiness: Prepare scenario-oriented information products for maintenance planning and operational decision-making. | Maintenance scenario outputs; simulation notes; visual briefing package; asset information checklist aligned to O&M use cases. |

Table 5 synthesises these findings into delivery-node requirements and clarifies how competence becomes assessable through verifiable artefacts. Across key railway delivery gates-such as interface coordination, review and acceptance,


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change/version control, handover packaging, and as-built verification-the mapping shows that competency expectations consistently combine governance (data and platform control), coordination (integration and closure), and execution (review-ready outputs). This is where the railway-specific contribution becomes most explicit: the competencies are not presented as generic attributes, but as requirements attached to nodes where evidence is produced and checked. Taken together, the results support a layered interpretation of railway BIM competency as an integrated capability chain: data governance enables controlled integration; controlled integration supports compliance and acceptance; and these, in turn, condition whether outputs remain usable for verification and downstream operations.

The findings also have practical implications for competency development and project governance. For training, the clusters can inform modules organised around railway delivery nodes and observable artefacts rather than software commands alone. For professional certification or internal competency assessment, the competency-node-evidence logic can support evidence-based criteria in which practitioners demonstrate controlled model exchanges, issue closure, change traceability, or other reviewable outputs; however, this study does not establish a certification standard. For tendering, clients and lead organisations may use the clusters as a reference when specifying BIM personnel or team capability requirements, subject to project-specific validation. For BIM execution plans (BEPs), the identified requirements can be translated into role responsibilities, workflow controls, review gates, and expected deliverables so that competency expectations are linked to implementation arrangements. These applications should be treated as potential uses of the exploratory findings rather than validated prescriptions, and further testing across roles and projects is required before formal adoption.

## CONCLUSION

This study addressed RQ1 by identifying the BIM competencies practitioners consider necessary for railway infrastructure projects. The interviews show that competency is typically judged at delivery gates-where outputs must be reviewable, traceable, and acceptable-rather than through tool familiarity in isolation. Five clusters capture how requirements are articulated in practice: information governance and traceability; integration and platform-enabled coordination under dense subsystem interfaces; compliance and configuration discipline under change; execution capability expressed through repeatable, review-ready modelling and delivery workflows; and lifecycle readiness supported by scenario-oriented thinking and reality-capture/verification practices.

The study contributes a preliminary, railway-contextualised competency structure organised with Succar's layers as a reporting baseline and

operationalised through delivery nodes and verifiable artefacts. This operational framing is the main point of difference from generic competency lists: it specifies where each requirement becomes visible (e.g., interface coordination, review and acceptance, change/version control, deliverable submission, as-built verification and handover) and what can be checked as evidence (e.g., issue-closure records, compliance check outputs, baseline registers, controlled transmittals, and handover packages). For practitioners, the results support competency development and role profiling that start from these gates and evidentiary outputs, so that training and assessment align with the controls and coordination cycles that dominate railway BIM delivery.

The findings remain exploratory and reflect practitioner-perceived requirements from a limited qualitative sample; they should not be treated as an industry standard, a validated taxonomy, or a validated measurement framework. Future work should (i) triangulate the competency claims against project documents and delivery requirements, (ii) translate the clusters into measurable indicators for survey-based assessment and validation, and (iii) test how requirements vary by role, stage, and interface intensity across different railway project types. These steps would strengthen external validity and support the development of robust competency assessment instruments and targeted capability-building programmes for railway infrastructure organisations.

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# IMPROVING SEGMENTATION PERFORMANCE AND OBJECT IDENTIFICATION IN THERMAL ROOF IMAGERY USING ARTIFICIAL INTELLIGENCE

**Liu Yuexiang[1], Farazeira Mohd Raslim[2]*, Nurul Sakina Mokhtar Azizi[3], Muhammad Hafeez Abdul Nasir[4]**

[1,3,4]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[2]*Civil Engineering Programme, Faculty of Engineering,*
UNIVERSITI MALAYSIA SABAH

## Abstract

The segmentation performance for boundary delineation of rooftop areas and the identification of objects in thermal images is often inaccurate due to low contrast and thermal noise. Improving both boundary delineation and object identification is essential to support further analyses. Therefore, the research objective of this paper is to identify roof-level elements in thermal images and improve boundary delineation accuracy for segmentation. This research employed an experimental methodology, examining 100 thermal images from a case study done at Universiti Sains Malaysia. Thermal images were captured using an unmanned aerial vehicle (UAV) and subsequently processed by frame extraction, similarity-based filtering, and manual polygon-based annotation. The study uses an artificial intelligence (AI) framework to execute the analysis. The findings showed that the AI framework was able to identify roof related objects, such as solar panels, roof equipment, and roofs. The proposed Mask R-CNN model achieved a segmentation mAP (AP averaged over IoU 0.50–0.95) of 77.2%, an AP50 of 95.1%, and an AP75 of 90.2%, indicating strong segmentation performance in the present case-study setting. Compared with the benchmark studies reviewed in this paper, which reported performance levels ranging from 9.4% to 80.8% depending on the task and evaluation metric, the present study showed a markedly stronger reported segmentation result. The delineation boundary of the roof elements was also improved, leading to more accurate assessments of the roof's condition and better identification of potential maintenance needs.

***Keywords***: Thermal imaging, Image segmentation, Boundary delineation, Rooftop inspection, Building assessment

[2] Corresponding author. Email: faraziera@ums.edu.my

## INTRODUCTION

Thermal infrared imaging has been widely applied in building inspection and energy-related assessment because it reveals surface temperature patterns associated with building conditions, heat loss, and rooftop components relevant to building operation (Mastrucci et al., 2021). In rooftop analysis, thermal images can provide useful information on roof surfaces, solar panels, and roof-mounted equipment, which are closely related to building operation and energy performance. However, for thermal images to be used more systematically in building analysis, these rooftop elements must first be identified and separated with sufficient spatial clarity.

This makes segmentation performance in thermal image boundary delineation an important issue. In rooftop thermal imagery, the usefulness of the image does not depend only on whether an object is visible, but also on whether its boundary can be identified clearly enough for further interpretation, comparison, and analysis. Accurate segmentation is therefore important because boundaries between rooftop components define the regions of interest for later assessment (Khan & Bhattacharjee, 2021). However, unlike RGB images, thermal images often contain weak texture contrast and gradual temperature transitions. As a result, boundaries between adjacent rooftop elements may appear thermally continuous rather than visually distinct, which makes both object identification and boundary delineation more difficult.

A further challenge is that progress in rooftop thermal-image segmentation is limited not only by the nature of thermal imagery itself, but also by the availability of appropriate data. Building-oriented thermal datasets remain limited (Balaras & Argiriou, 2002), and many existing thermal datasets are designed for surveillance or autonomous driving rather than for individual buildings or rooftop-level semantic components (Choi et al., 2022). This affects both model development and the reliability of performance interpretation in real building contexts. In other words, segmentation performance in rooftop thermal imagery is shaped not only by model capability, but also by whether the available data are sufficiently representative of rooftop conditions.

To address this problem, the present study adopts a UAV-based rooftop thermal case study and applies an artificial intelligence framework to examine segmentation performance in rooftop thermal image boundary delineation. Rather than treating the dataset only as an end product, the study uses it as an empirical basis to evaluate whether roof-level elements can be identified and segmented effectively in a rooftop thermal-image setting. In particular, the study focuses on roof, solar panel, and roof equipment as rooftop semantic classes, and examines how segmentation performance can support clearer rooftop interpretation in a building-related context.

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This focus is also relevant to built-environment applications because rooftop thermal information is useful only when it can be interpreted and organised with reasonable spatial consistency. In institutional building settings, unclear rooftop boundaries can weaken the consistency of inspection records, reduce the comparability of condition observations across building components, and limit the usefulness of thermal imagery for maintenance review, inspection prioritisation, and asset-related documentation. Recent studies have similarly highlighted the importance of building condition assessment, digital built-environment workflows, and cost- and facility-related decision-making (Mohd Nazri et al., 2025; Che Haron & Muhd Zafir, 2025). In this sense, the present study is not only about applying image segmentation to thermal imagery, but also about improving the reliability of rooftop information used in building-related interpretation and decision support.

## LITERATURE REVIEW

### Thermal Imaging Applications in Building Assessment

Balaras and Argiriou (2002) demonstrated that infrared thermography has long been used in building diagnostics and energy-related assessment. Nardi et al. (2016) demonstrated that thermographic methods can also be applied to quantitative building-performance evaluation, such as U-value assessment. Chicherin et al. (2023) demonstrated that aerial thermography can support large-scale building energy audits by revealing insulation-related deficiencies across residential areas. Kim et al. (2023), Pedranzini et al. (2024), and Rosti et al. (2025) further demonstrated that thermal imaging has been extended to moisture detection, air leakage assessment, and building-envelope monitoring.

However, Mondal et al. (2025) demonstrated that automation in image-based analysis is still constrained by limited training data, while many building-related thermal studies still rely heavily on expert interpretation. These studies showed that thermal imaging is valuable in building assessment, but they also showed that practical interpretation still depends on how clearly building elements can be separated and understood in the image.

### Adoption of artificial intelligence in segmentation performance

Hernandez et al. (2020), Naiman et al. (2022), Peng et al. (2021), and Xu et al. (2023) demonstrated that traditional thermal-image segmentation methods, such as thresholding, edge detection, region growing, and clustering, can be used to separate thermal regions under controlled conditions. However, Acorsi et al. (2020) demonstrated that aerial thermal imagery often contains weak contrast and variable image quality, which makes segmentation more difficult in real scenes.

Batchuluun et al. (2020) demonstrated that deep learning has improved thermal-image analysis by enabling stronger feature learning than traditional


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methods. Hou et al. (2021) demonstrated that Mask R-CNN can be applied to building-component segmentation in multichannel aerial imagery. However, Hou et al. (2021) also showed that segmentation performance still varies with scene complexity and object type. Together, these studies demonstrated that AI has strong potential for segmentation improvement, but its application to rooftop thermal imagery remains limited and still requires further validation in building-oriented settings.

Although thermal segmentation techniques have advanced substantially, most existing work has been developed in controlled or non-building contexts. Their applicability to rooftop thermal imagery remains uncertain because building elements often present weak, overlapping, and thermally ambiguous boundaries(Acorsi et al., 2020).

**Existing Thermal Image Datasets**

Chu et al. (2024) demonstrated that large thermal datasets have been developed for pedestrian detection, while Dai et al. (2020) demonstrated that thermal datasets are also widely used in autonomous driving research. Gou et al. (2023) demonstrated that some thermal datasets have been developed for defect-related studies, but these datasets are generally small and task-specific. These studies showed that publicly available thermal datasets mainly focus on transportation, surveillance, or laboratory-based defect detection rather than rooftop-level building analysis.

**Evaluation of Segmentation Performance**

Hou et al. (2021) demonstrated that segmentation performance in building-related imagery can be evaluated using precision-based measures. Mayer et al. (2021) demonstrated that rooftop thermal detection may still show very low recall when the target is difficult to identify. Mayer et al. (2023) demonstrated that stronger deep learning models can improve rooftop thermal detection performance, especially for larger rooftop targets. Park et al. (2021) demonstrated that F1 score can be used to evaluate thermal segmentation performance in building-envelope studies.

## RESEARCH METHODOLOGY

This study adopted a case-based methodology to evaluate segmentation performance in rooftop thermal boundary delineation. Figure 1 shows the workflow, which includes UAV thermal-image acquisition, frame extraction, similarity-based filtering, annotation, dataset preparation, and Mask R-CNN training. Python with OpenCV was used for frame extraction and filtering, LabelMe was used for polygon-based annotation, and Detectron2 with a ResNet-101 backbone was used for model training and evaluation.

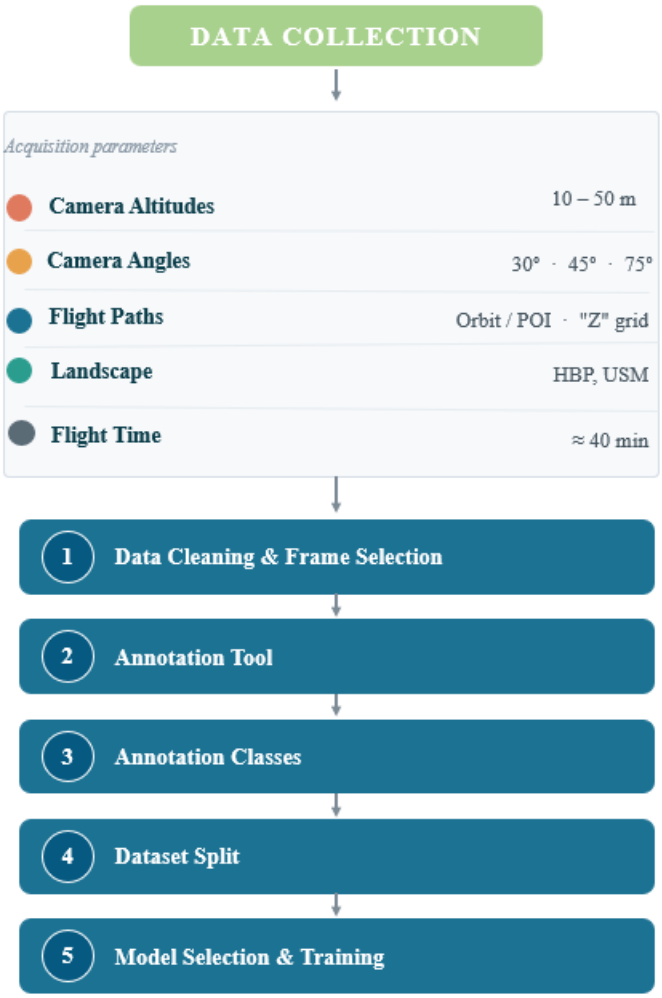



**Figure 1:** Workflow of UAV-based thermal dataset construction and annotation

The case study was conducted on Building E49 at the School of Housing, Building and Planning, Universiti Sains Malaysia (USM), with an estimated roof area of approximately 1649.31$m^2$. The rooftop was suitable for thermal-image acquisition because its main roof-level elements could be captured with limited occlusion from surrounding structures and vegetation.


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**Figure 2:** A general aerial view of the HBP, USM

**Data Collection**

Thermal images of the building were collected using an unmanned aerial vehicle (UAV) equipped with an infrared camera. The UAV platform enables flexible observation of building scenes from multiple viewpoints and heights, allowing comprehensive coverage of building structures and surrounding environments. Compared with fixed observation stations, UAV-based acquisition provides greater adaptability to complex building layouts while maintaining consistent thermal sensing capability. Thermal data were collected using a UAV-mounted infrared camera, as shown in Figure 3.



**Figure 3:** UAV platform used for rooftop thermal image acquisition

During each flight mission, thermal data were recorded in video format (MP4) rather than as isolated still images. This approach ensures continuous spatial coverage and captures dynamic variations in viewing angles and scene composition.

The recorded thermal videos were subsequently decomposed into individual image frames using a custom frame extraction program. Each frame represents a single thermal snapshot corresponding to a specific UAV position and viewing angle. This process generated a large pool of candidate thermal images, forming the raw dataset for further processing.

**Data Cleaning and Frame Selection**

Ejaz et al. (2012) and Zhang et al. (2020) demonstrated that key-frame extraction can reduce redundancy while retaining representative image content. Garrido et al. (2021) showed that thermographic preprocessing can support the learning process, while Deng et al. (2020) demonstrated that grayscale infrared images can be used for thermal-region analysis and feature extraction. Batchuluun et al. (2020) also showed that transformed thermal-image representations can support subsequent image analysis. Following this general approach, consecutive thermal frames were filtered by similarity and converted to gray-scale representations, and only frames with visual dissimilarity above 5% were retained. This resulted in a refined dataset of 100 thermal images.

**Annotation Tool**

After frame extraction and similarity-based filtering, the selected thermal images were manually annotated using the LabelMe (Dobbie et al., 2021) annotation tool. LabelMe was chosen due to its polygon-based annotation capability, which allows precise delineation of irregular and fine-grained object boundaries commonly observed in rooftop thermal imagery.

Polygon annotations are particularly suitable for thermal images, where object contours are often blurred and do not align with sharp pixel-level edges. Polygon-based annotation was selected because thermal boundaries in rooftop imagery are often blurred and transitional. This allowed the annotation process to reflect the practical difficulty of boundary delineation rather than imposing artificially sharp boundaries.

**Annotation Classes**

The dataset was annotated with a focus on roof-level semantic components that are critical for rooftop thermal inspection and boundary analysis. Each thermal image was annotated using the following labels of semantic classes: (1) solar panel, (2) roof, and (3) roof equipment. These semantic classes of annotation were selected because these objects in the thermal image are often adjacent and exhibit similar thermal patterns at their boundaries, making it difficult to clearly delineate the boundaries. This creates a challenging boundary-sensitive segmentation scenario that is appropriate for examining limitations in rooftop thermal image delineation. The images were annotated by three annotators using


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shared labelling conventions for the three classes (roof, solar panel, roof equipment), with attention to the ambiguous contact regions between them. All labels were then cross-checked in a review pass, where inconsistent boundaries or class assignments were re-examined and corrected to ensure a consistent standard across the dataset.

**Dataset Split**

Hou et al. (2021) demonstrated that separated data subsets can support building-component segmentation training and evaluation. Following this general approach, the 100 annotated images were randomly split into training (72), validation (13), and testing (15) subsets (Figure 4). The model was trained on the training subset, and the reported metrics were obtained on the validation subset during training; independent testing is left as future work.

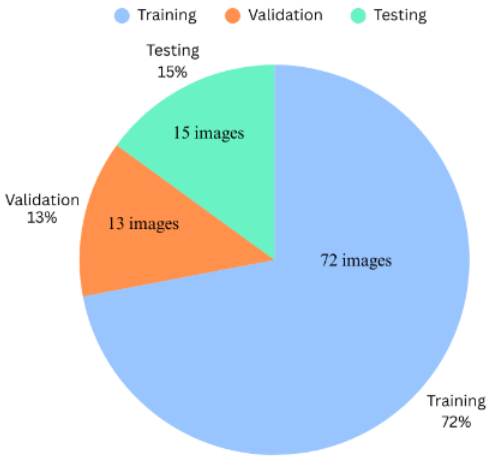



**Figure 4:** Distribution of the dataset into training, validation, and testing subsets

**Model selection and training**

Mask R-CNN was selected as the segmentation model in this study because it can perform object detection and instance segmentation simultaneously, which is suitable for separating the roof, solar panel, and roof equipment as distinct rooftop objects. The selection of Mask R-CNN was informed by the original work of He et al. (2017), who demonstrated its effectiveness for instance segmentation, and by Hou et al. (2021), who applied Mask R-CNN to building-component segmentation from aerial RGB–thermal imagery. Following this general line of research, Mask R-CNN was adopted in the present study to evaluate whether

rooftop elements in UAV thermal images could be identified and segmented effectively at the object level.

A ResNet-101 backbone was used in the present study because deeper residual networks can extract stronger hierarchical image features while remaining easier to optimize through residual learning. This choice was informed by He et al. (2016), who showed that deep residual networks improve visual recognition performance, and by He et al. (2017), who evaluated Mask R-CNN with ResNet backbones of 50 and 101 layers. In the present study, ResNet-101 was selected to provide richer feature extraction for rooftop thermal images, where rooftop elements may differ in size, shape, and thermal appearance.

The training process was set to 60,000 iterations. This follows the general practice of using fixed training schedules in instance-segmentation baselines, as seen in standard Detectron2 model-zoo configurations. However, the exact value of 60,000 iterations in the present study was chosen empirically for the current dataset rather than copied directly from a single previous study. It was retained because the model had already learned stably by the later stage of training, and further training was not expected to improve the result significantly. Therefore, 60,000 iterations were considered sufficient for the present case-study setting.

## ANALYSIS AND DISCUSSION

### Benchmark comparison and overall model performance

To make the model performance easier to understand, benchmark results from related thermal-image studies were first summarised in Table 1. Hou et al. (2021) showed that Mask R-CNN can be used to segment building-related components from aerial RGB–thermal imagery, but the reported precision was 39.70%, which indicates that segmentation in aerial thermal-related scenes is still not an easy task. Mayer et al. (2021) reported an average recall of 9.4% for rooftop thermal bridge detection, showing that many rooftop thermal targets were still missed in their early study. Mayer et al. (2023) later reported an average recall above 50% for large rooftop thermal bridge objects, which suggests that stronger pretrained models can improve rooftop thermal detection. Park et al. (2021) reported an F1 score of 80.8% for wall thermal anomaly detection, showing that segmentation can also support building-envelope thermal analysis beyond rooftop studies. Together, these studies show that thermal-image-based building analysis is feasible, but performance still varies greatly depending on the target object, image source, and evaluation metric. Hou et al. (2021), Mayer et al. (2021), Mayer et al. (2023), and Park et al. (2021) provide a useful benchmark context for the present study.

Against this benchmark context, the present study achieved a segmentation mAP of 77.2%, an AP50 of 95.1%, and an AP75 of 90.2% for roof,


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solar panel, and roof equipment in UAV rooftop thermal images. The mAP averages performance across IoU 0.50–0.95, AP50 reflects the lenient 0.50-overlap standard, and AP75 the stricter 0.75 standard. Because the studies in Table 1 used different datasets, targets, and metrics, Table 1 provides contextual reference rather than a same-dataset baseline comparison.

**Table 1:** Benchmark comparison with related studies

| Study | Main target | Image type | Model/method | Reported metric | Reported performance |
|---|---|---|---|---|---|
| **Hou et al. (2021)** | Building components and outdoor scenes | Aerial RGB–thermal imagery | Mask R-CNN | Precision | 39.70% |
| **Mayer et al. (2021)** | Rooftop thermal bridges | Aerial thermal images | Neural-network detector | Average Recall | 9.4% |
| **Mayer et al. (2023)** | Rooftop thermal bridges | Aerial thermal | Mask CNN / Swin-T | Average Recall | Above 50% |
| **Park et al. (2021)** | Wall thermal anomalies | Thermal visible building envelope images | CNN-based segmentation | F1 score | 80.8% |
| **Present study** | Roof, solar panel, roof equipment | UAV rooftop thermal images | Mask R-CNN | AP50<br>AP75<br>mAP | 95.1%<br>90.2%<br>77.2% |

## Training behaviour and model reliability

Hou et al. (2021) showed that Mask R-CNN can support building-component segmentation, whereas the present study further showed strong classification and mask-level performance in rooftop thermal imagery. As reported in Table 2, the proposed model achieved a Fast R-CNN classification accuracy of 99.85%, a foreground classification accuracy of 98.88%, and a mask accuracy of 98.99%. The corresponding error rates were also low, with a Fast R-CNN false negative of 1.03%, a mask false negative of 0.78%, and a mask false positive of 1.41%. These results showed that the model not only detected rooftop objects accurately, but also produced masks with a high level of consistency. Compared with the benchmark studies discussed earlier, the present study showed a stronger overall segmentation outcome in the current case-study setting, although direct comparison should still be interpreted carefully because Hou et al. (2021), Mayer

et al. (2021), Mayer et al. (2023), and Park et al. (2021) reported different evaluation metrics.

**Table 2:** Training-time diagnostic metrics of the proposed Mask R-CNN model

| Metric | Value |
|---|---|
| **Fast R-CNN classification accuracy** | 99.85% |
| **Foreground classification accuracy** | 98.88% |
| **Mask accuracy** | 98.99% |
| **Fast R-CNN false negative** | 1.03% |
| **Mask false negative** | 0.78% |
| **Mask false positive** | 1.41% |

Mayer et al. (2023) showed that stronger deep learning models can improve rooftop thermal detection performance, and Figure 5 in the present study further showed that the training process was stable throughout the learning stage. The loss curve decreased steadily to approximately 0.031 and became more stable in the later stage of training. This pattern showed that the model not only achieved strong final performance, but also learned rooftop thermal features in a consistent way over time. In this sense, Figure 5 provides additional support for the reliability of the proposed model by showing that the reported Table 2 results were achieved through stable convergence rather than unstable fluctuation.

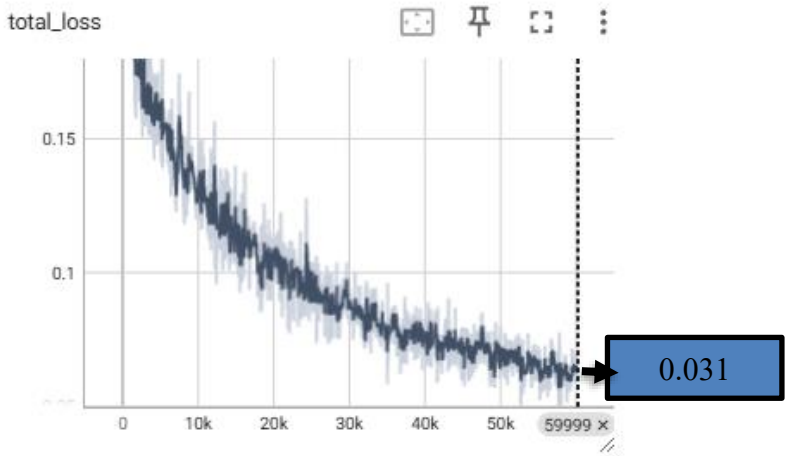


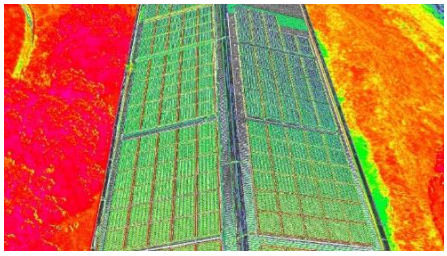

**Figure 5:** Total training loss of the proposed Mask R-CNN model


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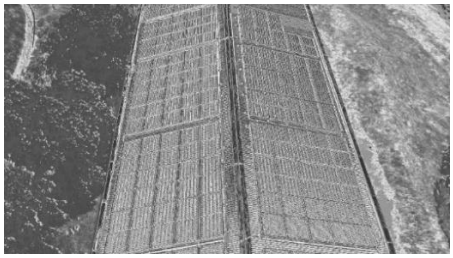
**Visual segmentation performance**

Although three rooftop classes were included, the qualitative discussion in Figure 6 focuses on the roof and solar panel because they are more visually prominent in the selected example. Krapf et al. (2022) showed that rooftop superstructure annotation can affect prediction quality, while Boccalatte and Chanussot (2025) showed that smaller rooftop superstructure-related classes tend to be less prominent and more difficult to interpret in segmentation outputs.

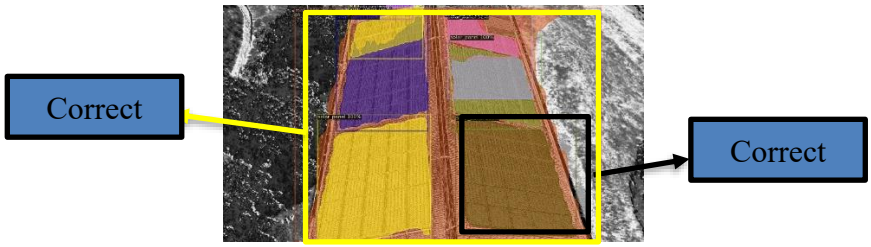
Figure 6 presents a representative visual result of the proposed Mask R-CNN model for rooftop thermal-image segmentation. As shown in Figure 6(c), the model was able to identify the main rooftop regions and generate segmentation masks that broadly followed the spatial extent of the rooftop scene. When read together with the original UAV thermal image and the gray-scale thermal image in Figure 6(a) and Figure 6(b), the segmentation output shows that the model not only produced a high numerical score, but also generated a visually meaningful object-level result. This supports the AP50 value of 95.1% reported in the present study and suggests that the model was effective in locating rooftop objects under the current case-study setting.



(a) Original UAV thermal image



(b) Gray-scale thermal image




(c)Segmentation mask thermal image

**Figure 6:** Representative visual result of rooftop thermal-image segmentation using the proposed Mask R-CNN model

This visual result supports earlier studies more directly and practically. Hou et al. (2021) showed that aerial image data can be used to segment building-related components, and the present study shows a similar result in rooftop

thermal imagery. Mayer et al. (2021) reported lower recall in early rooftop thermal bridge detection, while Mayer et al. (2023) later showed that stronger deep learning models could improve rooftop thermal detection performance. The present study is consistent with this general direction, because the segmented output in Figure 6 shows that rooftop elements can be identified clearly in the current dataset and case-study setting. However, these comparisons should still be interpreted carefully because the earlier studies focused on thermal bridge detection, whereas the present study focuses on roof, solar panel, and roof equipment segmentation.

The visual result is also meaningful in a building-related context. Park et al. (2021) showed that segmentation can improve the practical usefulness of thermal analysis in building-envelope studies. In the present study, the segmented rooftop image makes it easier to understand which rooftop part is being observed and where it is located. This gives the thermal image a clearer structure and makes it more useful for inspection review, condition assessment, and digital building workflows. In this sense, Figure 6 not only supports the numerical results reported earlier but also shows that rooftop thermal imagery can be translated into more structured rooftop information through segmentation.

These segmented outputs also support maintenance decisions: because the roof, solar panels, and roof equipment are separated into distinct regions, abnormal thermal patterns can be attributed to a specific component and prioritised for inspection, each element gains a stable spatial reference for tracking condition over repeated inspections, and roof and component extents can be measured directly for maintenance planning and documentation.

## CONCLUSION

This study evaluated the performance of a Mask R-CNN model for rooftop thermal-image segmentation using UAV thermal images. The model was used to identify the roof, solar panel, and roof equipment in the case-study dataset. The results showed strong segmentation performance, with a mAP of 77.2%, an AP50 of 95.1%, and an AP75 of 90.2%, supported by high accuracy values and stable training behaviour. This indicates that the model was able to identify rooftop elements effectively from the thermal images. The study also shows that rooftop thermal imagery can be transformed into more structured rooftop information through segmentation. Instead of remaining as a raw thermal image, the rooftop scene can be separated into clearer object-level regions that are easier to interpret. This is important for building-related applications because clearer rooftop information is more useful for inspection, condition review, and maintenance-related observation. Overall, the research objective was achieved. The proposed model was able to identify rooftop elements and provide measurable segmentation performance from UAV thermal images. This study has several


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limitations. It is based on a single building (E49, USM) and 100 thermal images, so the results indicate feasibility in this setting rather than general accuracy. The reported metrics were obtained on the validation subset; an independent test-set evaluation and per-class analysis are recommended for future work. Future work should expand the dataset across buildings and seasons and add a same-data baseline.

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# A STUDY ON THE TYPES OF INTERACTION MECHANISMS BETWEEN PUBLIC PARTICIPATION AND SPATIAL DESIGN IN THE MICRO-RENEWAL OF PUBLIC SPACES IN OLD RESIDENTIAL COMMUNITIES

**Fujuan Feng[1], Nor Arbina binti Zainal Abidin[2*], Zhihao Guo[3]**

[1,2,3]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

As urban renewal in China shifts from large-scale demolition and reconstruction to small-scale and incremental micro-renewal approaches, the regeneration of public spaces in old residential communities has become a crucial issue for optimizing urban stock and promoting social sustainability. In recent years, public participation has been widely encouraged at both policy and practice levels, yet the degree of synergy between public participation and spatial design varies significantly across different projects. This study adopts the Expression–Translation–Response–Feedback (ETRF) process logic, widely taken for granted in both theoretical discussions and practical operations, as an analytical framework to examine how public demands are conveyed, translated, and responded to within design and governance processes. Based on a comparative study of six representative old residential communities in Shanghai (Hongxu, Shanbei, Xiuyuan, Sanlinyuan, Boyi, and Bosan), five types of interactive mechanisms are identified: highly collaborative, balanced collaborative, partial feedback, representative collaborative, and technology-dominated types. Furthermore, a collaboration–disruption continuum is proposed. The findings indicate that institutionalized participation channels and the depth of design translation jointly influence the level of collaboration, while social trust and feedback continuity affect the long-term viability of the mechanisms. Theoretically, this study provides an analytical path for understanding different types of interactive mechanisms; practically, it offers type-based references and optimization strategies for participatory renewal in the fields of landscape architecture and community planning.

***Keywords***: Public spaces in old residential communities, Micro-renewal, Public participation, Spatial design, Interaction mechanism

[2] Corresponding author. Email: arbina@usm.my

## INTRODUCTION

As urban development enters the stage of stock renewal, high-density cities have increasingly shifted from large-scale demolition toward small-scale and incremental micro-renewal (Wu et al., 2023). In this context, the renewal of public spaces in old residential communities has become an important means of improving livability and social cohesion. Nevertheless, many communities continue to face aging facilities, underused spaces, and fragmented management (He et al., 2025). Recent policies, such as "Complete Community Construction" and "Community Micro-Renewal," therefore emphasize public participation to promote a transition from physical upgrading to social co-construction.

Despite this emphasis, collaboration outcomes vary substantially across projects (Innes & Booher, 2018; Sun et al., 2022; Watson, 2014). While some initiatives achieve effective coordination between public participation and spatial design, others remain dominated by formalistic participation or technical decision-making, resulting in weak integration of public demands. This discrepancy raises a key question: why do projects operating under similar participatory frameworks produce markedly different collaborative outcomes and resident perceptions?

Existing studies conceptualize public participation through collaborative rationality and responsive design, highlighting communication, adaptation, and alignment between social needs and spatial responses (Carmona, 2019; Dovey & Pafka, 2020; Innes & Booher, 2018; Yang, Bose, & Horrigan, 2025). However, prior research has largely focused on participation levels or procedural arrangements, with limited attention to how public demands are translated into design responses and how feedback is perceived and sustained in practice (Watson, 2014; Yang et al., 2025). Moreover, participatory processes are frequently shaped by institutional constraints, resource dependency, and trust relations (Li, Zhang, & Zhu, 2023; Marzukhi et al., 2022; Watson, 2014; Xue, Wang, & Li, 2021; Zanudin et al., 2024), which help account for persistent gaps between official participation narratives and residents' lived experiences in renewal practices.

Across related fields, elements such as expression, translation, response, and feedback are repeatedly discussed in a fragmented manner, often focusing on specific stages or actors, while their sequential and processual relationships remain largely implicit. Building on this observation, this study adopts the Expression–Translation–Response–Feedback (ETRF) process logic as an analytical lens for examining interaction patterns between public participation and spatial design. Rather than serving as a normative process model, the ETRF framework provides a structured lens for examining interaction patterns between public participation and spatial design. Using six micro-renewal cases in Shanghai's old residential communities, this study conducts a comparative

analysis to identify interaction mechanism types and to construct a collaboration–disruption continuum.

The contribution of this study is twofold. Theoretically, this study uses the ETRF process logic as an analytical basis to develop a type-oriented research pathway for identifying interaction mechanisms, thereby extending comparative research on public participation–spatial design interactions (Kamalipour & Dovey, 2020). Practically, it offers comparative insights into collaboration patterns across old residential communities, providing references for community governance, planning practice, and landscape architecture renewal (Li et al., 2023).

## LITERATURE REVIEW

As urban renewal enters the stage of stock transformation, micro-renewal of public spaces in old residential communities has become an important direction in China's urban governance (Wu et al., 2023). Beyond physical renovation, micro-renewal involves processes of social collaboration and design interaction (Yue, Lin, & Gong, 2021). Public participation has therefore been widely emphasized in planning, landscape architecture, and urban design as a mechanism for promoting sustainability and spatial equity (Yang et al., 2025). However, collaborative effectiveness varies substantially across projects, and disconnections between public expression and design response remain common, highlighting the need for a mechanism-oriented and type-sensitive analytical approach.

### Public Participation and Collaborative Governance

The theoretical roots of public participation are commonly traced to Arnstein's (1969) ladder, which conceptualizes participation through power redistribution. Innes and Booher (2018) further advanced collaborative rationality, emphasizing diversity, interdependence, and authentic dialogue as conditions for effective collaboration. Watson (2014) distinguished collaboration from co-production, noting differences in initiation mechanisms and power structures, thereby revealing persistent gaps between formal participation and substantive collaboration.

### Institutional Mechanisms and Interaction Differences

Collaborative governance theory highlights that participation outcomes depend not only on institutional design but also on trust, negotiation, and joint learning (Innes & Booher, 2018). Carmona (2019) emphasized that sustainable public space governance requires continuous coordination among planning, design, and management, with public participation playing a central role.


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Using the SFIC model, Yao and Li (2024) identified administrative dependence and symbolic participation as key barriers to collaborative evolution. Empirical studies further show that institutionalized participation does not necessarily generate genuine collaboration: gaps between procedural participation and substantive response persist (Hamideh, 2020; Zanudin et al., 2022), while cognitive and trust mismatches between residents and officials remain evident in practice (Cheng & Xu, 2021). These findings suggest that interaction differences are not only institutional but also socially perceived and spatially manifested (Chen, 2025; Li et al., 2023).

**Design Response and Spatial Translation**

In landscape architecture and urban design research, design is increasingly understood as a medium for social negotiation, where responsiveness reflects the capacity to translate public demands into spatial form (Chen, 2025; Yang et al., 2025). Kamalipour and Dovey (2020) demonstrated that spatial form emerges from negotiated rules and rights, offering an important analogy for understanding how public expression is translated and materialized through design processes.

Empirical studies indicate that weak linkage between participation and design response often results in low space utilization despite physical improvement (Yue et al., 2021). Similarly, insufficient feedback and management integration can undermine residents' sense of identity and long-term engagement (Li et al., 2023). Chen (2025) emphasizes that designers should shift from being "technical experts" to "social collaborators" in order to enhance the social adaptability of design schemes.

**Research Gaps and Theoretical Positioning**

In the Chinese context, studies show that although institutional arrangements such as community planner systems have increased participation visibility, actual interactions remain constrained by administrative logic and resource dependence (Xue et al., 2021). Comparative research has further identified hierarchical differences in participation depth and sustainability across co-creation models (Li et al., 2023).

Overall, three gaps remain in existing studies. First, most research focuses on isolated stages or actors, lacking a process-oriented mechanism analysis that explains the phenomenon of "participation without collaboration" (Watson, 2014; Xue et al., 2021). Second, type-based comparative research remains limited, particularly in revealing how institutional channels, design translation, and social trust interact to shape collaborative outcomes (Li et al., 2023; Yao & Li, 2024). Third, in landscape architecture and urban design,

operational frameworks linking participation mechanisms with spatial adaptability and user experience remain insufficiently developed (Chen, 2025).

Drawing on the above review, existing studies show persistent gaps in explaining how public demands are translated into spatial design responses and sustained through feedback mechanisms in micro-renewal practices. In particular, process-oriented and type-based analyses that link institutional arrangements, design translation, and residents' lived perceptions remain underdeveloped. These gaps call for an analytical perspective capable of systematically examining interaction patterns between public participation and spatial design across different renewal contexts.

## RESEARCH METHODOLOGY

This research aims to identify different types of interaction mechanisms between public participation and spatial design in the micro-renewal of public spaces in old residential communities. Based on the Expression–Translation–Response–Feedback (ETRF) analytical framework, a comparative study of six representative cases was conducted. A qualitative approach was adopted, combining textual materials, site observations, and interviews to support cross-case comparison of interaction mechanisms.

### Research Design

This study adopts the Expression–Translation–Response–Feedback (ETRF) process logic as a process-based analytical reference for mechanism comparison (Figure 1). The ETRF logic is not proposed as a formal theoretical model but as an analytical abstraction derived from recurring process elements in studies on collaborative governance, participatory planning, and responsive design (Carmona, 2019; Chen, 2025; Innes & Booher, 2018; Li et al., 2023; Watson, 2014). These studies collectively point to recurring processes through which public inputs are expressed, interpreted and translated into spatial interventions, reflected in design responses, and subsequently evaluated through feedback. These four stages are particularly suited to this study because they capture how public inputs move from initial articulation through design interpretation and response to subsequent feedback, providing a consistent analytical basis for comparing how participation–design interactions are sustained, weakened, or disrupted across cases.

Six old residential communities in Shanghai were selected as case studies, and their public participation and spatial design processes were examined in relation to the four ETRF stages. Through comparative analysis, the study identifies recurring patterns of collaboration and disruption. The research follows an analytical sequence of process reference → case-based analysis → pattern


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identification → comparative synthesis, emphasizing the inductive identification of interaction mechanism types based on observed process differences.

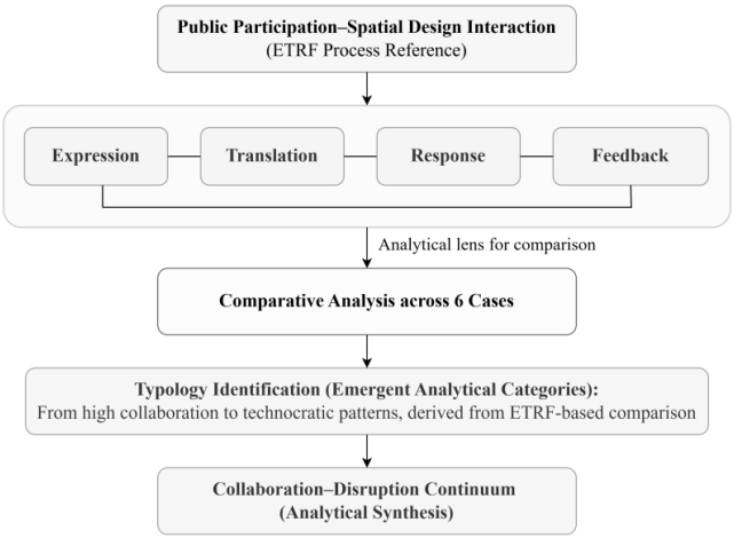



**Figure 1:** Process-Based Analytical Reference for Case Comparison
This figure illustrates how six cases are compared using the ETRF process reference to summarize interaction patterns and to synthesize a collaboration–disruption continuum.
*Source: Created by the Author(2025)*

## Case Selection

This study examines six old residential communities in Shanghai, all involving small-scale public space micro-renewal within comparable community contexts, which allows for cross-case comparison of interaction mechanisms between public participation and spatial design (see Figure 2).



(a) Hongxu: Renewed habitat garden (b) Shanbei: Renewed children's play area
(c)Boyi: Renewed Sunshine Sports Field

**Figure 2:** Representative Public Spaces of the Selected Case Communities
*Source: Google Images (a); Photographed by the Author (2025) (b、c)*

### Data Sources and Methods

Three categories of data were used. Public documents—including government announcements, Shanghai Urban Space Art Season reports, and district-level media coverage—were collected to understand project backgrounds and institutional arrangements. Each of the six cases was visited twice, in March and August 2025, to observe spatial use, resident activities, and post-renewal management. Interviews were conducted with 24 participants, comprising 18 residents and six community governance representatives, and lasted approximately 60 minutes each. Resident interviews focused on awareness of participation, participation experiences, and evaluations of renewal outcomes, while interviews with community governance representatives addressed participation procedures, design coordination, and feedback mechanisms.

### Analytical Process

A qualitative comparative analysis was conducted in four steps. First, case materials were organized according to the ETRF framework to identify key actors, channels, and interaction forms. Second, cross-case comparison was undertaken using four indicators: depth of expression, degree of design translation, perceptibility of response, and continuity of feedback. Third, interaction mechanism types (e.g., highly collaborative, balanced collaborative, partial feedback, representative collaborative, and technology-dominated) were summarized through horizontal comparison. Finally, by mapping the identified types onto a "collaboration–disruption" continuum, this continuum illustrates evolutionary tendencies in interaction mechanisms, while specific points of disruption require case-based analysis. This process emphasizes comparison between institutional narratives and residents' everyday experiences to identify gaps between procedural participation and substantive collaboration.

## RESULTS AND DISCUSSION

### Basis for Type Classification and Analytical Logic

Based on site observations, community committee interviews, and resident interviews in six old residential communities in Shanghai (Hongxu, Shanbei, Xiuyuan, Sanlinyuan, Boyi, and Bosan), this study applies the Expression–Translation–Response–Feedback (ETRF) framework to examine interaction mechanisms between public participation and spatial design. Although participatory procedures generally existed at the institutional level, substantial differences were observed in participation depth, design responsiveness, and feedback continuity. While some residents recognized and actively engaged with renewal outcomes, others were unaware of participation channels or expressed distrust.


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**Table 1:** Comparison of Public Participation and Spatial Design Interaction Mechanisms in Six Typical Communities

| Residential Community | Expression Mechanism | Translation Mechanism | Response Performance | Feedback Mechanism |
|---|---|---|---|---|
| **Hongxu (Changning District)** | Opinion wall, display boards, and residents' deliberation meetings established regular communication among the community committee, designers, and residents | The design team and ecological consultant (TNC) integrated opinions into three zones: conservation, interaction, and education | Formed a "discussion–announcement–execution" loop; facilities and management rules implemented | Feedback collected by the community committee and building representatives; volunteers maintained rotation duties; high resident recognition and frequent use of the Habitat Garden |
| **Shanbei (Huangpu District)** | Multiple channels including briefing sessions, WeChat groups, and children's councils | Opinions translated into the Wisteria Pavilion, play area, and under-forest garden | Facilities frequently used, forming both child-friendly and age-friendly adaptability | Maintained by community committees and volunteer networks; some residents mentioned funding and coordination issues |
| **Xiuyuan (Hongkou District)** | Combination of WeChat groups, online mini-programs, and opinion boards; residents' opinions were divided | Daily needs translated into the "One-Meter Garden," walking paths, and seating | Everyday functionality achieved, active community interaction; some residents dissatisfied with tree removal | Online feedback active but lacking formal response |
| **Sanlinyuan (Pudong New Area)** | Voting, questionnaires, Garden Festival, and co-creation with community planners; some | Opinions translated into the Neighborhood Living Room, Shanghainese | Self-managed and self-funded by residents; spaces in regular use | Voting and governance groups formed a collaborative network |

| Residential Community | Expression Mechanism | Translation Mechanism | Response Performance | Feedback Mechanism |
|---|---|---|---|---|
| | residents unaware of consultation | Culture Plaza, and garden | | |
| **Boyi (Pudong New Area)** | Joint inspections by subdistrict, community committee, school, and design team; insufficient resident consultation | Demands translated into body-testing paths and double-layer flooring | Original site optimized, facilities improved, high usage frequency | Jointly managed by school and volunteer teams; "FUN Electric Field" data returned for monitoring |
| **Bosan (Pudong New Area)** | Joint inspections by subdistrict, community committee, school, and design team; residents and students participated in facility selection and wall painting; insufficient resident consultation | Circulation optimized, new "Pocket Pavilion" and planting garden added | Renewed site became a popular community gathering spot; shared by school and neighborhood | Joint maintenance by volunteers and students; lacking formal feedback platform |

*Source: Compiled by the Author based on public data, community committee interviews, and random resident interviews (2025)*

Table 1 summarizes cross-case variations in interaction mechanisms, forming the basis for the following type classification.

## Types of Interactive Mechanisms and Typical Cases

***Highly Collaborative Type: Institutional Loop and Multi-Actor Co-Governance***
Typical Case: Hongxu Residential Community (Changning District)
Hongxu represents the highly collaborative type, evidenced by multi-channel resident deliberation, the translation of public input into three spatial zones, a "discussion–announcement–execution" loop, and ongoing volunteer-based feedback and maintenance.


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***Balanced Collaborative Type: Multi-Party Negotiation and Everyday Response***
Typical Case: Shanbei Residential Community (Huangpu District)
Shanbei represents the balanced collaborative type, evidenced by multiple participation channels, the translation of resident input into child- and age-friendly spaces, and continuing community and volunteer involvement, although funding and coordination constraints remained.

***Partial Feedback Type: Digital Interaction and Localized Response***
Typical Case: Xiuyuan Residential Community (Hongkou District)
Xiuyuan represents the partial-feedback type, with active digital and offline input and some needs translated into spatial improvements, but without a stable formal feedback mechanism after renewal.

***Representative Collaborative Type: Limited Expression and Procedural Participation***
Typical Case: Sanlinyuan Residential Community (Pudong New Area)
Sanlinyuan represents the representative collaborative type, evidenced by formal voting, questionnaires, and co-creation activities, while participation operated mainly through representatives and some residents remained unaware of the consultation process.

***Technology-Dominated Type: Professional Logic and Limited Public Influence***
Typical Cases: Boyi and Bosan Residential Communities (Pudong New Area)
Boyi and Bosan represent the technology-dominated type, where professional and technical priorities shaped spatial improvements, while resident influence remained limited and formal feedback mechanisms were weak.

The five mechanism types are comparatively synthesized across the four ETRF dimensions in Table 2.

**Table 2:** Typology Matrix of Interaction Mechanisms

| Mechanism Type | Case | Expression | Translation | Response | Feedback |
|---|---|---|---|---|---|
| Highly collaborative | Hongxu | Diverse, sustained input | Deep design translation | Clear design response | Ongoing feedback |
| Balanced collaborative | Shanbei | Diverse public input | Effective translation | Clear design response | Stable feedback |

| Mechanism Type | Case | Expression | Translation | Response | Feedback |
|---|---|---|---|---|---|
| Partial feedback | Xiuyuan | Active public input | Partial translation | Local design response | Irregular feedback |
| Representative collaborative | Sanlin yuan | Representative input | Moderate translation | Formal design response | Limited feedback |
| Technology-dominated | Boyi; Bosan | Limited public input | Expert-led translation | Functional response | Weak feedback |

**"Collaboration–Disruption Continuum"**

Based on the five mechanism types, this study proposes a "collaboration–disruption continuum" (Figure 3) to illustrate interaction patterns between public participation and spatial design. The horizontal axis represents participation and design response strength, while the vertical axis reflects feedback continuity and social trust.

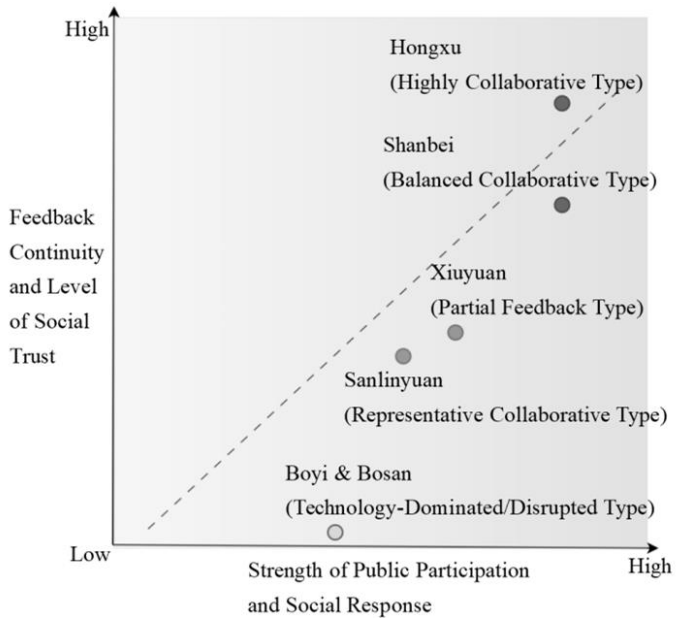



**Figure 3:** "Collaboration–Disruption Continuum" of the Interaction Between Public Participation and Spatial Design in the Micro-Renewal of Public Spaces in Old Residential Communities

*Source: Created by the Author (2025)*


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The highly collaborative case (Hongxu) demonstrates an integrated configuration of institutional mechanisms, design response, and resident trust, whereas technology-dominated cases (e.g., Boyi, Bosan) show clear disconnections between procedures and public perception. Balanced collaborative, partial feedback, and representative collaborative types occupy intermediate positions, reflecting transitional configurations of collaboration and disruption.

**Interactive Differences Between Institutional Collaboration and Social Feedback**

Comparative analysis shows that while most projects established participatory procedures, representative participation and weak feedback institutionalization remained common. Design translation varied across cases: some achieved high spatial adaptability, whereas technology-dominated cases prioritized functional efficiency over social meaning. Residents' perceptions ranged from stable engagement to exclusion and distrust. These findings align with existing studies indicating that formal participatory arrangements do not necessarily lead to substantive collaboration, as gaps often persist between institutional procedures and lived experiences (Watson, 2014; Zanudin et al., 2022). They further show that design translation and feedback continuity shape interaction mechanisms beyond institutional arrangements.

**Explaining Variations in Collaborative Outcomes**

Differences in collaborative outcomes are mainly shaped by three interacting structural factors. Participation often operates through representatives rather than direct expression, leading to a disconnect between institutional participation and residents' perceptions. Technical domination is evident where design processes are driven by professional and safety-oriented logic, with public demands insufficiently reflected. Trust fracture emerges when feedback mechanisms are weak or invisible, leading to limited public recognition despite physical improvements. These findings align with previous research emphasizing the influence of institutional arrangements, power relations, and trust dynamics in shaping participation outcomes (Innes & Booher, 2018; Watson, 2014), while further highlighting the role of design translation as a key mediating mechanism linking participation processes and spatial outcomes. This suggests that collaborative outcomes depend not only on participation structures, but on how effectively public demands are translated and communicated through design processes.

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### Interpreting the Value of Interaction Mechanisms in Micro-Renewal

An ETRF-based analysis shows that effective interaction mechanisms enhance both spatial adaptability and social attachment. In collaborative cases, the translation of public demands into spatial form strengthens residents' sense of belonging, positioning landscape architecture as a mediator of social relations and supporting continuous design–governance integration and trust rebuilding. These findings align with studies highlighting the role of participatory design and collaborative governance in fostering social cohesion and spatial adaptability (Carmona, 2019), while further emphasizing the importance of feedback continuity and response visibility in linking social engagement with spatial production and sustaining micro-renewal outcomes.

### Pathways for Optimizing Interaction Mechanisms from a Landscape Perspective

From a landscape architecture perspective, mechanism optimization can be advanced across three interconnected dimensions. Institutionally, traceable response mechanisms are required to complete the expression–translation–response–feedback loop and ensure that public inputs are visibly acknowledged and incorporated. At the design level, designers should act as social translators, enhancing translation capacity through participatory, adaptive, and context-responsive practices. Socially, sustained collaboration networks linking community planners, volunteer groups, and resident organizations are essential for supporting long-term co-governance and continuous spatial management. These recommendations align with studies emphasizing integrated governance, adaptive design processes, and multi-stakeholder collaboration in public space regeneration (Innes & Booher, 2018; Watson, 2014), while further proposing a type-based understanding of interaction mechanisms, showing how different configurations of participation, design translation, and feedback shape varying collaborative outcomes.

## CONCLUSION

### Main Findings and Interpretive Value

Based on site observations and multi-source interviews in six old residential communities in Shanghai, this study reveals significant variations in interaction mechanisms between public participation and spatial design in micro-renewal practices. By proposing the collaboration–disruption continuum, the study demonstrates that formal participatory procedures do not necessarily lead to substantive collaboration. Instead, the perceptibility of design responses, the continuity of feedback, and the level of resident trust are decisive in shaping collaborative quality.


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From a landscape architecture perspective, effective design translation enables micro-renewal to move beyond physical upgrading toward social mechanism optimization, positioning the interaction between public participation and spatial design as a key pathway for enhancing spatial justice, social resilience, and collaborative governance.

**Research Limitations**

This study has two main limitations. First, resident perspectives were primarily drawn from participating residents. Although the interaction types were identified through multiple data sources, direct accounts of professional design decision-making were relatively limited, limiting direct insight into how some design choices were made. Second, all six cases are located in Shanghai, and the city's specific governance and micro-renewal context may limit the transferability of the findings to other urban contexts. Future research could incorporate additional professional perspectives and cross-city comparisons to further examine the identified mechanism types.

**Future Research Prospects**

Mechanism refinement: Future research should examine institutional designs linking expression, response, and feedback. Digital tools: Interactive platforms and visualization can enhance participation quality and feedback transparency. Interdisciplinary integration: Landscape architecture can act as a mediator between social collaboration and spatial production through co-creative practices. Contextual extension: Comparative studies across cities and governance contexts are needed to test the transferability of interaction mechanism types.

**Concluding Reflections**

The core of micro-renewal in old residential communities lies in reshaping collaborative relations among residents, designers, and governance actors. Stable collaboration depends not on the quantity of participation but on the clarity of design translation, the visibility of responses, and the sustainability of feedback. Landscape architecture thus plays a dual role as a design profession and a mediator of social collaboration, supporting the transition from formal participation to substantive and sustained co-governance. This study shifts the focus from participation procedures to interaction mechanisms, highlighting the role of design translation and feedback as key mediating processes.

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# BIOPHILIC INTERVENTIONS IN GREEN ARCHITECTURE: DESIGN PROFESSIONALS' PERCEPTIONS ON ENHANCING HEALTH AND WELL-BEING THROUGH INDOOR PLANT LANDSCAPES

**Li Ang[1], Syarmila Hany Haron[2]**

[1,2]*Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

Indoor plant landscapes are an established strategy in biophilic design, yet their integration can reveal a divergence between aesthetic appreciation and technical implementation. Grounded in environmental psychology and the Stimulus–Organism–Response framework, this cross-sectional study examined design professionals' perceptions of the aesthetic, functional and well-being dimensions of indoor greenery. A multi-stage sampling approach yielded 185 valid responses from design professionals across major metropolitan regions in Malaysia. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to examine structural associations and the moderating role of professional experience. Respondents rated aesthetics (M = 4.35) and perceived well-being (M = 4.28) more highly than physical environmental functions (M = 3.12) and integration strategies (M = 2.85). Aesthetic cognition was not significantly associated with integration strategies ($\beta = 0.118$, $p = 0.150$), whereas functional cognition showed a positive association ($\beta = 0.462$, $p < 0.001$). Professional experience had a positive moderating effect ($\beta = 0.208$, $p = 0.005$). These findings inform a lifecycle framework encompassing evidence-based design briefs, maintenance governance, indoor environmental quality monitoring and post-occupancy evaluation. The results concern professional perceptions and reported practices rather than measured pollutant removal, occupant health effects or energy savings.

***Keywords***: biophilic design; indoor plant landscapes; design professionals; cognition–practice gap; PLS-SEM; indoor environmental quality; post-occupancy evaluation

[1] Corresponding author. Email: liang95@student.usm.my

# INTRODUCTION

## *Background and research problem*

Indoor environments accommodate work, domestic activities and social interaction. Their design requires attention to spatial usability, visual experience and occupant comfort. Indoor plant landscapes form one approach to incorporating nature into these settings. Biophilic design literature discusses connections between natural elements and human experience (Kellert et al., 2011; Heerwagen, 2009; Ryan et al., 2014). These conceptual and experiential benefits do not establish that a particular planting arrangement improves pollutant removal, ventilation efficiency or building energy performance.

Design professionals influence how plants are specified, located and maintained. Their perceptions are relevant to design decisions, but professional opinion is not a substitute for occupant outcome data or environmental measurements. A favourable assessment of a planted interior can reflect aesthetic preference, expectations, previous experience or the wider quality of the space. The present paper focuses on these perceptions and on the practical conditions needed to evaluate indoor planting responsibly.

A possible cognition–practice gap between aesthetic appreciation and technical integration motivates this inquiry. Professional perceptions may influence how indoor planting is specified, but self-reported practices do not directly establish performance in completed projects. This study therefore examines differences in reported evaluations and associations with integration strategies while distinguishing professional perceptions from measured environmental outcomes.

## *Research objectives and scope*

RO1 was to assess design professionals' perceptions of the aesthetic, functional and well-being dimensions of indoor plant landscapes. RO2 was to examine the associations of aesthetic and functional cognition with integration strategies, the association of functional cognition with perceived well-being, and the moderating role of professional experience in the relationship between functional cognition and integration strategies. Spatial layout, lighting and material selection provide the design context for these relationships.

# LITERATURE REVIEW

This review brings together environmental psychology, human-centred design and the literature on indoor plant landscapes. It considers how spatial layout, lighting and material selection relate to the integration of plants into indoor environments, while distinguishing potential and perceived benefits from measured performance.

### *Theoretical Foundation: Environmental Psychology and the S-O-R Model*

Environmental psychology examines relationships between physical environments and human behaviour, cognition and emotion. It provides a basis for considering how design features are experienced by occupants and how designers anticipate these experiences. For indoor plant landscapes, relevant questions include visual appreciation, perceived connection to nature, comfort and satisfaction.

The Stimulus–Organism–Response (S-O-R) model provides a conceptual framework for organising these relationships. Stimulus refers to environmental attributes, including spatial layout, light, material texture and planting. Organism refers to internal appraisal, such as emotional responses and perceived comfort. Response refers to subsequent experiences or behaviours, such as satisfaction and approach or avoidance. These distinctions help explain the proposed relationships without implying that all stages were measured in the present survey.

Biophilic design literature considers how contact with natural elements can inform experiences of built environments (Kellert et al., 2011; Heerwagen, 2009). Turki et al. (2023) discuss greening in healthcare spaces, providing a setting-specific context for this discussion. Introducing indoor plants may create opportunities for visual engagement and perceived connection to nature, but responses can differ with users, settings and the quality of implementation. In this study, S-O-R supports the conceptual discussion of professional perceptions; it is not presented as a statistically validated sequence from plant exposure through comfort to occupant satisfaction.

### *Human-Centered and User-Centric Design Principles*

Human-Centered Design (HCD) places users' needs, activities and experiences at the centre of the design process. In interior environments, this requires attention to aesthetic preferences alongside behavioural patterns, accessibility and everyday use. Indoor planting should therefore be considered in relation to how people occupy and move through a space, rather than through visual composition alone.

### *Unity of Function and Form*

Aesthetic composition and practical use are complementary design considerations. For indoor plant landscapes, this means coordinating plant size, arrangement and visibility with furniture, circulation and maintenance access. A visually attractive planting scheme may be unsuitable if it obstructs sightlines or movement. Conversely, planting can be considered as part of spatial zoning or the provision of visual interest, provided that its intended function is evaluated in the context of users' needs.


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### *Fusion of Sustainability and Health*

Sustainability adds questions about resources and operation to the consideration of user experience. Lee et al. (2013) examine practitioners' motivations for specifying sustainable materials, while Alfuraty (2020) discusses sustainable material selection in interior design. These concerns are relevant to planting specifications: irrigation, containers, growing media, replacement plants and supplementary lighting all have operational implications. Indoor plants may contribute to a design intention centred on nature and well-being, but their presence alone does not establish a net carbon benefit, improved air quality or lower energy consumption.

### *Interaction of Key Design Elements and Biophilic Interventions*

Indoor plant landscapes form part of a wider interior design system. Spatial layout, lighting and material selection influence where plants can be accommodated, how they are experienced and whether they can be maintained. These elements are considered here as design conditions, rather than as verified predictors in the professional survey.

### *Spatial Layout*

Spatial layout includes zoning, circulation and furniture placement. Plant arrangements can be designed to mark boundaries, frame views or create a degree of visual separation. Their suitability depends on mature plant size, visibility, accessible routes and the activities taking place nearby. The idea of a biophilic partition is therefore useful as a design strategy, but a visual boundary should not automatically be described as effective acoustic insulation or evidence of improved physical comfort.

### *Lighting Design*

Lighting design needs to consider both the visual experience of occupants and the growing conditions of plants. Daylight availability, shading and the distribution of supplementary light affect where planting is feasible. Leaf forms and changing light patterns may contribute to the visual experience associated with biophilic design (Ryan et al., 2014). However, plant lighting requirements and human lighting needs should be assessed separately. Neither relaxation nor energy savings can be inferred solely from the inclusion of plants or grow lights.

### *Material Selection*

Material selection concerns appearance, tactile qualities, durability, maintenance and potential emissions. Alfuraty (2020) provides a basis for considering sustainable materials in interior design. Plant foliage, containers and surrounding finishes can be composed with materials such as wood and stone to support a

coherent visual setting. Such combinations may be relevant to perceived naturalness and aesthetic preference, but do not establish improved environmental quality without an appropriate assessment. Container drainage and compatibility with adjacent surfaces also require attention during specification.

***Specific Benefits of Indoor Plant Landscapes: An Evidence-Based Perspective***
***Air Quality and Perceived Environmental Benefits***

The literature on indoor planting includes health, discomfort and environmental-performance questions, which should not be treated as equivalent outcomes. Fjeld (2000) addresses health and discomfort among workers and school children; such outcomes should not be equated with quantified removal of VOCs or particulate matter. Air-purification claims require evidence relevant to the pollutant, planting system and operating conditions. The present questionnaire asks about beliefs concerning indoor air quality and perceived physical improvements. These questions concern perceptions rather than measurements of pollutant removal, ventilation performance or energy savings. Cummings and Waring (2020) analysed reported VOC-removal efficiencies and showed why results from small sealed chambers should not be directly translated into substantial air-cleaning benefits from ordinary potted plants in ventilated buildings. Their findings reinforce the distinction between an experimental removal mechanism and a meaningful contribution under occupied-building conditions.

***Psychological Restoration***

Heerwagen (2009) discusses biophilia, health and well-being, providing a conceptual basis for considering restorative experiences associated with nature. Psychological restoration remains an important rationale for biophilic design and for investigating perceived comfort, mood and connection to nature. However, professionals' reports of noticed changes cannot establish a clinical benefit or isolate plants as the cause. The distinction between a theoretical explanation, a perceived experience and a measured outcome is maintained throughout this paper. Bringslimark et al. (2009) found that the experimental literature suggested potential psychological benefits, while highlighting variation in study designs and outcomes. Han and Ruan (2019) likewise reviewed self-reported perceptions across diverse exposure conditions. Together, these reviews support investigating perceived benefits without assuming that every planting arrangement produces the same restorative response.

***Design Patterns***

Ryan et al. (2014) discuss biophilic design patterns as nature-based parameters relevant to health and well-being in the built environment. These patterns provide a vocabulary for considering natural elements and design experiences. Here,


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design patterns serve as conceptual guidance rather than as validated questionnaire items or proof of a particular environmental effect.

Together, these perspectives support examining how professionals understand and integrate indoor planting. Budget, maintenance, spatial constraints and the interpretation of available evidence are relevant topics for inquiry, rather than barriers already demonstrated by this survey. The following methodology therefore focuses on professional perceptions and the available instrument, while the later recommendations address how design intentions could be assessed through maintenance records, environmental measurements and post-occupancy evaluation.

## RESEARCH METHODOLOGY

### *Study design and scope*

A cross-sectional questionnaire survey examined design professionals' perceptions and reported integration practices. The study evaluated aesthetic cognition (AC), functional cognition (FC), perceived well-being (PW) and integration strategies (IS), with professional experience as a moderator. The S-O-R framework provided conceptual context; the analysis did not test mediation through psychological or physical comfort.

### *Participants and sampling strategy*

The target population comprised certified practitioners and active researchers across architecture, interior design, landscape architecture and green building consultancy. A multi-stage non-probability sampling strategy combining purposive and snowball approaches was executed between March and June 2025 across major urban design hubs in Malaysia, primarily Greater Kuala Lumpur/Klang Valley and Penang. The initial professional group was recruited through institutional directories, including the Malaysian Institute of Architects (PAM), the Institute of Landscape Architects Malaysia (ILAM) and Green Building Index (GBI) facilitator networks. This group subsequently disseminated the survey link across affiliated corporate design offices and private practices.

A total of 230 questionnaire invitations were issued online. Submissions with completion times under three minutes or duplicate IP addresses were excluded. The final sample comprised 185 usable responses, corresponding to a usable-response proportion of 80.4% of invitations. A post-hoc power analysis indicated power above 0.80 for detecting medium effects at $\alpha = 0.05$. The non-probability recruitment strategy nevertheless limits population generalisation.

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### *Questionnaire content and item sources*

The questionnaire recorded gender, age, educational level and years of professional experience. The four constructs were assessed using three items each, as shown in Table 1. Responses used five-point scales, anchored from 1 (strongly disagree/rarely) to 5 (strongly agree/always), according to whether a question concerned an evaluation or practice. Perceived well-being refers to designers' assessments of occupant experiences rather than directly measured clinical or physiological outcomes.

**Table 1.** Measurement constructs, operational items and sources

| Construct | Operational items | Sources |
|---|---|---|
| Aesthetic Cognition (AC) | AC1: Indoor plants markedly enhance visual spatial layering and aesthetic interest.<br>AC2: Plant foliage and forms harmonize effectively with architectural finishes (wood, stone).<br>AC3: Incorporating greenery elevates perceived indoor spatial luxury and environmental quality. | Kellert et al. (2011); Ryan et al. (2014) |
| Functional Cognition (FC) | FC1: Indoor plants actively regulate ambient indoor microclimates and relative humidity.<br>FC2: Dense vegetation layouts function as noticeable acoustic buffers against ambient noise.<br>FC3: Indoor planting systems contribute to mitigating perceived airborne particulates and stale air. | Fjeld (2000); Alfuraty (2020) |
| Perceived Well-being (PW) | PW1: Exposure to planted interiors significantly mitigates occupant mental fatigue.<br>PW2: Indoor greenery fosters an emotional sense of connection to nature (biophilia).<br>PW3: Biophilic plantscapes noticeably improve reported spatial satisfaction and stress relief. | Heerwagen (2009) |
| Integration Strategies (IS) | IS1: Plant layouts are systematically coordinated with HVAC airflow and circulation in early design.<br>IS2: Dedicated supplementary horticultural lighting is engineered to support plant biology.<br>IS3: Technical criteria (drainage, automated irrigation, maintenance access) are formalized into project specifications. | Turki et al. (2023); Lee et al. (2013) |

Items were adapted with reference to the biophilic design literature. Aesthetic cognition drew on Kellert et al. (2011) and Ryan et al. (2014); functional cognition on Fjeld (2000) and Alfuraty (2020); perceived well-being on Heerwagen (2009); and integration strategies on Turki et al. (2023) and Lee et al. (2013). The functional items elicited respondents' beliefs about environmental benefits; their wording should not be interpreted as independent evidence that plants deliver these effects.

The analysis focused on the four constructs in Table 1. Selection criteria were not treated as an additional numerical construct, and no mean or standard deviation is reported for that topic.


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### *Data collection procedures*

The survey was administered online during the March–June 2025 fieldwork period. The questionnaire introduction explained the research purpose and included assurances of privacy and research-only use of responses. Completion-time and duplicate-IP checks were applied before retaining the final analytic sample.

### *Data analysis strategy*

Quantitative data were processed using SPSS 26.0 for descriptive statistics and SmartPLS 4 for structural equation modeling, following the reporting considerations of Hair et al. (2019). The measurement model was assessed for internal consistency using Cronbach's alpha and composite reliability, convergent validity using average variance extracted (AVE), and discriminant validity using the heterotrait–monotrait ratio (HTMT). Reference values of 0.70 for alpha and composite reliability, 0.50 for AVE and 0.85 for HTMT guided interpretation. The use of HTMT follows Henseler et al. (2015), who proposed this criterion to improve the detection of discriminant-validity problems in variance-based structural equation models.

Structural paths and the moderating role of professional experience were evaluated using non-parametric bootstrapping with 5,000 resamples. The analysis reported path coefficients, standard errors, t-values, p-values and $f^2$ effect sizes. Model assessment also included variance inflation factors (VIF), $R^2$, the standardized root mean square residual (SRMR) and $Q^2$predict. The bootstrap resample count is distinct from the respondent sample size of 185.

H1 specified a positive association between aesthetic cognition and integration strategies; H2 specified a positive association between functional cognition and integration strategies; and H3 specified a positive association between functional cognition and perceived well-being. H4 proposed that professional experience positively moderated the association between functional cognition and integration strategies. These relationships were examined as cross-sectional associations rather than causal effects.

## ANALYSIS AND DISCUSSION

### *Demographic profile of respondents*

Table 2 summarises the demographic characteristics of the 185 respondents. The sample comprised 102 men and 83 women. The largest reported age category was 30–40 years (36.8%); 48.1% held a master's degree, and 51.9% were in the 5–15

years of experience category. The distribution provides variation in professional tenure but does not establish population representativeness.

**Table 2.** Demographic profile of respondents

| Variable | Category | n | % |
|---|---|---|---|
| Gender | Male | 102 | 55.1 |
| | Female | 83 | 44.9 |
| Age | Less than 30 years | 45 | 24.3 |
| | 30–40 years | 68 | 36.8 |
| | 40–50 years | 52 | 28.1 |
| | 50 years and more | 20 | 10.8 |
| Educational Level | Diploma / Bachelor's | 74 | 40 |
| | Master's Degree | 89 | 48.1 |
| | Ph.D. / Professional | 22 | 11.9 |
| Years of Experience | Less than 5 years | 38 | 20.5 |
| | 5–15 years | 96 | 51.9 |
| | 15 years and more | 51 | 27.6 |
| Total | | 185 | 100 |

***Descriptive Statistics of Reported Perceptions***

Aesthetic cognition had a mean rating of 4.35 (SD = 0.62), and perceived well-being had a mean of 4.28 (SD = 0.68). Functional cognition was rated at 3.12 (SD = 0.85), while integration strategies had a mean of 2.85 (SD = 0.91). These descriptive differences suggest stronger endorsement of aesthetic and well-being topics than of functional and technical integration topics. They are not presented as a statistically tested difference between means.

The cognition–practice gap provides an interpretive description of this pattern. It should not be equated with a measured shortfall in building performance or evidence that individual professionals lack competence. Selection criteria were not assigned a numerical score.


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### *Measurement model assessment*

Table 3 presents indicator-loading ranges and reliability and convergent-validity statistics. Cronbach's alpha ranged from 0.786 to 0.845, composite reliability from 0.842 to 0.895, and AVE from 0.573 to 0.682. Indicator loadings were reported as significant at $p < 0.001$. Table 3b presents the HTMT ratios, which ranged from 0.292 to 0.641 and were below the 0.85 reference value. Reported inner VIF values ranged from 1.352 to 1.502.

**Table 3.** Measurement model assessment

| Construct | Loading range | Alpha | CR | AVE | Inner VIF |
|---|---|---|---|---|---|
| AC | 0.762–0.841 | 0.824 | 0.881 | 0.650 | 1.352 |
| FC | 0.735–0.814 | 0.786 | 0.842 | 0.573 | 1.418 |
| PW | 0.791–0.863 | 0.845 | 0.895 | 0.682 | 1.502 |
| IS | 0.754–0.832 | 0.801 | 0.858 | 0.603 | — |

Note: All indicator loadings were reported as significant at $p < 0.001$. Alpha = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted. Inner VIF values are reproduced as reported.

**Table 3b.** Discriminant validity assessed using HTMT

| Construct | AC | FC | PW |
|---|---|---|---|
| AC | — | | |
| FC | 0.435 | — | |
| PW | 0.518 | 0.612 | — |
| IS | 0.292 | 0.641 | 0.485 |

### *4.4 Structural model and moderation*

Table 4 presents the structural path estimates. H1 was not supported ($\beta = 0.118$, $p = 0.150$). H2 and H3 were supported, with positive associations of functional cognition with integration strategies ($\beta = 0.462$, $p < 0.001$) and perceived well-being ($\beta = 0.389$, $p < 0.001$). The experience interaction was positive and significant ($\beta = 0.208$, $p = 0.005$), supporting H4. The corresponding $f^2$ values were 0.016, 0.252, 0.185 and 0.065, respectively.

**Table 4.** Structural hypotheses tested using 5,000 bootstrap resamples

| Hypothesis and path | β | SE | t | p | $f^2$ | Decision |
|---|---|---|---|---|---|---|
| H1: AC → IS | 0.118 | 0.082 | 1.439 | 0.150 | 0.016 | Not supported |
| H2: FC → IS | 0.462 | 0.085 | 5.435 | < 0.001 | 0.252 | Supported |
| H3: FC → PW | 0.389 | 0.091 | 4.275 | < 0.001 | 0.185 | Supported |
| H4: Experience × FC → IS | 0.208 | 0.074 | 2.811 | 0.005 | 0.065 | Supported |

Note: SE = standard error. Respondent N = 185; bootstrap resamples = 5,000.

The reported SRMR was 0.067, below the 0.08 reference value. $R^2$ was 0.345 for integration strategies and 0.224 for perceived well-being, corresponding to explained variance of 34.5% and 22.4%. The reported $Q^2$predict was 0.278. Its positive value supports further consideration of predictive relevance but is not,

by itself, a basis for classifying predictive performance as medium or strong. Shmueli et al. (2019) distinguish explanatory assessment from prediction-oriented evaluation and provide guidance for interpreting PLSpredict against appropriate benchmarks.

## DISCUSSION

Functional cognition was positively associated with integration strategies, whereas the aesthetic-cognition path was not statistically significant. This pattern suggests that recognising functional considerations is associated with reported technical integration beyond aesthetic appreciation alone. However, a non-significant aesthetic path does not establish that aesthetics is unimportant, and the cross-sectional design does not demonstrate a causal sequence from knowledge to implementation.

The positive interaction between professional experience and functional cognition is consistent with a stronger association between functional cognition and integration strategies at higher values of the coded experience measure. Functional cognition was also associated with perceived well-being. These findings extend the professional perspective on biophilic design discussed by Heerwagen (2009), Kellert et al. (2011) and Ryan et al. (2014), while remaining subject to the limits of self-report and the sampling design. More recently, Abbasoğlu and Kahramanoğlu (2025) examined plant-related perceptions of indoor air quality and subjective well-being in a Northern Cyprus survey. Their results linked favourable assessments of plant characteristics with perceived benefits, providing a relevant comparison for the present perception-based approach while involving a different setting and population.

The distinction between perceptions and performance is particularly important for air quality. A respondent's belief that indoor plants improve air quality is a report about that belief. Without exposure measurements and an appropriate comparison, it cannot quantify VOC removal, particle reduction or ventilation savings. Similarly, a perceived well-being benefit does not establish a clinical effect or identify plants as the sole cause. These limits define the scope of the recommendations below.

## IMPLICATIONS FOR DESIGN AND PROFESSIONAL PRACTICE

The following recommendations are design and evaluation proposals informed by the questionnaire topics and conceptual literature. They have not been validated as causal effects by the present survey. Their purpose is to make design intentions, operational responsibilities and evidence requirements explicit.


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***Evidence-based design guidelines***

A project planting brief should identify intended experiential goals, target users and spatial constraints. Designers should document species suitability for available light, mature size, circulation and accessible routes, sightlines, proximity to services and access for maintenance. Plant placement should be coordinated with furniture, cleaning and building operation. For each intended benefit, the brief should specify whether it is an aesthetic objective, an occupant-perception objective or an environmental performance claim, together with an appropriate evaluation method. Aesthetic preference should not be used as a proxy for pollutant removal or energy performance.

Plant growth lighting and occupant visual or circadian lighting objectives should be assessed separately. A grow-light specification does not by itself establish suitability for human lighting needs. Plant installations should complement the intended use and operation of a space. Active planted systems connected to mechanical airflow require specialist assessment, commissioning and operating evidence. No ventilation reduction or energy-saving allowance should be assigned on the basis of this questionnaire; quantified claims require measurements under relevant operating conditions.

***Maintenance and operational governance***

Design proposals should identify the facilities management team or other party responsible for routine care, inspections, repairs and replacement. A handover plan should record species and locations, irrigation and drainage arrangements, maintenance access, care schedules and the procedure for reporting faults. Routine records should cover leak checks, pruning, pest inspection, cleaning, plant survival and replacement rates. Water use, labour, replacement materials and other operating costs should be recorded over a defined period to assess the continuing resource requirements of the installation. Responsibilities and the maintenance budget should be agreed before installation.

***Quantified indoor environmental quality metrics***

Evaluation should distinguish subjective responses from physical measurements. Perceived comfort, satisfaction and nature connection can be assessed through clearly worded questions with consistent response anchors. A parallel environmental protocol can record temperature, relative humidity, illuminance and relevant acoustic conditions. Air-quality evaluation can include $CO_2$ as contextual information about occupancy and ventilation and particulate or pollutant-specific measurements selected for the stated objective. If total volatile organic compounds (TVOC) or individual VOCs are monitored, the method should identify the metric, instrument, calibration, locations, sampling duration and reporting units.

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These measurements should be accompanied by records of occupancy, ventilation operation, outdoor conditions, cleaning and other potential influences. Sensor placement and sampling times should be documented so that comparisons refer to similar conditions. A single reading near plants does not demonstrate removal efficiency or causation. Energy claims require measured system consumption and an appropriate baseline, including lighting, pumps and fans where present. Plant visibility or density may describe an installation, but should not be treated as a validated proxy for health or air quality.

***Post-occupancy evaluation protocol***

A post-occupancy evaluation should compare the planting brief with the occupied setting during routine operation. For a prospective installation, the protocol should establish a pre-installation baseline and follow-up observations after installation, using consistent instruments, questions and sampling locations where possible. Follow-up should include normal operation rather than only commissioning conditions. Comparable spaces without the intervention can strengthen the comparison where feasible. Timing, occupancy, ventilation settings, seasonal changes and concurrent modifications should be recorded. Occupant satisfaction and complaints should be reviewed alongside environmental measurements and maintenance records.

This approach allows teams to assess whether a planting scheme remains usable and maintainable and whether anticipated experiential benefits are reported. It also enables revision when shading, access, leaks, replacement burden or user preferences differ from expectations. Any claim of an environmental effect should depend on the actual comparison and uncertainty, rather than on the presence of monitoring equipment.

***Professional and cross-disciplinary education***

Professional education can connect biophilic design concepts with horticultural requirements, building services, building biology, questionnaire design and evidence appraisal. Case-based teaching should ask learners to distinguish professional perceptions, laboratory findings and occupied-building measurements. Exercises can include a planting brief, an operating-cost estimate, a maintenance handover plan and a post-occupancy evaluation protocol. Joint work among architects, interior designers, horticultural specialists, facilities teams and ventilation engineers can help balance aesthetic goals with plant viability, usability and the evidence required for performance claims.

## LIMITATIONS AND FUTURE RESEARCH

The cross-sectional design limits causal interpretation and cannot establish how professional perceptions or practices change over time. Purposive and snowball


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recruitment may overrepresent connected professional networks in the surveyed urban regions. Self-reported constructs may also share response tendencies, and designers' assessments of occupant well-being are not equivalent to reports collected directly from occupants.

The study did not measure pollutant removal, acoustic performance, ventilation efficiency or energy savings. Consequently, the functional-cognition results reflect professional beliefs rather than demonstrated environmental effects. The reported positive $Q^2$predict value alone does not establish the magnitude of out-of-sample predictive performance; prediction-error comparisons and further external validation would strengthen assessment.

Future research could extend recruitment to additional regions and professional groups, collect direct occupant feedback and examine completed projects longitudinally. Detailed conditional-effect analysis could further characterise the experience interaction. Combining questionnaire responses with maintenance records, environmental monitoring and post-occupancy evaluation would help assess how professional intentions relate to operation and user experience.

## CONCLUSION

The study examined design professionals' perceptions of indoor plant landscapes using 185 survey responses. Aesthetics and perceived well-being received higher descriptive ratings than functional cognition and integration strategies. Functional cognition was positively associated with integration strategies and perceived well-being, while the aesthetic-cognition path to integration strategies was not significant. Professional experience showed a positive moderating association with the functional cognition–integration relationship. These results concern perceptions and reported practices rather than causal environmental performance.

The practical contribution is a set of recommendations linking plant specification with maintenance, explicit evaluation criteria, post-occupancy feedback and professional education. Indoor planting should be assessed against stated project goals and operating requirements. Perceived benefits and measured performance should be reported separately, with claims concerning air purification, health outcomes or energy savings supported by appropriate evidence.

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# STUDY ON THE PROTECTION STATUS, PROBLEMS AND STRATEGIES OF RELIGIOUS GARDENS IN YANGZHOU - A CASE STUDY OF DAMING TEMPLE, QIONGHUA GUAN AND PUHADING GARDEN

**Wang Xiu[1], Syarmila Hany Haron[2],**

[1,2] *School of Housing, Building & Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

Yangzhou religious gardens represent an important heritage where multi-religious culture integrates with classical gardens. However, they are confronted with conservation dilemmas due to urbanization and tourism development. To improve relevant conservation theories and provide practical references, this paper conducts a horizontal comparison by adopting methods of literature research, field investigation and case analysis, with Daming Temple, Qionghua Guan and Puhaddin Garden as case studies. The results indicate significant differences in the conservation levels among the three gardens. The study reveals that the gardens share common problems such as single funding sources, shortage of professionals, and imbalance between conservation and development, together with respective distinctive dilemmas. Accordingly, a hierarchical strategy is proposed, including classified conservation, diversified funding and talent channels, and promotion of living inheritance, so as to support the sustainable conservation of Yangzhou religious gardens and the protection of multi-religious heritage.

***Keywords:*** Yangzhou Religious Gardens, Diverse Religions, Cultural heritage Protection, Daming Temple, Qionghua Guan,Puhading Garden

[1] Corresponding author. Email: cleverwx@163.com

## INTRODUCTION

As one of the first batch of national historical and cultural cities announced by the State Council, Yangzhou is located at the intersection of the Grand Canal and the Yangtze River. Historically, it thrived due to canal transportation (Zhao, 2018, p. 2), becoming a hub where diverse cultures converge. Religions such as Buddhism, Taoism, and Islam have coexisted here for a long time, (Chu Weilin, 2015, p. 80) thus fostering distinctive religious gardens represented by Daming Temple, Qionghua Guan and Puhading Garden. These gardens integrate religious doctrines with the art of garden-making, embody Yangzhou's cultural context and memories of faith, and also form an integral part of the Grand Canal Cultural Belt.

Religious doctrines have exerted a profound influence on the distinctive characteristics of gardens. The Buddhist concept of "Zen", the Taoist notion of "following the laws of nature", (Yi, 2011, p. 190) and the Islamic idea of the " paradise " or "Heavenly Garden" have each shaped their unique design logics respectively. (Putra, Caisarina, & Fuady, 2025, p. 651) Furthermore, these gardens have served as important venues for literati gatherings and cultural exchanges between China and foreign countries. For instance, Daming Temple embodies the cultural legacy of Ouyang Xiu and Su Shi, while Puhading Garden preserves the historical memories of China-foreign friendship.

A "religious garden" takes garden landscapes as the material carrier (Fu Jin, 1996, p. 60) and is a special type of garden that integrates religious culture with secular aesthetics (Zhao Guanghui, 1987, p. 7). Its core lies in the layout of mountains, waterwork, landscapes, architecture, and plants, combined with the construction of religious ornaments such as pagodas, stone pillars engraved with Buddhist scriptures, and stone inscriptions (Zhao Guanghui, 1987, p. 8), forming a unique landscape with both garden charm and religious atmosphere. The essential criterion for judging it lies in whether its fundamental purpose is to "serve religion".


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**Figure 1:** Qiling Pagoda Plaza of Daming Temple, Yangzhou
*Source: Photo by the author (2025)*

The three typical religious gardens in Yangzhou each have their own characteristics. Daming Temple (Figure 1), a Buddhist garden, is located on the middle peak of Shugang in Yangzhou, adjacent to Slender West Lake. Founded during the Daming period of Emperor Xiaowu of the Southern Song Dynasty (Southern Dynasties, 457–464 CE), it combines natural and courtyard-style architectural layouts and is regarded as the top ancient temple in Yangzhou (Guijie, 2018, pp. 57,63). Qiong hua Guan, a Taoist garden, is situated on Wenchang Middle Road in Yangzhou, formerly known as Fanli Guan. Founded in 11 BC, it preserves relics such as the Qionghua Platform, the Memorial Archway of "Fanli Guan"(Figure 2), and the "Wushuang Pavilion" (Xiaofei, 2001, p. 58) and retains the traditional layout of "temple in the front and garden at the back". Puhading Garden, an Islamic garden, is built on a high hill beside the ancient Grand Canal, divided into the tomb on the hill and the temple at the foot of the hill. It creates a pattern of "mountains standing in front of water" by artificially piling up hills and digging ponds, integrating Arabic architectural styles into the Chinese courtyard style, and fully demonstrating the characteristics of "being surrounded by mountains and water with vigorous ancient trees" (Leyun, 1985, p. 36).



**Figure 2:** Memorial Archway of Qionghua Guan, Yangzhou, Yangzhou
*Source: Photo by the author (2025)*

At present, the interweaving of issues such as accelerated urbanization, intensified tourism development and backward conservation technologies has left some of Yangzhou's religious gardens facing predicaments including architectural aging, weakened cultural connotations, and an unclear division of responsibilities and powers among conservation entities. However, scholarly research has not kept pace with these realities, resulting in notable research gaps: firstly, there is a paucity of in-depth specialized studies on the diverse types of religious gardens in Yangzhou—Buddhist, Taoist, Islamic and others—and a lack of cross-religious horizontal comparisons; secondly, existing research on religious garden conservation lacks sufficient depth and systematic discussions integrated with the social, cultural and technological context of the new era; thirdly, most existing studies focus on the isolated analysis of individual gardens, failing to form a systematic and holistic understanding of the conservation of Yangzhou's religious gardens as a whole.

Against this backdrop, this study focuses on typical cases of diverse religious gardens, breaks free from the constraints of the vertical management mindset, and conducts targeted research through horizontal comparative analysis. Academically, it can enrich the research on Yangzhou's religious gardens and improve the protection system for diverse religious heritage; in practice, it can address the conservation dilemmas with pinpoint accuracy, provide a reference for administrative departments, and facilitate the continuation of cultural context and the development of this renowned historical city.


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## RESEARCH METHODS

As a branch of classical gardens, religious gardens exhibit a particularly prominent interdisciplinary characteristic. (Jiahua, 1999, p. 127) Research on Yangzhou's religious gardens involves multiple disciplines including religious studies, history, garden studies, architecture, fine arts, horticulture and botany, constituting a research field that demands the integration of knowledge from a wide array of disciplines.

According to the views of Y. Lincoln and N. Denzin, qualitative research is an interdisciplinary, transdisciplinary, and sometimes counter-traditional research field, spanning the humanities, social sciences, and natural sciences. (DENZIN & LINCOLN, 1994, p. 576) Yangzhou's religious gardens, as complex cultural landscapes bearing diverse cultures and embodying prominent multidisciplinary characteristics, have their core conservation issue in balancing the restoration of material relics and the inheritance of religious connotations, as well as reconciling the integrity of historical context with adaptability to practical scenarios—this also serves as the core research question orientation of this study. Therefore, under the paradigm framework of the discipline of Chinese garden studies and cultural heritage conservation, this study adopts the methods of literature review, field investigation and case analysis that are commonly applied in qualitative research, to systematically analyze the conservation problems of Yangzhou's religious gardens and propose targeted strategies.

In the subsequent research, based on the aforementioned research methods, the study will be carried out in a progressive manner. This ensures that the analysis of the conservation issues of Yangzhou's religious gardens is both in-depth and practical, thus providing a solid theoretical foundation for relevant conservation practice.

### Literature Research Method

Literature research is the core method of history. It explores historical facts and evidence by using existing secondary data, lays a foundation for subsequent field investigations, and is an indispensable part of this study (Fang, 1997, p. 143). Given the time-honored nature of Yangzhou's religious gardens, literature research shall be carried out from a multi-dimensional perspective: to excavate local chronicles such as Yangzhou Fu Zhi (Records of Yangzhou Prefecture) (Yang , 1991) and Jiangdu Xian Zhi (Records of Jiangdu County), (Xie & Liu , 1991) as well as scriptural classics including the Buddhist Tripiṭaka and the Taoist Daozang, so as to sort out the evolution of religious gardens and the influence of religious thoughts on their construction; to integrate archives of cultural relic conservation and restoration, existing academic achievements and relevant domestic and international research, thus clarifying the evolution and

conservation foundation of the research objects and drawing on advanced experience; to sort out the evolution of China's cultural relic conservation policies, and combine this with the practice of Yangzhou's ancient city conservation over the past few decades to define the guiding role of such policies.

Existing research has notable limitations: the number of published outcomes is limited, and systematic achievements are mostly concentrated in the fields of Buddhism and Taoism, with studies related to Islam being extremely scarce. (Qian, 2022, p. 70) the published achievements are insufficient in exploring the construction characteristics and religious atmosphere (Zou Linhai, 2017, pp. 3-4); the research on tourism development planning is not in - depth (Zou Linhai, 2017, pp. 93-95); and most of them are attached to projects such as the Grand Canal heritage, making it difficult to highlight their own religious and cultural characteristics (Huhua, 2016, pp. 283-292) .

**Field Investigation Method**

The field investigation method is a comprehensive means in cultural heritage research (Wang Chen & Wang, 2016, pp. 15-16), which can study social changes across time dimensions (Earl & Qiu, 2005, p. 276). It needs to carry out field investigations from the interdisciplinary perspectives of architecture (building restoration technology), cultural heritage protection (classified protection theory), religious studies (analysis of religious space functions), and sociology:

From the perspective of architecture, analyze the style characteristics, structural forms, and construction techniques of religious garden buildings, compare the differences with ordinary civil buildings, and check the safety of building structures, such as wall cracks and decay of wooden structures. (Figure 3)



**Figure 3:** Reclining Buddha Hall of Daming Temple, Yangzhou
*Source: Photo by the author (2025)*


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From the perspective of garden science, study the garden spatial layout, garden - making techniques (such as borrowing scenery, opposite scenery, and screened scenery), and plant configuration, analyze the construction logic of religious atmosphere and aesthetic artistic conception, and evaluate the integrity of garden landscapes, such as water pollution and plant decay.

From the perspectives of sociology and religious studies, the protection of cultural landscape heritage should attach importance to historical context and cultural connotations (Jixiang, 2015, pp. 98-99).

Explore the composite value of religious gardens as "carriers of religious culture, media for dialogue between humans and nature, and containers of historical memory". Through informal interviews, first-hand feedback on conservation challenges was collected from garden managers and religious representative Mr. Ma. This approach avoids the limitations of single-dimensional conservation thinking and ensures the systematicity and scientific rigor of the research. (Table 1)

**Table 1:** Field-investigation dates for each case in this study are presented below

| Case | Religious Category | Field-investigation Date |
|---|---|---|
| Daming Temple | Buddhism | 13 October 2025,<br>27 October 2025 |
| Qionghua Guan | Taoism | 25 October 2025 |
| Puhading Garden | Islam | 14 October 2025,<br>17 October 2025,<br>27 October 2025 |

*Source: Author's own field survey, October 2025.*

## Case Study Method

The case study method is a dynamic, multi - object, and multi - level research strategy that requires the use of various data collection methods (Li & Cao, 2012, pp. 3-4) and has become a common tool for multi - disciplinary research on complex social phenomena (Yin, 2014, p. 4).

**Table 2:** Case-selection Criteria of This Study

| Case | Religious Category | Conservation Grade | Current Condition |
|---|---|---|---|
| Daming Temple | Buddhism | National-level | Intact religious buildings and affiliated gardens |
| Qionghua Guan | Taoism | Municipal-level | Intact religious buildings and affiliated gardens |
| Puhading Garden | Islam | National-level | Intact religious buildings and affiliated gardens |
| Tianning Temple | Buddhism | National-level | Only major religious buildings remain; the garden area no longer exists |

| Case | Religious Category | Conservation Grade | Current Condition |
|---|---|---|---|
| Wudang Palace | Taoism | Municipal-level | Only major religious buildings remain; the garden area no longer exists |
| Xianhe Mosque | Islam | National-level | Only major religious buildings remain; the garden area no longer exists |

*Source: Author's own field survey, October 2025.*

This study selects three typical types of religious gardens in Yangzhou—Daming Temple (Buddhist), Qionghua Guan (Taoist), and Puhading Garden (Islamic)—as its case studies (Table 2), with the specific research approaches outlined as follows:

Field survey and data collection: Conduct on - site visits to the three gardens, record the existing status of the building itself (wooden structures, walls) and garden landscapes (water bodies, vegetation, ornaments); use tools such as total stations and drones to measure the location, size, and scale of buildings, terrain, and plant communities, and draw current situation maps.

Analysis of problems and measures: Sort out the specific problems faced by the case gardens in the protection process (such as fund shortage, tourist carrying pressure), the protection measures adopted (such as building renovation technology, landscape improvement methods), as well as the protection effects and shortcomings.

Theoretical Verification and Experience Summary: Combine the findings of literature analysis and field investigations, verify the effectiveness of conservation theories, and reveal the local particularities of religious garden conservation in Yangzhou; integrate the disciplinary knowledge of sociology and public administration to summarize the conservation experiences and models adapted to local conditions in Yangzhou.

## ANALYSIS: SORTING OUT THE PROTECTION STATUS OF TYPICAL RELIGIOUS GARDENS IN YANGZHOU

### Daming Temple - A Representative of Buddhist Gardens: Protection Practice of a "Key Cultural Relics Protection Unit"

Daming Temple was first constructed in the Daming reign period of the Liu Song Dynasty of the Southern Dynasties. Renowned for Jianzhen's eastward voyage to Japan, it was designated as a Major Historical and Cultural Site Protected at the National Level in 2006, and stands as the case with the most well-established conservation foundation among Yangzhou's religious gardens. (Association, 2021, p. 74). Its conservation practice has advanced centering on "cultural relic restoration, mechanism improvement and cultural activation", and is carried out in adherence to the principles of "restoring the old as it was, advancing in phases and functional adaptation". (Figure 4)


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In the protection of material relics, Daming Temple underwent renovations in 1963, 1973 and 1988 to commemorate Master Jianzhen. (Editorial Committee of Daming Temple Chronicle, 2004, pp. 11-12,20). It has since carried out successive renovations across the entire temple complex in 2013, (qianzhi, 2013, p. B1), 2014 (zhiqun, 2014, p. T1)，2015 (kongsheng, Qiling Pagoda Square Debuted, 2015, p. A2) and 2024 (Tao, 2024, p. 5).

In terms of the conservation and management mechanism, as introduced by Venerable Renbai, the administrative person in charge, Daming Temple has established a mechanism of "dedicated personnel responsibility, dynamic supervision and control, and zoned management", set up a Cultural and Historical Hall, and compiled archives for cultural relics. In terms of collaborative cultural conservation, Daming Temple takes *Jianzhen Culture* as its core and relies on the Jianzhen Institute to promote the integration of religious culture and garden conservation.




**Figure 4:** Layout plan of Daming Temple, Yangzhou
*Source: Photo by the author (2026)*

**Qionghua Guan - A Representative of Taoist Gardens: Protection Dilemma of a "Minor Relic"**

Qionghua Guan, the oldest existing Taoist garden in Yangzhou, is characterized by a small relic scale and limited funding, leading to fragmented conservation. In terms of material relics, basic restoration has been the primary focus since the 1990s. (Yunguan, 2003, p. 104). In the early 21st century, there was insufficient follow-up maintenance, with efforts merely confined to maintaining the existing

condition. (Zhang, Tile - Lifting Maintenance of Qionghua Guan, 2022). As found by the author through on-site investigations, there exist an ambiguous management subject, unclear allocation of powers and responsibilities, and absent participation of the Taoist community; collaborative cultural conservation has weakened, the Sanqing Hall has been converted into an art gallery, resulting in the loss of Taoist statues and their original functions, and obvious deviations in cultural display. (Figure 5)



**Figure 5:** Mountain-Gate Hall of Qionghua Guan, Yangzhou
*Source: Photo by the author (2025)*

**Puhading Garden - A Representative of Islamic Gardens: Protection Exploration of "Integration of Chinese and Foreign Styles"**

Puhading Garden, an Islamic Sino-foreign integrated architectural complex first constructed in the Southern Song Dynasty, is a Major Historical and Cultural Site Protected at the National Level. (Figure 6) Its conservation efforts focus on restoring the main structure in adherence to the principle of "restoring the old as it was", (Committee, 2004, p. 12) and carrying out environmental improvement. (Zhang, New Scenery on the East Bank of the Ancient Canal, 2023, p. A5) It has established a management mechanism of "Religion-led, Multi-level Supervision" and upgraded the security system. Meanwhile, it has separated religious and


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tourism activities through "Zoned Supervision and Control", and set up institutions including the Islamic Culture Exhibition Hall, Puhading Memorial Hall and Cultural and Historical Hall. While safeguarding the solemnity of religion, it displays Islamic garden culture, thus achieving a balance between heritage conservation and living inheritance.




**Figure 6:** Layout plan of Puha Ding Garden, Yangzhou, Yangzhou
*Source: Photo by the author (2025)*

## DISCUSSION：COMMON AND INDIVIDUAL PROBLEMS IN THE PROTECTION OF TYPICAL Religious Gardens in Yangzhou

### Common Problems: Common Challenges for Diverse Religious Gardens

The protection of typical religious gardens in Yangzhou is confronted with three major common challenges: funding shortages, talent gaps, and the imbalance between protection and development. Their funding is highly reliant on government fiscal allocation, (Editorial Committee of Daming Temple Chronicle, 2004, pp. 11-12) resulting in a single financing channel constrained by the gardens' own development capacity. While Daming Temple can partially supplement its funds with tourism revenue, Qionghua Guan and Puhading Garden face more acute funding shortfalls due to their small scale and low popularity. All three types of gardens lack interdisciplinary talents with both religious knowledge and garden conservation expertise, which hinders the authentic inheritance and value interpretation of cultural heritage. For instance, the wood and stone carvings embodying the integration of Chinese and Arab cultures in Puhading Garden are in urgent need of inheritance by professional talents. A long-standing imbalance exists between protection and development across the gardens: Daming Temple has continuously advanced renovation and supporting construction to cope with a large tourist flow, yet it still faces the pressure of

carrying capacity oversaturation and disrupted religious atmosphere. In contrast, Qionghua Guan and Puhading Garden have fallen into the vicious circle of "protection-idleness", merely maintaining the physical existence of their architectures while losing their religious and cultural functions. If this vicious circle remains unbroken, these gardens will gradually become relics with physical existence but no cultural connotation, endangering their long-term heritage value.

**Individual Problems**

Beyond the common challenges, the three gardens face unique individual predicaments due to their distinct cultural traits and location conditions. Daming Temple (Buddhist) suffers from the separation of tourism development and religious functions. The massive tourist flow and commercial facilities have damaged its Zen ambiance, and its cultural display remains superficial, failing to fully explore the profound historical connotations associated with historical figures such as Jianzhen, Ouyang Xiu, Su Shi and Emperor Qianlong, which restricts the exertion of its core cultural value. Qionghua Guan (Taoist) is constrained by limited physical space and weakened Taoist attributes. Surrounding constructions have left no room for its expansion; moreover, the lack of management by Taoist practitioners has led to the loss of its cultural essence, and fragmented relics have made systematic protection difficult to implement. Puhading Garden (Islamic) is plagued by the disconnection between its garden style and the inheritance of traditional craftsmanship. (Figure 7) The style of commercial buildings outside the garden is incompatible with the garden's core feature of the integration of Chinese and Arab styles, and the unique stone carving craftsmanship is on the verge of extinction, threatening the authentic preservation of its historical style and features.

By sorting out the conservation issues of the three types of religious gardens and comparing them with existing literature, this study finds that previous research has mostly focused on the discussion of issues concerning a single garden or a single religious type, with relatively general analyses of common problems and insufficient attention to the individualized differences among different religious gardens. While verifying such common problems as funding shortage, talent scarcity, and imbalance between conservation and development, this study further reveals the differentiated characteristics, namely tourism overloading in Buddhist gardens, cultural hollowing in Taoist gardens, and stylistic alienation in Islamic gardens. This research improves the systematic understanding of conservation issues regarding Yangzhou religious gardens and addresses the weaknesses in existing studies.(Table 3)


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**Table 3：** Common and Individual Conservation Problems of the Cases

| Case | Common Problem: Funding | Common Problem: Professional Talents | Common Problem: Unbalanced Development | Individual Problem |
|---|---|---|---|---|
| Daming Temple | Reliant on government finance | Shortage of interdisciplinary professionals | Unbalanced development | Tourism activities disturb the religious atmosphere |
| Qionghua Guan | Reliant on government finance | Shortage of interdisciplinary professionals | Unbalanced development | Lack of specialized management |
| Puhading Garden | Reliant on government finance | Shortage of talents skilled in Chinese Arab stone carving techniques | Unbalanced development | Changes in garden style and risk of loss of traditional craftsmanship |

*Source: Author's own field survey, October 2025*



**Figure 7:** Puhading Garden, Yangzhou
*Source: Photo by the author (2025)*

## HIERARCHICAL PROTECTION COUNTERMEASURES FOR DIVERSE RELIGIOUS GARDENS IN YANGZHOU

After years of development, Yangzhou has gradually formed a system of laws, governmental regulations and planning policies serving diverse objectives and dimensions. Laws and regulations enacted by the National People's Congress as well as provincial-municipal authorities, such as the *Cultural Relics Protection Law of the People's Republic of China* and its Implementing Regulations,

constitute the fundamental legal basis for heritage conservation. At the administrative implementation level, the *Regulations on the Protection of Famous Historical and Cultural Cities, Towns and Villages*, issued by the State Council, provides practical instruments for cultural relic conservation.

Meanwhile, China's conservation system for historic and cultural cities has moved beyond the protection of individual buildings or heritage sites. It places greater emphasis on large-scale conservation of historic building clusters. This system protects not only officially-designated cultural-relic protection units but also their surrounding environments, representing an advanced form of heritage conservation.

The *Outline of the Plan for the Protection, Inheritance and Utilization of the Grand Canal Culture* is a national-level development plan that charts future conservation and development pathways. Though not statutory legislation, its forward-looking, open, proactive and flexible features help attract more personnel and resources for heritage conservation. It enables full-scale discussions prior to conservation actions, maximises public attention, and facilitates access to adequate resources.

**Establishing a Protection System of Classified and Targeted Measures**

Centering on the respective pain points of Daming Temple, Qionghua Guan and Puhading Garden, a classified and targeted protection system is established to avoid a one-size-fits-all approach. For Daming Temple, the measures include strict tourist flow control with zonal and hierarchical guidance, standardizing commercial operations, further exploring Buddhist culture, and building a digital dissemination platform. Documentation of heritage data is the foundation of the essential procedures that facilitate and advance the conservation of cultural heritage buildings in the contemporary era. (Baharuddin, Bahardin, Nawawi, Harun, & Hussain, 2024, p. 32) For Qionghua Guan, protection is promoted in phases: consolidating historical research foundations in the short term, and expanding spatial scope, restoring Taoist management and maintenance, and revitalizing its Taoist attributes in the medium and long term. For Puhading Garden, the strategies involve regulating the surrounding environment through interdepartmental collaboration, inheriting its distinctive craftsmanship, and fostering a positive cycle of protection and activation. These efforts collectively form a scientific and systematic protection system for Yangzhou's diversified religious gardens.

**Expanding the "Diversified Collaboration" Channels for Funds and Talents**

To address the development bottlenecks of the three religious gardens, diverse and collaborative channels for funding and talent cultivation are expanded. In terms of funding, a special fund for the protection of Yangzhou's religious


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gardens is established, and a social donation platform is built to break the over-reliance on fiscal allocation. Tailored to the characteristics of Qionghua Guan and Puhading Garden, efforts are made to upgrade their cultural relic protection grades and secure funding support from home and abroad respectively, with strengthened efficiency in fund supervision. In terms of talent development, it has deepened university-local cooperation with Southeast University and other institutions, offered special courses and jointly built internship bases, invited religious community members to participate in conservation work to uphold authenticity, organized special training sessions and public lectures on a regular basis, and laid a solid foundation for a team of interdisciplinary talents.

**Exploring a "Living Inheritance" Path for Cultural Protection**

Based on the religious characteristics of the three gardens and targeting the pain points in cultural inheritance, differentiated paths of living inheritance are explored to transform the religious gardens from static relics into dynamic cultural carriers. For Daming Temple (Buddhist), in collaboration with intangible cultural heritage inheritors, it restores Tang-dynasty Buddhist rituals, sets up a Zen meditation experience area, and develops research and study routes to form a closed loop of cultural inheritance. For Qionghua Guan (Taoist), it holds cultural exhibitions on traditional festivals such as the Lantern Festival, organizes Taoist ritual performances and interpretations, and explores Taoist health culture to launch experience classes. For Puhading Garden (Islamic), it hosts Islamic Food Festivals on traditional holidays and builds cultural and creative spaces to expand its influence and bridge cultural gaps. Art and cultural activities can help people foster local cultural awareness in the context of cultural heritage and social interaction. (Isa & Shan, 2024 VOLUME 22, p. 496) The ultimate goal of living inheritance is to activate the cultural and religious functions of the gardens and realize the effective inheritance of their core cultures.

## CONCLUSION

The core contribution of this study is to address the limitations of existing research on Yangzhou's religious gardens by breaking the research perspective of focusing on a single garden or a single religious type. Through a horizontal comparison of Buddhist, Taoist and Islamic gardens, this study systematically analyzes the current protection status and existing problems, thus enriching the breadth and depth of research on Yangzhou's religious gardens. At the practical level, the proposed hierarchical protection strategies are closely aligned with the actual predicaments of the three gardens and feature strong operability. They can provide direct references for the local government of Yangzhou and relevant administrative institutions in their religious garden protection work, helping Yangzhou's religious gardens break through protection dilemmas and achieve

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sustainable development, while continuing the cultural context of the harmonious coexistence of diverse religions along the Grand Canal cultural belt.

Based on the findings and unresolved issues of this study, future research can be further advanced from four aspects: First, focus on the refined conservation of Yangzhou's religious gardens, conduct an in-depth exploration of the specialized restoration techniques for material relics of different types of religious gardens (including timber structures, stone carvings, water systems, etc.), and enhance the professionalism and pertinence of conservation efforts. Second, expand the research scope, integrate Yangzhou's religious gardens with the surrounding historic blocks and cultural tourism resources, explore the synergistic development model of "Garden + Block + Cultural Tourism", and address the imbalance between conservation and development. Third, strengthen cross-regional comparative research, compare the conservation experiences and challenges of other diverse religious gardens in China, and extract replicable and promotable conservation models. Fourth, combine the policy directions and technological advancements of cultural heritage conservation in the new era, explore the in-depth application of digital technologies in the conservation and cultural communication of religious gardens, promote the in-depth integration of religious garden conservation with the digital age, and conduct an in-depth study on the synergistic pathways between cultural heritage conservation, local economic development and social and cultural construction, so as to maximize the value of cultural heritage.

## ETHICS STATEMENT

All on-site investigations, interviews and data collection in this study were conducted in accordance with the relevant ethical guidelines for academic research. All research participants provided informed and voluntary consent, which was obtained through verbal confirmation or written informed consent forms.

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# MICRO EVIDENCE FOR MACRO POLICY: HIDDEN BARRIERS TO AGING-IN-PLACE IN HIGH DENSITY CHINESE HOUSING ENVIRONMENT

**Tianli Wang[1], Norazmawati Md. Sani @ Abd. Rahim [2*]**

[1,2] *School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

Aging in place policy relies on community, but policy priorities often top-down and miss lived barriers in dense apartments. This study aims to identify environmental barriers that constrain older adults' priority everyday activities in high density Chinese apartments, to inform evidence-based aging-in-place policy and priorities. This research conducted activity-based in-home assessments for 30 old adults over 60 years, with 41 activities categories in 22 high density estates, using a culturally adapted In-home occupational performance evaluation (I-HOPE), observation and unstructured interviews. In total, 226 barrier instances were coded and scored. The results indicate that digital media use, public transport access, carrying items, cleaning, and bathing were repeatedly identified as priority difficulties. Frequent barriers involved high-reach storage, digital usability, and external mobility interfaces. Many constrained activities were still self-rated as high performance, revealing hidden barriers. So, performance-based micro-evidence can refine priorities and evaluation for policy, which need focus on every day activity chains across unit, building, and urban mobility interfaces, instead of one activity or only at home.

***Keywords***: High Density Housing, Aging in Place, Housing Environment, Hidden Barriers

[2] Corresponding author. Email: norazmawati@usm.my

## INTRODUCTION

Aging in place have become major policy concerns worldwide, as governments seek ways to support older adults to remain in their homes and communities rather than rely excessively on institutional care (Ay & Götze, 2025). This challenge is particularly acute in most of high-density urban settings. High-density residential development with built environment has been identified as creating layered planning challenges if not addressed through proper planning and mitigation measures (Chen et al., 2023; Husin et al., 2021). In response, China has promoted aging in place because institutional care alone is unlikely to meet demand (Fang et al., 2015), and policy attention has shifted from service provision toward improving the physical home environment to enhance the feasibility and quality of aging at home (State Council, 2022). Urban regional planning is inherently an iterative process. The frictions observed in post-development phases underscore the critical need for planners to utilize experiential feedback as empirical evidence to adjust and optimize subsequent macro-level policies (Husin et al., 2021).

China is promoting the renovation of old urban residential communities, focusing on existing residential areas with insufficient supporting facilities and services but strong resident demand for renovation. The renovation content is divided into basic, improvement, and enhancement categories. The improvement category explicitly includes installing elevators in buildings where conditions permit, to address the vertical mobility difficulties commonly faced by residents of multi-story buildings, especially the elderly(General Office of the State Council, 2020). According to official statistics from the Ministry of Housing and Urban-Rural Development (2025), during the 14th Five-Year Plan period, China launched renovation projects for over 240,000 old urban residential communities and installed approximately 129,000 renovated elevators. Furthermore, digital technology is also encouraged to be integrated into home-based elderly care services, such as smart health and elderly care products, aiming to alleviate the shortage of caregivers and improve monitoring and service coordination (Hung, 2022; Zhang et al., 2020). Overall, China's current policy mix constitutes a comprehensive support system covering building renovation, home renovation, and technology enabled care, aiming to create a suitable living environment for most elderly people who age at home.

Despite this ambitious policy agenda, a substantial gap remains between what aging-in-place policies deliver and what older adults need in everyday life. Aging-related welfare measures are not fully integrated with broader urban sustainability and community planning frameworks, limiting the extent to which neighborhood resources can function as coordinated support systems for ageing in place (Jia et al., 2025). However, age-friendly city planning, requires coordinated attention to housing, mobility, facilities, and neighborhood

design rather than isolated interventions (Rashid et al., 2021). This need is especially evident in high-density housing, where high-rise residential development creates multiple planning challenges and requires proper planning and mitigation to address mobility, accessibility, and density-related pressures (Husin et al., 2021). Meanwhile, existing policy and implementation logics often privilege visible and measurable outputs, such as service coverage, technological deployment, and infrastructure upgrading, even though policy-led interventions do not necessarily align with older adults' actual capacity, preferences, or convenience (Jung, 2025; Zhang et al., 2020). In such environments, everyday independence depends less on any single facility than on whether activity can be supported continuously across housing environments. Therefore, the key planning gap is not simply whether more policies or technologies are introduced, but whether planners have sufficiently fine-grained evidence to identify which activities, spaces, and environmental interfaces should be prioritized in high-density urban renewal.

To advance evidence-based urban planning, scholars emphasize the critical need for methodologies that reduce bias and enhance the certainty of evidence (Ravensbergen & El-Geneidy, 2023). This means planners urgently require high-fidelity data that better captures how built environments shape older adults' everyday lives. Aging in place has been discussed as a multidimensional issue involving housing features, housing environment, and technology(Azmi et al., 2021), assessing it solely through subjective feedback often obscures the true friction between the user and the environment. So, this study adopts an activity-based approach that combines self-report and direct observation to identify environmental barriers affecting functional independence in high-density housing. Specifically, it aims first, to identify which housing-related daily activities older adults most frequently priorities as difficult; second, to determine which types of environmental barriers, and in which domestic spaces, most strongly constrain the performance of these priority activities; and third, to reveal barriers to aging in place that may remain hidden when assessment relies on self-report alone.

## LITERATURE REVIEW

Person-environment (P-E) fit explains aging in place as the interaction between older adults' capabilities, needs, and preferences and the demands and affordances of their housing environments (Van Vianen, 2018). In high-density apartments, compact layouts, standardized forms, and reliance on vertical circulation can turn minor frictions into sustained environmental press on daily activities. Fit is also temporal. Older adults often adapt through routines, workarounds, and adjusted expectations, so appearing to manage well may still


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involve hidden constraints and long-term risk (Vleugels et al., 2023). This temporal lens motivates repeated, in-situ observations.

Performance-based assessment links daily activity to the environmental features that enable or constrain them, which translate P-E fit into actionable design and policy evidence. The In-Home Occupational Performance Evaluation (I-HOPE) operationalizes this logic by identifying resident-prioritized activities, capturing self-rated performance and satisfaction, and observing activities to document environmental barriers affecting functional independence in context (Keglovits et al., 2015; Susan Stark et al., 2009; Susan L. Stark et al., 2010).

Observation in natural settings reveals how activities actually unfold and what demands environments impose (Baker, 2006; Kawulich, 2005), which self-report may understate because of habituation and coping. Accordingly, this study defines hidden barriers as situations where participants report high performance or satisfaction despite observed environmental constraints during activity performance.

## RESEARCH METHODOLOGY

### *Study Design and Setting*

This study used an activity-based, performance-oriented assessment to examine how housing environments shape older adults' ability to perform everyday activities. In-home assessments covered dwellings and their surrounding environments in high-density urban housing in China, characterized by compact layouts and standardized building forms. Observation and unstructured interviews captured environmental constraints, perceived sources of difficulty, coping strategies, and priorities for change. The aim was to identify constraints that may remain hidden in building-centered audits but are crucial for aging in place. The findings are not intended for statistical generalization. Instead, recurring activity-environment patterns may be transferable to other high-density housing contexts, including those in Malaysia, where participant, housing, and service characteristics are comparable.

### *Participants and Recruitment*

Participants were community-dwelling adults aged 60 years or older who lived independently, had resided in their current dwelling for at least six months, and could communicate and participate in the assessment. Individuals with acute medical instability or severe cognitive impairment preventing meaningful engagement were excluded. Purposive sampling through community organizations and neighborhood networks captured typical housing conditions. Thirty older adults from 22 residential estates participated. Recorded characteristics included age, sex, living arrangement, residence duration, Lawton IADL score, building type, floor level, toilet type, and balcony availability.

Sample size was guided by analytic depth. Information saturation was approached around the 14th participant, when principal activity priorities and environmental barrier patterns became recurrent. Subsequent cases mainly extended contextual variation. Therefore, the final sample was considered adequate for the pattern-oriented analysis.

***Instruments***

Functional competence was assessed using the Lawton Instrumental Activities of Daily Living (IADL) scale for descriptive and interpretive purposes (Graf, 2008). Housing environments and activities were assessed using an adapted In-Home Occupational Performance Evaluation (I-HOPE), a performance-based assessment of environmental barriers to everyday activities (Keglovits et al., 2015; Susan Stark et al., 2009; Susan L. Stark et al., 2010).

The English-language materials were translated into Chinese by qualified personnel. The original 44-activity set was adapted to high-density Chinese housing, retaining its focus on everyday activity performance. Before pilot testing, adaptations addressed gardening (A8), movement within the housing environment (A19), digital media consumption (A17), and writing or typing (A41). A formal pilot involved six older adults, all included in the final sample of 30. Following the pilot, activity content was adjusted to incorporate getting into and out of public transport (A11) and collecting express deliveries (A23), based on participants' reports. The assessment procedure and scoring criteria remained unchanged. The final set comprised 41 activities covering basic activities, instrumental activities, leisure activities, and social participation.

***Data collection***

The assessment followed the three-step I-HOPE procedure. First, participants sorted activities into five categories: (1) I do not do and do not want to do; (2) I do now with no problem; (3) I do now with difficulty; (4) I do not do but wish to do; and (5) I do now but am worried about my ability in the future. Second, participants ranked activities in Categories 3-5 by importance and selected up to ten priorities. Performance and satisfaction were self-rated on five-point scales (1 = very poor/very dissatisfied; 5 = very good/very satisfied).

Third, where privacy and practical conditions permitted, the researcher directly observed priority activities in the relevant settings, identified environmental barriers, and rated their influence on functional independence using the original 0-5 I-HOPE scale, on which higher scores indicated greater independence. The complete scoring anchors are reported in the Barrier Coding and Scoring section. Observations took place across one or more visits as needed.

Locations were recorded using predefined spatial codes: bathroom (O1), bedroom (O2), function room (O3), kitchen and dining (O4), living room


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(O5), balcony and hallway (O6), roads and trails (O7), community square and green space (O8), streets and commercial areas (O9), and block-level square and green space (O10).

***Barrier Coding and Scoring***

The barrier typology was developed from the literature and refined during fieldwork. It comprised 29 environmental barrier types (EB01-EB29), covering dwelling circulation, surfaces, fixtures, storage, indoor conditions, building and estate access, logistics, digital connectivity and interfaces, thermal comfort, and external mobility. Each type had an operational definition and inclusion and exclusion rules. These rules distinguished related conditions, such as high-reach storage from low-level access and internet connectivity from digital-interface usability. EB30 denoted reported-only evidence without direct performance observation. It was treated as an evidence-status code rather than an environmental barrier type.

Quantitative coding and scoring were restricted to directly observed activity performance. For each retained activity instance, the single environmental condition judged to impose the greatest constraint was coded as the primary barrier. Its influence on functional independence was rated using the original per-instance 0-5 I-HOPE anchors: 0 = no activity; 1 = total dependence; 2 = moderate assistance; 3 = minimal assistance; 4 = standby assistance, safety risk, or extreme energy expenditure; and 5 = independence with or without a device. Thus, higher ratings indicated greater independence rather than greater barrier severity. One researcher conducted all field assessments and completed the initial coding and scoring. A second researcher reviewed the coding framework and ambiguous cases, which were resolved through discussion with reference to the operational definitions and boundary rules.

***Ethical Considerations***

Ethical safeguards focused on informed consent and privacy protection. All participants provided informed consent. Privacy-sensitive activities, including those performed in bathrooms and bedrooms, were not directly observed. Participant codes and predefined spatial codes were used in analytical records to support privacy protection.

***Data Analysis***

Qualitative and quantitative data were analyzed in an integrated manner. Descriptive statistics summarized participant characteristics, housing features, and Lawton IADL scores. Analyses focused on activity, spatial, and barrier patterns rather than individual comparisons. Frequencies and mean self-rated performance and satisfaction identified priority problem activities.

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The quantitative barrier analysis retained 226 directly observed, coded, and scored instances. 71 records without direct performance observation were excluded. Counts, affected participants, rating distributions, typical locations, and associated activities were summarized by barrier type. Observation and linked interview accounts informed the qualitative cause patterns reported in Table 4; interview accounts did not generate quantitative barrier scores.

Barrier impact ratings were grouped into three tiers: assistance needed (1-3); standby assistance, safety risk, or extreme energy expenditure (4); and independent performance (5). These tiers were compared with self-rated performance and satisfaction, with scores ≥4 considered high. Hidden barriers were defined as observed environmental constraints in activities participants felt they managed well. Analysis identified recurrent activity-environment configurations.

## ANALYSIS AND DISCUSSION

### *Sample characteristics and housing context*

The study included 30 older adults living in 22 high density housing unit. Table 1 shows the sample context.

**Table 1:** Participant and housing characteristics (n = 30)

| Variable | Category / Statistic | Value |
|---|---|---|
| Age (years) | Mean (SD) | 66.9 (5.1) |
| | Range | 60-78 |
| Sex | Male | 17 (56.7%) |
| | Female | 13 (43.3%) |
| Living arrangement | live Alone | 5 (16.7%) |
| | With spouse only | 16 (53.3%) |
| | With family | 9 (30.0%) |
| Years in current home (year) | Mean (SD) | 17.5 (4.0) |
| | Range | 11-25 |
| Lawton IADL total (0–8) | Mean (SD) | 6.6 (0.9) |
| | Median (min–max) | 7.0 (5-8) |
| Building type | Elevator building | 25 (83.3%) |
| | No elevator | 5 (16.7%) |
| Floor level | Mean (SD) | 9.6 (5.3) |
| | Range | 2-21 |
| Toilet type | Sitting toilet | 22 (73.3%) |
| | Squat toilet | 8 (26.7%) |
| Number of estates | Distinct housing estates | 22 |

*Source: Data and Author's Calculation*

Participants were on average 66.9 years old (SD = 5.1, range 60-78), with 17 men and 13 women. Most lived with a spouse (53.3%), followed by living


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with family (30.0%) and living alone (16.7%). On average, they had resided in their current homes for 17.5 years. Lawton IADL scores indicated relatively preserved functional competence (mean = 6.6/8; median = 7). Most lived in elevator-served apartments (83.3%), at a mean floor level of 9.6.

***Priority problem activities***

Across the 41 predefined activities, several tasks were repeatedly prioritized as problematic in Table 2.

**Table 2:** Priority problem activities and self-rated performance (n = 30)

| Code[1] | Activity name | n selected | % selected | n in Top3 | % in Top3 | Mean perf.[2] (SD) | Mean satisf.[3] (SD) |
|---|---|---|---|---|---|---|---|
| A17 | Media consumption-Digital | 28 | 93.33 | 17 | 56.67 | 3.36 (0.68) | 3.25 (0.52) |
| A11 | Public transport | 27 | 90 | 15 | 50 | 3.00 (0.88) | 2.74 (0.59) |
| A4 | Carrying Items | 27 | 90 | 10 | 33.33 | 3.00 (0.78) | 2.81 (0.83) |
| A5 | Cleaning Living Area | 27 | 90 | 10 | 33.33 | 3.59 (0.57) | 3.26 (0.81) |
| A33 | Taking a Bath/Shower | 26 | 86.67 | 17 | 56.67 | 3.04 (0.77) | 2.50 (0.58) |
| A26 | Reaching for Things Up High | 23 | 76.67 | 0 | 0 | 3.87 (0.55) | 3.52 (0.73) |
| A23 | Pick up express delivery | 15 | 50 | 2 | 6.67 | 3.27 (0.96) | 3.13 (0.74) |
| A41 | Writing or typing | 14 | 46.67 | 2 | 6.67 | 3.57 (0.76) | 3.21 (0.70) |
| A13 | Getting Up from Chair/Sofa | 13 | 43.33 | 1 | 3.33 | 4.00 (0.41) | 3.77 (0.60) |
| A30 | Responding to an Emergency | 12 | 40 | 3 | 10 | 3.83 (0.58) | 3.50 (0.67) |

*Source: Data and Author's Calculation*

Note: [1] The complete adapted 41-item activity set comprised: basic activities: A4 Carrying Items, A7 Eating, A9 Getting Dressed, A10 Getting In/Out of Bed, A13 Getting Up from Chair/Sofa, A14 Going Up/Downstairs, A15 Grooming, A24 Picking Something Up off the Floor, A32 Sleeping, A33 Taking a Bath/Shower, and A37 Toilet; Instrumental activities: A5 Cleaning Living Area, A6 Controlling the Environment (air conditioning and light switches), A8 Gardening, A11 Getting In/Out of Public Transport, A12 Getting In/Out of Entrance Doors, A16 Ironing Clothes, A20 Opening Bottles or Packaged Food, A21 Opening/Closing Doors, A22 Paying Bills, A23 Picking Up Express Deliveries, A25 Preparing a Meal, A26 Reaching for Things Up High, A28 Repairing Clothing, A29 Repairing Household Objects, A34 Taking Medication, A35 Taking Out the Trash, A39 Washing and Drying Clothes, and A40 Washing Dishes; Leisure activities: A3 Caring for Pets, A17 Digital Media Consumption, A18 Television Viewing, A27 Reading, and A31 Resting; And social participation: A1 Answering the Door or Phone, A2 Caring for Children, A19 Moving Around in the Housing Environment, A30 Responding to an Emergency, A36 Talking on the Phone, A38 Visiting Family and Friends, and A41 Writing or Typing. [2] Performance score: 1 = very poor to 5 = very good (lower scores indicate greater difficulty). [3] Satisfaction score: 1 = very dissatisfied to 5 = very satisfied.

Digital media use (A17), using public transport (A11), carrying items (A4), cleaning the living area (A5), and bathing or showering (A33) were most often selected as problems, each by more than 85% of participants and frequently ranked within the top three concerns. These activities were self-assessed by participants regarding performance and satisfaction, which showed moderate perceived difficulty, with mean performance scores around 3 on a 5-point scale.

While relatively low satisfaction for bathing, getting in/out of public transport and carrying. Second, reaching for things up high (A26), picking up express delivery (A23), writing or typing (A41), getting up from a chair or sofa (A13), and responding to an emergency (A30) formed a second tier of commonly perceived difficulties.

***Environmental barrier types***

Table 3 summarizes 226 observed and scored environmental barriers across 24 coded types. The most frequently recorded barriers were high-reach storage/fixtures (EB12; n=39, 27 participants), digital interface usability (EB27; n=35, 26 participants), and external mobility system barriers (EB29; n=27, all 27 participants). A second cluster included load-handling logistics (EB25; n=19), low-level access demands (EB13; n=14), and unsuitable seating/transfer surfaces (EB06; n=13). Across barrier types, ratings were predominantly moderate (3) or mild (4-5), while EB29 showed a comparatively higher share of severe (0-2) ratings (14.8%), indicating stronger constraints at mobility interfaces. Additional commonly observed barriers included storage depth/organization (EB17; n=11), level changes (EB03; n=11), poor lighting (EB05; n=10), and building access control (EB21; n=9). Spatially, barriers clustered in hallways (O6), key interior rooms (O4/O5), and around building/neighborhood entrances (O7/O10), most often linked to carrying (A4), reaching up high (A26), digital media use (A17), bathing (A33), and public transport access (A11). Several further barrier types were reported only in interviews and are examined in the subsequent qualitative analysis.

**Table 3:** Environmental barrier types, severity and spaces (n = 226 observed barriers)

| Barrier code | Barrier name | n barriers | n participants | Severe[1] 0-2 n (%) | Moderate 3 n (%) | Mild[2] 4-5 n (%) | Top locations | Top activities[3] |
|---|---|---|---|---|---|---|---|---|
| EB12 | High-reach storage | 39 | 27 | 2 (5.1) | 13 (33.3) | 24 (61.5) | O4, O6 | A4, A26 |
| EB27 | Digital interface | 35 | 26 | 2 (5.7) | 15 (42.9) | 18 (51.4) | O5, O6 | A17, A41 |
| EB29 | External mobility | 27 | 27 | 4 (14.8) | 14 (51.9) | 9 (33.3) | O6, O10 | A11, A38 |
| EB25 | Load-handling | 19 | 17 | 1 (5.3) | 7 (36.8) | 11 (57.9) | O6, O5 | A4, A23 |
| EB13 | Low-level access | 14 | 13 | 0 (0.0) | 4 (28.6) | 10 (71.4) | O6, O10 | A33, A25 |
| EB06 | Seating/transfer surface unsuitable | 13 | 13 | 0 (0.0) | 0 (0.0) | 13 (100.0) | O6, O10 | A33, A5 |
| EB17 | Storage depth constraint | 11 | 10 | 2 (18.2) | 3 (27.3) | 6 (54.5) | O4, O6 | A4, A26 |
| EB03 | Level change | 11 | 11 | 1 (9.1) | 4 (36.4) | 6 (54.5) | O5, O6 | A4 |
| EB05 | Poor lighting | 10 | 8 | 0 (0.0) | 1 (10.0) | 9 (90.0) | O5, O6 | A41, A27 |
| EB21 | Building access control barrier | 9 | 9 | 0 (0.0) | 0 (0.0) | 9 (100.0) | O10, O7 | A38, A12 |

*Source: Data and Author's Calculation*


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Note: Barrier codes: EB01-EB29 denote the 29 environmental barrier types in the full coding framework, of which 24 occurred in the observed dataset. The table presents the ten most frequently recorded types, accounting for 188 of the 226 observed instances; the remaining 38 instances were distributed across 14 lower-frequency types and are not shown individually. EB30 was a reported-only evidence-status code, rather than an environmental barrier type. [1] Severe = barrier score ≤2; Moderate = score 3; Mild = scores 4-5. [2] Although scores 4-5 is reported as one group, 99.3% of these instances were scored 4, indicating standby assistance, safety risk, or extreme energy expenditure; only one instance was scored 5. Location codes: O4 Kitchen and Dining Area, O5 Living Room, O6 Balcony and Hallway, O7 Roads and Trails, and O10 Block-Level Square and Green Space. [3] Activity codes are defined in the note to Table 2.

### *Causes of key environmental barriers*

Table 4 summarizes the main cause patterns for selected barrier clusters derived from both observed performance and interview accounts. Each row combines barrier codes that were frequently observed or repeatedly self-reported by participants, and that have been synthesized into environmental evidence pointing towards specific policy and design directions. Vertical circulation and entrance systems in no elevator estates (EB21, EB22, EB03) were repeatedly described as making going out and returning home the most exhausting part of daily life. Interior storage and layout barriers (EB12, EB17, EB13) reflected cupboards and storage cabinet placed too high, too low or too deep. Ground height difference (EB25, EB21) made carrying groceries and parcels difficult. Digital accessibility barriers (EB26, EB27) were linked to unstable connections, complex interfaces and fear of making mistakes. External mobility barriers (EB29, EB23) were tied to unclear wayfinding and fast-moving crowds. Thermal comfort and indoor environmental quality (EB28, EB20) have a significant impact on daily life activities, especially bathing. The lack of appropriate space (EB10) constrained the elderly from attempting interest activities such as gardening and caring for pets.

**Table 4:** Main causes of environmental barrier from interview

| Barrier code | Environmental evidence for policy direction | Paraphrased from interviews | Key activities affected |
|---|---|---|---|
| EB21, EB22, EB03 | Building entrance and vertical circulation systems | No lift and repeated stair flights make going out the hardest part; heavy doors and thresholds add to the effort. | A14, A11, A23, A38 |
| EB12, EB17, EB13 | Interior storage design and layout | Cupboards too high or low and deep cabinets force reaching or deep bending, especially for seasonal storage/cleaning. | A26, A5, A4, A33 |
| EB25, EB21 | Load-handling and parcel logistics | Routes for carrying groceries or parcels are long and segmented, with distant lockers and no resting or trolley support. | A4, A23, A12 |
| EB26, EB27 | Home internet and digital interface design | Connections feel unstable and app interfaces confusing; older adults fear “pressing the wrong button” and cannot read small text. | A17, A41 |

| Barrier code | Environmental evidence for policy direction | Paraphrased from interviews | Key activities affected |
|---|---|---|---|
| EB29, EB23 | External mobility and public transport interface | Wayfinding is unclear, and crowded, fast-moving flows at stops and doors make it hard to follow the pace. | A11, A38 |
| EB28, EB20, EB04 | Thermal and (semi-)outdoor environmental conditions | Winter bathrooms and balconies are very cold; hot water and wet, slippery tiles increase discomfort and fall concerns. | A33, A5, A32, A8 |
| EB20, EB30 | Access to restorative outdoor/pet-friendly micro-spaces | Residents would like to garden or keep pets but feel there is no suitable or neighbor-friendly place to do so. | A8, A3 |

*Source: Data and Author's Calculation*

### *Hidden barriers*

For each activity instance with an observed barrier score (n = 226), self-rated performance and satisfaction from Step 2 were explained parallelly with observer-rated environmental impact from Step 3, rather than treating these as equivalent scales. Self-ratings were used as indicators of how well older adults felt they managed an activity, while barrier scores indexed how strongly the home environment constrained that performance. For every activity, the most constraining barrier score was used to classify observed impact into three tiers: assistance needed (any barrier scored 1-3), standby support / safety risk or extreme effort (any barrier scored 4), and independent (all barriers scored 5). In Table 5, 86 instances (38.1%) required some assistance, and 139 instances (61.5%) involved standby support or safety risk, yet within these constrained tiers 38.4-59.7% of activities were still rated as high performance (≥4), and 25.6-43.9% as high satisfaction. Overall, 51.3% of constrained activities were self-rated as high performance and 36.7% as high satisfaction, indicating that a substantial share of environmental constraints would remain partially hidden if assessment relied on self-report alone.

**Table 5:** Self-rated outcomes by observed impact tiers (n = 226 activity instances)

| Barrier score based on observed activities | n instances | % with high performance (≥4) | % with high satisfaction (≥4) |
|---|---|---|---|
| Assistance needed (any barrier scores 1-3) | 86 | 38.4 | 25.6 |
| Standby / safety risk or extreme effort (any barrier score =4) | 139 | 59.7 | 43.9 |
| Independent with/without device (all barrier scores =5) | 1 | 100 | 100 |

*Source: Data and Author's Calculation*


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### *Discussion*

This study shows that the difficulties older adults face when aging in place in high-density apartments are concentrated in a limited set of recurring daily activity chains and are shaped by both domestic and external environmental conditions. First, difficulties in high-density housing are often chain-like. The high frequency of barriers related to storage height, depth, and low-level retrieval reflects the importance of storage, retrieval, and cleaning to the organization of compact homes. When these constraints intersect with carrying activities, individually minor obstacles can accumulate into substantial recurring burdens (Cha, 2025; Sheth & Cogle, 2023). Although home modifications often emphasize fall prevention and physical safety, long-term adaptation, individualized contexts, and technological interventions receive less attention (Cha, 2025; Sheth & Cogle, 2023). Therefore, interventions should support the continuity of everyday activity chains rather than address isolated spatial features.

Second, external mobility systems formed an important barrier category. Aging in place does not occur only within the dwelling but across connections among the home, building, community, and city. Older adults may experience transportation inequalities and psychological stress in everyday travel (Jahangir et al., 2022), while declining mobility can progressively reduce independence (Dilian et al., 2025). Barriers such as absent ramps, long walking or waiting times, and unavailable station information can restrict public-transport use (Mwaka et al., 2024). The present findings therefore position external mobility barriers as part of aging in place itself, rather than as separate transport problems. Planning should address neighborhood circulation, short-distance mobility, and usable public-transport interfaces as connected supports for everyday living.

Third, digital media use was a high-frequency difficulty, showing that digital systems are embedded in daily errands, communication, service access, and information management. The observed usability barriers should not be attributed solely to individual inadequacy. Older adults' digital engagement is also shaped by self-efficacy, technology anxiety, perceived usefulness, and digital-risk perceptions (Aleti et al., 2025; An et al., 2024; Zian Fang et al., 2024). Together with participants' interview accounts, the observed interface difficulties suggest that essential daily activities increasingly depend on digital systems. When interfaces offer limited opportunities for low-cost trial, error, and recovery, technology can shift from support to burden. Age-friendly planning and service guidance should therefore treat usability and error recovery as components of everyday infrastructure. Figure 1 synthesizes three recurring activity-environment chains identified across the observed barrier patterns and interview accounts.

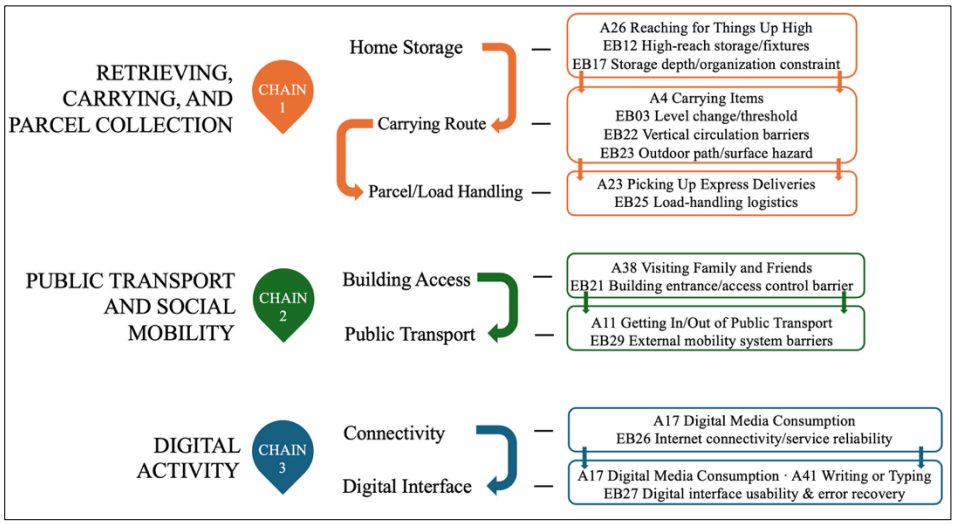



**Figure 1:** Activity-environment Chains
*Source: Author's Drawing*

Fourth, the key finding is not that most barriers were severe, but that many activities remained apparently manageable while involving safety risks, standby assistance, or extreme effort. Such conditions may be treated as minor when assessment focuses only on task completion, visible accidents, or minimum accessibility thresholds. However, for older adults, continued completion may require greater physical effort, time, and risk tolerance. This represents constrained or forced adaptation rather than an absence of environmental difficulty. The coexistence of high self-rated performance with observed constraints shows how reliance on self-report alone may normalize difficult conditions and underestimate threats to the sustainability of independent living. Therefore, more rigorous, multi-source evidence is needed to reduce bias in planning decisions (Ravensbergen & El-Geneidy, 2023).

The study's potential transferability lies in these recurring patterns: linked constraints across activity chains, dependence on interfaces beyond the dwelling, and high self-rated performance despite observed environmental barriers. These patterns may be relevant to high-density housing contexts where residents' functional profiles, housing layouts, shared circulation systems, and dependence on transport and digital services are comparable. This conditional relevance is consistent with a capability-oriented understanding of aging in place across home and neighborhood environments (Bigonnesse & Chaudhury, 2022). Malaysian strata-housing research similarly identifies housing features, the wider housing environment, and technology as relevant domains (Azmi et al., 2021), providing a basis for contextual comparison but not evidence of identical barriers.


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The sample's relatively preserved IADL functioning and predominance of elevator-served apartments further limit direct extrapolation. Therefore, local activity priorities, climate, family support, management arrangements, and service systems must be reassessed before applying the findings elsewhere.

### *Implications for Urban and Housing Planning*

Broad principles of accessibility, safety, and inclusion do not indicate which activities, spaces, and interfaces should receive priority in high-density housing. Activity-based evidence can make these priorities more specific and reduce assumptions in planning decisions (Ravensbergen & El-Geneidy, 2023). The findings suggest coordinated action at five levels.

At the unit level, retrofit priorities should address high- and low-reach storage, deep cabinets, level changes, inadequate lighting, unsuitable transfer surfaces, and bathing conditions. Interventions should support activity chains such as retrieving, carrying, cleaning, and bathing rather than isolated physical features. At the building level, vertical circulation, entrances, and load-handling routes should be planned as connected elements. Elevator access, manageable doors and thresholds, and resting or trolley support between dwellings, entrances, and parcel points can reduce the accumulated burden of leaving home and carrying items. At the estate level, barrier-free walking routes should connect entrances with communal spaces, parcel facilities, neighborhood services, and transport. Path continuity, surfaces, lighting, resting opportunities, and access arrangements require attention because interruptions can undermine otherwise accessible dwellings and buildings. At the digital-interface level, stable connectivity should be accompanied by readable displays, clear feedback, simple navigation, and error-recovery options. Assisted or alternative channels are needed when essential tasks cannot be completed digitally. Digital usability should be treated as everyday service infrastructure rather than solely an individual skill issue. At the transport-interface level, routes to stops, waiting conditions, wayfinding, service information, and boarding accessibility should be evaluated together. Planning should consider whether older adults can complete the journey from the dwelling to essential destinations rather than assessing vehicles, stops, and pedestrian routes separately.

Across these levels, performance-based assessments can complement compliance checklists by revealing where apparently independent activity still involves excessive effort or safety risk. Planners, housing authorities, estate managers, transport providers, and digital-service designers can use this evidence to set local priorities and evaluate activity continuity.

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## CONCLUSION

In summary, this study demonstrates how micro-level activity evidence can optimize macro-level aging in place policies in China's high-density apartment environments. Using performance-oriented home assessments combined with unstructured interviews, the study found that older adults most frequently cited key aspects of daily life. Difficulties with digital media use, public transportation, carrying items, and bathing were listed as priorities. Within these activity chains, compact layouts and systemic constraints amplify minor frictions into recurring burdens. Crucially, participants tended to rate their performance and satisfaction relatively well, yet many limitations were still observed. This discrepancy suggests that relying solely on self-reporting may normalize limitations and underestimate potential barriers crucial for long-term autonomy and security. The findings indicate that aging-in-place policies should shift from checklist-based upgrades to an activity chain-based approach. Priorities should include accessibility of carrying; digital availability and recovery as part of daily infrastructure; connectivity between the home, community, and urban interface. Although the study was conducted in China, its contribution extends to other high-density Asian urban contexts with similar structural housing conditions, including compact apartment layouts, standardized residential forms, ageing building stock, and growing reliance on community facilities, public transport, and digital services in everyday life. These shared conditions are increasingly visible across high-density Asian cities such as those in Malaysia, where ageing in place is also being discussed through strata housing, age-friendly neighborhoods, and the interrelated roles of housing environment, accessibility, and technology.

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# THE NEGATIVE EFFECTS OF NON-MOTORIZED LANE MANAGEMENT REGULATORY TOLERANCE IN CHENGDU, CHINA

**Chen Qixiang[1], Norazmawati binti Md. Sani @ Abd. Rahim[2]***

[1,2]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA

## Abstract

The expansion of Non-Motorized Lanes (NML) is a cornerstone of urban sustainable development. However, spatial encroachment often undermines the practical effectiveness of NMLs. This study examines how regulatory tolerance may interact with roadside obstruction and facility design to affect the spatial integrity of NMLs in Chengdu, China. Based on field data and secondary literature, the study conducted direct effective width assessments on four pre-selected road segments. The Space Loss Index ($L_s$) quantifies the proportion of designated NML space that is unusable under documented obstruction conditions. Research reveals contrasting combinations of facility design, observed roadside occupation, and implementation conditions. The physically separated segment on Jianshe Road retained its delineated travel space, whereas the other cases showed varing degrees of space loss with motor vehicle stopping or parking within the Non-Motorized space. These findings suggest that physical separation can offer more reliable protection of NML than administrative controls alone. They also indicate that the effects of roadside management should be assessed together with facility design and local access needs, rather than being attributed to single enforcement factor. The study therefore proposes differentiated spatial management that combines context-sensitive regulation with physical measures to safeguard Non-Motorized users.

***Keywords***: Non-Motorized Lane, Spatial Encoachment, Space Loss Index (Ls), Regulatory Tolerance, Sustainable Development

[2] Corresponding author. Email: norazmawati@usm.my

## INTRODUCTION

It seems there are countless proposals for urban transportation planning, enhancement, and modification. From an urban planning perspective, these initiatives all aim to improve residents' quality of life. However, during implementation, unforeseen obstacles often arise(Zakka et al., 2017). Chengdu, as a megacity in central-western China, is undergoing continuous dynamic adjustments in its spatial utilization (Miao, 2019; Schneider et al., 2005). Regulatory frameworks and physical design can both influence these spatial forms.

In recent years, Chengdu has undergone a dramatic urban transformation (Srinivasan et al., 2020; Jing Zhao et al., 2025). This shift is evident not only in the renewal of its architecture but also in the friction between new regulations and old ways of life. On one hand, the Chengdu municipal government is committed to enhancing transportation efficiency and sustainability through high-standard Non-Motorized Traffic (NMT) planning. On the other hand, the established logic of daily life and the dimensions of roads in the older districts still possess powerful inertia.

Regulatory tolerance may arise when transportation planning encounters complex public needs. In this study, regulatory tolerance refers to the flexible or inconsistent implementation of formal road management rules in response to actual traffic, parking, or livelihood needs. This interpretation stems from the operational model of grassroots bureaucracy, where frontline implementers may possess a degree of discretion in the face of conflicting public needs (Lipsky, 2010). Research on street commerce governance in Chengdu and local policy documents on inclusive and prudent regulation also demonstrate the actual tension between formal regulation and daily livelihood activities (Jin & Zhao, 2022; Sichuan Provincial People's Government Website, 2022). This tolerance may be related to the gap between formal regulations and actual street conditions, but it is not the only reason for road encroachment.

Existing design guidelines emphasize providing continuous and unobstructed space for non-motorized travel, including sufficient road width and measures to prevent motorized vehicle intrusion (National Association of City Transportation Officials, 2011). Multimodal traffic analysis also recognizes that the configuration and operation of road facilities affect the space available to road users. Therefore, this study compares four pre-defined road segments in Chengdu. The study uses the Space Loss Index ($L_s$) to quantify the proportion of designated non-motorized space that is unusable under recorded obstruction conditions and examines the correlation between observed space loss and road facility configuration, as well as existing roadside management and enforcement evidence. This analysis aims to identify correlations between different cases, rather than to establish independent causal effects of regulatory tolerance.

## METHODS

To address the research questions, this study employs a mixed-methods approach. Through policy text analysis, Field observation, and quantitative calculations, it systematically investigates right of way conflicts on Non-Motorized Lanes (NML) in Chengdu.

### Site Selection

As a populous province in western China (with approximately 90.605 million residents), Sichuan's provincial capital, Chengdu, exhibits a typical radial loop structure. As Roberts (1995) aptly described the provincial capital Chengdu, it resembles a dartboard—a highly vivid analogy.

To represent different urban environments in Chengdu, this study compares the physical road separation, roadside parking pressure, and development environment along Chengdu's southward development axis. This study adopts the Urban Transect strategy as outlined in the Chengdu Territorial Spatial Master Plan (2024), which guides the Transect Strategy (Talen, 2002). The author selected four road corridors. Within each corridor, a clearly defined section was demarcated for on-site measurement and analysis. The analysis boundaries are marked A-B in Figure 1.

1. Jianshe Road: authors selected a 270 meter analysis segment. The NML on this segment is 3.97 meters wide and physically restricts motor vehicle access.

2. Ximianqiao Street: a 375 meter analysis segment was selected, with a width of 3.00 meters. Intermittent parking was observed within the designated curb space.

3. Jinxiu Road: a 60 meter section with a partial curb entrance was selected, with a width of 1.92 meters.

4. Haichang Road: a 170 meter designated NML was selected, with a width of 2.28 meters. Adjacent parking areas outside the boundaries were excluded from the analysis.

These four segments represent different configurations in terms of physical protection, roadside parking interference, and facility continuity. Measurements and spatial loss calculations were performed only for segments A-B.


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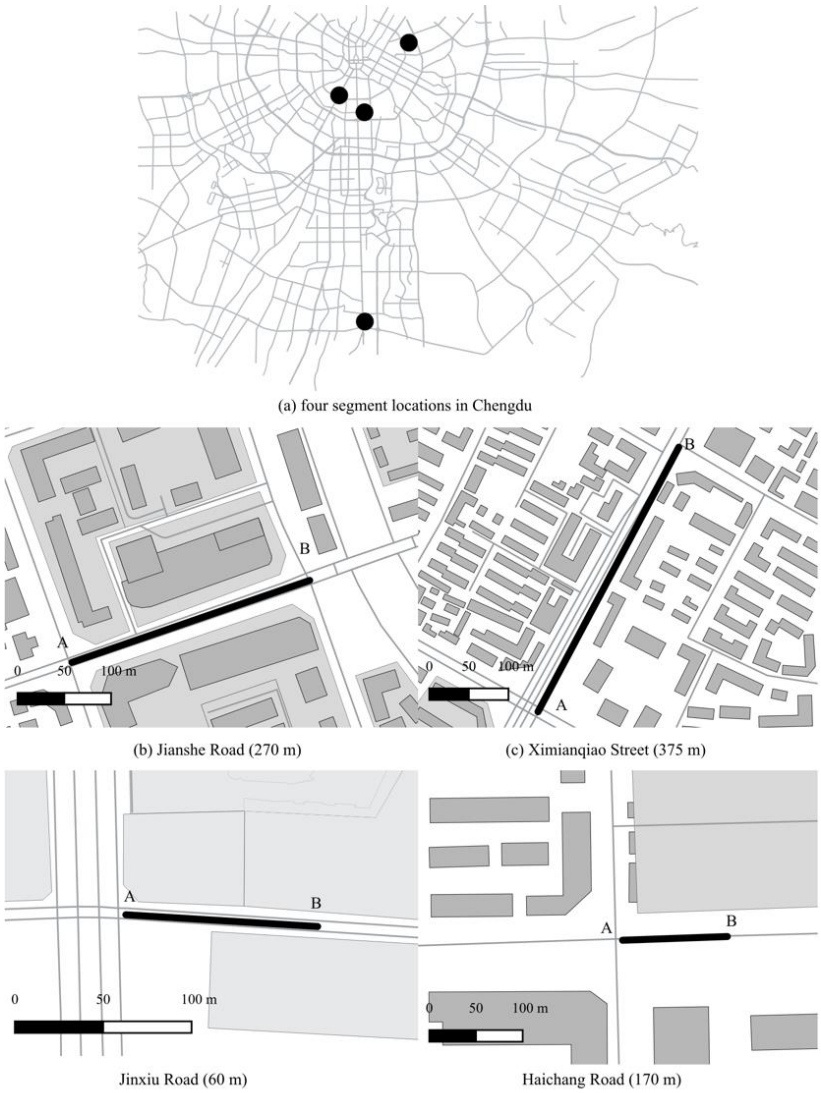



**Figure 1:** Locations and boundaries of the four segments in Chengdu
*Source: Authors' compilation based on OpenStreetMap and field investigation*

## Data Collection and Quantitative Assessment

Field data collection comprised two components. First, a single on site measurement campaign was conducted to verify the physical dimensions of the four pre defined A–B study segments. Designated NML width ($W_d$) and the remaining traversable width under the recorded obstruction condition ($W_e$) were

measured using a tape measure; a laser distance meter was used where site conditions allowed.

Second, repeated visual observations of roadside conditions were undertaken by the authors during separate, no scheduled site visits between 2024 and 2026, covering spring and summer. These visits recorded visible roadside conditions, including vehicle stopping or parking, informal tricycle or vendor activity, access activity, and facility configuration. Photographs were taken as contemporaneous field records.

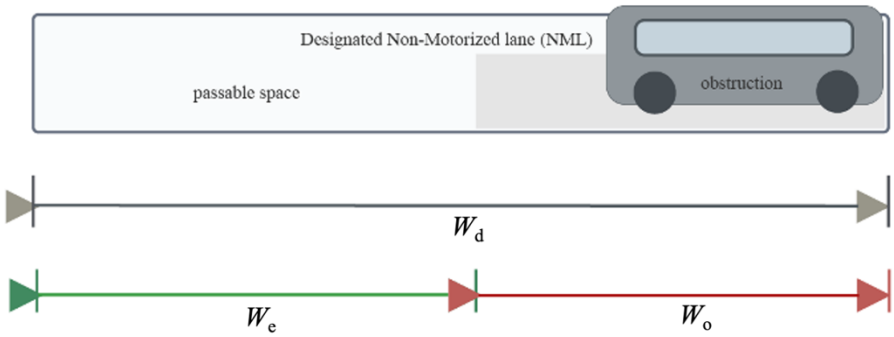



**Figure 2:** Direct measurement logic for the Space Loss Index
*Source: Authors' illustration*

Existing bicycle facility guidelines emphasize the importance of continuous, unobstructed passageways and physical measures to limit motor vehicle intrusion (National Association of City Transportation Officials, 2011). This study was designed based on these guidelines, recording directly observed occupancy widths; no additional buffer coefficients based on capacity or perception were applied when calculating Ls.

The direct measurement results are summarized using the spatial loss index ($L_s$), which is defined as follows.

The Space Loss Index ($L_s$) measures the proportion of designated NML space that is unusable under the recorded obstacle conditions in each A-B study segment. To quantify this reduction, the study recorded three geometric variables: designated width ($W_d$), remaining usable width ($W_e$), and occupied width ($W_o$). $W_d$ represents the designated NML width under obstacle free conditions, We represents the remaining traversable width under the recorded obstacle conditions, and $W_o$ is calculated as $W_d - W_e$ (figure 2). The calculation is performed in two steps:


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$$W_e = W_d - W_o$$
$$L_s = (1 - \frac{W_e}{W_d}) \times 100\%$$

where

$L_s$ = Space Loss Index (%)
$W_e$ = Effective Width (m)
$W_d$ = Delineated Width (m)
$W_o$ = Occupied Width (m)

These formulas are applied in sequence: this paper record the remaining usable width under the recorded obstacle conditions, and then $L_s$ represents the resulting space loss as a percentage of $W_d$. $W_d$ and $W_e$ are obtained through field validation on each predefined study segment, and Wo is calculated as $W_d - W_e$. A higher $L_s$ value indicates a larger proportion of usable space in the defined NML space under the recorded conditions.

## FINDINGS AND DISCUSSION

This study compared the spatial conditions of four pre-selected road sections in Chengdu, revolves around three dimensions: structural design, traffic control, and enforcement implementation. Within each dimension, the observed spatial loss results are interpreted in conjunction with the specific road section conditions, rather than being treated as evidence of a single causal factor.

**Table 1:** Measured geometry and Space Loss Index ($L_s$) in the analysed road segments

| Road Segment | Analysed Length(m) | $W_d$ (m) | $W_e$ under observed obstruction (m) | $L_s$ (%) |
|---|---|---|---|---|
| Jianshe Road | 270 | 3.97 | 3.97 | 0.0 |
| Ximianqiao Street | 375 | 3.00 | 0.20 | 93.3 |
| Jinxiu Road | 60 | 1.92 | 0.00 | 100.0 |
| Haichang Road | 170 | 2.28 | 0.20-0.40 | 82.5-91.2 |

*Source: Field verification and authors' calculations*

Table 1 summarizes the measured geometry and space loss index ($L_s$) of the four road segments analyzed. Under the recorded conditions, the physically isolated section of Jianshe Road maintained its full designated width, and no space loss was recorded. In contrast, the effective NML was reduced on Ximianqiao Street, Jinxiu Road, and Haichang Road due to vehicles occupying the designated areas.

**Table 2:** Cross-case comparison of facility configuration and observed condition

| Road Segment | Facility Configuration | Primary Observed Constraint | Functional Outcome |
|---|---|---|---|
| Jianshe Road | Physically separated NML | No vehicle intrusion observed | Continuous passage maintained |
| Ximianqiao Street | Delineated curbside NML | Intermittent vehicle stopping | Bicycle passage disrupted |
| Jinxiu Road | Short approach NML segment | Parked vehicles despite no-parking controls | Bicycle passage blocked |
| Haichang Road | Delineated NML section within a discontinuous corridor | Irregular vehicle parking | Bicycle passage disrupted |

*Source: Field verification and authors' analysis*

## Structural Design and Space Loss Observation

These four case studies demonstrate how facility configurations correspond to varying levels of observed Non-Motorized Traffic (NMT) space availability (table 2). The following discussion interprets the recorded geometry in conjunction with structural design, traffic control, and existing enforcement evidence

The 270 meter section of Jianshe Road analyzed includes physical barriers, including green medians and pillars. On site verification revealed no motorized car encroachment on the designated NML. Therefore, its designated width and effective width are both 3.97 meters, with a space loss rate ($L_s$) of 0.0%.

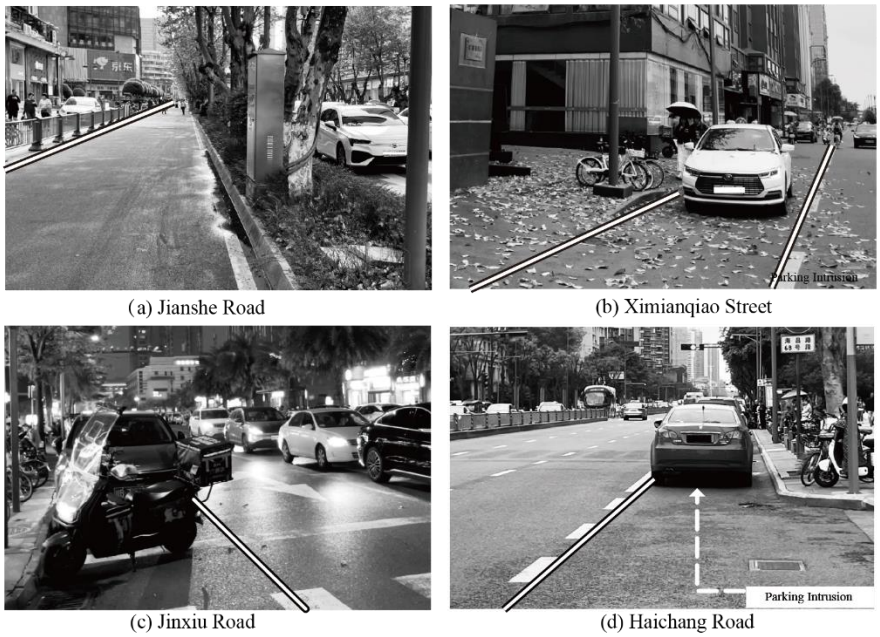
while lane markings were drawn on the 375 meter long A-B section of Ximianqiao Street, continuous physical separation was not achieved. During recorded instances of intermittent vehicle parking, the actual effective width was only 0.20 meters, compared to the marked width of 3.00 meters ($L_s$ = 93.3%). This situation obstructed bicycle traffic, forcing cyclists to detour or merge into adjacent motorized lanes.

In the 60 meter section of Jinxiu Road analyzed, the lane marking width was 1.92 meters. Despite the presence of no-parking signs nearby, vehicles were still parked in this section. Under the observed conditions, the NML within the markings had no effective width, resulting in a capacity ($L_s$) value of 100%. The presence of parking tickets indicates that enforcement action was taken; therefore, this case is interpreted as a challenge in enforcement rather than a complete lack of evidence.

In the 170 meter section of Haichang Road analyzed, the lane marking width was 2.28 meters. Improperly parked motor vehicles within the NML resulted in an effective width of only 0.20 to 0.40 meters, with Ls values ranging from 82.5% to 91.2%.


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In summary, the sampled segments differ in configuration and functional role, and these differences are associated with varying observed conditions of NML right.




(a) Jianshe Road (b) Ximianqiao Street

(c) Jinxiu Road (d) Haichang Road

**Figure 3:** Observed roadside conditions in the four analysed road segments
*Source: Field photographs by the Author (2025-2026)*

As shown in table 1, the four analysed segments exhibit different observed levels of space loss. This suggests that, this phenomenon demonstrates that merely increasing road width does not directly guarantee the rational use of road rights. Space allocation is profoundly influenced by grassroots livelihood logic and individual opportunism (Lipsky, 2010; Ogunyemi et al., 2024).

**Transportation Policy and Regulatory Dimensions**

Transportation policy is not merely a set of static regulations; it is also the institutional adjustments made by policymakers to balance traffic efficiency with social needs.

The implementation of preventive policies can reduce the need for subsequent regulation, the most notable achievement of Jianshe Road lies in its low-maintenance nature. Orderly traffic flow has reduced the need for daily enforcement by traffic management authorities. This defensive regulatory approach has replaced the long-term costs of regulation. This case suggests that robust physical boundaries may reduce reliance on frequent on-site enforcement.

Policies must be tailored to local conditions, Ximianqiao Street exemplifies the conflict between the continuous flow of non-motorized traffic (NMT) and the daily need for roadside access. Its dashed markings and roadside layout seem designed to accommodate short-term activities such as hotel pick-ups and dropoff, and store deliveries. This design detail reflects urban micro-tolerance toward street-side commercial activities. This tolerance does not stem from institutional gaps but rather represents a conscious institutional trade off. However, on site observations show that this flexibility reduces the continuity of NMT access space when motor vehicles are parked or stopped. whose spatial impact requires careful assessment.

This study conducted an indepth analysis of 10 representative complaint samples sourced from the "Sichuan Government Inquiry" platform. Qualitative analysis of these unstructured texts revealed a high degree of consistency in citizens' grievances, with 80% of complaints centering on the core issue of de facto reduction of NML due to informal operations (tricycles) or street vendors occupying roadways.

To identify the temporal distribution characteristics of bicycle lane conflicts on Haichang Road, this study conducted statistical analysis on the collected citizen appeals:

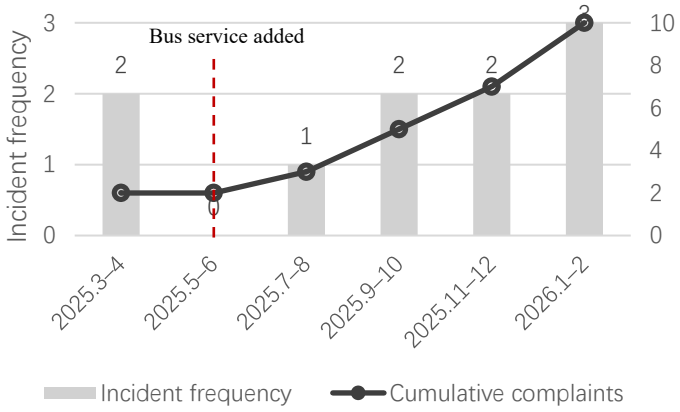



**Figure 4:** Monthly recorded roadside incidents and cumulative public complaints on Haichang road

*Source: Authors' compliation of 10 public Records from the Sichuan Government (2025 to Feb.2026)*

As shown in Figure 4, local residents have complaints with the street vendors on Haichang Road and the shuttle buses that occupy the road.

To address this governance challenge, Chengdu's transportation authorities implemented proactive intervention measures on April 17, 2025, introducing a short-distance shuttle bus connecting the eastern end of Haichang


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Road to the Haichang Road subway station (Cover News, 2025). This initiative aimed to squeeze out informal tricycle services by providing safer, more formal public transportation, enhancing residents' convenience in commuting home, and increasing utilization of NML.

Preliminary data analysis indicates that this initiative significantly alleviated social tensions in the short term, with citizen complaints declining in the months following the intervention. However, long-term tracking of complaint records on government websites reveals that since September 2025, starting in July 2025, related complaints began to surface, intensifying by December. This exposes the limitations of formal systems when replacing informal shuttle services. The door-to-door convenience and low barriers offered by tricycles demonstrated remarkable informal resilience in competing with fixed-schedule public transit services.

In recent years, Chengdu has introduced a series of measures to improve the utilization of limited road space, including setting up straight ahead waiting areas, connecting dead end alleys, and allowing residents to report violations (2022). The Haichang Road shuttle service embodies this precise traffic management approach, providing local residents with a formal last mile travel option. While these measures may improve operational efficiency, their spatial impact on NMT users still needs to be assessed.

**The Law Enforcement and Regulatory Dimension**

If policy provides the space for tolerance, then law enforcement determines the degree of tolerance. This research finds that regulatory boundaries exhibit a significant tendency to retreat amid the tension between social anxiety and administrative costs.

To further explore the institutional logic underlying responses to spatial conflicts, this study developed a standardized flowchart for the handling of complaints regarding NML in Chengdu (see Figure 5).

This flowchart illustrates how initial complaints submitted through the 12345 Mayor's Hotline and the Sichuan Government Inquiry platform undergo administrative triage (Zhao et al., 2025), ultimately balancing between rigid enforcement and flexible persuasion. This institutionalized triage process is the underlying reason for the weariness effect observed in Haichang Road's governance outcomes.

According to figure 4 of the Chengdu 12345 Hotline Platform, the platform is defined as the city's central customer service hub and a key reference for government decision making (2023). This confirms that the complaint data selected for this study is not marginal social discourse, but an indicator of public sentiment formally incorporated into the city's governance monitoring system (Wang et al., 2025).

Chengdu's governance approach is not solely reliant on tolerance. On the law enforcement front, the government implements both static, strict street management systems and introduces drone patrols and executes to address blind spots (2026), which caused by insufficient police resources. Regarding road rights, the city enforces a strict access system for bus only lanes on its Second Ring Road, featuring heavy penalties with no upper limit on the number of offenses, demonstrating rigid rule enforcement.

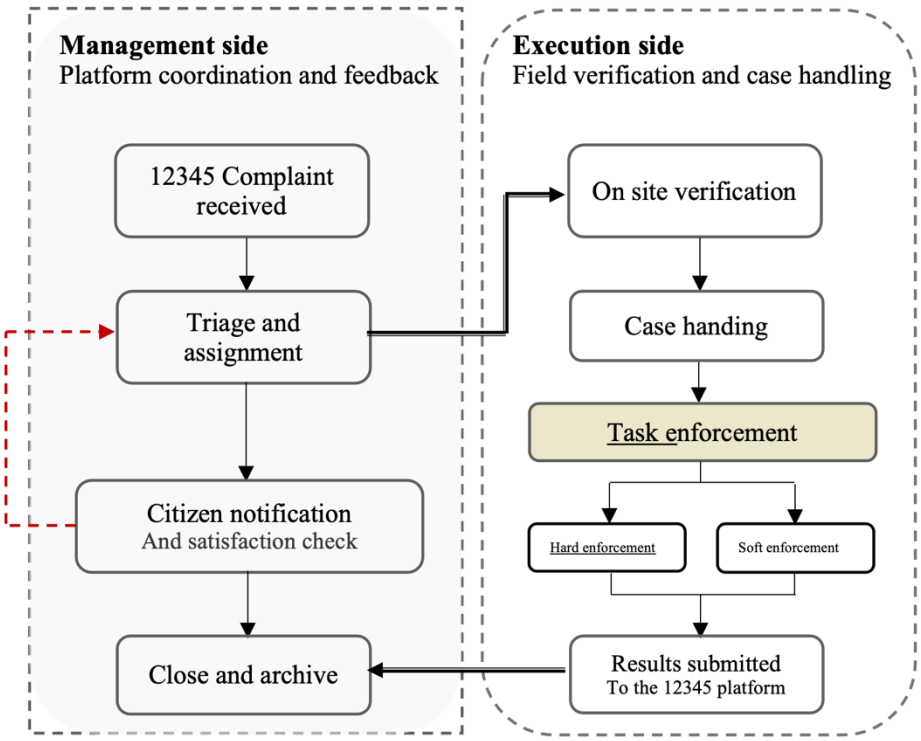



**Figure 5.** Enforcement and regulatory dimensions
*Source: Author' illustration based on the Chengdu 12345 hotline Platform work measures (2023)*

Meanwhile, the Haichang Road case illustrates a different logic—a social buffer zone created by flexible law enforcement. In this section of the road, the proactive withdrawal of administrative deterrence stems not from a lack of governance capacity, but rather from a form of benevolent tolerance toward informal employment and the essential transportation needs of nearby residents.


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**Why Regulatory Tolerance Needs?**

Although Jianshe Road demonstrates the exceptional effectiveness of physical separation in protecting road rights, below structural reasons pose significant challenges to its large scale citywide implementation:

Streets are not merely transportation corridors but also conduits for social activities. Before 2020, Chengdu imposed strict restrictions on street-level commerce. To counter economic downturn pressures, the city pioneered the "street vendor economy" pilot program, revitalizing streets' social functions to safeguard livelihoods, an initiative that garnered high praise at the national level (Jin & Zhao, 2022). For groups reliant on this policy, the forced physical isolation implemented on Jianshe Road risks severing primary income streams and informal connections (such as tricycle services), potentially causing severe impacts on the livelihoods of vulnerable populations.

Chengdu's implementation of soft enforcement essentially serves as a dynamic adjustment mechanism addressing the tension between physical space constraints in the city and the demands of social life.

Since 2018, Chengdu's traffic management authorities have consciously moved beyond rigid, black and white enforcement frameworks(Jin & Zhao, 2022). By introducing flexible measures such as adding temporary parking spaces, implementing first offense warnings, and replacing penalties with persuasion.

The notifications in figure 6 are example records received by the authors, not a system sample; they show that the observed law enforcement communications included both immediate penalties and expedited reminders or exemptions. These practices may create a temporary buffer for everyday social and livelihood activities. This zone provides a vital buffer before fully adapt for urban infrastructure, to the explosive growth in public needs.

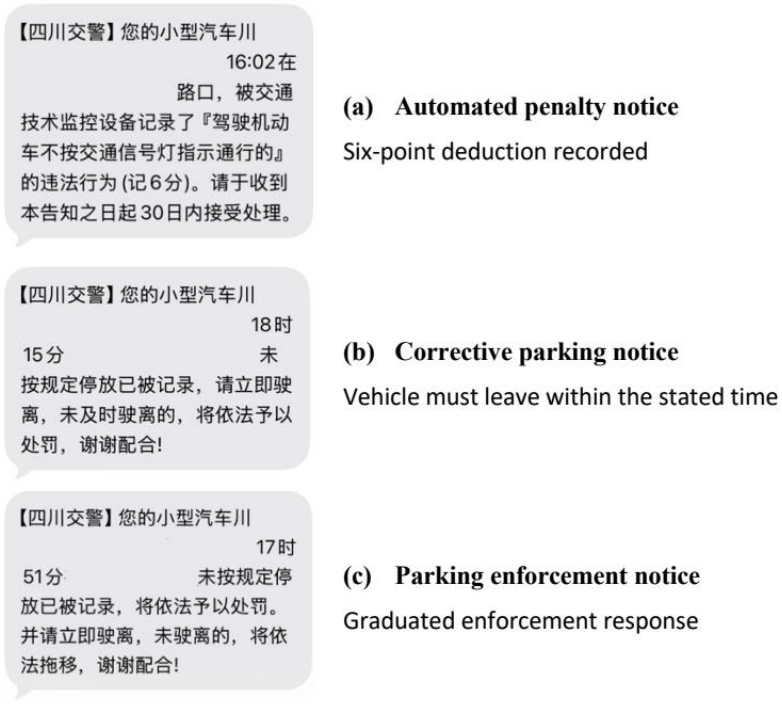



**Figure 6.** Examples of differentiated traffic violation notice received by the author
*Source:* Author's personal traffic records: identifying information redacted. *English translations by the authors*

Within this context, Chengdu's law enforcement officers are not mere tools of administrative execution, but street-level bureaucrats with discretionary authority (Lipsky, 2010). They not only enforce legal provisions, but also uphold community consensus and warmth. A widely circulated social media case documented a touching moment, when Chengdu traffic police addressing illegal street vending, spontaneously purchased an elderly vegetable vendor's remaining produce to ensure she could return home earlier.

This act transcended traditional administrative boundaries, embodying empathy based governance within law enforcement. Such compassionate policing does not condone violations but represents a socially just balancing act, when confronting vulnerable informal economy participants, guiding them back to order through administrative care, which often garners greater public acceptance and cooperation than mere economic penalties. This warm community touch builds trust between enforcers and those being managed, thereby reducing overall social governance costs at the macro level and achieving a paradigm shift from adversarial enforcement to collaborative governance.


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However, this discretion based compassion also poses challenges to governance consistency. When compassion is misinterpreted as permanent exemption, the spatial integrity of NML risks prolonged erosion. Therefore, how to maintain this administrative warmth while establishing clear legal boundaries is a critical challenge for Chengdu, it must overcome to advance toward high-level, refined governance.

Considerations of fairness are central to interpreting regulatory tolerance. Informal transportation providers, street vendors, service workers, and residents without private vehicles may rely on short-term roadside access and low cost last mile travel. Therefore, flexible management approaches can meet their reasonable livelihood and mobility needs. However, if these activities are restricted to designated NML, the resulting burden may shift to cyclists and other vulnerable road users, who may be forced to take detours or merge into motorized traffic. A more equitable approach combines affordable last mile transportation, designated loading/unloading or short-term parking spaces, and time limited management, while maintaining the continuity of NMT flow.

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## CONCLUSION
This study selected four predetermined road segments in Chengdu to examine the relationship between road facility design, roadside obstacles, traffic control conditions, and the spatial integrity of NMLs. The physically separated section on Jianshe Road maintained its designated passage space, whereas the segments on Ximianqiao Street, Jinxiu Road, and Haichang Road experienced a significant reduction in effective width when blocked by vehicles. These differences suggest that road facility design, roadside passage demands, traffic control measures, and enforcement conditions should be considered comprehensively, rather than attributed to a single enforcement factor.

In this study, regulatory tolerance is not a uniform or inherently negative policy, but rather a form of discretionary enforcement tailored to local conditions. Its spatial impact becomes particularly pronounced when a lack of flexibility or deterrence leads to vehicles stopping or parking within designated non-motorized lane spaces without alternative parking locations being provided.

The Space Loss Index ($L_s$) provides a transparent and reproducible metric for measuring the proportion of space that is unavailable within designated NML areas under documented obstacle conditions. By standardizing the designated width, effective width, and occupied width, this index enables direct comparisons of space loss across road segments with different roadside management environments. Consequently, this index can serve as a common benchmark for

repeated field observations, before and after evaluations of street interventions, and cross city comparative studies. Its advantage is its ability to present information clearly and repeatably.

The contribution of this study lies in linking measured spatial losses to the structure of potential regulatory tolerance, as well as the regulatory and enforcement environment; where continuous NML passage is necessary, physical separation provides the most reliable protection. At the same time, flexible management can accommodate legitimate livelihood, freight transport, and last-mile access needs. A more equitable approach is not to shift these needs onto NML, but rather to combine protected bicycle space with designated loading and unloading zones or short term parking areas, affordable last mile alternatives, and clearly communicated time limited traffic controls.

This study has limitations. It documented conditions only on four relatively short, pre selected road segments and does not provide a representative assessment of Chengdu's entire road network. The observations describe the documented presence of obstacles, rather than systematic, round-the-clock parking frequencies or the long term effects of enforcement. Qualitative evidence regarding policies and enforcement provides contextual explanations but does not establish independent causal relationships.

Future research could apply the $L_s$ measurement protocol to road segments with larger sample sizes and conduct repeated observations at different times and seasons. By combining parking records, bike-sharing trajectory data, or where ethical and legal requirements permit, intersection observations, this method can build a longitudinal evidence base for assessing how physical separation, roadside management, and local travel demand interact over time.

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# ENHANCING BIM MANAGER PROFICIENCY: EXPLORING COMPETENCIES AND COMPETENCE LEVEL

**Farah Salwati Ibrahim[1], Muneera Esa[2], Fatin Umaira Muhammad Azian[3]**

[1] *Department of Built Environment and Technology,*
*Faculty of Built Environment,*
UiTM PERAK, SERI ISKANDAR CAMPUS
[2] *School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[3] *Centre for Research in Development, Social & Environment,*
*Faculty of Social Sciences & Huminities,*
UNIVERSITI KEBANGSAAN MALAYSIA

## Abstract

In effective BIM project delivery, BIM Managers' roles and responsibilities are pivotal across the project lifecycle, significantly influencing project performance. Despite this, no empirical studies have assessed BIM Manager proficiency in Malaysia's construction industry. This study addresses this gap by investigating required competencies and competence levels for BIM Managers in BIM environments. A concurrent mixed-methods approach provided comprehensive insights. Qualitative data from interviews with 8 BIM Subject Matter Experts underwent content analysis. Quantitatively, 58 BIM Managers completed a questionnaire on 8 competency sets comprising 57 items, analyzed descriptively. Triangulation enabled robust comparison, contrast, and synthesis of results. Findings classified competencies into four tiers: essential for expert level, requisite for advanced, ancillary for intermediate, and complementary for basic. Notably, 5 of 8 competency sets were deemed important at intermediate-to-expert levels, while 3 were basic-to-intermediate. This research advanced BIM Manager proficiency understanding by identifying novel competency sets and delineating competence levels. It enhances requirements for competent BIM Managers and supports developing skilled BIM talent for future industry needs.

***Keywords***: Building Information Modelling, BIM Manager, Competency, Competence Level, Malaysia Construction Industry

[1,2] Corresponding authors. Email: muneera_esa@usm.my & farahsalwati@uitm.edu.my

# INTRODUCTION

The construction industry drives economic development by providing essential infrastructure (Cucos & Țurcan, 2025). Construction 4.0 promotes digitalisation, with Building Information Modelling (BIM) enhancing project productivity. Malaysia introduced BIM in 2007, but adoption initially lagged behind Singapore, Hong Kong, and China (Ismail et al., 2017). Adoption rates rose from 17% in 2016 to 49% in 2019 and 55% in 2021 (CIDB, 2021), spurred by government initiatives such as the Construction Industry Transformation Programme (CITP 2016–2020), the Twelfth Malaysia Plan (12th MP), and the Construction 4.0 Strategic Plan 2021–2025. These plans mandate BIM for 50% of Public Works Department (PWD) projects worth RM10 million and above, increasing by 10% annually to 2030 (CIDB, 2024).

Despite progress, expertise shortages persist (Mamter et al., 2024). Achieving these targets requires BIM competence among professionals, particularly BIM Managers, Coordinators, and Modellers. BIM Managers coordinate across the project lifecycle, allocating approximately 80% of their effort to management (CIDB, 2024; Fuzi et al., 2024; Haron, 2021; Sampaio et al., 2023). Strong competencies are vital for performance (Abdulqader et al., 2025; Fuzi et al., 2024), yet shortages in skilled BIM Managers hinder adoption due to skill gaps (Abdulqader et al., 2025; Ariffin et al., 2023; Fuzi et al., 2024). Industry needs more BIM talent as deficiencies impede technology uptake (Abdulqader et al., 2025; Fuzi et al., 2024; Mamter et al., 2024; Ariffin et al., 2023; Mahazir et al., 2024; Tajuddin et al., 2025).

Limited studies address BIM Manager proficiency in Malaysia, especially for public projects (Abdulqader et al., 2025; Fuzi et al., 2024), forming this study's gap. This research identifies required competencies and levels to boost performance. Subsequent sections cover literature review, methodology, findings, discussion, and conclusions.

# LITERATURE REVIEW

## The Roles and Responsibilities of a BIM Manager

A BIM Manager oversees BIM-related processes by integrating BIM concept knowledge with project management expertise (Sampaio et al., 2023). Core responsibilities include leading BIM teams, managing BIM processes and information across the project lifecycle, implementing standards, resolving coordination issues, and facilitating training (Adekunle et al., 2022; Chernobay et al., 2021; Holzer, 2016; Succar et al., 2013). In Malaysia, the Public Works Department, formalises these responsibilities, positioning the BIM Manager as Head of the Project Team, overseeing BIM strategies from inception to handover (Hashim et al., 2024). Key duties span three main functions: **strategy** (setting objectives, work processes, standards, implementation, and training);

**management** (BIM Execution Plan, model audit, coordination, and requirements); and **preparation** (model and drawing oversight). Unlike BIM Coordinators and Modellers who focus on technical execution, the BIM Manager concentrates on strategic leadership and project governance throughout the project lifecycle (Haron, 2021; Sampaio et al., 2023).

In BEP management, the BIM Manager holds full responsibility for four key sections: Section D (Project Goals/BIM Uses), Section F (BIM Process Design), Section L (Model Structure), and Section M (Project Deliverables), ensuring all deliverables meet client requirements (CIDB, 2017). Although the BIM Manager has primary responsibility for these sections, they are also accountable for overseeing the remaining BEP sections to ensure compliance with PWD BIM guidelines, standards, and established workflows. The information contained in the BEP is essential to the success of a BIM project and serves as a benchmark for evaluating the BIM Manager's competence in project management (CIDB, 2017).

**The Competencies of a BIM Manager**

Competency is defined as a cluster of knowledge, personal attributes, and performance abilities that impact project success and can be improved through training (PMI, 2017). Various BIM competency frameworks exist, but many are outdated or region-specific. The Individual BIM Competency Hierarchy (IBCH) proposed by Succar et al. (2013) offers a comprehensive framework aligned with this study. It structures competencies into three tiers: core, domain, and execution (refer to Figure 1).

- **Core competencies** include foundation traits, situation enablers, qualifications, and experience.
- **Domain competencies** measure multi-task performance via primary sets (managerial, functional, technical, supportive) and secondary sets (administration, implementation, operation, research & development).
- **Execution competencies** distinguish roles by specialised tool/technique use (e.g., software, programming).

In this study, the core competency tier functions as an initial screening criterion, ensuring that participants meet the fundamental requirements common to all BIM roles (Olorunfemi et al., 2021; Succar et al., 2013). The domain competency tier comprises eight competency sets encompassing 57 items, reflecting the professional capabilities required for multi-task BIM execution (Olorunfemi et al., 2021; Succar et al., 2013). The execution competency tier further differentiates BIM Managers by evaluating advanced and specialized competencies that extend beyond standard BIM roles (Succar et al., 2013).


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The Individual BIM Competency Hierarchy (IBCH) proposed by Succar et al. (2013), comprises eight domain competency set, namely Managerial, Functional, Technical, Supportive, Administration, Operation, Implementation, and Research and Development. All the associated items were reviewed, consolidated, and adapted to reflect Malaysian BIM Manager roles, public BIM project requirements, and MyBIM Centre and CREaTE JKR training modules. BIM Matter Expert review confirmed the relevance of the final 57 items.

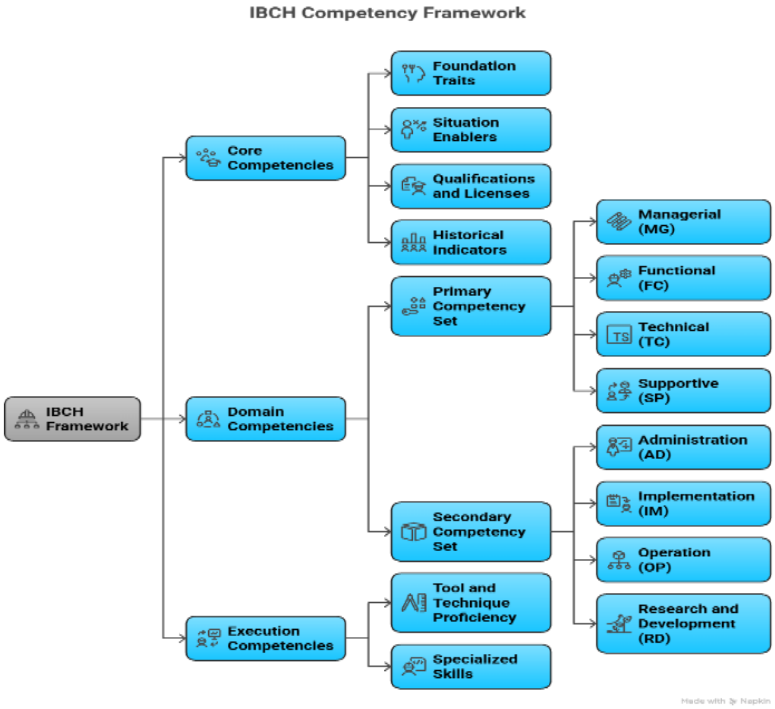



**Figure 1:** Individual BIM Competencies Hierarchy (Succar et al.,(2013)

## The Competency Measurement Level

To accurately measure individual competencies, an appropriate measurement level must be selected to ensure consistency. Established construction frameworks include the ICB-IPMA Competence Baseline Version 3.0, Project Manager Competency Development framework, and Individual Competency Index (Rustam et al., 2024). These differ in components and readiness across knowledge, skills, and behaviors for project success (Abebe & Tsehayae, 2024; Rustam et al., 2024). However, Succar et al. (2013), recommend the Banner's Individual Competency Index, suited to the IBCH framework is ideal for BIM from an individual perspective due to new technology adoption. Its five indexes with robust indicators are more accessible than IPMA's 10-scale, especially given

immature BIM knowledge and skills in Malaysia. Table 1 shows the ICI features levels from learning divide (levels 0-1) and time/repetition divide (3-4) (Gillies & Howard, 2003).

**Table 1:** The Description of Five Distinct Levels

| LEVELS | COMPETENCY | DESCRIPTIONS |
|---|---|---|
| **LEVEL 0** | None | Lack of competence in a specific area or topic |
| **LEVEL 1** | Basic | Have some understanding and practical application |
| **LEVEL 2** | Intermediate | Comprehensive conceptual understanding and practical application. |
| **LEVEL 3** | Advanced | Significant knowledge and consistent high-standard performance |
| **LEVEL 4** | Expert | Extensive knowledge, refined skill, and prolonged experience |

## METHODOLOGY

### Data Collection

A concurrent mixed-methods approach combined semi-structured interviews (qualitative) and a questionnaire survey (quantitative) to explore BIM Manager competencies. This design provides breadth and depth, enabling corroboration of industry needs and existing competencies (Wing et al., 1998). The interview examined the competencies and competence levels required for the BIM Manager role, whereas the questionnaire measured the current self-assessed competence of certified BIM Manager across the eight competency sets. Interviews were conducted with eight BIM Subject Matter Experts (SMEs) from PWD and MyBIM Centre, selected based on their involvement in BIM guideline development and BIM Manager training. The questionnaire was distributed via Google Forms to 58 certified BIM Managers for self-assessment, drawn from PWD and MyBIM Centre records.

### Participant Selection

A purposive sampling was used. There a several criteria that has been provided for the selected participants. Inclusion criteria are;

- **Interviews:** For qualitative component, the accessible population comprised 16 BIM Subject Matter Experts (BIM-SMEs) from the Public Works Department (PWD) and the Construction Industry Development Board (CIDB). Eight BIM-SMEs participated, comprising four representatives from each organisation. The participants have more than 5 years BIM experience, directly involved in BIM Manager assessment and syllabus or training-module development at the MyBIM Centre and CREaTE JKR. They were purposively selected based on their relevant experience and willingness to participate. The


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sample of eight experts was considered appropriate for an in-depth qualitative study and provided insights from the two principal organisations involved in BIM Manager competency development and certification for Malaysian public projects. Table 2 shows the background of the participants.

**Table 2:** Background of BIM Matter Experts

| ID | Position | BIM Experiences |
|---|---|---|
| **J1** | BIM-SME | 10 years |
| **J2** | BIM-SME | 15 years |
| **J3** | Unit BIM, PWD | 6 years |
| **J4** | Unit BIM, PWD | 6 years |
| **C1** | BIM - CIDB | 12 years |
| **C2** | BIM - CIDB | 9 years |
| **C3** | BIM - CIDB | 10 years |
| **C4** | BIM - CIDB | 8 years |

- **Survey:** For the quantitative component, the defined population comprised 65 BIM Managers certified by MyBIM-CIDB or CREaTE JKR. These certifications were selected because they are highly recognised for participation in Malaysian public BIM projects. An a priori G*Power analysis, using a statistical power of 0.80, an effect size of 0.35, an alpha level of 0.05, and a maximum of nine predictors, indicated a minimum sample of 54 respondents. The study targeted 60 respondents to accommodate potential non-response, and 58 completed questionnaires were obtained. Thus, the achieved sample exceeded the minimum requirement and represented 89.2% of the defined population, providing strong coverage of the eligible certified BIM Manager population. All the participants were certified BIM Manager completed BIM Manager training (Part 1 & 2) under MyBIM Centre and currently involved in public BIM projects. Table 3 shows the tabulation of the participants.

**Table 3:** Background of Certified BIM Manager

| BIM Manager Criteria | Population |
|---|---|
| Certified BIM Manager | 29 |
| Complete BIM Manager Training Part 1 & 2 from MyBIM CIDB | 16 |
| BIM Manager Competency Certification by CREaTE JKR | 8 |
| BIM Manager involved in 16 public BIM project | 12 |
| **TOTAL** | **65** |

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## Data Analysis

Interview recordings were transcribed and analysed using content analysis. Quantitative data were analysed using SPSS for descriptive statistics (mean, standard deviation). Triangulation involved comparing qualitative and

quantitative results in a matrix table to compare, contrast, and synthesise findings systematically.

## RESULTS AND DISCUSSION

### Qualitative Findings

Throughout the comprehensive discussion with the BIM-SME in the qualitative section, the competencies and levels of competence required for a BIM Manager were categorized into four categories, representing the most required competencies to the least required competencies with the competence level. The categories are also applied by Uhm et al., (2017) in their research to classify the competencies. Table 4 describes the key terms for those four categories of competencies that are being used in this study.

**Table 4:** Categories and the Competence Level Required for a BIM Manager

| Categories | Descriptions | Level of Competencies Required |
|---|---|---|
| **Essential competencies** | The competencies that **are highly required** for a competent BIM Manager. | Expert |
| **Requisite Competencies** | The competencies that **are required** for a competent BIM Manager. | Advanced |
| **Ancillary competencies** | This competency **is encouraged** for a BIM Manager to possess as it can enhance the ability of a BIM Manager | Intermediate |
| **Complementary competencies** | This competency **is not essential** for a BIM Manager but still required as the value added. | Basic |

The qualitative findings identified eight competency sets comprising 57 items, of which 27 were classified as essential, 9 as requisite, 9 as ancillary, and 12 as complementary. The Management (MG) and Administration (AD) competency sets were deemed essential for expert-level BIM Managers, particularly in areas related to leadership, strategic planning, project management, and BIM Execution Plan development. Client management, business development, and partnership-related competencies were classified as requisite, as they extend beyond core BIM responsibilities.

The Functional (FC) competency set was also essential, as it underpins BIM collaboration, workflow coordination, and effective project delivery. In contrast, the Operational (OP) set was largely non-essential, since it focuses on modelling and simulation tasks typically undertaken by BIM Modellers and Coordinators; only general modelling oversight and monitoring were considered essential.

The Technical (TC) set showed a mixed classification, with core BIM system, documentation, and data management knowledge identified as essential,


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while modelling, hardware, presentation, and model management were classified as complementary. The Implementation (IM) set included essential, requisite, and complementary competencies: fundamental implementation knowledge was essential, standardisation and training-related competencies were requisite, and component development and library management were complementary.

Supportive (SP) competencies were mostly ancillary or complementary, except for general IT support, which was essential for troubleshooting. Finally, the Research and Development (RD) set was primarily ancillary, with essential competencies in BIM research and strategic planning and requisite competencies in training and knowledge management, while other RD activities were considered optional.

## Quantitative Findings

Descriptive analysis, using mean and standard deviation, was employed to determine the current self-assessed competence of the BIM Manager participants. The questionnaire used a five-point competence scale ranging from None to Expert. Mean scores were categorised using the ICI scale: None (1.00–1.80), Basic (1.90–2.60), Intermediate (2.70–3.40), Advanced (3.50–4.20), Expert (4.30–5.00). The results of the descriptive analysis for current BIM Managers in MCI across the eight competency sets are presented in Table 5.

**Table 5:** Overall Mean, Std. Deviation, Scale Range, and Cronbach's Alpha for the BIM Manager Competency Set

| | Variables | Mean | Std. Deviation | Scale Range | Cronbach's alpha |
|---|---|---|---|---|---|
| **Domain Competencies** | **MG** | 4.44 | .32 | Expert | 0.721 |
| | **FC** | 4.57 | .37 | Expert | 0.872 |
| | **TC** | 3.29 | .64 | Intermediate | 0.908 |
| | **SP** | 2.50 | .42 | Basic | 0.806 |
| | **AD** | 4.65 | .36 | Expert | 0.956 |
| | **OP** | 3.07 | .66 | Intermediate | 0.957 |
| | **IM** | 3.77 | .53 | Advanced | 0.862 |
| | **RD** | 3.24 | .56 | Intermediate | 0.899 |

Table 5 shows the overall mean score, std. deviation, scale range, and Cronbach's alpha for each competency set consisting of Managerial (MG), Functional (FC), Technical (TC), Supportive (SP), Administration (AD), Operation (OP), Implementation (IM), and Research and Development (RD). According to the mean score, AD has the highest mean scorer at 4.65, followed by FC (4.57), MG (4.44), IM (3.77), TC (3.29), RD (3.24), and OP (3.07), while SP was the lowest at 2.50. Thus, Table 5 indicates that the participants reported expert-level competence in MG, FC, and AD; advanced competence in IM; intermediate competence in TC, OP, and RD; and basic competence in SP. The

Cronbach's alpha values ranged from 0.721 to 0.957, indicating acceptable to excellent internal consistency across all eight competency sets.

**Triangulation Analysis**

Triangulation was conducted by comparing qualitative and quantitative findings, which were synthesised into four competency categories: essential, requisite, ancillary, and complementary. Both qualitative and quantitative findings consistently identified Administration (AD), Functional Competency (FC), and Management (MG) as the most essential competency sets for BIM Managers in the Malaysian construction industry (MCI). Qualitatively, AD was ranked highest, with 8 out of 9 items classified as essential, followed by FC (all items) and MG (4 out of 6 items). Quantitatively, AD recorded the highest mean score (4.65), followed by FC (4.57) and MG (4.44), indicating expert-level competency characterised by advanced knowledge, refined skills, and extensive experience (Benner, 1994). AD emerged as the most critical competency, complementing MG by translating strategic objectives into effective project management practices, particularly in developing and maintaining the BIM Execution Plan and controlling BIM processes and information (Succar et al., 2013). FC was identified as the second most essential competency, encompassing collaboration, facilitation, and workflow management, which are vital for effective BIM project delivery and risk reduction.

AD emerged as the most critical competency, complementing MG by translating strategic objectives into effective day-to-day project management practices. While MG focuses on project goals, strategic planning, and organisational management at the early stages of a project (Succar et al., 2013), AD supports implementation through operational control, project coordination, and BIM information management. Together, AD and MG enable BIM Managers to develop and maintain the BIM Execution Plan (BEP), manage BIM processes, and control BIM information, consistent with prior studies (Olorunfemi et al., 2021; Sampaio et al., 2023). These competencies have also been shown to significantly influence overall project performance and success.

FC was identified as the second most essential competency set at the expert level, encompassing collaboration, facilitation, project management, and team and workflow coordination. Triangulation results confirmed that all FC items are essential, reflecting the importance of non-technical competencies in initiating, managing, and delivering BIM projects effectively. FC competencies enhance collaboration among project stakeholders, reduce project risks, and improve communication, thereby contributing to improved BIM project performance. This statement was supported by Ariyachandra et al., (2020).

The Information Management (IM) competency set was classified as requisite at the advanced level, particularly for standardisation, system and


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process testing, and the development of BIM guides and manuals. These competencies are critical for ensuring interoperability, consistency, and improved BIM project outcomes, as supported by existing literature by (Ariyachandra et al., 2020; Haron, 2021; Kassem et al., 2018). Also, the IM competency set is crucial for improving BIM project performance (Ariyachandra et al., 2020).
Research and Development (RD) was identified as an ancillary competency at the intermediate level, supporting knowledge management, organisational change, and continuous improvement. This results reflected the findings by Mahamadu (2016), which research and development are important to support learning and continuous improvement in BIM. Similarly, Simulation and Production (SP), Technical Coordination (TC), and Operation and Maintenance (OP) were classified as ancillary or complementary competencies, typically required at basic to intermediate levels and more closely aligned with BIM Coordinator responsibilities (Sampaio et al., 2023). The synthesises of the triangulation findings demonstrates in Table 6.

**Table 6:** Triangulation Matrix of BIM Manager Competencies

| Category | Qualitative Findings | Quantitative Findings | Synthesised Outcome | Relationship |
|---|---|---|---|---|
| Essential (Expert) | MG (4 items), FC (all), AD (8 items) | MG (4.44), FC (4.57), AD (4.65) | MG, FC, AD: Essential at Expert level | Strong Agreement |
| Requisite (Advanced) | IM (4 items), RD (2 items) | IM (3.77), RD (3.24) | IM: Requisite at Advanced. RD: Ancillary at Intermediate | Agreement |
| Ancillary (Intermediate) | SP (3 items), RD (3 items), OP (3 items) | TC (3.29), OP (3.07), RD (3.24) | RD: Ancillary TC, OP: Complementary | Partial Agreement |
| Complementary (Basic) | TC (5 items), OP (4 items), SP (1 item) | SP (2.50) | SP, TC, OP: Complementary at Basic/Intermediate | Differences |

Overall, triangulation findings indicate strong agreement between BIM Subject Matter Experts and BIM Managers regarding competency priorities. AD, FC, and MG were confirmed as essential expert-level competencies, followed by IM at the advanced level, while RD, SP, TC, and OP were considered supportive competencies. These findings provide clear guidance for the Malaysian construction industry in defining appropriate competency requirements and proficiency levels for BIM Managers.

## CONCLUSION

The objective of this paper was achieved by identifying the most required competencies to the least required competencies, and the level of competencies needed for each of the competency sets through the triangulation of the qualitative and quantitative results. As anticipated, the AD, FC, and MG competency sets were the essential competencies required for a BIM Manager at the expert level, followed by the IM competency set at the requisite competency and the level of competencies was at the advanced level. These four competency sets were critically important in developing the objective and goal of the BIM project, developing a BIM execution plan, managing the BIM process and procedure, managing the BIM information, monitoring and controlling the entire BIM project lifecycle, and managing collaboration among the project team and the stakeholders. Subsequently, the RD competency set are required at an intermediate level for the ancillary competencies and should be based on the BIM Manager's interest and the willingness to participate in knowledge sharing with industry, education, and research fields. Finally, for the TC, OP, and SP competency set, these three competencies are required for a BIM Manager at the basic to intermediate level as those competencies were categorized as ancillary and complementary competencies. Furthermore, as mentioned in the literature based on the roles and the responsibilities of a BIM Manager, these three competencies' sets were taken from the roles and the responsibilities of a BIM Manager and perfectly suit the roles of BIM Coordinator and BIM Modeller.

The findings from both methods have been validated. The validation is done through three steps to ensure all the information is relevant to the current BIM requirement for a BIM Manager in MCI contexts. In the first step, the data were triangulated by gathering all the data into a table, then, the data were compared, contrasted, and synthesized for the outcome. Then, peer-differing was conducted to check the findings of the triangulation. Finally, the data is then validated using member-checking, and the results have been reviewed by three experts, in which the same experts participate in the interview session. The validation was done by checking the content of the findings from both results twice. From the validation, the three of them were given positive comments to the researcher and agreed with the findings.

Moreover, this study provides a clear definition of the relevant competencies and the competence level required for the BIM Manager in line with their roles and responsibilities in a BIM project. Overall, this study has contributed to the theoretical, methodological, and practical dimensions of the competencies of a BIM Manager. This study facilitates CIDB, MyBIM Centre, and PWD in strengthening BIM Manager certification and assessment criteria. Universities and training provider can use the identified competencies to improve BIM curricula and professional training, while construction firms can apply them


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in recruitment, performance assessment, and staff development. These finding can strengthen the construction and the educational sector by supporting the development of competent BIM Manager in the future.

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# VISITORS BEHAVIOR PATTERNS IN PRODUCING SPACE ON HISTORIC SHOPPING STREET IN TUNJUNGAN STREET CORRIDOR, SURABAYA CITY, INDONESIA

**Yusfan Adeputera Yusran[1*], Elsa Berliana Oktaviani[2], Lisa Dwi Wulandari[3], Joko Triwinarto Santoso[4]**

[1,2,3,4] *Department of Architecture,*
UNIVERSITAS BRAWIJAYA, MALANG – INDONESIA

## Abstract

In recent years, the pedestrian space in the Jalan Tunjungan Corridor has been massively developed by the Surabaya City government to fulfill the image as a street-oriented architecture. This development was carried out by changing the concept, form, and atmosphere along the corridor, which ultimately created different spaces at certain periods of time. This study explains the production of space in a historic pedestrian corridor by examining the interaction between visitor activities and government interventions through Lefebvre's spatial triad. This research uses a case study method by mapping the behavior of visitors, daily workers and trader who carry out their activities in the pedestrian area of the Jalan Tunjungan corridor. The data obtained coupled with interviews conducted by purposive-convenience method sampling shows that there are differences in visitors' perspectives in producing space along the corridor. The visitor's preference for choosing an activity space is part of a lifestyle that makes this place a 'place for gathering' and 'communal activity'.

***Keywords**:* Behavior pattern; Historical street corridor; Space production

[1] Corresponding author. Email: yusfan@ub.ac.id

## INTRODUCTION

Tunjungan Street has been an economic center and a prominent landmark in Surabaya from the 1950s to the late 1960s (Effendi, 2015; Patriajaya & Kusliansjah, 2019). The unique features of this destination have been observed to facilitate the continuous efforts made by the Surabaya government to develop the area and restore its former glory. Since 1906, Tunjungan Street has been renowned as a pedestrian shopping street (Benlin & Sigit, 2013). Initially, the area's corridor was designed with two vehicle flows, but due to certain factors, it was turned into a one-way vehicle flow. These factors include a widening of the pedestrian lane size, a reduction in traffic, and changes in the type of intersection (Patriajaya & Kusliansjah, 2019).

In an effort to develop Tujungan Street as a tourist landmark, it is important to comprehend and map the behavioral patterns of visitors when interacting directly with the corridor of the cultural heritage area. In this context, mapping is considered significantly crucial because the behavioral patterns can have either positive or negative effects, especially on pedestrian paths which affect space, movement, and action (Poerbantanoe, 1999; Benlin & Sigit, 2013). Therefore, this research aimed to explain how visitor activities and government interventions interact to produce space in a historic pedestrian corridor, drawing on Lefebvre's spatial triad.

Beyond its local context in Surabaya, this study offers valuable empirical insights for heritage street revitalization and pedestrian corridor planning across Southeast Asia, particularly in Malaysia (Chua & Ahmad, 2021). Historic corridors in Malaysian cities face similar socio-spatial challenges, where authorities must balance heritage building preservation with active night economies, informal street vending, and pedestrian accessibility (Chua & Ahmad, 2021; Wan Ismail et al., 2026). By framing the transformation of Tunjungan Street through Lefebvre's spatial triad, this study provides a transferable planning framework for historic street management in comparable regional urban settings.

## LITERATURE REVIEW

The relationship between human socioeconomic activities and physical space, which impacts urban design development and growth, has been examined using various approaches, including the socio-spatial approach (Hegazi et al., 2022; Akcali & Cahantimur, 2023). As stated in previous research, the socio-spatial approach identifies the mental factors influencing visitors in the creation of social spaces (Rahmi et al., 2022). Henri Lefebvre, in his book "The Production of Space" (1991), emphasized socio-spatial aspects through three principles namely spatial practices, representations of space, and representational space. These principles can be empirically implemented, with the inclusiveness of humans and the surrounding environment (Pierce & Martin, 2015). In validating the


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relationship between humans and the environment through social, economic, and environmental interactions, a common method used is the behavior mapping method (Chai et al., 2016).

Numerous studies on socio-spatial-related topics have been observed to utilize the behavior mapping method. For instance, the investigation carried out by Shamekh and Ashour (2023) on the socio-spatial aspects of pedestrian spaces in Cairo, was similar to Al-Maimani et al. (2014) in Oman, though with different observation variables. Shamekh and Ashour (2023) focused on daily activities such as walking and cycling, while Al-Maimani et al. (2014) examined the socio-cultural aspects influencing the activities of visitors. Both studies share similarities in terms of data collection procedures, which included open interviews and the distribution of questionnaires.

Another study was carried out by Loebach et al. (2020), where it was shown that the behavior mapping method effectively identified certain behavioral patterns occurring in specific objects. During the course of the research, the method served as a valuable observational tool for understanding interactions in public spaces. Based on this finding, it can be inferred that the method is useful for mapping the activities of visitors, particularly when identifying spatial practices.

**Table 1:** Study Observation Parameters

| Sources | Behavior Mapping Aspects |
|---|---|
| Shamekh and Ashour (2023) | User's postures (standing, seating, walking, lying, cycling/skating) |
| Al-Maimani et al. (2014) | Illustrate gender, age group, and socio-economic background |
| | The map illustrates the movements occurring at the study location, such as sitting, walking, and cycling. |
| Loebach et al. (2020) | Group size, group composition, play type, activity type, initiator of activity, activity intensity, environmental interaction |

In this research, the behavior mapping method was applied to analyze place-centered mapping along the Tunjungan Street corridor in Surabaya City. In order to improve the analysis results, open interviews were conducted to collect relevant and accurate information about the activities of the visitors. Following the reviewed works of literature, the present research specifically examined pedestrian spaces in the Tunjungan Street corridor, focusing on the activities of visitors throughout the day at the research location.

## METHODOLOGY

The present research was carried out with the aim to explain the production of space in a historic pedestrian corridor by examining how visitor activities and government interventions interact across time and space, using systematic observation, behavior mapping, and Henri Lefebvre's spatial triad as the analytical framework. To achieve this objective, the study adopts a qualitative

case study design grounded in a naturalistic inquiry paradigm, focusing on the socio-spatial dynamics of Tunjungan Street, Surabaya. A methodological triangulation approach was employed, combining systematic behavior mapping and open-ended interviews to capture both spatial patterns and user perspectives.

The observation unit covered the behavior patterns of visitors in pedestrian corridor spaces from a socio-spatial perspective, drawing on Lefebvre's (1991) theory of the production of space resulting from human activity. Accordingly, the first observation unit, "Behavior Pattern of Visitors' Activity", was based on prior studies, including Elsheshtawy (2013) and Al-Maimani et al. (2014), and incorporated sub-units such as social activities, actors, and behavior patterns. The second observation unit, "Space Production in Socio-Spatial Context", referred to previous studies by Leary (2009), Al-Maimani et al. (2014), Cihanger (2018), Harani et al. (2023), and Shamekh & Ashour (2023). This unit comprised sub-units including spatial practice, spatial representation, and representational space.

Observations were conducted 24 times within the period of two weeks period from December 27, 2023, to January 10, 2024 (Al-Maimani et al., 2014; Shamekh & Ashour, 2023). To reflect temporal variations in space usage, each observation day systematically tracked pedestrian activity across three time slots (Al-Maimani et al., 2014; Loebach et al., 2020; Sari & Alhamdani, 2021; Petrtýlová & Jaššo, 2022; Gümüş & Yılmaz, 2022; Shamekh & Ashour, 2023; Hasibah, et al., 2025):

- Morning Slot: 07:00 – 10:00 AM
- Afternoon Slot: 01:00 – 04:00 PM
- Evening Slot: 07:00 – 10:00 PM

Activity observation took place during clear weather and post-rain periods, capturing moments when visitors actively moved through and inhabited the pedestrian space. Physical activity counts identified pedestrian behaviors on-site, categorized them through standardized symbols, and plotted spatial data directly onto base maps prior to digital synthesis.

During field observations, visual data were collected using cameras, visitor activities were documented through systematic field notes for behavior mapping, and open-ended interview responses were recorded with audio recorders. These data served as the basis for the analysis process, which was conducted in the NVivo program to create a project map and concept map.

These observations were carried out in four predetermined corridor zones along the Tunjungan Street corridor (Sommer & Sommer, 1991). Accordingly, it is important to emphasize that this research was carried out on the pedestrian path of Tunjungan Street in Surabaya. In order to facilitate behavior


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mapping (Sommer & Sommer, 1991), the corridor was divided into four zone segments namely:

- Zone One, consists of buildings that function as public facilities and offices.
- Zone Two, comprises buildings that function as business places. A zone for Micro, Small, and Medium Enterprises (MSMEs), and shops.
- Zone Three, consists of buildings that function as shops, cafes, and hotels.
- Zone Four, which is made up of hotels and abandoned buildings.




**Figure 1.** Location of research object

This investigation adopted a naturalistic qualitative paradigm to objectively observe the behavior of people. Focusing on tangible materials capable of being used as an object of study, it used a naturalistic approach to achieve behavior mapping goals, all of which were implemented through the behavior and place-centered mapping methods.

Open interviews were conducted with 31 respondents, including visitors, daily workers, and government officials, to explore the production of pedestrian space in the Tunjungan Street corridor, Surabaya. The primary criterion for respondent selection was visitors who stopped within one of the pedestrian zones and were willing to participate in interviews. No restrictions were imposed regarding age or gender. Selection focused on visitors (27 individuals), and daily workers (3 individuals: a trader, and 2 street artists) who were actively engaged in activities within the pedestrian space. In addition, one staff government official from the Department of Culture, Tourism, and Sports, the primary policymaking body responsible for the revitalization and development of the research locus, was included as a key informant.

**Table 2:** Demographic and Spatial Activity Profiles of Respondents (N = 31)

| Respondent Category | Role | Total | Age Range | Gender Ratio (M/F) | Spatial Activity |
|---|---|---|---|---|---|
| Visitors | Pedestrian Visitors | 27 | 13-60 years | 20 M<br>7 F | Walking, standing, posing for a photo, cycling, and sitting (in public or commercial chairs) |
| Trader | Street Vendor's Owner | 1 | 47 years | F | Trading and organizing visitor placement |
| Daily Workers | Street Artists | 2 | 22-23 years old | M | Sitting, interacting with pedestrians |
| Government Official | Key Informant (Dept. of Culture, Tourism, & Sports) | 1 | 27 years old | F | Spatial management, heritage corridor policymaking, and oversight of public amenities |

The questions, which were adapted from previous studies by Liu et al. (2022) for the government, and Raulet-Croset & Borzeix (2014) and modified to align with the research focus, addressing the development process of Tunjungan Street from the government's perspective and visitors' direct experiences while engaging in activities within the area. Interview transcripts were analyzed using NVivo through a three-stage process:

1. Code Development: Primary coding extracted key units of meaning regarding spatial experiences, regulations, and commercial activities.
2. Map Modeling: NVivo Project Maps visually organized codes into two core themes: Government Involvement in Pedestrian Space Development and Visitor Impressions.
3. Relational Analysis & Inter-Coder Checking: NVivo Concept Maps were generated to model the structural connections between the two themes.


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**Table 3:** Open Interview Questions

| Source | Question |
|---|---|
| Liu et al. (2022) | What is the main purpose of developing the pedestrian space in the Tunjungan Street corridor? |
| | Does the development of the pedestrian space in the Tunjungan Street corridor reflect heritage areas in other cities? |
| | What meanings and values does the government expect in the development of the pedestrian space in the Tunjungan Street corridor? |
| | What factors are considered in its development? |
| | Who is involved in the development of the pedestrian space? |
| | What further developments should be made in the pedestrian space of the Tunjungan Street corridor in Surabaya? Why? |
| | What type of tourism is expected in the development of the pedestrian space in the Tunjungan Street corridor? |
| | What is the main purpose of developing the pedestrian space in the Tunjungan Street corridor? |
| | What positive impacts have been felt after the development of the pedestrian space in the Tunjungan Street corridor? |
| | Are there any differences in goals between visitors and developers after the pedestrian space development in the Tunjungan Street corridor has been completed? |
| Raulet-Croset & Borzeix (2014) | What do you feel when engaging in activities in the pedestrian space of the Tunjungan Street corridor? |
| | What are the reasons for choosing this place for activities? |
| | What comes to mind when thinking about the pedestrian space in the Tunjungan Street corridor? |

## ANALYSIS AND DISCUSSION

The analysis of behavior patterns observed at the research location was divided into two parts. The first part included an extensive discussion of the behavior mapping patterns in the pedestrian spaces on Tunjungan Street, Surabaya. The second part synthesized these findings through Lefebvre's socio-spatial perspective, incorporating the information obtained from the open interviews conducted with 31 respondents. The interview results, which were processed using the Nvivo program, showed two key themes namely direct government inclusiveness and the diversity of impressions possessed by different visitors. The first theme examined the participation of the government in spatial representation in correspondence with the principles of socio-spatial production. Meanwhile, the second theme explored the impressions of visitors towards the physical space, corresponding to Lefebvre's (1991) principles of spatial practices and representational space.

### Visitors' Behavior Patterns in Pedestrian Spaces on Tunjungan Street Surabaya

The analysis of behavior patterns included an observation of the postures that showed the activities of visitors in the pedestrian space during the observation period. Based on the analysis, significant differences were observed in the activities carried out and behaviors possessed by people in each zone at different

times, especially during holiday nights. These activities include walking, sitting, standing, eating, selling, and shopping. The variety of activities allows visitors to use the pedestrian spaces for social activities such as meeting people, enjoying free time together, and engaging in group activities, contributing to the vibrancy of the street (Mehta, 2007).

During the course of the investigation, Zone One was particularly crowded with public service office workers and visitors staying at the Platinum Hotel or visiting cafes. It is also important to state that on holidays, community events organized by cycling, MSMEs, and arts communities increase visitor density. The high-density locations in Zone One were observed to typically around cafes, close to locations where artists perform.

Zone Two is a location crowded with visitors and office workers. During holidays, some visitors engage in reading activities on mats near the T-junction to Genteng Besar Street while enjoying a car-free day, creating significant interaction in the pedestrian space. Additionally, a cycling community often takes a break here to enjoy coffee in the morning. At night, this zone, similar to others, becomes increasingly busy with the activities of visitors.

Zone Three was observed to have significant differences in activity throughout the day. In the morning, visitors in the area were mainly tourists and daily workers such as hotel staff, street sweepers, newspaper sellers, and photographers. On Sundays, the cycling community frequents this zone in the morning to rest. Shops and cafes in the area are usually closed in the morning and open only in the afternoon and evening. At night, musical performances attract a dense crowd of visitors who sit, enjoy the music, and walk around Zone Three.

In Zone Four, activities vary according to the observation time. At night, significant economic activities were usually carried out including street vendors and buyers, primarily young people, engaging in the traditional '*angkringan*' (*Angkringan* derived from the Javanese '*Angkring*', which means sit down is a push cart that sells a variety of foods and beverages commonly contained in each side of roads) culture. Furthermore, buyers in the area often come in groups and engage in social activities such as chatting, taking photos, and purchasing snacks from street vendors around collector roads towards Tunjungan Street.

> "*Also, at night, many people visit the street food stalls (angkringan), so selling from late afternoon to evening is much better*." (Yani, Traders).

The following figures compare the density of activities during weekdays and holidays in the research area. Accordingly, Figures 2 and 3 show comparisons for the morning, Figures 4 and 5 for the afternoon, and Figures 6 and 7 for the night.


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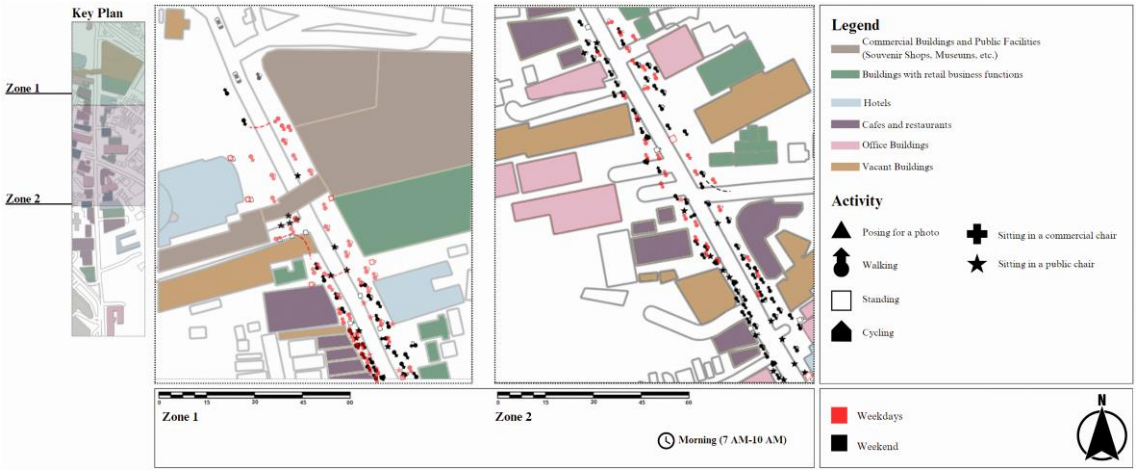



**Figure 2.** Combined behavior patterns on weekdays and weekend in the mornings of zones 1 & 2

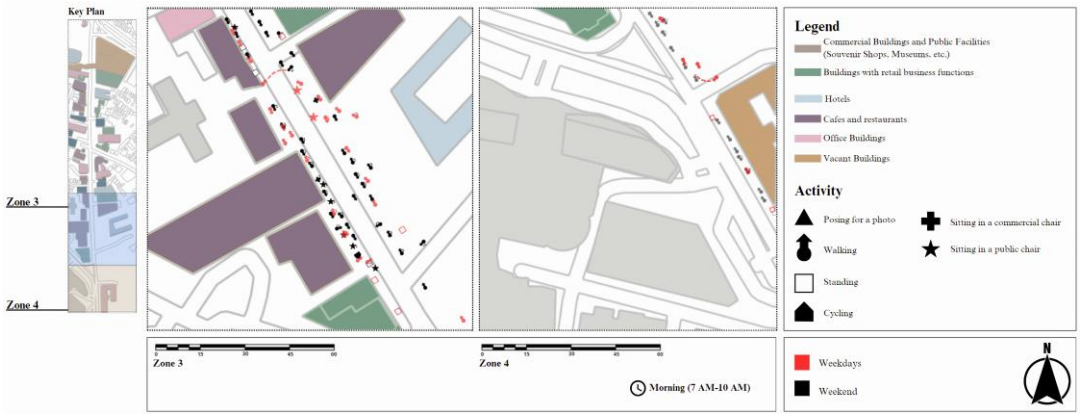



**Figure 3.** Combined behavior patterns on weekdays and weekend in the mornings of zones 3 & 4

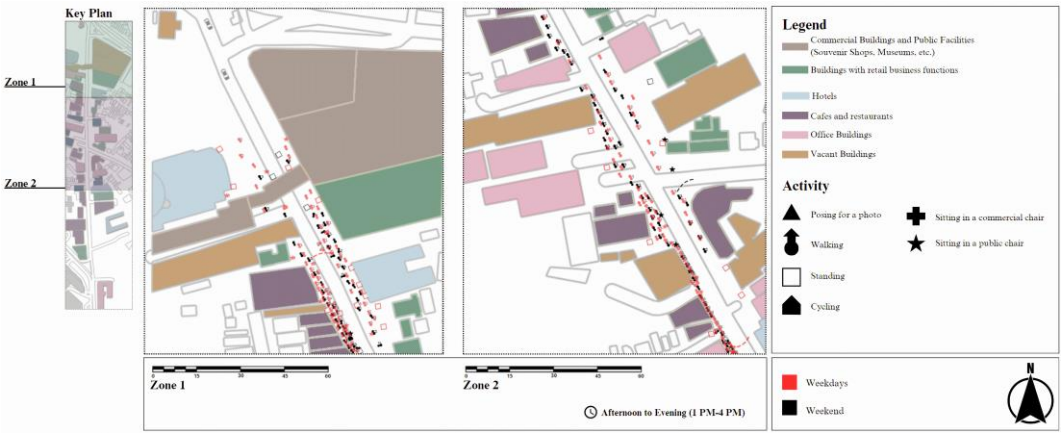



**Figure 4.** Combined behavior patterns on weekdays and weekend during the afternoon in zones 1 & 2

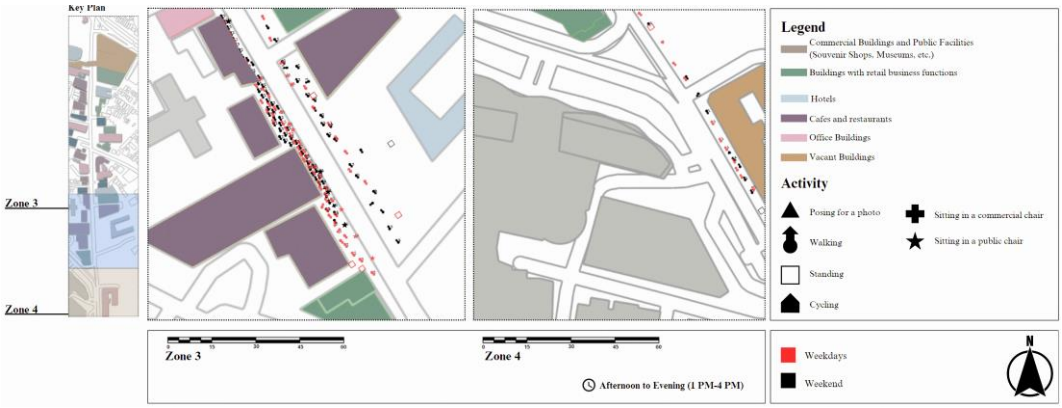



**Figure 5.** Combined behavior patterns on weekdays and weekend during the afternoon in zones 3 & 4


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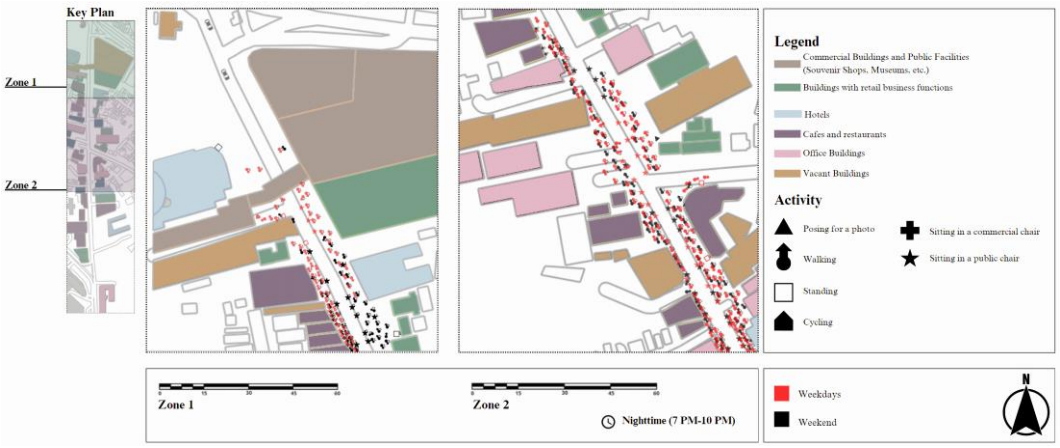



**Figure 6.** Combined behavior patterns on weekdays and weekend in the evenings of zones 1 & 2

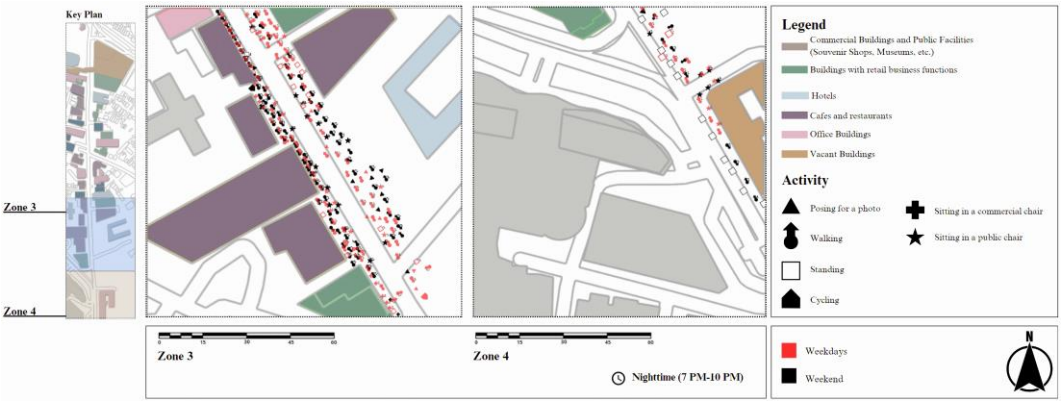



**Figure 7.** Combined behavior patterns on weekdays and weekend in the evenings of zones 3 & 4

## Government Participation as a Supporter of Spatial Representation

The government has physically developed the pedestrian area on Tunjungan Street, Surabaya. Interviews with the Surabaya City government showed the several concepts and themes applied in developing the pedestrian space in this corridor. The overarching themes include lifestyle, modern ethics, and heritage. For the pedestrian space, the government is implementing an al fresco dining concept, which would allow visitors to enjoy the city atmosphere while eating and drinking outside cafes or restaurants. It is also important to state that the government has collaborated with cultural heritage experts to preserve the value and identity of the buildings in the area and partnered with the Department of Cooperatives and Trade to stimulate economic activity and support MSMEs as a primary step in economic advancement.

Direct government inclusiveness in this context is evident through economic categorization and the enhancement of the regional image. Tunjungan Street has become known as an icon of Surabaya City due to the perceptions and stigma of visitors (Mutfianti, 2013). The presence of cultural heritage buildings along the location further reinforces this "regional image". However, the government acknowledges that the street does not fully represent the entire image of Surabaya City. Regardless of this perception, some respondents believe that the area has the potential to develop into a prominent tourist destination with its own distinct identity.

> "*… our current activation focuses specifically on the street corridor rather than the entire district, which extends into the inner urban settlements (kampung). Therefore, while it does not represent the entire heritage area of the city, it serves as one of its key cultural heritage corridors*." (Ms. Lidya, Government Staff)

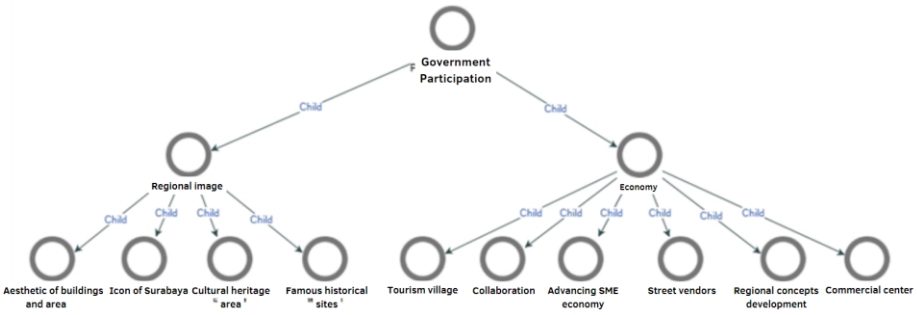



**Figure 8.** Project map for theme 1 by Nvivo program

The economic aspect is shaped by factors such as tourist village development, cooperation with street vendors, and the implementation of regional concepts that support the image of the area as a commercial center. In accordance with this, the efforts of the government to revitalize the economy include supporting MSMEs through direct guidance from the Tourism Awareness Group (POKDARWIS) as well as collaboration with sports and arts communities in Surabaya.

**Diversity of Visitors' Impressions of Physical Space as Spatial Practice and Representational Space**

Visitors play a crucial role in the development of the Tunjungan Street pedestrian corridor as planned by the government. This is evident by the observations made and interviews carried out, which showed both similarities and differences in visitors' perspectives on the destination. In this context, the commonalities


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include views on comfort, accessibility, and building aesthetics, which contribute to the creation of gathering spaces due to repeated activities in the morning, afternoon, and evening in Zones One and Three. This space also established a distinct territory among visitors, pedestrians, and street vendors.

Differences in visitors' perspectives primarily concerned the atmosphere. During the interviews, 27 out of 31 respondents emphasized the impact of the atmosphere on daily activities at the location.

> "*I was quite surprised because it was my first time visiting and it was so crowded. It really took me by surprise*." (Bayu, Visitor)

The majority (22 respondents) viewed a busy atmosphere as a positive factor in the Tunjungan Street corridor. This variance in perspective creates a relaxing space in Zone Three, which is evidenced by visitors frequently sitting in front of the Tunjungan Market booth and enjoying music performances at night.

> "*I've only been to Tunjungan a few times. It's really pleasant here because there are so many young people hanging out. There are plenty of culinary options, it's close to Genteng Street, and there are many coffee shops, making it an ideal public space for social gathering.*" (Farurozi, Visitor)

It is important to comprehend that these relaxing spaces were developed following visitors' preference for less crowded areas, while the music performance space caters to those who enjoy a vibrant atmosphere. Although sometimes uneven expectations can also create negative senses in a place (Pramudito & Ikaputra, 2023).

This phenomenon shows how visitor behavior patterns relate to comfort, impressions, and lifestyle during activities on Tunjungan Street. Additionally, the habit of the Surabaya locals, including gathering and socializing while walking, contributes to the creation of spaces through repeated communal activities, shaping spatial practices.

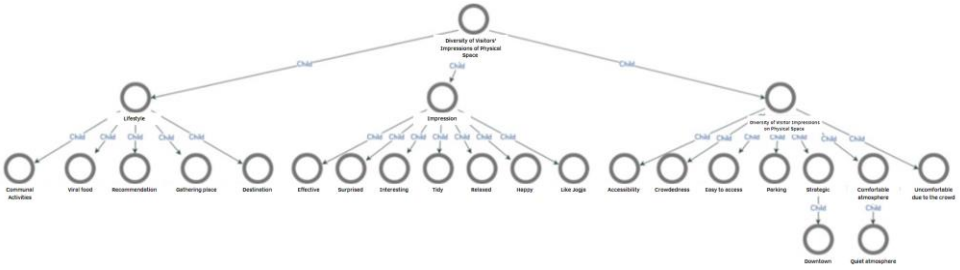



**Figure 9.** Project map for theme 2 by Nvivo program

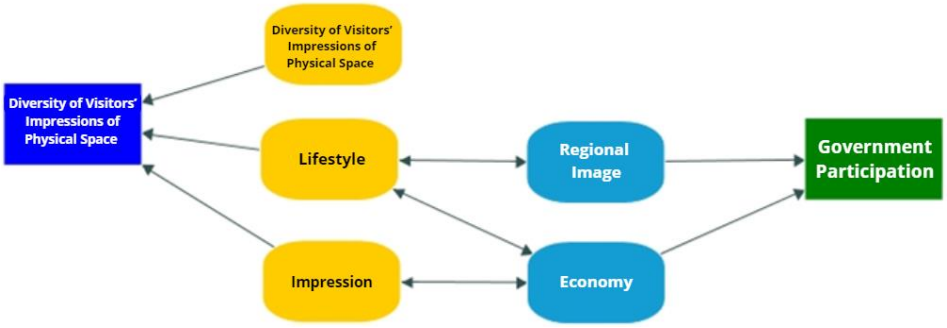



**Figure 10.** Concept map of the relationship between two themes

In Zone Two, art performances by local artists at night have become a key feature. This feature was introduced and sustained following the collaboration between the government and the arts community in Surabaya. Based on observations, these performances enhance activities in the pedestrian spaces, attract visitors, and contribute to the creation of informal spaces in the area. The observed relationship between lifestyle, impressions, and the regional image and economy in this study is in line with Lefebvre and Bononno's (2003) principle of "the right to the city". This concept advocates that social movements should shape open spaces, and economic activities, long supported by the government, are expected to drive economic growth and development in these spaces.

**Synthesis of Socio-Spatial Production via Lefebvre's Spatial Triad**

The empirical interaction between government initiatives and daily visitor activities along Tunjungan Street clearly demonstrates the mechanics of Lefebvre's spatial triad. Municipal heritage policies, commercial zoning regulations, and physical infrastructure developments represent conceived space (representations of space), establishing the official spatial framework intended to promote economic regeneration. This formal framework is materialized through perceived space (spatial practice), where daily pedestrian movement, morning cycling routines, and evening informal vending (*angkringan*) physically occupy and reconfigure the corridor. Concurrently, youth community gatherings, live art performances, and social media interactions transform these physical settings into lived space (representational spaces), imbuing the historic street with contemporary lifestyle meanings and emotional resonance. Consequently, Tunjungan Street operates not merely as a static municipal heritage asset, but as a dynamically produced public space continuously reshaped through the ongoing dialectic between institutional planning and everyday social practices.


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## CONCLUSION

In conclusion, this study demonstrates that the revitalization of the Tunjungan Street corridor in Surabaya extends beyond physical heritage preservation into a process of dynamic socio-spatial production. By integrating behavior mapping and qualitative thematic analysis with NVivo, the findings reveal that pedestrian space is continually reshaped by everyday human activities and visitor engagement. Specifically, the analysis identified two primary themes: the diversity of visitor impressions and direct government inclusiveness.

Grounded in Lefebvre's spatial triad, these findings illustrate a continuous interplay between municipal heritage policies (conceived space), daily pedestrian routines and nighttime activities like the angkringan phenomenon (perceived space), and the emotional or lifestyle meanings attributed by youth communities (lived space). Visitors perceive the corridor not only as a commercial hub amplified by social media but as a vital communal gathering space anchored by historical imageability. Ultimately, this study contributes to socio-spatial literature by providing an empirical framework for pedestrian corridor revitalization in historic urban contexts.

To translate these empirical insights into practice, municipal authorities should implement targeted spatial planning interventions along the corridor. Pedestrian comfort should be enhanced through strategic, shaded public seating, while street vendors (*angkringan*) require designated zones and regulated operating hours to support the night-time economy without compromising sidewalk circulation. Additionally, peak-hour crowd management and curated event programming are essential to prevent spatial bottlenecks. To preserve the corridor's historic character, clear heritage guidelines must regulate facade alterations and commercial developments to balance modern lifestyle uses with architectural preservation. Finally, upgrading barrier-free infrastructure, including continuous tactile paving and accessible curb ramps, is crucial to ensure inclusive access for all user groups.

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# DEVELOPING A HERITAGE BUILDING REVITALISATION MANAGEMENT FRAMEWORK FOR COMMERCIALISATION

**Umi Kalsum Zolkafli @Zulkifly[1], Norhanim Zakaria[2,] Maisarah Makmor [3], Loo Siaw Chuing[4], Ali Sunandar[5]**

[1,2,4,5]*Department of Quantity Surveying, Faculty of Built Environment,* UNIVERSITI MALAYA
[1,2,4] *Centre for Building, Construction and Tropical Architecture, Faculty of Built Environment,* UNIVERSITI MALAYA
[3] *Centre of Surveying and Management (Quantity Surveying), Faculty of Built Environment,* UNIVERSITI TEKNOLOGI MARA
[5]*Department of Civil Engineering, Faculty of Engineering,* UNIVERSITAS MERCU BUANA

## Abstract

Heritage buildings represent valuable cultural and economic assets that can generate long-term social and financial benefits when managed effectively. However, many heritage buildings continue to deteriorate because of neglect, high maintenance costs, limited management guidelines, and insufficient understanding of conservation practices, creating significant technical and economic uncertainty. This study aims to identify the value added generated through heritage building revitalisation by developing a management framework to support sustainable commercialisation. A qualitative research design was adopted, comprising a review of conservation contract documents for heritage shophouses and two rounds of Delphi discussions involving 10 to 15 experts to refine and validate the framework. The findings identified six key characteristics influencing commercialisation potential, namely location, historical significance, aesthetic value, architectural value, tourist attraction, and economic and social value, with location emerging as the most influential factor. The analysis further identified five interrelated management variables consisting of revitalisation scope, construction cost, maintenance, operational cost, and value appreciation. Building works accounted for the largest proportion of construction costs at 68 percent, while value appreciation was demonstrated through social, political, aesthetic, historical, cultural, and economic dimensions, including substantial improvements in rental and capital values following revitalisation. The proposed framework provides a practical decision support tool for investors and practitioners involved in heritage shophouse revitalisation by balancing heritage conservation with commercial viability while supporting the long-term preservation of cultural, historical, social, and architectural values.

***Keywords***: Commercialisation; Cost Analysis; Heritage; Revitalisation Management Framework; Shophouses

[1] Corresponding author. Email: umi@um.edu.my

## INTRODUCTION

Heritage buildings constitute important cultural assets that preserve historical identity while contributing to social, cultural, and economic development through tourism, adaptive reuse, and urban regeneration. When managed effectively, these assets generate long-term economic benefits by increasing property values, attracting investment, and supporting local businesses. Consequently, conserving heritage buildings has become an important strategy for achieving sustainable development while safeguarding cultural significance for future generations. Despite their importance, the conservation of heritage buildings is a highly complex and unique process (Chami, 2026; Wang et al., 2025; Wang et al., 2026). Heritage conservation involves considerable technical and economic uncertainties, including hidden structural defects, undocumented building conditions, difficulties in sourcing traditional materials, specialised workmanship requirements, unpredictable repair interventions, cost overruns, and extended project durations (Dişli & Ankaralıgil, 2023; Ma et al., 2024). Consequently, professionals often cannot accurately predict the actual condition of heritage buildings until conservation works commence (Xu et al., 2025). Furthermore, Marmaya et al. (2025); Penjor et al. (2024) reported that technical knowledge and specialised training among conservation professionals remain insufficient. These challenges are further aggravated by inadequate maintenance and management guidelines, resulting in poor maintenance practices that accelerate the deterioration of heritage buildings (Chen et al., 2025; Marmaya et al., 2025; Zaid et al., 2021).

Balancing heritage conservation with contemporary development therefore remains a major challenge. Through appropriate revitalisation and adaptive reuse strategies, heritage buildings can continue to fulfil modern economic functions without compromising their cultural significance. In Malaysia, effective collaboration among relevant stakeholders has the potential to enhance heritage asset values while generating economic returns through heritage tourism and commercial activities. Nevertheless, despite the recognised economic contribution of heritage buildings, commercialisation should not be viewed solely as a mechanism for financial return. When appropriately managed, commercialisation provides a means of sustaining heritage conservation by generating the resources required for long term maintenance while preserving historical, architectural, cultural, and social significance. However, limited management frameworks are available to systematically integrate conservation values, commercial viability, adaptive reuse requirements, conservation permission, local authority approval, and heritage tourism considerations when evaluating heritage building revitalisation. Consequently, decision makers often lack a structured approach for balancing regulatory compliance, heritage

protection, and commercial sustainability throughout the revitalisation process. To achieve the aim, the research objective are as follows:

1. To identify the characteristics of heritage buildings that has potential for commercialization.
2. To investigate the value appreciation of heritage buildings through the process of revitalization (adaptation and retrofitting).
3. To establish a heritage buildings' management revitalization framework for the purpose of commercialization.

## LITERATURE REVIEW

According to National Heritage Act 2005 Act 645, the definition of heritage building is if a building, a group of distinct or related buildings that is homogeneity is due to their architecture or their location in the landscape, have exceptional universal value in terms of history, art, or science (National Heritage Act, 2005). On 7 July 2008, Melaka and George Town, Historic Cities of the Straits of Malacca were declared and listed in UNESCO World Heritage List as World Heritage Sites. Both cities constitute a unique and unparalleled architectural and cultural townscape in East and Southeast Asia (Tan et al., 2018; Wahab et al., 2018). The dominant building type within the core zones of Melaka and Georgetown, Penang is the shophouse. There are a lot of shophouses, mostly two and three storey, in World Heritage Sites. The shop-houses in Malaysia were recognized by UNESCO in 2008, and their conservation has been intensified due to fast urbanization (Tan et al., 2018; Wahab et al., 2018). The Southeast Asian traditional shophouse is a long-standing architectural tradition of mixing dwelling and commerce that originated in Malaysia in the late 1800s and continued until the 1960s.

The usage of historic shophouses buildings commonly used to be a combination of commercial and residential use. According to Maghsoodi Tilaki et al. (2026); Zhao (2025), the ground level is utilized for retail, light industrial, or service enterprises such as laundries, repair shops, and so on. In a single shophouse, more than one business may share the ground floor space. The residential portion of some shophouses is located behind the shop. The upper levels are for residential use and may comprise housing units for multiple families or individuals who may share kitchens and baths (Maghsoodi Tilaki et al., 2026; Zhao, 2025). However, the current usage allowed in heritage buildings mainly under the buffer zone of UNESCO is strictly controlled to preserve the value of the building. Commercial activities such as coffee houses, handicraft shops, traditional gift shops, and more are preferred to preserve the value of the heritage buildings. In general, revitalization is an effort to restore the dynamics and to revive the assisted environment, which is affected by various factors such as


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social, cultural, economic and political policies (Musyawaroh & Pramesti, 2024). Heritage revitalisation therefore extends beyond physical rehabilitation and economic utilisation. Its primary objective is to ensure that heritage buildings remain socially relevant, culturally meaningful, and financially sustainable through adaptive reuse that respects their heritage significance while supporting their continued conservation.

## RESEARCH METHODOLOGY

Qualitative method is selected for this research as it able to offer an in-depth understanding, begins with the understanding on the theory or concept within literature review until the final step where to develop the framework (Creswell & Creswell, 2023; Sunandar et al., 2025a, 2025c, 2025d). Figure 1 show research framework developed for this study. In this research, three heritage shophouse case studies were undertaken across two study locations, namely Lebuh Kimberley, George Town, Pulau Pinang, and Jalan Laksamana, Banda Hilir, Melaka. Case Study 1 consisted of six shophouses located within the buffer zone of Lebuh Kimberley. Case Studies 2 and 3 consisted of twelve and fourteen shophouses, respectively, both located within the core zone of Jalan Laksamana. Although three separate case studies were undertaken, the findings are presented according to the two study locations because Case Studies 2 and 3 represent the same heritage precinct and were analysed collectively for comparison with the Pulau Pinang case.

The selection was based on ten criteria, namely project title, owner, type of heritage building, building age, heritage characteristics, form of contract, restoration commencement date, restoration completion date, total restoration cost, and total gross floor area. These criteria ensured that all selected cases represented completed heritage shophouse revitalisation projects with sufficient technical, contractual, physical, and financial information to support the analysis of value appreciation and the development of the proposed management framework. Focus Group Discussion (FGD) was employed as a structured Delphi process consisting of two iterative rounds to refine and validate the proposed management framework (Sunandar, Andriyanti, et al., 2026; Sunandar et al., 2025b). Experts were selected using purposive sampling based on their professional experience (Sunandar, Abd Karim, et al., 2026a, 2026b). The expert panel comprised consultant quantity surveyors, architects, contractors, valuers, clients, and heritage investors to ensure multidisciplinary perspectives.

The first Delphi round involved 15 experts in a one day face to face discussion. Participants reviewed the preliminary list of heritage building characteristics, value appreciation variables, and management components identified from the literature and case studies. They were asked to evaluate the relevance, completeness, practical applicability, and clarity of each component

and to recommend modifications where necessary. Consensus was achieved through group discussion until no substantial disagreement remained, and the agreed comments were used to refine the framework. The second Delphi round involved 13 experts, including five participants from the first round to ensure continuity. The validation process was conducted in two stages comprising a face to face session followed by online consultation with recognised heritage conservation practitioners.

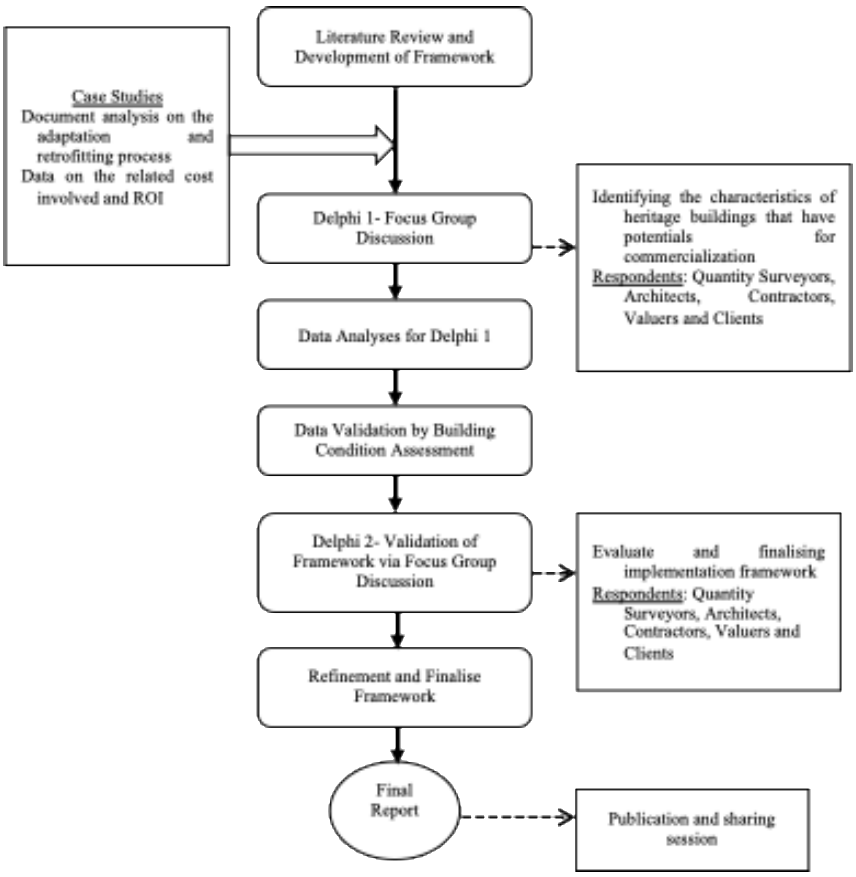



**Figure 1:** Research Framework
*Source: Author's Own Creation* (2026)

In addition, a standardized calculation template was developed from the case study data to ensure that construction cost, maintenance cost, operational cost, rental value, capital value, yield, life cycle cost, and return on investment were analysed using a consistent procedure across all cases, thereby improving the transparency and replicability of the proposed framework. Rental and capital


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value data were primarily obtained from market surveys and official transaction records provided by the Valuation and Property Services Department (JPPH). Where recent transaction evidence was unavailable, particularly in Jalan Laksamana, Melaka, market values were estimated using established comparison and investment valuation methods based on comparable heritage shophouses within the same locality.

## ANALYSIS AND DISCUSSION

### *Findings for Research Objective 1*

The first objective of this research is to identify the characteristics of heritage buildings that have potential for commercialization. The preliminary literature review were collected prior to the FGD 1. In the preliminary literature review, the characteristics of heritage buildings that have potential for commercialization were collected. The characteristics are strategic location, historical significant, aesthetic value, tourism potential, tourism attraction, space for commercial activities, structures in good condition and suitable and practical design. These characteristics were presented and analysed by the respondents in the FGD 1.

Figure 2 present the characteristics that were extracted from the literature review and analysed by the participants in FGD 1. 14 respondents have agreed that strategic location, history significance and tourist attraction to be the important heritage buildings characteristics for commercialization potential. Tourism potential and suitable/ practical design of heritage buildings are secondary heritage buildings characteristics for commercialization potential that were agreed by 13 respondents. As for aesthetic values and space for commercial activities, only 11 respondents agreed that the two was important heritage buildings characteristics for commercialization potential. Three respondents (R8, R9 and R11) have included sustainability as a heritage buildings characteristic for commercialization potential. Following the FGD 1, further literature review were conducted and the findings in the preliminary literature review and the FGD 1 were refined. There were two extra characteristics on the heritage buildings characteristic for commercialization were discovered which are environmental and political factor. Through the refinement process, some of the findings in FGD 1 were categorised in new categories. The changes were conducted as shown in Table 1. Based on the further literature compiled, the nine characteristics collected in FGD 1 are now grouped into six characteristics. The two additional characteristics (environmental and political factor) will be included in the data collection in FGD 2.

**Table 1:** Refined Characteristic

| Characteristic in FGD 1 | Refined Characteristic |
|---|---|
| Strategic Location | Location |
| Historical Significance | Historical Significance |
| Aesthetic Value | Aesthetic value |
| Tourism Potential | Economic & Social Value |
| Tourist Attraction | Tourist Attraction |
| Space for Commercial Activities | Architectural value |
| Structures in Good Conditions | Architectural value |
| Suitable and Practical Design | Architectural value |
| Sustainability | Architectural value |

*Source: Author's Own Creation* (2026)

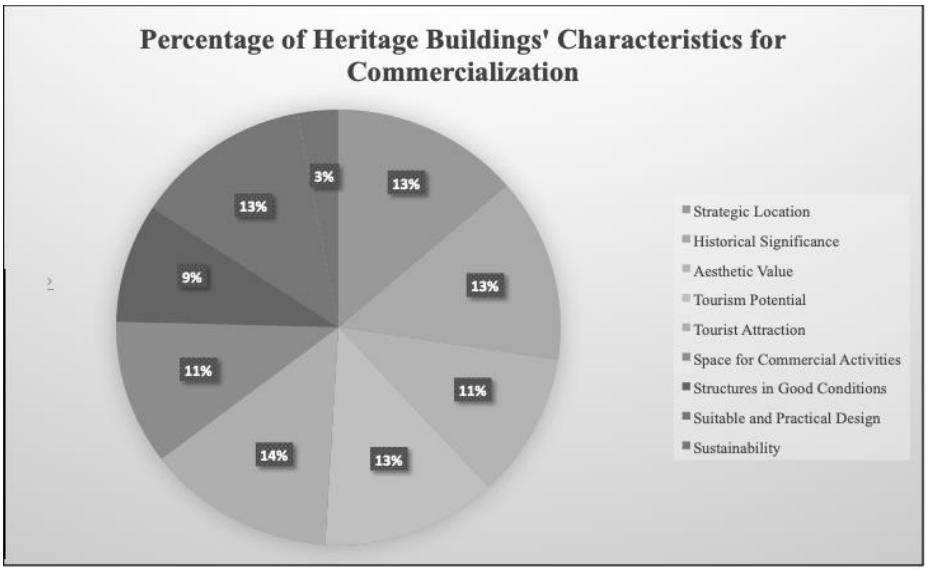



**Figure 2:** Pie Chart on Heritage Buildings' Characteristics that have Potential for Commercialization
*Source: Author's Own Creation* (2026)

### *Findings for Research Objective 2*

The findings are organised according to the two study locations. Although the study comprised three case studies, Case Studies 2 and 3 are presented together because they are located within the same heritage precinct at Jalan Laksamana, Banda Hilir, Melaka. Through a comprehensive literature, there are 6 variables that have been identified as value appreciation after the shophouses has been revitalised namely: Social, Political, Aesthatic, Historical, Cultural and Economic Value. Further analysis using case study has been made to identify the economic value appreciation.


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i. Analysis on Economic Value Appreciation
Economic value appreciation was evaluated using a consistent calculation procedure across all case studies. The assessment comprised rental value, capital value, yield, life cycle cost, and return on investment, allowing direct comparison between buildings before and after revitalisation. Rental and capital value appreciation were calculated by comparing pre and post revitalisation market values, whereas yield, life cycle cost, and return on investment were incorporated into the management framework as decision support indicators for commercial feasibility.

ii. Rental Value Appreciation
Study Area 1 – Lebuh Kimberley, Pulau Pinang
There was a significant increase in rental of a two- storey shophouse located at Kimberley Road which had been revitalised compared to before revitalisation. Unit No. 96 which was rented out before revitalisation works done at a rental rate of RM600 per month was successfully rented out at a rental rate of RM2,500 per month after revitalisation work done. A comparison in terms of rental between units that are in their original condition and units that have been revitalised were also conducted to determine the differences. From the rental survey conducted, it is found that the rent for units with land areas in the range of 850 - 1,000 square feet which have been revitalized are rented out at rental ranging from RM2,500 to RM4,000 per month whilst units with the similar land size and in its original condition are rented in the range of RM600 - RM1,500 per month. For larger units where the land area are approximately 1,500 square feet, the rents for revitalised units are in the range of RM4,000 – RM7,000 per month. The increment of rental if the units are revitalised compared to units which are not revitalised ranging from 166% to 316%.

**Table 2:** Comparison of Rental Price at Lebuh Kimberley, Pulau Pinang

| No. | Land Area (sq. ft.) | Monthly Rental (units not revitalised) | Monthly Rental (units revitalised) |
|---|---|---|---|
| 1 | 850–1,000 | RM600–RM1,500/month | RM2,500–RM4,000/month |
| 2 | Approximately 1,500 | Not available | RM4,000–RM7,000/month |

*Source: Author's Own Creation* (2026)

Study Area 2 – Jalan Laksamana, Bandar Melaka
Significant differences between the revitalised units and the units in their original condition were also detected in Melaka Our rental survey revealed that units which is in poor condition (have not gone through revitalisation work) were rented out at monthly rental ranging from RM350 to RM2,000 whilst the shophouses that have been restored can fetch rental of RM5,000 to RM7,000 per

month. Two adjoining units of two-storey shophouses (Unit No 17 & 19, Jalan Laksamana) which are in poor state of repair (not restored/revitalised) are rented out at RM4,000 (RM2,000 per unit) per month whilst the two-storey shophouse that has gone through revitalisation process located opposite, across Jalan Laksamana is currently rented out at RM5,000 per month. The increment of rental if the units are revitalised compared to units which are not revitalised ranging from 150% to 215%.

**Table 3:** Comparison of Rental Price at Jalan Laksamana, Melaka

| No. | Land Area (sq. ft.) | Monthly Rental (units not revitalised) | Monthly Rental (units revitalised) |
|---|---|---|---|
| 1 | 850–1,000 | RM350–RM2,000/ month | RM5,000–RM7,000/month |
| 2 | Approximately 1,500 | RM2,000/month | RM5,000/month |

*Source: Author's Own Creation* (2026)

iii. Capital Value Appreciation

Study Area 1 – Lebuh Kimberley, Pulau Pinang

Comparison between the transacted prices of the two-storey shophouses that have gone through restoration works with the two-storey shophouses which are in its original condition (not restored, poor condition) has been done. It can be clearly seen that shophouses that have undergone restoration (although not full renovation) have been able to fetch higher prices in the market compared to the property that is in its original condition.

For 2- storey shophouses with land area of approximately 800 to 1,000 square feet which have undergone restoration works, its were transacted at prices of RM1.2 to RM1.25 million per unit whilst the one with same land area that has not undergone any restoration work was transacted at RM325,000 per unit. The incremental of price is about 269%.

**Table 4:** Transacted price of 2-storey shophouses at Jalan Kimberley

| Address | Transacted Price (RM) / Date of Transaction | Land Area (sq ft) | Analysis (RM) per sq ft (over land area) / per unit |
|---|---|---|---|
| 120, Lebuh Kimberley | RM1,200,00026 July 2021 | 839 | 1,430 per sq. ft. / RM1,200,000 per unit |
| 64D, 64E, 64F, 64G, 66 & 68, Lebuh Kimberley | RM7,500,0005 July 2021 | 6,423 (1,070 sq. ft. per lot) | 1,168 per sq. ft. / RM1,250,000 per unit |
| 14, Lebuh Kimberley | RM1,700,0002 April 2021 | 1,546 | 1,100 per sq. ft. / RM1,700,000 per unit |
| 208, 210, 212 & 214, Lebuh Kimberley | RM650,000 (1/2 share)29 Jan 2020 | 3,511 (878 sq. ft. per lot) | 370 per sq. ft. / RM325,000 per unit |

*Source: JPPH Sales Data (2024)*


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Study Area 2 – Jalan Laksamana Melaka

There were no recent market transactions involving comparable two storey heritage shophouses along Jalan Laksamana during the study period for direct comparison between buildings in their original condition and those that had undergone revitalisation. Consequently, capital values were estimated using established comparison and investment valuation methods based on comparable heritage shophouses within the surrounding heritage area. This approach is consistent with professional valuation practice when direct transaction evidence is limited and provides a reasonable basis for comparative analysis. Based on this assessment, the capital value of two storey shophouses with land areas ranging from 1,100 to 1,300 sq. ft. that had not undergone restoration works (poor condition) was estimated at approximately RM400,000 to RM650,000 per unit, whereas comparable revitalised shophouses were estimated at RM1,200,000 to RM1,500,000 per unit. The estimated increase in capital value following revitalisation ranged from 130% to 200%.

**Table 5:** Transacted price of 2-storey shophouses at Jalan Laksamana

| Address | Transacted Price (RM) / Date of Transaction | Land Area (sq ft) | Analysis (RM) per sq / per unit |
|---|---|---|---|
| 2 storey shophouses along Jalan Laksamana | RM400,000.00 – RM650,000.00 per unit | 1100–1300 sq. ft. | RM330.00 per sq. ft. |
| 2 storey shophouses along Jalan Laksamana | RM1,200,000.00 – RM1,500,000.00 per unit | 1100–1300 sq. ft. | RM1,125.00 per sq. ft. |

*Source: JPPH Sales Data (2024)*

iv. Yields

The analysis of yield shows that yields for revitalised and not revitalised shophouses in Jalan Kimberley Pulau Pinang are about the same i.e in the region of 3% to 5%. For Jalan Laksamana, Melaka, the yields are in the region of 3% - 5% for the units not revitalised while the yields for the units that have been revitalised are also in the same region, i.e. 3% - 5%. Coincidently the yields for shophouses in the both study areas are about the same. The range of yields of unrestored and restored units are in similar range (3%-5%) since the units restored not only increase in rental but also increase in capital value with similar range of percentage.

**Table 6:** Yields of 2-storey shophouses

| No. | Location | Yield for units not revitalised | Yield for units revitalised |
|---|---|---|---|
| 1. | Jalan Kimberley, Pulau Pinang | 3%–5% | 3%–5% |
| 2. | Jalan Laksamana, Melaka | 3%–5% | 3%–5% |

*Source: Author's Own Creation* (2026)

***Findings for Research Objective 3***

All the variables has been considered in the development of Heritage Building's Revitalization Management Framework as per Figure 3 for the Purpose of Commercialization. It is comprising of the following item:

i. Revitalisation: Scope, Work Categories, and Standardised Construction Cost Calculation.
ii. Maintenance: Annual maintenance cost categories comprising architectural, civil and structural, mechanical, electrical, housekeeping services, and pest control.
iii. Operation: Operational cost estimation according to commercial use, including dress shop, café, and beauty product shop.
iv. Financial Evaluation: Life cycle cost (LCC), rental income, capital value appreciation, yield, and return on investment calculated using a standardised assessment template for each commercial scenario.

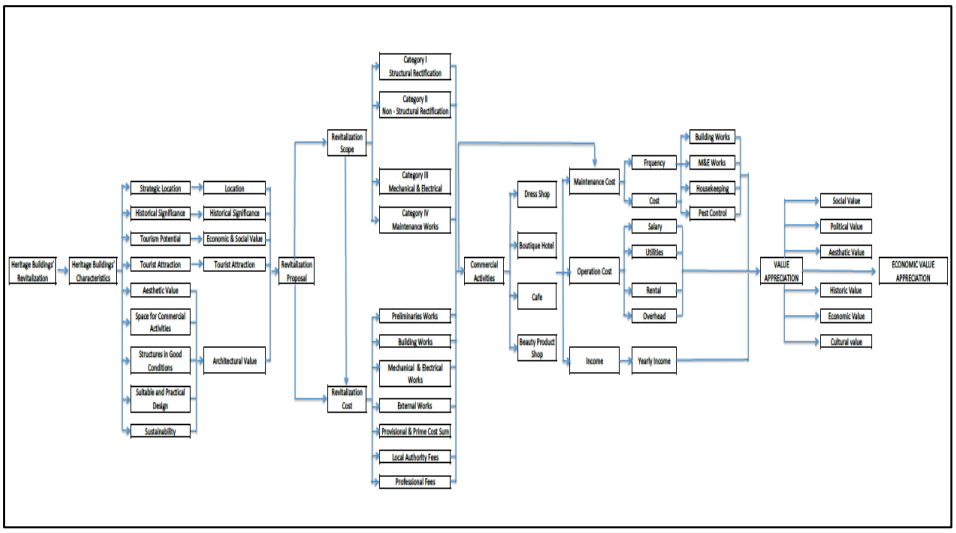



**Figure 3:** The Final Framework
*Source: Author's Own Creation* (2026)

The framework integrates a standardized sequence of calculations beginning with revitalisation cost estimation, followed by maintenance and operational cost assessment before evaluating rental income, capital value appreciation, yield, life cycle cost, and return on investment. It also functions as a planning and heritage management tool by supporting adaptive reuse decision making, facilitating conservation permission and local authority approval, and ensuring that commercial development remains consistent with conservation


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principles by protecting the authenticity, architectural integrity, and cultural significance of heritage buildings while maintaining appropriate public and local community access and supporting heritage tourism objectives. This sequential structure enables consistent application and facilitates replication in future heritage revitalisation projects.

## CONCLUSION

Heritage building conservation involves significant technical and economic challenges, while inadequate maintenance and management continue to threaten many heritage assets. Sustainable revitalisation requires balancing conservation with development through effective policies and collaboration among relevant stakeholders. Commercialisation should be viewed as a mechanism to support long-term conservation by generating resources for maintenance, adaptive reuse, and public appreciation rather than merely increasing financial returns. Revitalisation creates social, cultural, historical, architectural, and economic value, enhancing asset value, supporting heritage tourism, and contributing to local economic development.

The proposed heritage building revitalisation management framework provides a transparent and replicable decision support tool by integrating standardised procedures for construction cost estimation, maintenance and operational cost assessment, rental and capital value analysis, yield evaluation, life cycle cost assessment, and return on investment analysis. Consequently, the framework assists investors, practitioners, and local authorities in balancing commercial viability with long-term heritage conservation. The framework also emphasises that commercialisation should proceed only where proposed adaptive reuse is compatible with conservation principles, protects the authenticity and cultural significance of the heritage asset, maintains appropriate public and local community access, and does not compromise the historic character that underpins its heritage value.

Beyond financial assessment, the framework supports adaptive reuse planning, facilitates conservation permission and local authority approval processes, and promotes heritage tourism management by ensuring that commercial activities remain compatible with the cultural, historical, and architectural significance of heritage buildings. Since the framework was developed from heritage shophouse case studies in George Town and Melaka, its direct application to other heritage building types should be interpreted with caution and validated within their respective conservation contexts.

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## DISCLOSURE

The authors declare that there is no conflict of interest associated with this research.

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# BEYOND BARRIERS: MUSEUM ACCESSIBILITY IN INDONESIA THROUGH THE EYES OF PERSONS WITH DISABILITIES

**Nevine Rafa Kusuma[1], Mastura Adam[1*], Ziad Baydoun[3], Mamasharipov Yakubjon Gulamitdinovich[2] and Kamol Allayorov[2]**

[1] *Department of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA
[2] *Department of Architecture,*
TASHKENT UNIVERSITY OF ARCHITECTURE AND CIVIL ENGINEERING, UZBEKISTAN
[3] *Department of Interior Design, College of Architecture, Art and Design,*
AJMAN UNIVERSITY, AJMAN, UNITED ARAB EMIRATES

## Abstract

Museums are increasingly recognised as inclusive cultural institutions, yet accessibility remains severely limited for Persons with Disabilities (PwD) in developing countries, including Indonesia. This study systematically identifies urgent issues and persistent challenges in museum accessibility through two case studies: the Jakarta History Museum (JHM) and the Fort Vredeburg Museum (FVM) in Yogyakarta. A multi-method qualitative approach was employed, combining semi-structured interviews with 25 participants, including PwD and key museum stakeholders, and Community-Based Observation (CBO) using the Inclusive Museum Appraisal Tool (IMAT) with 12 PwD representing diverse disability groups. Findings reveal pervasive, systemic inaccessibility across three accessibility attributes: communication, external elements, and internal elements. Critical barriers, such as the complete absence of sign language services (100%), inaccessible interior design (80%), inadequate facilities (76%), and the lack of accessible elevators, demand immediate improvement. External barriers significantly hinder initial entry, rendering access a fundamental challenge from the outset. The findings reveal a critical gap between global inclusive design standards and prevailing practices in Indonesian museums, emphasising the urgency of comprehensive and strategic interventions to achieve equitable and meaningful cultural participation for visitors with disabilities.

***Keywords***: Museum Accessibility, Universal Design Principles, Inclusive Museum Appraisal Tool and Community Based Observation

[1] Corresponding author. Email: mastura@um.edu.my

## INTRODUCTION

Museum accessibility encompasses more than merely allowing entry into the building; it also involves ensuring that visitors can navigate the space comfortably and comprehend the information presented. Within this broader conception, two components are especially central: physical accessibility and communication accessibility (Solima, 2017).

Physical accessibility refers to the design of spaces and facilities that accommodate a range of mobility needs. Essential features include ramps, elevators, wide circulation paths, and barrier-free entrances, all of which facilitate safe, independent navigation for visitors with physical disabilities (Rocha et al., 2022). Communication accessibility, by contrast, aims to eliminate information barriers through clear signage, tactile guides, *Braille* labels, audio descriptions, captioned videos, and digital resources in accessible formats, elements that support visitors with sensory or learning disabilities. By addressing both dimensions together, museums can move towards becoming inclusive environments where all visitors, regardless of ability, can participate equally in cultural and educational experiences.

Building on this understanding, the present study has two interrelated aims: (1) to systematically assess museum accessibility conditions for PwD across communication, external, and internal elements using empirical, multi-method evidence; and (2) to examine the lived experiences of PwD as visitors, grounding the findings in user-centred perspectives. By bridging the gap between experiential evidence and policy discourse, this study provides a validated framework designed to guide both future design interventions and broader accessibility policy in Indonesia.

## LITERATURE REVIEW

### Communication Accessibility in Museum Environment for Persons with Disabilities (PwD)

Communication accessibility serves as a fundamental prerequisite for inclusive cultural engagement, yet its current application in the Indonesian museum sector reveals a persistent dissonance between institutional aspirations and the lived reality of PwD. Barriers exist in both digital and physical formats. Digitally, museum websites and online platforms frequently fail to meet accessibility standards such as the WCAG; accessible practices, including alternative text for images, captions for videos, adjustable layouts, and narrated tours, remain uncommon (Bogdanova et al., 2021; Vila et al., 2024). Emerging technologies such as virtual reality (VR) and 3D simulations, along with social media, are likewise underutilised for fostering inclusive participation (Brischetto et al., 2023; İşlek, 2023).


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Physically, communication access can be enhanced through multimodal interpretation, such as *audio descriptions, tactile exhibits, sign language interpretation, and clear visual signage*, though inconsistent implementation often undermines their effectiveness. However, inconsistent implementation currently undermines the efficacy of these tools. It is imperative to recognize that technology alone cannot bridge the accessibility gap; well-trained staff capable of deploying auxiliary aids and providing inclusive guidance are indispensable partners in this ecosystem (Chidiac et al., 2024). Ultimately, for Indonesian museums to transition into truly inclusive institutions, they must embed Universal Design (UD) principles as an operational logic that permeates both their digital infrastructure and the physical interpretation of their cultural narratives, rather than treating accessibility as a secondary, elective feature.

**External Element in the Museum**

Accessibility extends beyond the museum threshold, it is intrinsically tied to the physical environment visitors navigate before entering the building. These external elements, such as *approaches, surrounding environments, and entrance areas*, act as the initial point of contact for PwD, effectively shaping their perception of the institution's inclusivity. Approaches should ensure seamless connectivity with public transportation and parking facilities; pedestrian pathways leading from drop-off zones, bus stops, and parking areas must feature appropriate gradients and level transitions (Adi et al., 2024), since barriers commonly arise from uneven pavements, clutter, and sudden elevation changes (İşlek, 2023). Tactile paving and orientation cues are similarly essential for assisting visually impaired visitors (Ma et al., 2021).

Entrances and reception areas, in turn, serve as the vital transition points between external and internal access. Main entrances should be equipped with clear signage and designed to be operable and direct, supplemented by sensory cues such as lighting, colour coding, or acoustic signals (Zallio & Clarkson, 2021; Zulpiani & Rusyani, 2023), while reception areas should minimise barriers and facilitate effective communication (Lamirande, 2022). UD principles further advocate for sheltered waiting areas, weather-protected routes, and accessible online updates (Berget & Kvikne, 2024; Bringolf, 2022). Collectively, these measures promote inclusivity and predictability, ensuring that all visitors experience a welcoming and accessible environment from the moment they arrive.

**Internal Element in the Museum**

Once inside, internal elements become equally crucial for ensuring equitable, safe, and dignified access. *These include circulation systems, sanitary facilities, wayfinding strategies, emergency preparedness, and interior design*, each

shaping the inclusivity of the cultural experience in distinct ways.

Circulation forms the foundation of internal accessibility. Horizontally, corridors, galleries, and open spaces should be wide, unobstructed, and fitted with easy-to-operate doors to facilitate seamless movement (Yılmaz, 2018); vertically, stairs, ramps, and lifts must provide barrier-free connections between floors to accommodate diverse mobility needs (Zulpiani & Rusyani, 2023). Sanitary facilities are equally vital for maintaining dignity and independence: inclusive restrooms should be strategically located, spacious, and equipped with grab rails, emergency alarms, and high-contrast fittings to aid recognition (Singh & Saxena, 2023). Wayfinding systems, meanwhile, promote autonomy through clear signage, maps, tactile guides, and raised tactile maps with high-contrast text (Brischetto et al., 2023), while consistent lighting reduces glare (Wall Emerson, 2017; Wendorff, 2023) and thoughtfully managed soundscapes accommodate visitors with hearing impairments (Kruczek et al., 2024). Emergency preparedness, in turn, requires multi-sensory alerts, accessible evacuation routes, and regular staff training to ensure equitable safety (Centre for Accessible, 2023). Interior design ultimately ties these elements together, shaping orientation, exhibition layouts, and sensory interactions; intuitive pathways, contrasting colours, and multisensory features such as tactile models, acoustic elements, and interactive displays allow visitors of all abilities to engage meaningfully (Bošková Filová, 2025; Kasemsarn et al., 2024).

Taken together, the existing literature has addressed museum accessibility globally and examined specific aspects of the Indonesian context, such as exhibition displays, but it remains fragmented, lacking a holistic, user-centred approach that considers communication and external and internal barriers together, particularly regarding the lived experiences of diverse PwD across different urban settings. This study addresses that gap by developing an empirically grounded conceptual framework that integrates these three accessibility dimensions, moving beyond isolated assessments and technical compliance to center user perspectives. In doing so, it advances a more complete understanding of inclusive museum environments and contributes to policy and design discourse on genuinely inclusive cultural participation in Indonesia.

This relevance extends beyond Indonesia, as comparable challenges recur throughout Southeast Asian built-environment research. Zahari et al. (2023) found that regional heritage sites similarly exclude PwD through physical, informational, and attitudinal barriers, pointing to a systemic pattern of inaccessibility that demands inclusive design beyond mere physical modification. Omi et al. (2024) showed that even internationally recognised heritage sites with genuine improvement intentions still fail to resolve core outdoor and communication barriers, and that staff training and capacity-building remain essential to any real progress. Together, these regional findings situate the present


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study within a broader pattern of institutionalised exclusion, underscoring the urgency of the holistic, user-centred approach adopted here.

## RESEARCH METHODOLOGY

A multi-method qualitative approach was employed to examine physical accessibility in Indonesian museums, integrating institutional perspectives with the lived experiences of PwD. Drawing on multiple sources of evidence, the study enabled comprehensive qualitative data collection through an iterative, reflective process that achieved thematic saturation. Ethical approval was obtained through the UMREC Research Ethics Protocol (2024), ensuring strict adherence to research integrity standards throughout (see Figure 1).

The empirical inquiry centers on two case studies: the Jakarta History Museum (JHM) and the Fort Vredeburg Museum (FVM) in Yogyakarta. These museums, despite being in different cities, share key characteristics, such as preservation and exhibition of historical artifacts and heritage buildings with Dutch architectural styles, as well as centers for education and research that serve students, researchers, and the public. Both museums maintain and preserve extensive collections of archaeological artefacts, artworks, and historical documents. They are significant tourist attractions that draw visitors interested in local culture and history. These criteria, together with FVM's 2024 recognition by Indonesia's Ministry of Culture as the country's most inclusive museum, which positions it as an evidence-rich comparator against JHM's more typical, less-adapted metropolitan condition, were therefore judged sufficient to represent the range of accessibility challenges characterising Indonesian museums broadly. These criteria align with Yin et al. (2018) multiple case study protocol, where contrasting but comparable sites serve as strategic exemplars for analytical generalisation rather than statistical representation.

Data collection was structured around two primary instruments: semi-structured interviews and Community-Based Observation (CBO). Twenty-five stakeholders were recruited via purposive and snowball sampling, with participants divided between Jakarta (n=13) and Yogyakarta (n=12). The sample comprised a diverse array of PwD (including those with visual, mobility, and hearing/speech impairments), alongside architects, museologists, and local authority regulators. Interviews, spanning 60 to 90 minutes, employed the Appreciative Inquiry (AI) method, which encourages an action-oriented dialogue to build shared community visions (Ab Ghafar et al., 2022). To ensure the process was fully inclusive, adaptive communication techniques were applied, including a sign language interpreter, with strict adherence to informed consent and participant anonymity protocols. The participants were required to be 18 years or older with prior museum-visit experience and gender was not recorded as a selection variable in this study. Participants represented a diverse cross-section

of stakeholders, including the PwD in several categories as follows:

(i) Visual impairment *(P1_JT, P2_JT, P1_YK, P4_YK)*,
(ii) Wheelchair user *(P3_JY, P4_JT, P5_JT, P2_YK, P6_YK),*
(iii) Deaf and muted (*P6_JT, P7_JT, P3_YK, P7_YK),*
(iv) Physically disabled *(P5_YK),* (v) Architect *(P8_JT & P8_YK),*
(v) Museum representative *(P10_JT, P13_JT, P9_YK, P12_YK),*
(vi) Museologist *(P11_JT & P11_YK),* and
(vii) Local authority in museum and building regulation *(P9_JT, P12_JT, P10_YK).*

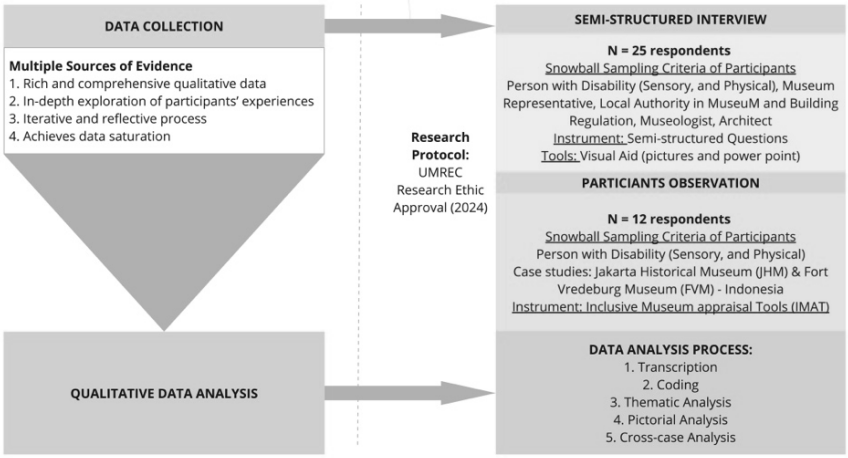



**Figure 1:** Data Collection Method and Stages *Source: Author (2025)*

The CBO was performed by 12 PwD (six per site) using the *Inclusive Museum Appraisal Tool* (IMAT), developed directly from semi-structured interview findings and grounded in established international and national policies. Unlike traditional institutional audits, IMAT evaluates accessibility from the firsthand, embodied perspective of the user: including PwD as inspectors allowed the study to capture direct feedback on how physical environments genuinely shape user experience, enhancing the authenticity of the evaluation beyond what compliance-based checklists alone can offer. The instrument was developed iteratively, synthesising *UD principles (Centre for UD, 1997), the MS 1184:2014 Malaysian Standard, and the Smithsonian Accessible Design Guidelines (2021)*. It maps 17 observable indicators across three dimensions, *communication, external elements, and internal elements*, with each feature assessed as *absent/non-compliant, partially present, or fully present and functional.* Reliability and content validity were verified by a PwD


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experienced in access auditing of public buildings in Indonesia, reinforcing the tool's credibility for the local context. To ensure systematic coverage, the checklist followed a journey-based sequence, such as *arrival, entrance, circulation, facilities, and exit,* enabling structured assessment of access, amenities, and signage at each stage, with observations documented through annotated photographs and floor plans. This design allows IMAT to generate both qualitative and quantitative evaluations of museum spaces, producing actionable insight for improving inclusivity and advancing UD in practice.
All qualitative data subsequently underwent a five-stage analysis, comprising transcription, coding, thematic analysis using NVivo 14, following Braun and Clarke's (2019) framework, pictorial analysis, and cross-case analysis. By triangulating interview transcripts, IMAT-based observational data, and policy documentation review, this study offers a robust, holistic account of the current accessibility landscape in Indonesian museums. This layered methodological approach strengthens the credibility and transferability of the findings, situating the study's recommendations within broader academic discourse on social equity and cultural participation.

## ANALYSIS AND DISCUSSION

### Findings on Semi-Structured Interviews

Based on thematic analysis of the interviews, three accessibility attributes emerged as follows:

i. Communication Accessibility
ii. External Elements
iii. Internal Elements

These attributes reflect how physical and communicative access significantly shape the experiences of diverse visitors with disabilities. Each attribute provides criteria that highlight the importance of the elements and design considerations necessary for inclusive museum environments.

### Communication Accessibility

According to the participants' feedback, five interconnected criteria of communication accessibility in Indonesian museums emerged (see Table 2). These criteria highlight how communication barriers and opportunities shape the inclusivity of cultural participation for PwD.

Semi-structured interview analysis reveals persistent, systemic gaps in inclusive communication and interpretation across both museum sites. Sign language provision was identified as the most significant barrier, cited by all

participants (100%). The absence of institutionalized sign language services indicates a fundamental structural failure, as one participant stated: *"Ideally, all museum guides should be able to serve visitors using sign language"* (P10_JT). Although some initiatives have been reported, these remain sporadic and are not integrated into routine practice. This suggests that accessibility is still primarily viewed as a compliance requirement rather than an essential aspect of the inclusive visitor experience.

**Table 1:** Attributes and Criteria for Communication Accessibility from Participant's Feedback

| ATTRIBUTES | CRITERIA | | |
|---|---|---|---|
| Communication Accessibility | 96% | Sign Language | 100% |
| | | Inclusive Exhibition Display | 80% |
| | | Information | 68% |
| | | Digital Communication | 68% |
| | | Auxiliary Aids | 56% |
| | | Total criteria, n=5 | |

Physical communication barriers were also prominent. Deficiencies in wayfinding (68%) and interior design, particularly inadequate lighting and lack of visual contrast (80%), compounded the challenges experienced by visitors with sensory disabilities. As one blind participant stated, *"proper lighting and guiding blocks are very important"* (P1_YK). The lack of tactile guides and sufficient sensory cues makes independent navigation nearly impossible, reinforcing systemic exclusion that prioritizes heritage aesthetics over UD principles. Additionally, gaps in auxiliary aids and digital accessibility (56%) contributed to participants feeling marginalised from museum platforms, as one participant remarked, *"it seems we are not the target audience"* (P3_JT). Collectively, these findings indicate that accessibility remains fragmented and insufficiently integrated into museum practice, demonstrating a limited shift from a medical to a social model of disability.

**Internal Elements and Inclusive Experiences**

Internal elements were identified as the second-most-critical attributes for enabling PwD to access museums independently (see Table 3). Interior design, cited by 80% of participants, emerged as a primary concern. Participants frequently described dark environments and insufficient spatial navigation. For instance, one participant stated, *"museums tend to be dark and frightening"* (P12_JT), while another suggested using *"stronger color contrast, like bright floor markings"* (P1_JT).

Wayfinding (68%) was similarly problematic, with approximately 80% of participants reporting a lack of tactile guides, clear signage, and sufficient


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lighting. One blind participant emphasized that *"proper lighting and guiding blocks are very important"* (P1_YK), underscoring the inadequacy of current navigation systems in supporting independent movement for a diverse range of users. Facilities and amenities (76%) revealed critical gaps in basic accessibility, particularly in restroom provision. More than half of participants reported inaccessible toilets, with one wheelchair user stating, *"If the restroom is not accessible, it becomes a significant issue"* (P4_JT). Furniture and exhibit design (36%) further limited inclusive engagement, as physically disabled visitors were often restricted to passive viewing rather than hands-on interaction (P4_JT).

**Table 2:** Attribute and Criteria for Internal Elements from Participant's Feedback

| ATTRIBUTES | | CRITERIA | |
|---|---|---|---|
| Internal Elements | 96% | Interior Design Aspects | 80% |
| | | Museum Facilities Amenities | 76% |
| | | Wayfinding | 68% |
| | | Furniture | 36% |
| | | Emergency Escape Area | 16% |
| | | Total criteria, n=5 | |

Although less frequently raised, emergency preparedness (16%) remains a concern, with participants noting the absence of evacuation systems and designated assembly points (P5_JT). Collectively, these findings demonstrate a fundamental failure to apply UD principles throughout the museum's internal environment, indicating that safety, dignity, and inclusion remain secondary considerations rather than integrated design requirements.

**External Elements Accessibility**

External elements accessibility conditions constitute a significant barrier to inclusive museum access, with critical challenges identified in approach infrastructure and entrance design (see Table 4). Disability parking and pedestrian pathways were highlighted as essential yet currently insufficient, as participants noted: *"parking areas must have these marked"* (P3_JT) and *"there should be easy access from the parking lot to the entrance for wheelchair users"* (P2_YK).

**Table 3:** Attributes and Criteria for External Elements from Participant's Feedback

| ATTRIBUTES | | CRITERIA | |
|---|---|---|---|
| External Elements | 64% | External Approaches and Environment | 72% |
| | | Entrance Area | 20% |
| | | Total Criteria, n=2 | |

Unsafe and disorienting pedestrian environments further exacerbated exclusion, with one participant stating, *"it's as if the museum forgot that not everyone walks"* (P4_JT), and another reporting difficulty navigating the approach (P3_JT). Transportation inequalities, reported by 44% of participants, imposed additional constraints, as limited and expensive options restricted independent arrival. The lack of sheltered drop-off zones further reinforced dependency, as reflected in the statement: *"I need help from others just to get from the car to the entrance; I want to be independent"* (P1_JT).

At the point of entry, both physical and service-related barriers persist in ticketing, reception, and circulation areas. Participants identified narrow corridors, uneven surfaces, and non-inclusive service counters as frequent obstacles, emphasizing that *"ticket counters also need to be taken into account"* (P12_JT). One participant mentioned, *"equitable use means I should be able to access the same entrance as everyone else"* (P3_JT), highlighting the disparity between UD principles and current implementation.

Collectively, these findings demonstrate that external and entrance features remain fragmented and insufficiently designed, indicating the need for a systemic transformation that integrates accessibility into national building regulations, institutional accreditation processes, and collaborative audit mechanisms involving PwD, designers, and museum stakeholders.

**Internal elements Accessibility**

Auxiliary communication aids frequently exhibited structural deficiencies, such as inadequate speaker audibility, excessive sound reflection resulting from the lack of acoustic treatments, and insufficient provision of essential assistive technologies, including infrared listening systems and consistent sign language interpretation. Digital platforms, which are vital for pre-visit planning among most disability groups, also displayed significant deficiencies in both museums. These deficiencies included inconsistent caption accuracy and the use of complex language, both of which substantially hinder accessibility for Deaf. It was echoed by a Deaf participant, who noted the limits of understanding captions: "*...not all deaf individuals have the same level of language proficiency"* (P6_JT). Another Deaf participant emphasised the value of text-based alternatives over reliance on residual hearing: *"clear subtitles or captions on videos and audio guides are really helpful... written text gives me equal access"* (P3_YK). At the institutional level, JHM lacked an operational framework for accessibility. Conversely, FVM showed slightly greater preparedness by offering a wider range of assistive devices and maintaining a stronger digital presence through its website and social media channels.

Crucially, the physical exhibition spaces in both case studies were found to lack comprehensive inclusive design, indicating that access for PwD was


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not independent. Shared limitations include minimal or absent tactile interaction, inconsistent placement of small and high-mounted objects, and a universal deficiency in providing alternative label formats such as Braille, audio descriptions, or large print. Interpretive media, including audio-visual elements and interactive displays, frequently lacked descriptive content and were physically inaccessible to wheelchair users.

Although FVM generally provided a more accessible exhibition environment, evidenced by better object placement, contrast in backdrops, and bilingual labels, both institutions require substantial, systematic improvements to ensure equitable engagement across all exhibit elements and to adhere to truly inclusive design principles.

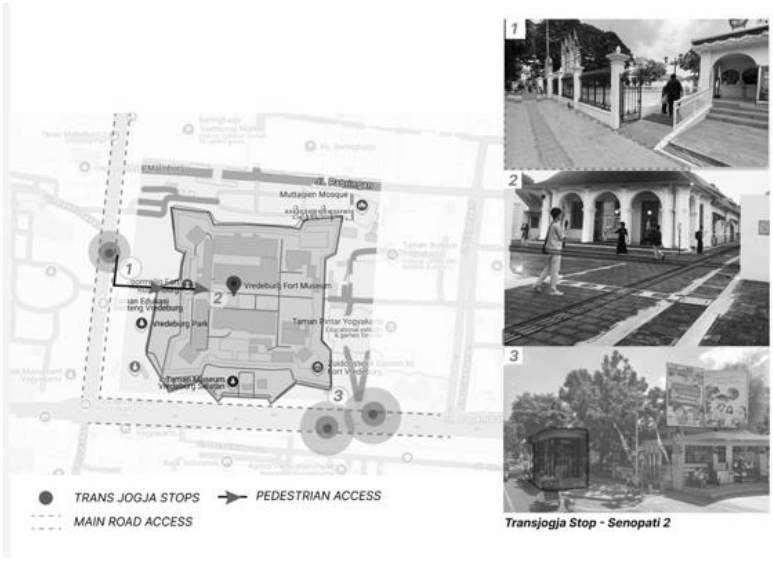



**Figure 3:** External elements, including provision of pedestrian pathway *(1)*, tactile pathway around the museum *(2)* and the bus stop close proximity *(3)* to FVM. *Source: Author (2025)*

Both museums exhibit significant deficiencies in *external accessibility*, including inadequate infrastructure, insufficient wayfinding, and poorly designed service areas that fail to provide a safe, continuous path of travel. JHM (see Figure 2) is especially limited in accessibility due to non-low-floor buses, long distances to transit points (approximately 300 meters), poorly maintained pathways, damaged tactile paving, and the absence of dedicated visitor parking.

FVM offers marginally better transit proximity and accessible parking within the complex (see Figure 3), supported by a buggy service; however, it still

presents obstacles, including excessively steep ramps, uneven level transitions, and inconsistent drop-off zone markings. Wayfinding at both sites remains insufficient, with an absence of tactile elements, inadequate contrast, and unclear directional signage, resulting in unreliable navigation for sensory-impaired users.

Additionally, entrance and reception areas perpetuate exclusion, as neither location provides lowered ticketing counters, manoeuvring space compliant with accessibility standards, nor companion seating for wheelchair users. Inconsistent and insufficient external lighting further undermines safe navigation and visual communication for Deaf visitors.

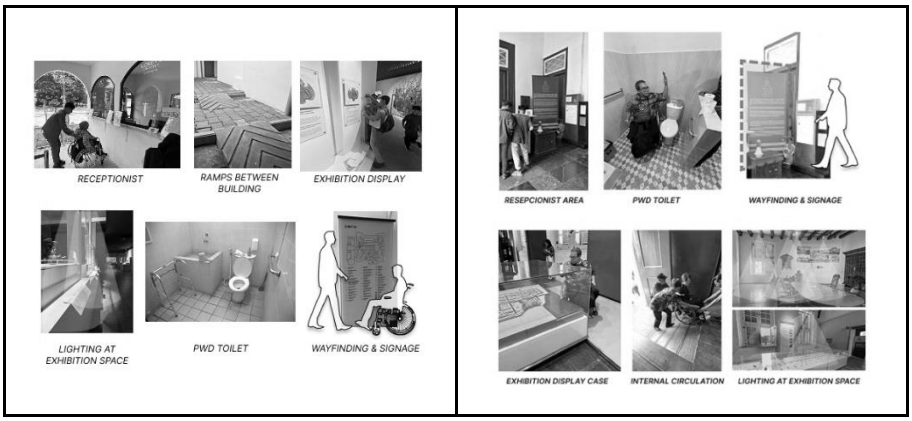



**Figure 4:** Internal Elements in JHM (left) and in FVM (right). *Source: Author (2025)*

*Internal* circulation, facilities, and emergency preparedness are substantially non-compliant, restricting independent use, particularly for PwD who require vertical mobility or enhanced safety features. The most significant barrier is the complete absence of accessible elevators at both JHM and FVM, which prevents wheelchair users from independently accessing different museum levels. Ramps at both sites are either retrofitted (JHM) or excessively steep and unmarked (FVM), reducing overall usability. Horizontal circulation is further impeded by cluttered pathways, frequently uneven or slippery flooring, especially at FVM, and a lack of clear wayfinding signage or glass wall markings.

Internal lighting is inconsistent and inadequate and does not support visual communication; the unregulated use of spotlights and strobe lighting may cause sensory distress (see Figure 4, left and right). Museum facilities are severely deficient: PwD restrooms lack compliant turning space and accessible fixtures, such as grab bars, sinks, mirrors, flush mechanisms, and multi-sensory emergency alarms. JHM lacks a lactation room entirely, and both prayer rooms are characterised by inadequate wayfinding and insufficient space. Emergency preparedness is critically inadequate: neither museum provides visible or


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accessible evacuation plans, audible or visual (strobe) alarms, reachable fire alarm activation points, or designated accessible emergency exits or refuge areas, which poses significant safety risks for all PwD.

## DISCUSSION

The findings demonstrate that museum inaccessibility in Indonesia is systemic, fundamentally contradicting museums' globally recognised role as inclusive institutions serving cultural, social, and educational functions. Solima (2017) identifies physical and communication accessibility as equally essential to an inclusive museum experience, yet evidence from both case studies shows these components remain fragmented and unintegrated in practice. The most significant deficiency lies in communication access: all participants reported a complete absence of institutionalised sign language services, directly contradicting the established importance of human-mediated interaction in museum engagement (Chidiac et al., 2024). Compounding this, limitations in auxiliary aids and digital accessibility further marginalise PwD, illustrated by one participant's observation that museums do not appear to consider them their target audience. Together, these findings point to a systemic failure to implement multimodal interpretation strategies and leverage technology for equitable participation, both central to UD principles (Brischetto et al., 2023; İşlek, 2023).

Analysis of external and internal physical elements reveals a parallel failure to apply UD principles in ensuring safe, independent museum navigation, consistent with Rocha et al. (2022). Externally, unsafe pedestrian pathways and inequitable transportation access violate the principle of seamless connectivity, compelling visitors to depend on external assistance rather than navigate independently. Internally, inaccessible interior design, characterized by dark atmospheres and insufficient visual contrast, fails to meet the sensory needs of diverse visitors, aligning with Wendorff (2023) and Kusuma et al. (2025), while the complete absence of accessible elevators constitutes a fundamental limitation of physical accessibility standards (Zulpiani & Rusyani, 2023). Additional gaps in sanitation facilities and emergency preparedness further suggest that safety, dignity, and inclusion remain secondary rather than primary institutional considerations. Collectively, these findings indicate that Indonesian museums continue to operate within a fragmented, compliance-focused approach that falls significantly short of genuine inclusivity. The *Museum Accessibility Framework* proposed in this study, encompassing physical access across external and internal elements alongside communication access, offers an empirically validated tool to address this gap, underscoring the need to reconcile heritage conservation and inclusive design as complementary institutional imperatives.

These implications extend beyond Indonesia. The IMAT was itself

partly constructed from the Malaysian Standard (MS1184:2014), the barriers identified at JHM and FVM, such as absent sign language provision, non-compliant elevators, and inadequate wayfinding, offer a directly transferable diagnostic lens for Malaysian heritage institutions facing comparable constraints between conservation and accessibility. Many of Malaysia's own heritage museums, housed in colonial-era buildings similar to JHM and FVM, confront the same tension between preservation mandates and UD retrofitting. The proposed framework therefore offers Malaysian planners, heritage agencies, and cultural-tourism authorities an empirical reference for assessing inclusive cultural-space planning across comparable Southeast Asian urban heritage contexts, reinforcing regional efforts toward ASEAN-wide accessible heritage tourism standards.

## CONCLUSION

This study demonstrates that Indonesian museums experience systemic, rather than incidental, inaccessibility. To analyse this structural exclusion, the research introduces the *Framework of Museum Accessibility, which comprises three attributes: Communication, External elements, and Internal Elements* (see Figure 5). This framework underscores the importance of balancing efforts to address physical inaccessibility with efforts to enhance communication access.

Physical inaccessibility, often rooted in heritage preservation perspectives, requires a paradigm shift in which accessibility is recognised as enhancing, rather than compromising, cultural value. Achieving this balance requires addressing external barriers, inadequately designed entrances, inaccessible ticketing systems, insufficient pathways, and limited transportation and parking, that hinder access before entry, alongside internal barriers such as unsafe circulation, non-intuitive wayfinding, inadequate lighting, inaccessible restrooms, and insufficient emergency preparedness, all of which compromise safety and the overall visitor experience.


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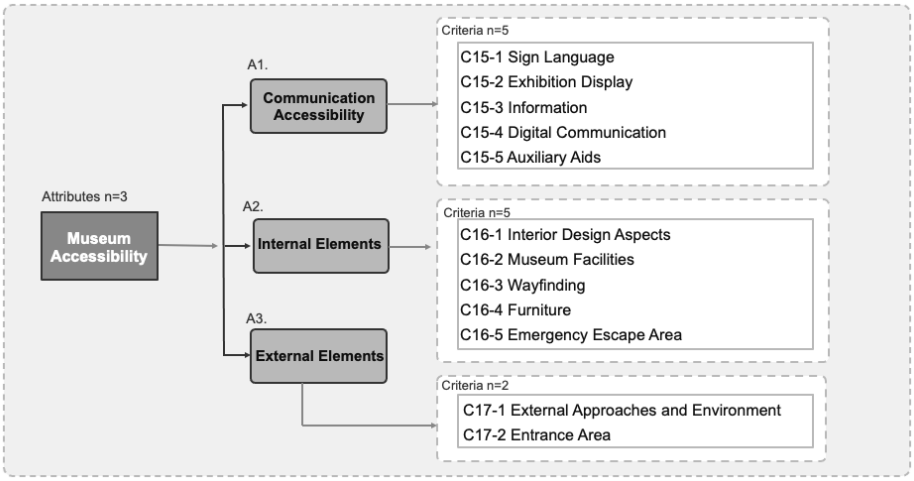



**Figure 5:** Framework of Museum Accessibility. *Source: Author (2025)*

Simultaneously, genuine inclusivity requires museums to prioritise communication accessibility, ensuring that access extends beyond the physical environment to encompass the interpretation of information. Achieving this demands a comprehensive, collaborative framework that reconciles heritage conservation with inclusion by balancing physical accessibility elements (external and internal) with communication access, guided by user-centred design, inclusive planning, and the active participation of PwD in both design and evaluation processes.

These improvements can be prioritised across three timeframes. Urgently, museums must address the absence of sign language services, the lack of accessible elevators, non-compliant PwD restrooms, and absent emergency evacuation provisions through immediate remedial retrofitting and staff-facing service protocols. In the medium term, attention should turn to wayfinding, tactile guides, lighting and contrast, digital accessibility (WCAG compliance), and auxiliary aids, requiring museum-level design and procurement upgrades over a one- to two-year horizon. Longer term, institutional and policy reform should establish a unified national accessibility standard, mandate museum-specific technical guidelines, and strengthen enforcement and accreditation linkages through coordinated action from the Ministry of Public Works, the Ministry of Education and Culture, and museum accreditation bodies.

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# QUANTITY SURVEYORS AS ENABLERS OF ENVIRONMENTAL, SOCIAL AND GOVERNANCE INTEGRATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

**Iris Ng Chin Rou[1], Mohd Suhaimi Mohd-Danuri[2], Mahanim Hanid[3], Zul Zakiyuddin Ahmad Rashid[4,] Mohd Hanizun Hanafi[5]**

[1,2,3]*Centre for Building, Construction & Tropical Architecture,*
*Faculty of Built Environment,*
UNIVERSITI MALAYA
[4]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[5]*Faculty of Architecture and Ekistics,*
UNIVERSITI MALAYSIA KELANTAN

## Abstract

The increasing emphasis on sustainability in the Malaysian construction industry highlights the importance of Environmental, Social and Governance (ESG) practices as a structured approach to sustainable development. As a major contributor to Malaysia's economic growth, the construction sector faces growing pressure to balance economic performance with ESG considerations. This study explores the evolving role of Quantity Surveyors (QSs) as enablers of ESG practices in the Malaysian construction industry. ESG indicators from the FTSE Russell ESG Scores published by Bursa Malaysia were used to examine the alignment between ESG principles and QS professional practices across construction stages. A qualitative approach was adopted through semi-structured interviews with six middle-management professionals from contractor firms. The findings reveal that QSs contribute significantly to ESG implementation through green procurement, occupational safety and health (OSH), and ethical governance. However, implementation is constrained by resistance to change, supply chain limitations, reporting challenges, project characteristics, and limited client support. The study highlights the need for stronger governance, digital solutions, incentives, standardized ESG reporting, and greater involvement of professional bodies.

***Keywords:*** Construction industry, ESG practices, Long-term value, Quantity Surveyors (QSs), Sustainability

[2] Corresponding author. Email: msuhaimi@um.edu.my

# INTRODUCTION

In the construction sector, the integration of Environmental, Social and Governance (ESG) principles has increasingly been recognised as a comprehensive framework for advancing sustainable practices. In Malaysia's construction sector, ESG disclosure has become increasingly formalized through Bursa Malaysia's reporting requirements and frameworks aligned with FTSE Russell and the GRI. Within these disclosures, the social pillar, particularly regarding health and safety, consistently receives the highest reporting scores (Ahmad et al., 2021; Ngu & Amran, 2020; Sulaiman et al., 2024). Empirical studies suggest that strong governance mechanisms significantly enhance overall ESG performance by ensuring effective oversight, ethical conduct and responsible decision-making within organizations (Baran et al., 2022; Chodnicka-Jaworska, 2021). Governance mechanisms that promote transparency, accountability and effective monitoring are critical in guiding organizational behaviour and strengthening stakeholder confidence. Such governance practices not only support environmental and social performance but also contribute to the development of a more resilient and trustworthy built environment. Consequently, the environmental, social and governance pillars are widely regarded as interdependent components that collectively drive sustainable construction and long-term industry transformation.

In the Malaysian construction industry, ESG integration is gaining increasing attention as stakeholders align project delivery with sustainability agendas and regulatory expectations. As projects become more complex and sustainability-driven, construction professionals are required to expand their traditional roles to support ESG implementation. Among these professionals, Quantity Surveyors (QSs) are strategically positioned to support ESG practices through their roles in cost management, procurement, contract administration, and financial governance across the project lifecycle. Their involvement in decision-making enables them to influence sustainable procurement, resource efficiency, risk management, and ethical project practices. Existing literature indicates that project-level ESG performance in Malaysia's construction sector remains underexplored. To address this gap, this paper leverages the strategic positioning of Quantity Surveying (QS) practices to explore the role of QS professionals as enablers of ESG integration in construction projects.

# LITERATURE REVIEW

## Overview of ESG Practices in Construction Industry

ESG enables stakeholders to assess how firms manage risks and opportunities associated with environmental and social challenges while maintaining strong governance practices (Duuren et al., 2016). Its growing importance is evident in

the rise of ESG investing, reporting, and indicators, which collectively support transparent evaluation, comparability, and accountability across industries (Gong et al., 2023; Akomea-Frimpong et al., 2024). ESG investing applies sustainability criteria to guide investment decisions, while ESG reporting provides structured disclosure of organisational performance, and ESG indicators offer measurable benchmarks for assessing responsible practices. The increasing reliance on ESG ratings in global financial markets further underscores its role as a dominant tool for sustainability assessment, surpassing traditional approaches such as Corporate Social Responsibility (CSR) (Kamińska-Witkowska, A. & Matuszak-Flejszman, A., 2023; Lin, 2023).

The construction industry encompasses a broad range of activities, including the development of transportation systems, water infrastructure, and public facilities, alongside the production of construction materials (Scott et al., 2013). ESG practices are particularly critical due to the sector's significant role in economic development, infrastructure provision, and environmental impact. Effective implementation of ESG in this sector relies heavily on strong corporate governance, which underpins the ability to achieve sustainability goals, reduce greenhouse gas emissions, enhance resource efficiency, and improve worker welfare.

## ESG Rating

A range of ESG evaluation methods and standards has been developed to facilitate systematic performance assessment, as summarised in Table 1 and Table 2. It provides structured guidance for measuring and reporting ESG performance across economic, environmental, and social dimensions (Gong et al., 2023; Kocmanova et al., 2012; Sulaiman et al., 2026). Collectively, these standards enhance comparability, reliability, and consistency in ESG disclosures, enabling stakeholders to evaluate corporate sustainability performance more effectively across industries and regions.

**Table 1:** Evaluation Methods

| No. | Evaluation Method | Scope/ Indicator | Description |
|---|---|---|---|
| 1. | Organization Global Reporting Initiative (GRI) | Economic, Environmental, Social | In 2006, the third version of Sustainability Reporting Guidelines (G3) was released and G3.1 which is an update and completion of the Guidelines' most recent generation was released in March 2011. |
| 2. | United Nations Conference on Trade and Development (UNCTAD) | Corporate Responsibility | Issuing guidelines on corporate responsibility indicator including the measurement methodology. |


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| | | | |
|---|---|---|---|
| 3. | Chartered Financial Analyst (CFA) Institute | Environmental, Social, Governance | Creating a manual for investors, proposing indicators of ESG practices which can be used in investment. |
| 4. | The European Federation of Financial Analyst Societies (EFFAS) | Environmental, Social, Governance | As a company association financial analysts, it was appointed by the European Commission in integration of ESG factors into investment decision-making. |
| 5. | International Federation of Accountants (IFAC) | Economic, Environmental, Social | Preparing a comprehensive performance features and key performance indicators within each of three pillars of sustainable development. |

*Source: Kocmanova et al. (2012)*

**Table 2:** ESG Standards and Objects

| Standard | Abbreviation | Scope | Industry | Target | Detailed Name |
|---|---|---|---|---|---|
| Global Reporting Initiative | GRI | ESG | Universal | All parties involved | GRI200, GRI300, GRI400 |
| Sustainability Accounting Standards Board | SASB | ESG, Business Model | Industry assessment | Investors | SASB Standards |
| Organization for Standardization | ISO | ESG | Universal | All parties involved | ISO 9001, ISO 26000, ISO 14001, ISO 50001 |
| Carbon Disclosure Project | CDP | Environment | Universal | All parties involved | CDP Standards |

*Source: Gong et al. (2023)*

Bursa Malaysia introduced the FTSE4Good Bursa Malaysia Index (F4GBM) to recognise public-listed companies demonstrating strong ESG practices, serving as a benchmark for ESG-focused investment decisions while promoting transparency and wider ESG adoption (Atan et al., 2018; Maryssa et al., 2022). Inclusion in the index is determined using the FTSE Russell ESG Score Model (refer to Figure 1), which adopts a structured bottom-up approach to assess companies' exposure to and management of ESG risks across environmental, social, and governance pillars (Wong et al., 2022; Maryssa et al., 2022).

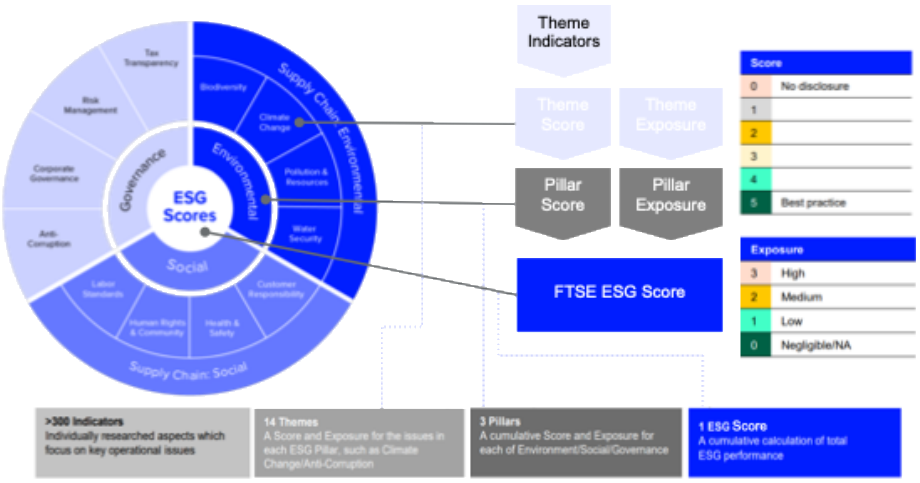



**Figure 1:** FTSE Russell ESG Scores
*Source: LSEG (2025)*

## QS Practices as Enablers of ESG

This study employs the FTSE Russell ESG Rating as the primary framework to evaluate how quantity surveyors' (QS) professional practices or services align with ESG principles, highlighting their role as key enablers of ESG implementation. It systematically examines the evolution of traditional QS functions which historically centred on cost, time, and quality towards supporting broader ESG objectives such as environmental protection, social well-being, and governance transparency. According to the RISM (2021), QS services are broadly categorised into basic and supplementary services. This classification was used as the basis for analysing the alignment between QS professional practices and ESG principles.

QS often traditionally referred to as construction economists, are key professional advisors who collaborate with architects, engineers, contractors, suppliers, project owners, and financiers to manage cost, value, and contractual matters throughout the project lifecycle (Khan et al., 2024; Osunsanwo & Dada, 2019). Contemporary literature highlights a broad consensus that core QS professional responsibilities now encompass a comprehensive suite of strategic and operational tasks, most notably: cost planning, procurement advisory, tender evaluation, and contract administration. Furthermore, modern QS practice increasingly integrates advanced competencies such as value engineering, life cycle costing, post-contract valuation, and rigorous documentation and reporting. By executing these essential roles, increasingly supported by digital tools and ICT-enabled approaches, QS professionals safeguard financial probity, integrate


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contractual and strategic considerations, and ensure sustainable, value-driven project delivery (Omotayo et al., 2022; Yap et al., 2021; Zhang et al., 2024).

In response to growing sustainability and ESG imperatives, QS practices are evolving beyond traditional cost management toward an integrated role that incorporates environmental and social considerations (Latif et al., 2020; Rahim et al., 2023). Highlighting this necessary adaptation, Omotayo et al. (2022) demonstrate how the QS profession is transitioning to meet the demands of sustainable construction within the Singaporean context. Ultimately, this shift positions QS professionals as critical contributors to ESG implementation, enhancing their advisory function by aligning project cost efficiency with broader sustainability objectives.

## RESEARCH METHODOLOGY

Given the limited empirical evidence on the roles of Quantity Surveyors (QSs) in ESG implementation, this study adopts an exploratory qualitative research design to map and clarify their contributions. Qualitative methods are particularly appropriate in under-researched areas, as they enable an in-depth understanding of participants' experiences, perceptions, and professional practices (Njie & Asimiran, 2014). Accordingly, semi-structured interviews were selected as the primary data collection method, as they allow for rich and detailed insights while maintaining flexibility in probing relevant issues (Adams, 2007).

A minimum sample size of 12 participants was targeted, consistent with qualitative research recommendations for achieving data saturation while ensuring manageable and in-depth analysis (Laari et al., 2022). Each interview lasted approximately 45 minutes and was conducted face-to-face to minimise potential miscommunication. Where necessary, virtual interviews were conducted using platforms such as Microsoft Teams and Google Meet, depending on participants' availability. Prior to data collection, a pilot study was undertaken to assess the clarity, relevance, and comprehensibility of the interview questions.

Purposive sampling was adopted, targeting QS and management-level professionals in contractor firms within Kuala Lumpur and Selangor due to the high concentration of construction activities. Given that ESG implementation often entails higher upfront costs (Widia & Wibisono, 2024), the sample focused on large firms classified as G6 and G7 by the Construction Industry Development Board Malaysia (CIDB) and further restricted to publicly listed companies on Bursa Malaysia, reflecting stronger governance and mandatory sustainability reporting (Yang, 2023; Sulaiman et al., 2024). Company selection was guided by stock performance data from iSaham (2025), with firms ranked accordingly, and interviewees approached sequentially until the target sample size or data saturation was achieved.

This study explores the role of Quantity Surveying (QS) professionals as enablers of ESG integration in construction projects. To analyse and interpret the collected data, thematic analysis was employed due to its flexibility and broad applicability across qualitative research designs (Cedervall & Åberg, 2010; Mooney-Somers et al., 2008). This approach is highly appropriate for this study, as it facilitates the identification of recurring patterns within participants' perceptions and professional practices.

## DATA COLLECTION, ANALYSIS AND DISCUSSION

### Interviewees' Particulars

Based on iSaham (2025), 71 public-listed construction companies exist in Malaysia, with 64 G6 and G7 firms located in Selangor (45) and Kuala Lumpur (19). To recruit participants, 100 email and 60 LinkedIn invitations were sent to professionals from these companies, however within one month, as depicted in Table 3 only six agreed to participate. Similar to a study by Sulaiman et al. (2025), the limited participation was attributed to heavy workloads, confidentiality concerns, and restrictive HR policies in public listed companies. Ultimately, this limited participation mirrors existing literature: it highlights both the underexplored nature of project-level ESG performance in the Malaysian construction sector and the ongoing, complex adaptation required by QS professionals to meet sustainable construction demands. Tóth et al. (2021) argues that smaller participants can suffice when the information power is high due to focused aims and strong theoretical framing. Villarreal-Samaniego (2021) reinforces that even small, well-justified participants can yield rich qualitative insights when sampling is purposive and instrument design is rigorous. Furthermore, this sample size proved sufficient for qualitative inquiry; data saturation was achieved by the fifth interview, after which no new themes or insights emerged during subsequent analysis.

**Table 3:** Interviewees' Profile

| Interviewee | Gender | Position | Years of Experience | Contractor's Grade |
|---|---|---|---|---|
| 001 | Male | Senior QS | 6 | G7 |
| 002 | Female | Asst. Manager, Sustainability Department | 5 | G7 |
| 003 | Male | Senior QS | 12 | G7 |
| 004 | Female | Senior QS, Asst. Contract & Commercial Manager | 10 | G7 |
| 005 | Female | Senior QS | 5 | G7 |
| 006 | Female | Asst. Manager, Sustainability Department | 3 | G7 |


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## ANALYSIS AND DISCUSSION

The following thematic analysis findings, as illustrated in Figure 2, are structured around the roles of Quantity Surveyors (QS) across the three ESG pillars.

### Main Theme 1: QSs' Roles in the Environmental Pillar

The findings show that all six interviewees recognised QS as key contributors to environmental sustainability in construction projects. Interviewee 001 emphasised their role in developing and managing green supply chains, including ensuring compliance with recognised certification standards, with the following excerpt:

> "I am currently handling a terrace housing development that is subject to ESG requirements. Part of my role is updating the Green Building Index (GBI) score sheet every monthly. That means I need to track material orders like concrete and reinforcement bars, and making sure the relevant green certifications are in place to show compliance" (Interviewee 001)

Interviewee 005 highlighted their ability to bridge the cost-sustainability gap through value engineering and life cycle costing in evaluating green materials and approaches which supports earlier studies indicating that QS's roles have expanded beyond traditional cost management to include sustainability considerations (Ma and Luu, 2013).

> "Quite often, green materials appear more expensive than conventional options, can be almost double the original budget. When that happens, clients usually ask us to justify the cost difference. That is where our role as QSs really come in. Instead of focusing only on upfront costs, we rely heavily on value engineering and life-cycle costing. We look at how the material performs over the entire building lifecycle, things like operational savings, durability, and lower maintenance." (Interviewee 005)

Consistent with prior studies by Bonifazi et al. (2025) and Anifowose et al. (2013), the findings also emphasise QS's involvement in construction waste management and carbon-related practices. The views expressed by Interviewee 001, who noted that QS, particularly those who are site-based, are responsible for monitoring material usage, coordinating delivery schedules, and overseeing on-site waste segregation practices. They are also increasingly involved in embodied carbon assessment and documentation, reflecting a growing alignment with global sustainability practices.

**Main Theme 2: QSs' Roles in the Social Pillar**

Compared to the environmental dimension, QS's roles in the social pillar are perceived as less prominent, with only four interviewees recognising their contributions. Nevertheless, all respondents highlighted QS's involvement in occupational safety and health (OSH), indicating that this is the most visible social responsibility undertaken by QS. Their responsibilities include ensuring adequate provision of personal protective equipment (PPE), labour accommodation, safety signage, and compliance with safety requirements. Consistent with Anugwo and Okorie (2021), this observation emphasizes the crucial role of QS in driving health and safety (H&S) improvements within the industry.

In addition, interviewee 001, 003 and 005 emphasised that QS contribute to quality control by ensuring that construction materials comply with specifications and statutory requirements, including fire safety standards. Despite ongoing challenges in aligning costs with social sustainability goals, both this study and prior research emphasise the important role of QSs in budgeting for safety measures, monitoring their implementation, and ensuring compliance (Yang et al., 2021; Anugwo & Okorie, 2021; Aag & Latief, 2023).

> "I remember at the early stage of my project, we organised a workshop specifically to brief site workers on ESG and QSHE requirements, which really helped set the right expectations from the start." (Interviewee 001)
> "It is also very important for us to make sure that all construction materials strictly comply with approved specifications and statutory requirements, such as fire safety standards. If materials do not meet fire or safety requirements, it directly puts occupants, workers, and also the public at risk." (Interviewee 005)

**Main Theme 3: QSs' Roles in the Governance Pillar**

Similar to the social dimension, QS's roles in the governance pillar are perceived as less prominent, although four interviewees acknowledged their contributions. The findings suggest that increasing emphasis on transparency and traceability in the construction industry is reshaping QS practices. Interviewees 001 and 004 noted the growing use of digital procurement platforms to enhance transparency in tendering and payment processes, reduce information asymmetry, and strengthen accountability. These practices are supported by literature highlighting the role of e-procurement and e-tendering systems in reducing fraud, improving auditability, and enhancing governance standards (Aduwo et al., 2020; Gupta et al., 2020).


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> "Tender evaluations are guided by a structured scoring framework that looks at both technical requirements and ESG-related criteria, rather than simply awarding the contract to the lowest bidder… this digital and transparent procurement approach helps strengthen governance by improving fairness, accountability, and auditability, while also supporting ESG objectives through ethical sourcing and responsible contractor selection." (Interviewee 004)

Furthermore, according to interviewees 005 and 006, QSs play an important role in documentation and record management to support ESG reporting and auditing. Their responsibilities include collecting and verifying ESG-related data, such as greenhouse gas emissions, and ensuring accurate documentation for submission to sustainability teams. This function is critical in strengthening the reliability and credibility of ESG disclosures, as robust documentation underpins effective audit processes and compliance with both financial and non-financial reporting requirements (Hossain et al., 2024; Fernández et al., 2025; Bamahros et al., 2022).

> "From my experience, the challenge with ESG data collection is not just about gathering the information, it is also about managing the documents. A lot of ESG-related data is scattered across different sources, like site records, procurement documents, delivery orders, and consultant reports." (Interviewee 006)

The FTSE Russell ESG scoring framework (Figure 1) comprises 14 themes and over 300 indicators, with each theme containing between 10 and 35 specific metrics. Consequently, based on the literature review, this study adopts these 14 overarching thematic areas as an analytical framework to examine and compare QS roles against established ESG standards. As illustrated in Figure 2, the overall findings map core QS roles (left) to these 14 ESG themes (centre). Furthermore, the right side of the figure details the specific practices identified by interviewees, e.g., green procurement and carbon accounting, demonstrating how QS professionals actively enable ESG integration in construction projects.

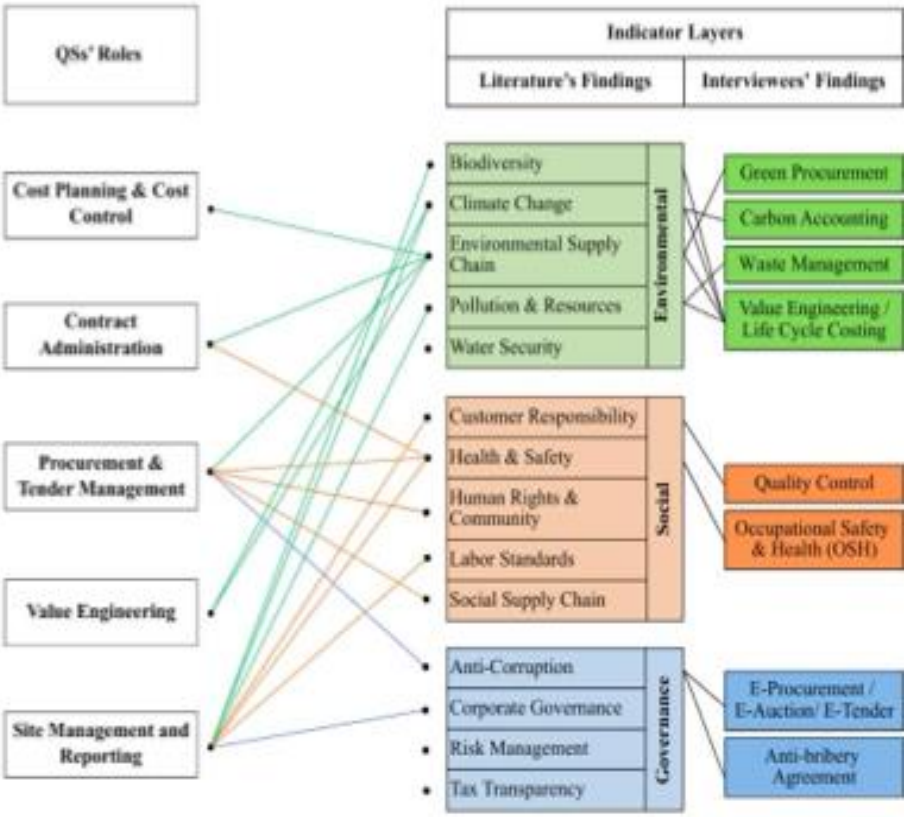



**Figure 2**: Interview Findings


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## CONCLUSION

By examining the alignment between QS roles and ESG principles, this study highlights the profession's pivotal role in advancing ESG integration within Malaysia's large-scale construction sector, particularly among G7 public-listed contractors. The findings reveal that QSs undertake multifaceted roles that significantly contribute to ESG implementation across all project stages. Environmentally, QSs advise on green material procurement and evaluate sustainable alternatives through value engineering. Socially, they safeguard worker and community welfare through stringent site safety and PPE provisions. In governance, QSs enforce transparency and accountability by maintaining confidential estimates, conducting fair tender evaluations, and validating ESG data for sustainability reporting.

To capitalise on this potential, construction firms are urged to integrate QS into their sustainability frameworks. Practically, this involves expanding the QS mandate to audit non-financial metrics for ESG reporting and embedding mandatory sustainability weightings into multi-criteria procurement evaluations. Furthermore, mandating LCC as an early-stage deliverable will ensure whole-life environmental value is prioritised over initial capital costs. Ultimately, by utilising contracts to enforce corporate ESG targets at the site level, QS professionals will act as vital anchors in the broader sustainability governance of construction projects.

To effectively implement ESG, QS must be well-versed in a wide range of ESG frameworks, standards, and regulatory requirements to support project-level application. Consequently, the respective professional bodies and contractor organisations must actively drive capacity building by embedding ESG-focused seminars, workshops, and industry forums into targeted continuing professional development (CPD) programmes. These structured, industry-led initiatives are essential for equipping QS professionals with the continuous learning needed to successfully operationalize ESG at the project level. Furthermore, integrating ESG principles into formal education is crucial, requiring close collaboration between construction professional bodies and universities or colleges to review and enhance existing curricula.

Overall, the study highlights that QS serve as enablers of ESG integration, bridging technical, financial, and regulatory aspects to promote sustainable construction practices. Their contributions position them as strategic drivers in advancing ESG agendas within the Malaysian construction industry. Future research may extend this line of inquiry by examining the roles of other construction professionals, such as architects and engineers, to provide a more comprehensive understanding of ESG integration across the industry.

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## DISCLOSURE STATEMENT
The authors declare no conflicts of interest.

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# PERCEIVED NEIGHBOURHOOD BUILT ENVIRONMENT AND PHYSICAL ACTIVITY FOR LEISURE PURPOSES: THE MODERATING EFFECTS OF NEIGHBOURHOOD SOCIOECONOMIC STATUS

***Noor Hashimah Hashim Lim[1], Nurdiyana Zainal Abidin[2], Liyana Hasnan[2], Nadzirah Hosen[3] and Junainah Abu Kasim[4]**

[1]*Faculty of Built Environment,*
UNIVERSITI MALAYA
[1]*International Institute of Public Policy and Management (INPUMA),*
UNIVERSITI MALAYA
[2]*Dept. of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA
[3]*Institute For Environment and Development (LESTARI),*
UNIVERSITI KEBANGSAAN MALAYSIA
[4]*Dept. of Landscape Architecture, Faculty of Design and Architecture,*
UNIVERSITI PUTRA MALAYSIA

## Abstract

Sedentary lifestyle is a persistent issue in Malaysia, contributing to the country's rising obesity rate. Evidence throughout the years has highlighted that built and social environments are significant factors of physical activity; however, the estimation of those factors is seldom approached in Malaysia. As such, this paper examines the association between perceived neighbourhood-built environment (PNBE) and physical activity for leisure purposes (PAL) among urban Malaysian adults, moderated by neighbourhood socioeconomic status (NSES). Urban residents of higher- and lower-NSES in Johor Bahru city (n=256) were approached through stratified random sampling. The PNBE factors included were residential density, walking and cycling facilities, surrounding aesthetics, as well as safety from traffic and crime. Multi-group moderator analysis revealed that the construct of PNBE is significantly different across areas of higher- and lower NSES (p= 0.017, 95% CI). The findings contribute to health-oriented urban planning, highlighting the importance of integrating both aspects of built and social environments when designing neighbourhood interventions to promote active living.

***Keywords:*** Perceived neighbourhood-built environment, Leisure purpose physical activity, Neighbourhood socioeconomic status

[1] Corresponding author. Email: shimalim@um.edu.my

## INTRODUCTION

The role of the environment in shaping human behaviour has long been recognised (Bronfenbrenner, 1979). Building on this, Sallis, Owen and Fisher (2015) suggested that prolonged exposure to physical, social, and political environments can influence individuals' health behaviours. A particular health behaviour of interest in this paper is physical activity for leisure purposes (PAL). As ascertained by Høyer-Kruse, Schmidt, Hansen & Pedersen (2024), physical activity is a key element to combating not only chronic diseases, but also non-communicable diseases, which then ultimately helps in improving population health. However, despite growing attention and acknowledgement to this understanding, physical inactivity remains a growing global concern, with prevalence increasing from 27% in 2022 to 31% in 2024, placing the world off track to meet the targets of the Global Action Plan on Physical Activity 2018–2030 (World Health Organization, 2018, 2024). Unfortunately, this proportion is concurrent with Malaysia, where, based on the country's National Health and Morbidity Survey 2023, it was discovered that approximately 30% of Malaysian adults engage in insufficient physical activity (Institute for Public Health, 2023). In other words, 1 in 3 people are physically inactive. Studies among Malaysian adults further show that physical inactivity is more prevalent among individuals with chronic conditions, disabilities, and prolonged sedentary lifestyles, which highlights the significant influence of socio-environmental factors on physical activity levels (Lim et al., 2025). These studies show that there is a need for targeted understandings and interventions when promoting active lifestyles among Malaysians.

Supported by numerous accounts, the socio-environmental factor represented by neighbourhood socioeconomic status (NSES) is studied as an underlying construct in influencing physical activity as exemplified by studies from different localities among populations from Australia (Owen et al., 2007), the Netherlands (Zhu et al, 2021), Sweden (Sundquist et al., 2011), the United States of America (Sallis et al., 2018) and Belgium (D'Haese et al., 2014). The mixed findings across previous studies suggest that the moderating role of NSES is context-dependent, warranting further investigation within the Malaysian setting. Additionally, in a scoping review published by Høyer-Kruse, Schmidt, Hansen & Pedersen (2024) which scrutinised a total of 72 papers relating to exploring patterns in physical activity participation within varying social environments with specific focus in looking at socio-economic status, only five papers originate from Asia. This further solidifies the fact that the variables of interest in this paper are understudied in the said region.

Examining the moderating role of NSES in Malaysia provides valuable insights into potential health disparities between communities of differing socioeconomic conditions. As suggested by Sallis (2009) in Van Dyck et al.


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(2009), NSES should be considered in place-based public health research because health behaviours are shaped by both physical and social environments. Incorporating these dimensions offers a more comprehensive understanding of physical activity behaviours and their underlying determinants. Such evidence can better inform health-oriented urban planning policies (Lim, et al., 2023) by enabling interventions that are responsive to local socioeconomic contexts and more effective in promoting active lifestyles and reducing health inequalities. Therefore, the current study aims to generate empirically grounded insights into how neighbourhood-built environment characteristics can be strategically shaped to enhance PAL among urban Malaysian adults, accounting for socioeconomic differences and socio-demographic contexts. Within this context, two study objectives were established; (i) to examine the relationship between perceived neighbourhood-built environment (PNBE) attributes and PAL among urban Malaysian adults; (ii) to assess the moderating effect of NSES on the relationship between PNBE and PAL, to identify differential influences across socioeconomic groups.

## LITERATURE REVIEW

Studies interested in the effects of the built environment attributes oftentimes found itself measuring the said variable either objectively or subjectively, or both. It is not surprising as both methods are widely recognised as valid approaches in understanding the connection between the living environment and human behaviours. Built environments measured objectively typically involves in quantifying the physical attributes of the spatial environment using geographic information systems and environmental audits (Li, Winter, Milburn & Padgett, 2021; Yu, Lin & Chen, 2025). The common characteristics captured can include but not limited to development density, land use zoning composition and distribution, connectivity as well as accessibility to places of interest respective to the studies. By contrast, the subjective perceived built environment quantifies a targeted population's lived experience by asking them to report their evaluations of their environments. This can include the perceived safety and security, accessibility to-and-fro destinations, and aesthetics of their surroundings; which oftentimes cannot be fully captured nor measured through objective assessments (Kent et al., 2017; Zhang & Mu, 2020).

While both approaches have been explored and utilised quite extensively, there is growing evidence that suggests that the subjectively perceived built environment is more direct in shaping individual behaviours and experiences (Zhang et al., 2024; Wei et al., 2024). It is argued this way purely due to the understanding that human actions are often guided not by the objective reality of the environment, but by how individuals interpret and respond to it. For instance, perceptions of safety, comfort, and attractiveness can significantly

influence whether individuals choose to engage in activities such as walking or recreational exercise, regardless of the objectively measured availability of facilities (Zhao et al., 2019). Similarly, perceived environmental qualities have been shown to have stronger associations with subjective outcomes such as happiness and neighbourhood satisfaction than objective measures alone (Kent et al., 2017; Lee et al., 2017).

Furthermore, discrepancies across objective and perceived measures are frequently observed, highlighting that the presence of infrastructure does not necessarily translate into its utilisation. For example, objectively walkable environments may still be underutilised if residents perceive them as unsafe or unattractive. Conversely, individuals may report higher levels of satisfaction and engagement in environments that may not score highly on objective indicators but are perceived positively due to personal or contextual factors (Zhang & Mu, 2020; Ye & Titheridge, 2017). As such, the study adopted perceived measures in order to gauge insights into how these environments are experienced and acted upon by individuals. It is thought that perception-based assessments may be more effective in explaining everyday behavioural patterns, particularly those related to PAL.

The World Health Organization conceptualises physical activity as a multidimensional construct undertaken across several domains, including activities exerted during work, while travelling through and from destinations, leisure-time, and sedentary behaviour (Bull et al., 2020). These domains differ fundamentally in their underlying context and motivations. Work and travelling-related activities are often utilitarian and necessity-driven, whereas leisure-time physical activity is discretionary and shaped by personal choice, preferences, and environmental affordances (Quinn, 2023). Consequently, while total physical activity captures overall energy expenditure, domain-specific measures provide a more nuanced insight into behavioural patterns and the contextual influences that shape activity engagement.

Physical activity for leisure purposes (PAL) is particularly important as it reflects voluntary engagement and intrinsic motivation, making it more sensitive to environmental and psychological influences compared to other domains. Unlike occupational or transport-related activity, which may be constrained by work demands or accessibility needs, PAL is largely influenced by individual perceptions, preferences, and perceived opportunities within the built environment. Empirical evidence suggests that PAL is more conducive to positive health outcomes, including mental well-being and provides better protection against chronic diseases, compared to other types of physical activity that may not yield equivalent benefits due to their obligatory or repetitive nature (Teno et al., 2024). This distinction reinforces the relevance of focusing on PAL when examining how environmental factors translate into behavioural outcomes.


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Furthermore, PAL serves as a critical indicator of how individuals interpret and respond to their surrounding environment, thereby offering a closer reflection of behavioural intention and agency. Because participation in PAL is discretionary, it is more directly shaped by perceived environmental qualities such as safety, accessibility, and aesthetics, which align closely with the concept of perceived neighbourhood-built environment. This makes PAL particularly valuable in urban management research, as it captures the extent to which planning interventions successfully translate into meaningful behavioural change. As such, isolating PAL enables a more precise understanding of how built environment interventions can foster active lifestyles at the individual level, beyond structural or necessity-driven forms of physical activity.

Residential density has been linked to PAL, although its influence is often shaped by context. In higher density neighbourhoods, it can support closer proximity to parks and recreational spaces, which encourages leisure walking and outdoor activities (Müller et al., 2024). However, Nigg et al. (2024) suggest that when density becomes too high, it may limit access to open spaces and reduce opportunities for recreation. Studies suggest that a balanced level of density is more supportive of PAL, as it provides both accessibility and liveable space for activity. Facilities for walking or cycling play a key role in supporting PAL by providing dedicated and safe spaces for movement. The presence of active living infrastructure, including pedestrian walkways and cycling lanes, reduces barriers and increases comfort to encourage more users (You et al., 2023). Empirical findings by Müller et al. (2024) indicate that individuals living in areas with better walking and cycling facilities are more likely to participate in leisure-based physical activities.

The perception and experience of people regarding their environment is oftentimes shaped by their surroundings' aesthetics. As put forth by You et al., (2023), supported by Zhong et al. (2024), visually appealing surroundings, such as an abundance of greenery and well-maintained spaces, enhance spatial enjoyment and encourage individuals to spend more time outdoors. Traffic and crime safety are quite critical in influencing whether individuals feel comfortable engaging in PAL. Even when infrastructure is available, concerns about traffic hazards, air pollution (Leh et al., 2011) or personal safety can discourage outdoor activity. Evidence shows that safer neighbourhoods, both in terms of traffic conditions and perceived crime, are more likely to support higher levels of PAL by reducing fear and increasing confidence in using public spaces (You et al., 2023; Yu et al., 2025).

As for neighbourhood socioeconomic status, it crucially moderates how the built environment attributes influence PAL. Individuals living in higher socioeconomic neighbourhoods are often found to be benefitting from better-quality infrastructure, accessible recreational public realms, and safer

environments, strengthening the positive effects of the environment on physical activity (Müller et al., 2024). In contrast, Yu et al. (2025) found that in lower socioeconomic settings, even well-designed physical environments may not translate into increased PAL due to constraints including but not limited to safety concerns. As such, NSES does not merely act as a background characteristic but actively conditions the relationship of the built environment and PAL, highlighting the need for this study.

## METHODS

### *Study Area, Subjects and Sampling*

Despite being one of Malaysia's fastest-growing urban cities, Johor Bahru, Johor has received less attention as compared to Klang Valley, especially in studies relating to uncovering urban obesogenic environment. As such, this leaves a geographical gap in understanding how obesogenic environments operate in other rapidly urbanising cities. Moreover, Johor Bahru provides a valuable setting for extending the evidence base beyond the Klang Valley where it experiences rapid urban expansion, increasing motorisation rate, and proximity to its neighbouring city-state, Singapore. Coffee et al. (2013) attested that housing property holds the highest value in terms of asset for a person, therefore, it is significantly associated to predicting socio-economic status. Employing this understanding, all neighbourhoods in the district of Johor Bahru were categorised into either "higher NSES" (higher than RM434) or "lower NSES" (lower than RM434) based on the neighbourhood areas' average transaction prices, as well as the median housing price per square foot of the said area reported by Malaysia's Valuation and Property Services Department. During data collection, the median housing price was RM434. Next, by using simple random sampling, 21 lower NSES and 22 higher NSES were chosen.

The sample size calculation of this study was calculated using *a priori* sample size calculation for Structural Equation Models put forth by Cohen (1988), supported by Westland (2010). The requirements were set as follows; probability level of 0.05, statistical power level of 0.80, 1 latent variable and 9 manifest variables, with an anticipated effect size of 0.30, the recommended minimum sample size to detect an effect is 87. The respondents were sampled using stratified random sampling, where the cross-sectional survey was conducted through face-to-face interviews on subjects aged 18 years and above. Only adults who had resided in their respective neighbourhoods for at least 3 years were included in the study. Self-reported socio-demographic information including gender, age, race, highest education level and housing address were collected. In the end, the study successfully engaged with 256 willing respondents from both neighbourhood categories to participate in the survey – far exceeding the sample size needed.


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***Measures***

*Outcome variable: Physical Activity for Leisure Purposes (PAL)*

Participants' PAL was assessed using the Global Physical Activity Questionnaire (GPAQ) developed by the WHO. Respondents reported the frequency (days per week) and duration (minutes per day) of physical activities performed across the GPAQ domains. Following WHO guidelines, activity intensity was converted into Metabolic Equivalent of Task (MET) values, with vigorous-, moderate-, and sedentary-intensity activities assigned 8, 4, and 1 MET, respectively. Weekly PAL was calculated by multiplying the assigned MET value by the reported frequency and duration of each activity, with the total expressed as MET-minutes per week. Based on WHO recommendations, participants were classified as sedentary (<600 MET-min/week), moderately active (600–3,000 MET-min/week), or vigorously active (>3,000 MET-min/week).

*Predictor variable: Perceived Neighbourhood Built Environment (PNBE)*

Perceived neighbourhood-built environment (PNBE) was measured using a modified version of the Neighborhood Environment Walkability Scale–Abbreviated (NEWS-A), originally developed by Saelens et al. (2002) and subsequently refined by Cerin et al. (2006). The instrument was adapted to reflect the Malaysian urban context while maintaining the original conceptual domains. Four neighbourhood attributes were evaluated: residential density, walking and cycling facilities, surrounding aesthetics, as well as safety from traffic and crime. Perceived residential density was assessed using six items measuring respondents' perceptions of the concentration of different housing types within their neighbourhood. Following the NEWS-A scoring protocol, housing categories were assigned weighted values according to their density, with higher-density housing receiving larger weights. A composite residential density score was obtained by multiplying the perceived prevalence of each housing type by its corresponding weight and summing the resulting values.

Walking and cycling facilities were assessed through four items examining the availability, condition, accessibility, and connectivity of sidewalks and bicycle or pedestrian paths. Neighbourhood aesthetics was measured using five items assessing street greenery, shade, cleanliness, and the visual attractiveness of both natural and built features. Finally, perceived safety from traffic and crime was assessed using six items addressing traffic conditions, vehicle speed, air pollution, street lighting, natural surveillance, and opportunities for social interaction while walking. All items were rated on a 4-point Likert scale of 1: Strongly agree, 2: Agree, 3: Disagree to 4: Strongly disagree, with higher scores indicating more favourable neighbourhood environmental perceptions. The scale was set to a 4-point scale to avoid collecting a 'neutral' answer. For the questions that are positively phrased, their reported answers were coded as is. On

the other hand, for the negatively phrased questions such as "there is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighbourhood", the answer of "strongly agree" indicates a less favourable walkability. As such, for such questions, the answers were reverse-coded items by flipping their numerical values before further analysis.

*Moderator variable: Neighbourhood Socioeconomic Status (NSES)*
Neighbourhood socioeconomic status (NSES) was determined using secondary property transaction data obtained from a local real estate database linked to the Valuation and Property Services Department Malaysia. Respondents' self-reported residential addresses were matched to the database using the street name, neighbourhood, and housing type to identify the median property value of their neighbourhood. As of July 2026, the median residential property value in Johor Bahru was RM434 per square foot. Neighbourhoods with property values above this threshold were classified as higher NSES, whereas those below the threshold were classified as lower NSES.

***Statistical Analysis***
For this cross-sectional study, Statistical Package for the Social Sciences (SPSS) version 22.0 and IBM SPSS AMOS version 23.0 were employed for data analysis, whereby the descriptive and latent variable's reliability analyses were conducted using the former, while Structural Equation Modelling (SEM) was conducted with the latter. Before further analysis, the latent variables involved were checked and passed reliability test where all items had a factor loading of not less than 0.5 and Cronbach's Alpha values of not less than 0.7. All data assumptions on the SEM requirements were checked and met. Physical activity for leisure purposes, residential density, race and education level were presented as single-measured items, therefore, only the remaining variables, i.e. surrounding aesthetics, walking and cycling facilities, as well as safety from crime and traffic; were put through the Pooled Confirmatory Factor Analysis. The fitness of the measurement model was established ($\chi^2$= 356.54, df= 298, $\chi^2$/df= 1.252, CFI= 0.970, TLI= 0.956, RMSEA= 0.016).

Convergent validity, discriminant validity, and composite reliability were subsequently established. Hence, data was imputed and the rest of the single-measured items, confounding variables and outcome variable were included to form an unconstrained structural model to be tested for NSES multi-group moderation analysis. Afterwards, the model fit for the unconstrained structural model was established ($\chi^2$= 857.400, df= 546, $\chi^2$/df= 1.986, CFI= 0.859, TLI= 0.890, RMSEA= 0.038). Next is to fully constrain the structural model so that the paths are forced to be equal in order to extract its chi-square value so as to compare the chi-square values of the unconstrained structural model and the


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constrained structural model. Multi-group moderation was tested with the establishment of the following hypothesis;

$H_o$: The relationship between perceived neighbourhood-built environment (PNBE) and physical activity level (PAL) does not differ across neighbourhood socioeconomic status (NSES); and
$H_1$: The relationship between perceived neighbourhood-built environment (PNBE) and physical activity level (PAL) differs across neighbourhood socioeconomic status (NSES).

As such, with the significance set at p= .05, a significant chi-square value indicates the rejection of the null hypothesis and vice versa. In the event of significant difference between areas of lower and higher NSES, individual path under the PNBE construct will be tested by constraining one path at a time.

## RESULTS

### *Demographic characteristics, physical activity for leisure purposes (PAL) and neighbourhood socioeconomic status (NSES)*

The sample consisted of 256 participants where the majority came from lower-NSES neighbourhoods (69%). Table 1 shows that the respondents were predominantly middle-aged, male, Malay, and had attained tertiary education. Also, PAL were generally low, with 77% of participants classified as sedentary. As shown in Table 2, sedentary behaviour was prevalent across both NSES groups, where the mean PAL was 464 ± 944 MET-min/week. An interesting finding is that, although a higher proportion of sedentary individuals was observed in higher-NSES neighbourhoods, the proportion of vigorously active persons was approximately twice that of those residing in lower-NSES neighbourhoods.

**Table 1: The respondents'** socio-demographic characteristics (n= 256)

| | **Overall** |
|---|---|
| **Age** | 39.4 ± 14.4 |
| **Gender, *% men*** | 59 |
| **Race, *%*** | |
| **Malay** | 50 |
| **Chinese** | 32 |
| **Indian** | 16 |
| **Others** | 2 |
| **Education, *%*** | |
| **Primary** | 19 |
| **Secondary** | 31 |
| **Tertiary** | 50 |
| **Leisure Time Physical Activity, *%*** | 464 METs/ week (SD= ±944) |
| **Vigorous level** | 4 |
| **Moderate level** | 19 |
| **Sedentary** | 77 |

**Table 2:** Proportion of **respondents'** leisure time physical activity (PAL) by neighbourhood socioeconomic status (NSES) (n= 256)

| **Neighbourhood Socioeconomic Status (NSES)** | **Leisure Time Physical Activity Level (PAL)** | | |
|---|---|---|---|
| | **Vigorous level** | **Moderate level** | **Sedentary** |
| **Lower *%*** | 3 | 23 | 74 |
| **Higher %** | 6 | 9 | 85 |

***Perceived neighbourhood-built environment (PNBE), physical activity for leisure purposes (PAL) and neighbourhood socioeconomic status (NSES)***

Figures 1 and 2 present the structural models for participants residing in higher- and lower-NSES neighbourhoods respectively. In the higher-NSES group, perceived walking and cycling facilities (β = .31) and perceived surrounding aesthetics (β = .37) were the only neighbourhood-built environment attributes significantly associated with PAL, with surrounding aesthetics exhibiting the strongest positive association. In contrast, among respondents from lower-NSES neighbourhoods, perceived residential density (β = −.15) and perceived safety from traffic and crime (β = .29) were the only significant neighbourhood predictors of PAL. Specifically, perceived residential density demonstrated a negative association with PAL, whereas perceived safety from traffic and crime was positively associated with PAL. Race and education level were significantly associated with PAL only in the lower-NSES group. Overall, the findings indicate that the environmental attributes associated with PAL differ between higher- and lower-NSES neighbourhoods.


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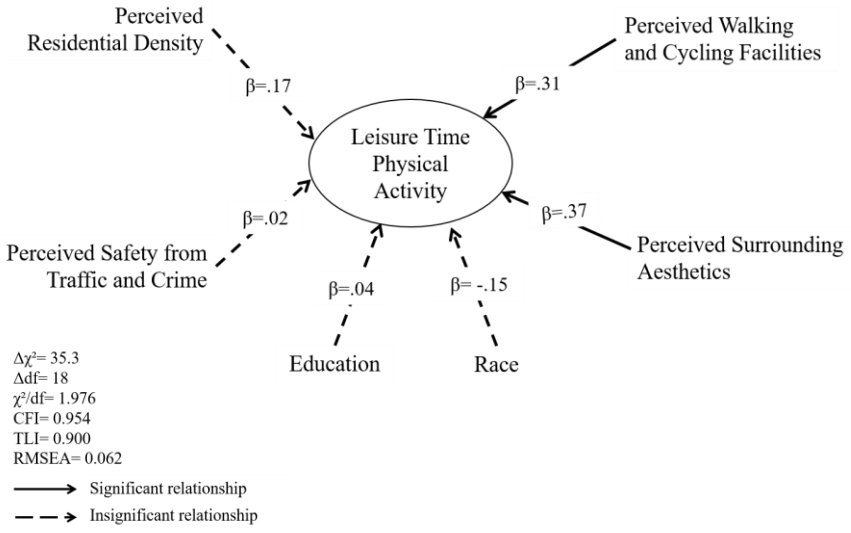



**Figure 1:** Perceived neighbourhood-built environment and physical activity for leisure purposes model for higher NSES

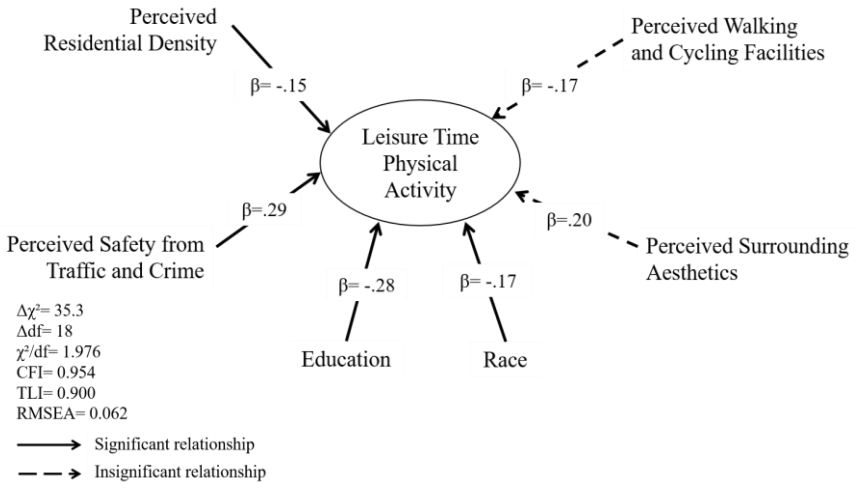



**Figure 2:** Perceived neighbourhood-built environment and physical activity for leisure purposes model for lower NSES

## DISCUSSION

The present study demonstrates that the neighbourhood characteristics associated with PAL differ according to NSES. Specifically, perceptions of walking and cycling facilities and surrounding aesthetics were significant predictors of PAL among residents of higher-NSES neighbourhoods, whereas perceived safety from traffic and crime and residential density were significant predictors among residents of lower-NSES neighbourhoods. Furthermore, multi-group analysis revealed that only the relationship between perceived residential density and leisure-time physical activity was moderated by NSES, suggesting that the influence of residential density is dependent on the socioeconomic context in which it is experienced. These findings support ecological models of health behaviour, which propose that physical activity is shaped by the interaction between environmental and social contexts rather than by the physical environment alone (Sallis, Owen and Fisher, 2015). More importantly, they indicate that neighbourhood planning interventions may not produce uniform health outcomes across different socioeconomic settings.

The significant role of walking and cycling facilities and surrounding aesthetics in higher-NSES neighbourhoods suggests that environmental quality becomes increasingly important once fundamental neighbourhood conditions have been met. Residents living in more affluent neighbourhoods are likely to have greater access to recreational opportunities and may therefore be more responsive to neighbourhood attributes that improve the quality of the walking experience, such as attractive streetscapes and connected walking and cycling networks. These findings are consistent with previous studies reporting that neighbourhood aesthetics and walkability are positively associated with PAL, particularly in socioeconomically advantaged communities where residents have greater flexibility to engage in recreational activities. Consequently, investments aimed at improving the quality of neighbourhood environments may provide greater health benefits within higher-NSES communities.

In contrast, perceived safety from traffic and crime are strong environmental predictor of PAL in lower-NSES neighbourhoods, while perceived residential density demonstrated a negative association. These findings suggest that residents are unlikely to engage in outdoor recreational activities if they perceive their neighbourhood to be unsafe, regardless of the availability of pedestrian infrastructure or recreational facilities. Similarly, higher residential density may discourage PAL when accompanied by overcrowding, poor maintenance, or limited recreational opportunities. Therefore, the health benefits commonly associated with compact urban development should not be assumed to occur automatically. Instead, residential density should be considered alongside the quality of neighbourhood infrastructure and the overall living environment.


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The moderating effect of NSES on residential density provides an important contribution to neighbourhood planning literature. Although compact development has frequently been promoted as a strategy for encouraging active living, the present findings indicate that the effectiveness of residential density depends on the socioeconomic conditions of the surrounding neighbourhood. In Malaysia, higher-density developments located within higher-NSES neighbourhoods are often characterised by better-maintained communal facilities, private recreational amenities, landscaped public spaces, and stronger neighbourhood management. Conversely, higher-density developments within lower-NSES neighbourhoods may experience challenges relating to limited recreational facilities, inadequate maintenance, traffic conflicts, and perceptions of insecurity. Consequently, residential density should not be viewed as an isolated planning objective but rather as one component of a broader neighbourhood system that includes accessibility, environmental quality, safety, and community management. This finding reinforces the need for planners to adopt a more context-sensitive approach when implementing compact city policies.

The findings also provide several practical implications for urban planning and health-oriented planning in Malaysia. First, neighbourhood planning strategies should move beyond a one-size-fits-all approach by recognising that different neighbourhood characteristics influence physical activity across socioeconomic contexts. In higher-NSES neighbourhoods, planning efforts should prioritise enhancing walking and cycling infrastructure, improving streetscape aesthetics, increasing urban greenery, and creating attractive public spaces that encourage recreational walking and active lifestyles. These interventions complement Malaysia's aspirations to develop liveable, low-carbon, and people-oriented cities under the National Physical Plan (NPP-4) and National Urbanisation Policy.

Conversely, planning priorities within lower-NSES neighbourhoods should focus on creating safe and supportive environments before promoting higher residential densities. Local authorities should strengthen traffic-calming measures, improve street lighting, enhance natural surveillance through Crime Prevention Through Environmental Design (CPTED), and ensure regular maintenance of neighbourhood parks and recreational facilities. At the same time, affordable higher-density housing developments should be accompanied by accessible open spaces, connected pedestrian networks, and community recreational facilities to ensure that compact development translates into healthier lifestyles rather than simply increasing residential concentration. Such interventions are particularly relevant given the increasing prevalence of physical inactivity, overweight, and obesity reported in the National Health and Morbidity

Survey (NHMS) 2023, which highlights the need to integrate health considerations into urban planning practice.

Overall, the present findings demonstrate that neighbourhood socioeconomic context influences how residents respond to the built environment. Integrating both physical and social environmental considerations into neighbourhood planning can contribute to more equitable and effective health promotion strategies. Future research should validate these findings using longitudinal designs and objective measures of both neighbourhood environments and physical activity to better understand the causal pathways linking neighbourhood design, socioeconomic context, and active living.

## CONCLUSION

As a conclusion, this study demonstrates that NSES influences the relationship between PNBE and PAL among Malaysian adults. While walking and cycling facilities and surrounding aesthetics were more influential in higher-NSES neighbourhoods, perceived safety and residential density played a greater role in lower-NSES neighbourhoods, with NSES significantly moderating only the association between residential density and physical activity. These findings highlight the importance of adopting context-sensitive neighbourhood planning strategies rather than a one-size-fits-all approach. Integrating both built and social environmental considerations into urban planning may contribute to healthier, more active, and equitable communities in Malaysia.

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# ARCHITECTURE WITHOUT ARCHITECTS: SPATIAL BEHAVIOUR OF THE HOMELESS IN KUALA LUMPUR

**Nadiyah Noor Hisham[1], Mastura Adam[2*], Nurdiyana Zainal Abidin[3], Nur Mazidah Che Ghani[4], and Nangkula Utaberta[5]**

[1,2,3,4] *Department of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA
[5] *School of Architecture and Built Environment,*
*Faculty of Engineering, Technology and Built Environment,*
UCSI UNIVERSITY

## Abstract

Shelter is one of the human basic needs. One of a person's necessities is a place to live. Homelessness in Kuala Lumpur is a growing concern, and this study explored how homeless people navigate through Kuala Lumpur's urban spaces for survival. It aimed to understand their sleeping habits and how the decisions reflect the basic human needs. The study employs a qualitative approach through observation and appraisal in five identified homeless concentrated nodes in Kuala Lumpur: Jalan Tunku Abdul Rahman, Chow Kit, Masjid Jamek, and Pudu. An appraisal was used to record homeless behaviours, using thematic analysis to detect trends. The data collected indicate that self-built shelters, valuable organisations, well-lit areas, and coverings are intentional survival strategies. Through the interpretation of the theories of Architecture without Architects, Hierarchy of Needs, and Environmental Psychology, the data show that homeless individuals may adapt to public spaces to secure safety, privacy, belonging, and dignity. These behaviours, even under deprived conditions, demonstrated that humans will naturally adapt themselves to meet their basic needs. The study found that homeless people's spatial behaviour was an intentional strategy and that, unlike current law enforcement strategies, understanding it may yield more inclusive design and policy solutions to eradicate homelessness in Kuala Lumpur.

***Keywords*:** Homelessness, Architecture without Architects, Spatial Behaviour, Kuala Lumpur, Maslow's Hierarchy of Needs

[2] Corresponding author. Email: mastura@um.edu.my

# INTRODUCTION

Homelessness is one of the major urban issues globally and is particularly visible in Kuala Lumpur. Homeless populations in Kuala Lumpur are mainly concentrated in central urban areas like Jalan Tunku Abdul Rahman, Chow Kit, Pudu and Masjid Jamek. These locations attract the homeless due to their access to welfare services, social connections, and potential economic opportunities (Jasni et al., 2022). However, the current literature on homelessness in Kuala Lumpur primarily focuses on policy, welfare, and rehabilitation initiatives, often overlooking discussions on the spatial behaviours of the homeless, which are crucial in understanding their lived experiences and survival strategies (Hisham & Amin, 2023). Understanding homelessness issues through an architectural perspective encourages deeper discussion of informal self-built shelters, as suggested by the concept of Architecture without Architects (Hisham & Amin, 2023; Rudofsky, 1987). The micro-architecture these homeless people build explains how they adjust to their situations. The features of these temporary shelters reflect their resilience in the face of financial and social barriers (Amir et al., 2024). Their spatial behaviours highlighted unmet needs as they navigate urban areas to ensure safety, visibility, and access to food for survival (Jasni et al., 2022).

Homelessness in Kuala Lumpur is affected by factors such as poverty, issues of mental health, and social stigma (Rom et al., 2022). Underprivileged homeless people often face disease threats due to living in poor living conditions (Ahmad et al., 2021). Moreover, homelessness in Kuala Lumpur has become more diversified, with an increasing proportion of families, women, and youth (Razak et al., 2024). The diversity highlights the need for effective strategies to address the fundamental root cause of homelessness in Kuala Lumpur. Therefore, the aim of this study is to explore the spatial behaviour of Kuala Lumpur's homeless people and interpret them through human needs theory to inform an inclusive design framework.

This study is guided by the research question: How do homeless people in Kuala Lumpur adapt to urban areas by building informal shelters, and what does this reveal about their basic human needs? The method of this study is behavioural observation to understand their survival strategies in urban spaces. The objectives are to investigate the spatial behaviours of the homeless in Kuala Lumpur with a focus on how informal shelter practices reflect the basic human needs.

# LITERATURE REVIEW

## Architecture Without Architects

Bernard Rudofsky's concept of Architecture without Architects highlights the importance of informal and vernacular architectural practices in addressing homelessness. (Rudofsky, 1964). The concept explains the demonstration of


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homeless survival-driven design as they navigate through the urban spaces (Whiteford, 2008). The homeless often set up or build their informal shelters to address immediate needs, using whatever materials they can find, demonstrating their thinking and resilience in design (Whiteford, 2008). Rudofsky's theory proposes that architecture comprises not only the works of architects but also the informal, practical responses of individuals to their environment. This is relevant to the homeless, who often create spaces that serve as shelter and places for community engagement (Moss & Irving, 2024). Homeless people in urban areas often creatively modify and repurpose urban spaces to enhance their sense of security and belonging in challenging situations. These behaviours align with their immediate survival needs and typically reflect local customs and cultural norms (Whiteford, 2008).

The characteristics of self-built informal shelters inform discussions of homelessness and adequate housing in urban areas. This shows that homelessness is related to architectural practice, where informal, survival-driven design is a response to the socioeconomic challenges it poses (Wittman, 2017). These informal shelters or settlements highlight the unmet needs of marginalised communities, often prompting innovative architectural solutions that can inform urban and housing policies (Meshkani, 2024). Furthermore, informal settlements often utilise locally accessible materials, and these practices may have significant implications for sustainability (Kozłowska, 2021). Research also highlighted that to address homelessness effectively, design practices must collaborate with homeless people and reflect their lived experiences (Wittman, 2017). Understanding homelessness through the concept of Architecture without Architects encourages us to explore effective solutions by shifting our approaches to urban design and architecture. In addressing homelessness, it is essential to recognise and integrate informal shelters into broader urban discussions, as homelessness is not just a social issue but also a challenge requiring more participatory and innovative architectural responses.

**Homelessness and Urban Spaces**

Homelessness is not a monolithic condition but a complex urban social phenomenon. This includes different segments of the population with diverse circumstances that produced different spatial needs and behaviour (Somerville, 2013). The European Federation of organisations working with people who are homeless (FEANTSA) has an developed The European Typology of Homelessness and housing exclusion (ETHOS) framework for classifying homelessness. There are four categories of homelessness, which are roofless, houseless, insecure and inadequate (Edgar, 2012). In the Malaysian context, all these categories are relevant, and this study will focus on the first category, the roofless.

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Globally, responses to homelessness have been divided, especially over how urban spaces are utilised. Infrastructure, such as flyovers, sidewalks, and benches, has become a haven for the homeless to live their daily lives. These public spaces are used for survival, as homeless individuals utilise any available structures for shelter, rest, and socialisation (Bergamaschi et al., 2014). However, this adaptation by the homeless often involves hostile architecture, which is used to discourage homeless people from using these spaces (Rosenberger, 2019). Hostile architecture, such as anti-homeless spikes, benches and barriers, discourages them from lying down and blocks access to possible sleeping areas (Petty, 2016). These elements are not just physical interventions but also a broader social mindset that marginalises the homeless population. Somehow, hostile architecture effectively prevented homeless people from accessing, making their efforts to survive even more difficult (Albertsen and Knight, 2025). This design strategy has sparked further discussion about how to address marginalised urban populations and how authorities prioritise maintaining aesthetics and functional urban environments over addressing the root causes of homelessness (Rosenberger, 2019).

**Kuala Lumpur Context**

In Kuala Lumpur, homelessness is linked to factors such as the legal framework, social and urban issues. The government has demonstrated approaches to eradicate homelessness through the implementation of the Destitute Persons Act 1977 and the Kuala Lumpur City Hall (KLKLCHCH) municipal law. This law grants authorities the power to act against individuals categorised as destitute (Jasni et al., 2023). Somehow, under the same law, government interventions are usually aimed at containing and removing rather than providing relevant support that addresses the root cause of homelessness (Hisham & Amin, 2023; Hisham et al., 2025).

Non-governmental organisations (NGOs) frequently support government initiatives by providing food supplies, welfare assistance and advocacy for the rights of homeless people Rom et al., 2022). NGOs tend to work towards creating a more compassionate environment for the homeless, while the government might focus more on the aesthetic value and functionality of these public spaces. However, from the overview of the legal framework and NGOs' initiatives, a gap is evident: a misalignment between current policies and the actual needs of the homeless population. Due to rapid urbanisation and the inadequate provision of affordable housing during the 1980s to 1990s, squatter settlements were visible around Kuala Lumpur (Aziz, 2012). These settlements were defined as self-built, informal structures that reflected a survival-driven approach to shelter. The dwellers built the structures from available materials, which not only provided immediate housing but also demonstrated the marginalised community's resiliency and resourcefulness under pressure from


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socioeconomic and urban policies (Neuwirth, 2016). Today's homeless people have adapted to the challenges of urban life by occupying urban spaces, such as sidewalks, benches, and underpasses or bridges, as shelters, a method like that used in setting up settlements as survival strategies (Hisham & Amin, 2023). Malaysia's rapid urbanisation and homelessness highlight the critical need for an inclusive policy that considers everyone's socioeconomic circumstances (Rusenko, 2014).

**Theoretical Understanding of the Spatial Behaviour of the Homeless in Kuala Lumpur**

The study is anchored in Rudofsky's (1964) theory of Architecture without Architects and supported by two explanatory theories: Maslow's (1943) Hierarchy of Needs and Appleton's (1975) Prospect and Refuge. The Architecture without Architects suggested that non-pedigreed and vernacular buildings were built in response to needs, climate, and material availability (Rudofsky, 1964). This concept acts as the central lens in the study of homeless behaviour when they choose or build their own shelter. The self-built improvised shelters, adapted to hostile street furniture or barriers used for territorial marking, are solutions developed by the homeless (Lehmann, 2020). Even though they are considered urban disorder, they are a sign of contemporary urban vernacular. And this architecture, without the architects, is generated by the same logic of necessity suggested by Rudofsky.

The Hierarchy of Needs is useful in understanding homelessness issues, particularly in Kuala Lumpur. The hierarchy consists of five levels of human needs: physiological, safety, belonging, esteem and self-actualisation. By meeting basic physiological needs, such as food, water, and shelter, human lives can progress to higher levels of the hierarchy (Omodan & Abejide, 2022). Somehow, for most homeless people, the basic physiological needs are often unmet. This is due to limited access to food, clean water, and proper shelter, which increases health risks and perpetuates the cycle of poverty (DeMuynck, 2017). The theory helps explain how the homeless choose their resting areas. During the physiological phase, the homeless are drawn to areas with access to basic human needs, including food, potable water, sanitation, and protection, particularly from Malaysia's tropical rain and heat.

For the homeless, reaching the level of self-esteem and actualisation is very challenging. One of the reasons is the social stigma that frequently results in loss of respect and dignity. This has made it challenging for them to develop positive self-perceptions (DeMuynck, 2017). The application of the Hierarchy of Needs theory to homelessness issues highlights the need for an inclusive solution that considers both immediate and higher-level needs. Understanding the importance of self-built informal shelters for these homeless individuals may

significantly inform current policy by creating spaces suitable for everyone, regardless of status.

The lived experience of homeless people is highly influenced by behavioural and environmental factors, particularly in the context of self-built shelters and the broader concept of Architecture without Architects. While the theory of Prospect and Refuge explores how behaviour interacts with the built environment, it encompasses aspects of territoriality, privacy regulations, and the design of self-built shelters (Moser & Uzzell, 2003). For safety and security, this theory supplies the spatial choice. It suggested that humans will occupy a space affording a vantage point from which they may observe or foresee environmental dangers. Refuge proposed the ability to create or choose safe spaces for rest or recharge without interruption (Appleton, 1975). Individuals who self-build their own shelters may control the level of exposure and public interactions by designing their shelters to reflect their sense of privacy and separation from the external environment (Evans, 2003). These design aspects may improve mental health conditions by creating a private and safe space that helps individuals cope with social and emotional challenges that may be caused by homelessness (Evans, 2003).

Prospect and Refuge can be applied to homelessness; however, an important gap remains in understanding the behavioural factors involved. It is how the built environment shapes homeless actions and lived experiences in urban settings that have not yet been thoroughly studied, largely due to the absence of spatial and design-oriented research (Verderber, 2014). For effective, inclusive urban design, it is essential to understand how self-built shelter design affects spatial behaviour, privacy, and the overall well-being of homeless people. This has highlighted the urgent need for thorough research in these areas. Addressing the issue of homelessness requires an understanding of the spatial behaviour and how the homeless interact with their environment to survive. These studies may help fill gaps in research on homeless behaviour and aid the development of design principles that foster a sense of security, belonging, and dignity.


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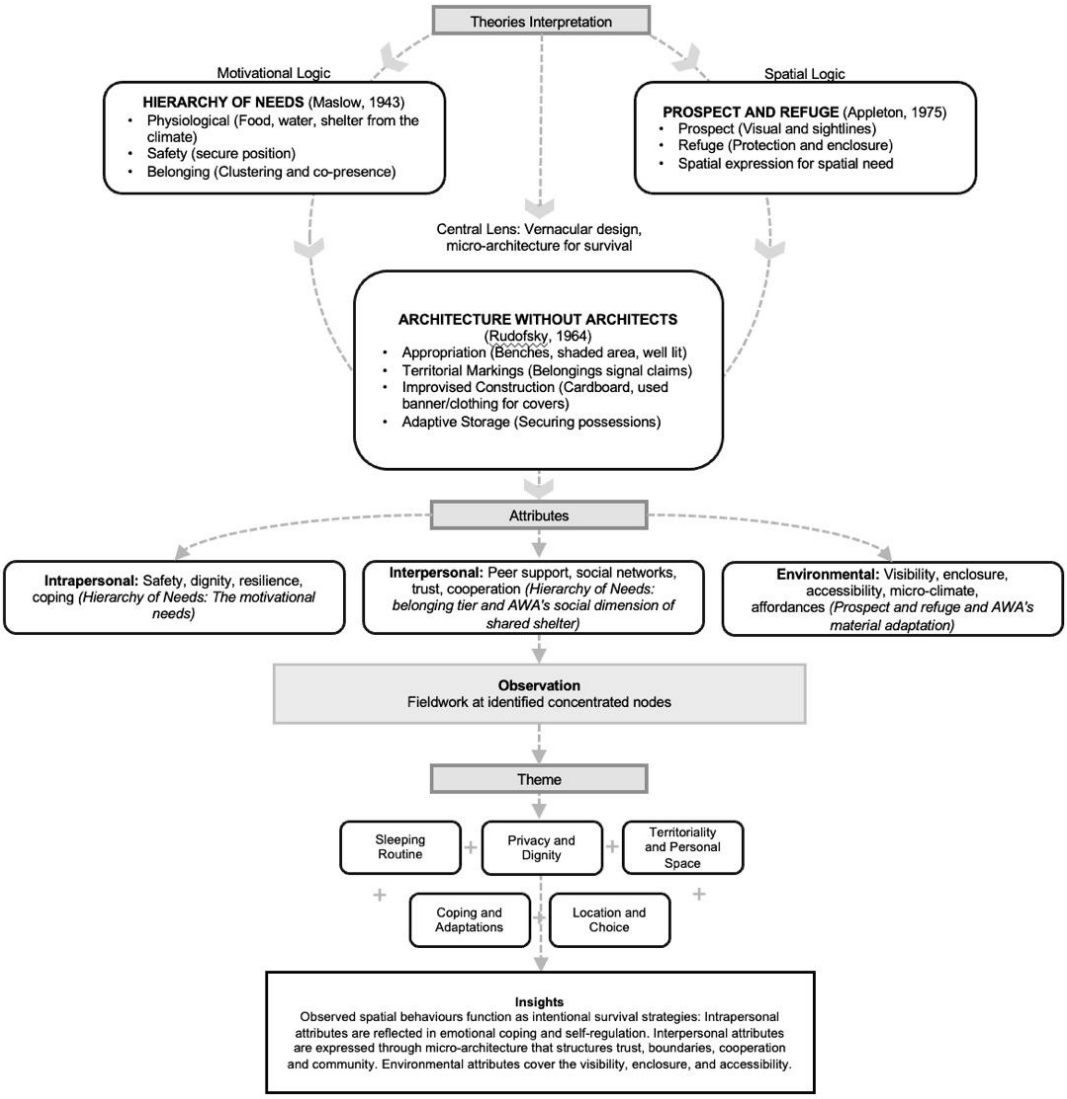



**Fig. 1.** Conceptual Framework of the study. *Source: Author, 2026*

The diagram above presents the conceptual framework of this study, which outlines the study of Kuala Lumpur's homeless spatial behaviour, beginning with observations at identified concentrated node areas. Architecture without Architects translated into four observable indicators coded for fieldwork observation: i) *Appropriation:* The repurposing of urban elements beyond the intended designed function, ii) *Improvised construction*: Material which are easy to assemble such as cardboards and used banners, being utilised as partitions,

covers for enclosures and bedding; iii) *Territorial marking*: The arrangement of personal belongings or bedding to mark as occupied claims; and iv) *Adaptive storage*: Any solutions in securing personal possessions such as bundling of personal belongings or concealment of the intended spaces. The three theories used to interpret attributes were the Architecture without Architects, which redefined the self-built shelter as micro-architectures of survival. The Hierarchy of Needs explains how their behaviours respond to safety, belonging, and dignity, while territoriality and adaptations to the urban environment are covered by Prospect and Refuge. There are three attributes derived from the theoretical framework: Intrapersonal, which consists of safety, dignity and resiliency; Interpersonal, which consists of peer support and social networks; and Environmental, which includes visibility, enclosure, accessibility, micro-climate, and affordances. The identified attributes are theoretically grounded and reflect both individual needs and social connections. From the attributes and through fieldwork observations, their behaviours were coded into themes: sleeping routines, privacy and dignity, territoriality and personal spaces, coping and adaptations, and location of choices. The identified themes revealed consistent data explaining how the homeless occupied and adapted urban spaces. The framework develops a theoretical understanding of spatial behaviours as intended spatial strategies that the homeless use to survive. These highlighted the contribution to design and policy implications.

## METHODOLOGY

This study examined the spatial behaviour of the homeless population in Kuala Lumpur using a qualitative observational method. Field observations were conducted for four days, from the 17$^{th}$ to the 20$^{th}$ of September 2025, for each identified homeless concentration node, including Jalan Tunku Abdul Rahman, Chow Kit, Pudu, and Masjid Jamek on separate occasions. The observation was conducted between 1 a.m. and 2 a.m. when the settlement is at its fullest. Observations were guided by a structured checklist that focused on their sleeping and belonging arrangements, covering privacy techniques and location selection, including sidewalks, bus stops, benches, and underpasses. Five behavioural themes were identified through thematic coding of the data: sleeping routine, territoriality and personal space, privacy and dignity, location of choice, and coping and adaptation. These themes clarify how the homeless arrange their shelter and adapt to their environment. The observations employed strictly non-participant observation. It is conducted from a distance without any direct interaction. The researcher did not initiate any interactions with the homeless individuals. No interviews, conversations, or solicited responses in which any incidental verbal activity occurred were not recorded as part of the dataset and were not analysed. All descriptions were limited to general behavioural patterns


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and not to individuals. It was non-intrusive, and all confidentiality and privacy were respected.

The analysis applies the observation-led form application of Interpretative Phenomenological Analysis (IPA) (Smith et al., 2021). Although interviews are specified as part of a common data source, IPA scholarship has extended to non-verbal and visual materials, recognising that lived experience is sometimes not expressible in words (Relja & Ward, 2026). In applying this research design, the research employs an appraisal checklist that provides a structured record of the datasets on which the researchers' interpretative analysis was performed. The appraisal checklist focuses on the concentration node areas within the urban fabric and the behavioural pattern perform by the homeless.

## FINDINGS

Each of the behavioural themes presented in Table 1 is analysed using three complementary databases: i) Frequency patterns were generated from the structured appraisal checklist, and the numbers of sessions and observed sites were recorded; ii) A behavioural map, which recorded the behaviour within the observed physical sites, and iii) All photographic documentation of spatial adaptations is limited to anonymised material arrangements.

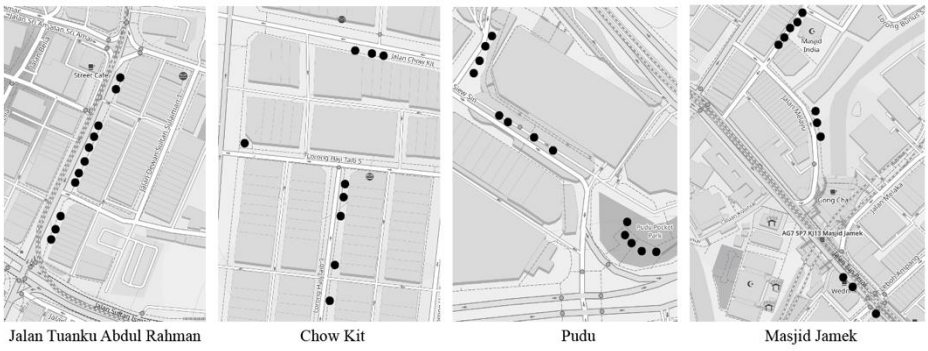



**Fig. 2.** Maps of each concentration nodes in Kuala Lumpur City showing the homeless's sleeping niches. *Source: OpenStreetMap and Author, 2026.*

Figure 2 maps the location of the sleeping niches across the identified concentration nodes in Kuala Lumpur. The sleeping area is clearly shown on the map; the homeless chose their sleeping spaces not randomly but arranged in sequence along building edges and covered walkways. Some prefer benches, such as around Masjid India. However, in the Pudu area, the homeless can be found around the Kota Raya bus stand and nearby pocket park.

Table 1 summarises the findings to organise the patterns found. The primary concentration nodes where the homeless usually reside, the factors that influence their location selection, and the behavioural themes that emerged from

the data analysis are highlighted in the table. These themes indicate that the selected locations are intentional and not random, influenced by the availability of food and water, social support, safety, and shelter resources. The themes also reveal how the homeless navigate urban spaces and adapt their environment to maintain territory and privacy, thereby ensuring dignity and survival.

**Table 1.** Summary of findings on Concentration Node Areas and Behavioural Themes.

| Category | Data Collected | Finding |
|---|---|---|
| Hotspots Areas |  | **Concentration node area:** Chow Kit, Jalan Tunku Abdul Rahman, Pudu and Masjid Jamek.<br><br>These areas are where homeless people frequents. The areas are not chosen randomly but intentional which influenced by the factors of:<br>1. Safety: Well-lit, visibility, near to peers<br>2. Shelter: Underpasses, bus stops, covered corridors<br>3. Resources: Food distribution, social supports<br>4. Community: Peer networks and mutual supports |


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| Category | Data Collected | Finding |
|---|---|---|
| Behavioural Themes | *Choice of Locations:* Preferences for well-lit, semi-sheltered and less busy areas  | Homeless people tends to choose well-lit and partially covered area, such as covered sidewalks and corridors and bus stop benches. The decision shows that they prefer to be visible to the public as protective strategy to prevent vulnerability so that others are close by in case of emergency. |
| | *Privacy and Dignity:* Use of coverings, symbolic partitions or partly exposed  | Covering themselves to establish privacy in public areas. Some remained expose, shows the desire for safety over privacy. |
| | *Territoriality:* Belongings as boundaries, use of bags, boxes or trolleys  | Organisation of personal belongings to demarcate sleeping area, which provide stability by converting public into private areas. |

| Category | Data Collected | Finding |
|---|---|---|
| | *Coping and Adaptations:* Benches, cardboards, blankets, makeshift cover for concealment  | The areas and items were repurposed and improvise where cardboard was used as floor covering to soften pavements, and benches which intended to discourage sleeping were used by sleeping while bending awkwardly across them. These methods show their inventiveness in addressing hostile architecture. |
| | *Sleeping Routines:* Usually sleeps around 1-2am and avoid nightlife zones  | Strategic planning is demonstrated by preparing sleeping areas in the early afternoon. They avoided chaotic night lives for more peaceful rest and sleep. |

*Source: Author, 2026*

These findings suggest that the spatial behaviour of the homeless population is consistent and relevant to immediate survival and to human desires for safety, dignity, and belonging. These behaviours can be further explained through the theoretical framework in Figure 1, which comprises Architecture without Architects, the Hierarchy of Needs, and Environmental Psychology.

## DISCUSSION

### Intentional Spatial Practice

The themes indicate a logical order of homeless behaviour clearly within the framework. The spatial behaviours of the homeless in Kuala Lumpur are influenced by factors such as safety, access to resources, community support, and social networks. Instead of randomly occupying the chosen concentration nodes, Jalan Tunku Abdul Rahman, Chow Kit, Masjid Jamek, and Pudu reflect


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intentional decisions made in response to their needs and limitations in the effort to survive. While behavioural themes such as choice of location, privacy and dignity, territoriality, coping and adaptation, and sleeping routines show how they interacted with hostile architecture and the environment. These actions demonstrate resilience and innovation in adapting to public spaces as a haven for survival. These behaviours can be understood through the theoretical perspectives of Architecture without Architects, Hierarchy of Needs and Prospect and Refuge.

**Theoretical Perspective**

The micro-architecture created by the homeless is an example of architectural adaptation to homelessness. Architecture without architects explains how this behaviour transformed urban features such as sidewalks, benches, bus stops, and underpasses into adaptive designs that allow the homeless to build for survival (Ferguson et al., 2015). The most basic need in the hierarchy of needs is physiological, which includes fundamental requirements for survival, such as food, water, shelter, warmth, and sleep. And, based on the availability of immediate needs, the homeless population chose locations including Jalan Tunku Abdul Rahman, Chow Kit, Masjid Jamek, and the Pudu area. For them, safety is their top priority, and, according to the study, they tend to choose well-lit areas for better visibility. According to research, these elements are important for reducing personal safety anxiety, suggesting that the chosen location is an intentional choice made under the pressure of unpredictable living circumstances (Paul et al., 2018). From the perspective of Prospect and Refuge, these choices are made through ongoing conflicts with their environment in an effort for safer conditions (Ferguson et al., 2015). This suggests that the concept of a safe environment is just as important as physical shelter. The preference for a well-lit, partially covered and visible sleeping area broadens the spatial logic as suggested by Prospect and Refuge theory. It is evident that homeless individuals prefer visibility to concealment, as evidenced by their reliance on the passive guardianship of potential passersby and on 24-hour restaurants or convenience stores as safety measures (Jacob, 1961).

Peer networks create a micro-community which reflects a sense of belonging. According to the hierarchy of needs, social connections can help individuals overcome isolation and loneliness (Nyamathi et al., 2010). Social connections built in shared spaces typically offer both practical and emotional support, increasing their resiliency (Paul et al., 2018). While dignity and esteem were expressed through coverings, partitions, and the organisation of personal items, creating boundaries. Homeless people often use their personal belongings to mark their personal space in public spaces (Ferguson et al., 2015). In addition, the behaviour exhibits territoriality, preserving their dignity by actively shaping their environment rather than passively accepting their situation (Nyamathi et al., 2010). This adaptability reflects their decision as they navigate a system that

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tends to marginalise them. For example, their coping mechanisms, such as using cardboard for insulation or making makeshift covers, show how resourceful humans are in adapting to their environment (Paul et al., 2018). Overall, these behaviours demonstrate that their choices and decisions for survival show resiliency. Understanding these connections will help create an inclusive intervention that addresses their fundamental needs while enhancing their dignity and self-esteem in the urban environment.

**Policy Implications**

The Destitute Persons Act 1977 is the legal framework governing homelessness in Malaysia. The strategies employed under this law have proven to be ineffective. A broader, supportive, and needs-driven policy, combined with initiatives under the National Housing Policy and the Kuala Lumpur Structure Plan 2040, may help address homelessness issues. Transitional shelters have proven effective in helping the homeless transition from street living to permanent housing by providing a sense of security and stability (Warren, 2025). From the observation, it is suggested that the existing government-initiated shelter accommodations for the homeless are situated outside the functional urban web, which may explain why the homeless still choose to occupy these concentrated nodes.

**Design Implications**

The design of transitional shelter should take into consideration the behaviours and actions of the homeless by recognising how they adapt to their environment, as these behaviours are intentional rather than random. For example, a person's sense of safety, dignity, and acceptance is strongly affected by having access to semi-private spaces (Ajeen et al., 2023). These spaces with personal storage can address their concerns about misplaced or stolen belongings, thereby improving their overall shelter experience (Warren, 2025). These ideas are aligned with trauma-informed design, which takes into consideration the psychological impact of living in temporary shelters (Grittner & Walsh, 2024). Shelters that prioritise emotional and psychological factors may affect their mental health positively and prepare them for successful rehabilitation (Ajeen et al., 2023)

## CONCLUSION

This study suggests that the homeless population in Kuala Lumpur chooses their locations intentionally rather than randomly, indicating a purposeful strategy. The selection of these locations, such as Jalan Tunku Abdul Rahman, Chow Kit, Masjid Jamek and Pudu, is based on safety, shelter, resource availability, peer networks and community support. Their spatial behaviours demonstrate resilience through selecting their own locations, devising privacy measures, marking their territories, employing coping mechanisms, and maintaining daily


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sleep routines. These behaviours create a micro-architecture of survival, as interpreted through the concepts of Architecture without Architects, the Hierarchy of Needs, and Prospect and Refuge. It points to their desire for safety, belonging and dignity even within exclusionary environments. The findings also emphasise that more inclusive, need-driven solutions should replace the government's current enforcement strategies. The design of transitional shelters should include an examination of homeless behaviours, as developing inclusive, equitable, and dignified policies and urban environments requires the involvement of homeless individuals, who are active participants in shaping urban spaces.

As a conclusion, the behaviours documented, where the homeless chose edge linear settlement along the five-footways, visibility, territorial demarcation, and improvisation of available material, correspond to the concept of Architecture without Architects, an informal design brief, written by the street occupants of Kuala Lumpur. The task of effective urban design and policy is not to erase these adaptations but to interpret them.

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# INCLUSIVE HERITAGE TRAILS: ACCESSIBILITY CHALLENGES FOR VULNERABLE USERS IN KUALA LUMPUR'S URBAN CONSERVATION AREAS

**Noor Ruzaini Adam[1], Mastura Adam[1]*, Mohd Firrdhaus Mohd-Sahabuddin[1], Runda Aduldejcharas[2], Camelia Kusumo[3]**

[1]*Department of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA
[2]*Department of Interior Architecture, Faculty of Architecture,*
CHULALONGKORN UNIVERSITY, THAILAND
[3]*School of Architecture, Building and Design,*
TAYLOR'S UNIVERSITY

## Abstract

Over the years, heritage trails within urban conservation areas have faced continuous threats as rapid development reshapes the surrounding landscape and alters the character of the city. These trails serve as vital pedestrian connectors and cultural storytellers, yet they remain physically inaccessible to vulnerable populations, including people with disabilities (PwD), the elderly, pregnant women, and families with young children. Therefore, the objective of this research is to identify the issues and challenges faced by vulnerable users and to examine the physical accessibility quality of heritage trails within Kuala Lumpur. Employing a qualitative case study research approach, data was collected using multiple sources of evidence. Semi-structured interviews were conducted with 11 vulnerable users, while participant observation involved 20 vulnerable users navigating the 2.57 km Kuala Lumpur Headquarters (KLHQ) Heritage Trail. Thematic analysis conducted via ATLAS.ti extracted 68 key phrases, which were synthesized into five core planning-relevant attributes: connectivity, usability, safety, information availability, and policy compliance. Findings reveal that the historic trail network fails to provide continuous accessibility. Therefore, this research proposes a comprehensive strategy based on universal design principles in creating inclusive heritage trails that inform the stakeholders and decision makers, directly advancing Sustainable Development Goal (SDG) 3 and 11.

***Keywords***: Inclusivity, universal design, heritage trail, vulnerable users, person with disability

[1] Corresponding author. Email: mastura@um.edu.my

# INTRODUCTION

Malaysia possesses a rich historic built environment, particularly in urban centres like Kuala Lumpur (KL), which holds over 500 historic landmarks reflecting its cultural identity. Heritage trails interconnect these historic buildings, spaces, and cultural elements, providing substantial social, educational, and economic benefits through heritage tourism. However, vulnerable users are frequently marginalized due to limited physical access and environmental barriers. The vulnerable group extends beyond PwDs to include individuals experiencing temporary disabilities, the elderly, pregnant women, and families with young children.

In Malaysia, heritage tourism is vital for the domestic economy. In 2019, domestic tourism was valued at approximately USD 23.4 billion (RM103.2 billion) (Department of Statistics Malaysia, 2020). However, despite the economic potential, previous studies indicate that vulnerable users are marginalized from historic spaces due to social and physical barriers. This exclusion directly contradicts the 11th Sustainable Development Goal (SDG), which mandates safe, inclusive, and accessible public spaces for all.

The research gap addressed in this study is the lack of qualitative evidence regarding the real experience of vulnerable users, specifically within heritage trails, rather than static buildings. While existing literature provides quantitative data on physical defects, there is insufficient understanding on how these groups navigate, perceive, and cope with the urban heritage trails.

A significant challenge in creating inclusive heritage trails lies in the conflict between Universal Design principles; which require physical alterations for accessibility and current conservation practices that prioritize strict originality and authenticity. This is further exacerbated by the unintegrated roles of stakeholders and unclear planning regulations regarding heritage trail jurisdictions. This research aims to recommend strategies for improving accessibility to create inclusive heritage trails within urban conservation areas for vulnerable users. The objective of this paper is; (i) to identify the issues and challenges faced by vulnerable users and (ii) to examine the physical accessibility quality of heritage trails within Kuala Lumpur. The outcome of this paper is a recommendation of strategy in improving accessibility to create inclusive heritage trails within urban conservation areas for vulnerable users.

# LITERATURE REVIEW

## Sustainable Heritage and the Social Model of Disability

Urban conservation areas preserve the tangible and intangible cultural identity of a city, with heritage trails serving as the vital links that interconnect these historic sites. Achieving sustainable heritage conservation requires not only preserving these physical assets but also ensuring they provide equitable social and cultural


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value to the entire community, aligning with Sustainable Development Goal (SDG) 11 for inclusive cities (UNESCO, 2026). The Social Model of Disability highlights that individuals are marginalized primarily by disabling environmental barriers rather than their own individual physical limitations (Kamarudin et al., 2022). In this context, the targeted vulnerable demographic extends beyond registered Persons with Disabilities (PwDs) to include the aging population, pregnant women, families with young children, and individuals with temporary impairments.

**Historic Urban Environments in Malaysia**

The historic urban environment encompasses not just buildings and monuments, but the broader urban fabric that reflects a society's cultural evolution. The identity of urban environment is formed by historical fabric, historic places and buildings as they are part of the culture, education, and tourism of the world (UNESCO World Heritage Centre, 2025). In Malaysia, this environment is pivotal to national identity, with cities gazetted as World Heritage Sites like Melaka and Georgetown. Other cities such as Kuala Lumpur, Kuala Kangsar, Kota Kinabalu and Kota Bharu also known for their rich cultural and historical traits among the locals and international visitors and act as the custodians of architectural history (Che Ghani et al, 2024). Under the Warisan KL initiative, over 500 historic icons have been identified in downtown Kuala Lumpur (Kuala Lumpur City Hall, Think City, 2024). However, managing this environment requires a delicate balance between preservation and the evolving needs of a modern, inclusive society. The challenge lies in maintaining the outstanding value of these sites while ensuring they remain functional for the living community.

**Universal Design in Historic Built Environments**

To dismantle these external barriers, the integration of Universal Design (UD) principles is critical, as UD ensures that spaces are usable by diverse groups with minimal physical effort and without specialized adaptations. For heritage trails, accessibility is fundamentally defined by four physical attributes: connectivity (continuous pathways, accessible public transport, and ramps), usability (available resting areas and family-friendly amenities), safety (hazard-free and well-lit environments), and information availability (clear wayfinding and assistive technologies) (Yakob et al., 2022). However, implementing these attributes frequently triggers a fundamental conflict between UD requirements, which necessitate physical modifications and traditional heritage conservation paradigms that prioritize strict authenticity and minimal intervention.

Recent literatures have transitioned from a static, building-centric conservation paradigm toward a dynamic 'living heritage' approach that

prioritizes active community engagement and equitable spatial access. Pawłowska et al., (2023) highlighted that physical accessibility is a core indicator of a 'friendly city' and directly determines the social sustainability of architectural heritage. However, integrating accessibility features within historic fabrics often triggers acute preservation conflict. As discussed by Althabhawi & Al-Khafaji, (2025) and Dipasquale et al., (2022), traditional conservation frameworks place immense emphasis on physical 'authenticity' and minimal intervention, which local authority frequently interpret as a blanket restriction against retrofitting additional physical elements. In the Malaysian planning context, this conflict manifests as a severe policy implementation gap where the Uniform Building By-Laws (UBBL) and Malaysian Standard MS1184:2014 mandate universal access, yet their statutory jurisdiction is heavily restricted when applied to buildings and sites governed by the National Heritage Act 2005. This policy friction creates a fragmented outdoor public realm where individual heritage buildings may be retrofitted internally, but the pedestrian networks connecting them remain highly inaccessible.

**Legislation and Policy Frameworks**

The successful integration of accessibility into heritage areas relies heavily on legislative frameworks. In Malaysia, key governing policies include the National Heritage Act 2005 (Act 645), the Persons with Disabilities Act 2008 (Act 685), and the Malaysian Standard (MS1184:2014) Universal design and accessibility in the built environment - Code of practice (Second revision) (Department of Standards Malaysia, 2014; Persons with Disabilities Act 2008, 2018; National Heritage Act 2005, 2006). Despite these foundational acts, literatures indicated that Malaysia struggles with unclear bureaucratic jurisdictions and a lack of integrated guidelines that specifically bridge heritage conservation with universal design (Kamarudin et al., 2022; Zahari et al., 2016). Unlike several developed nations that offer targeted funding and explicit guidelines for retrofitting historic buildings, current local practices often overlook the external environments and trails connecting these sites, leaving vulnerable users to navigate inaccessible public spaces (Abd Ghafar et al, 2022).

Developed countries worldwide have progressively and comprehensively integrated Universal Design into urban conservation areas, ensuring that heritage environments are accessible, inclusive, and responsive to diverse user needs. Numerous policy frameworks and guidelines have been established to support the implementation of universal design within heritage conservation contexts (Marsin et al., 2014). In contrast, the adoption and integration of such initiatives in Malaysia remain comparatively limited and less systematically embedded. A comparative overview of universal design policies


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and practices between developed countries and Malaysia is presented in Table 1 below, highlighting key gaps and opportunities for improvement.

**Table 1**: Comparison of Heritage and Universal Design Initiatives in Malaysia and Selected Developed Countries

| Country | Heritage Acts & Guidelines | Universal Design Act & Guidelines | Universal Design Guidelines for Built Heritage |
|---|---|---|---|
| Malaysia | National Heritage Act 2005 (Act 645)<br>Guidelines of Heritage Building Conservation 2017<br><br>Planning Guidelines for the Conservation of Heritage Areas and Buildings 2023 (PeWARIS) | Persons with Disabilities Act 2008 (Act 685)<br>Malaysian Standard: Universal design and accessibility in the built environment-Code of practice **(**MS1184:2014)<br><br>Universal Design Guidelines for the Built Environment | Not Available |
| Singapore | Preservation of Monuments Act 1971<br>Urban Redevelopment Authority Act 1989 | Code on Accessibility in the Built Environment 2019 (BCA)<br>Universal Design Mark Certification | Accessibility Fund |
| Ireland | Heritage Act 1995 | Building for Everyone: A Universal Design Approach (National Disability Authority) | National Disability Authority's heritage guidance documents* |
| Australia | Australian Heritage Council Act 2003 | Disability Discrimination Act 1993 | Improving Access to Heritage Buildings 1999 |

*Source:* (Marsin et al., 2014) *and author's compilation (2025)*

## RESEARCH METHODOLOGY

This study adopted a qualitative cross-sectional design using a case study approach with two units of analysis: the vulnerable users and the physical built environment of a selected heritage trail within an urban conservation area. Data collection involved multiple sources of evidence, specifically semi-structured interviews and participant observation. First, semi-structured online interviews were conducted with 11 vulnerable users who had prior experience visiting or working near the selected heritage sites. This approach was selected to capture the lived experiences of vulnerable users, which quantitative surveys often overlook. The participants were recruited through snowball sampling, representing a cross-section of vulnerabilities. The participants categories were further detailed in Table 2.

**Table 2**: Categories of interview participants

| **Interview Participants (experienced users)** | | |
|---|---|---|
| **Pseudonym** | **Age range** | **Vulnerable user category** |
| NS | mid 30s | Parents with young children |
| UW | late 30s | |
| SH | mid 30s | |
| HL | early 40s | |
| SY | late 30s | Visual impaired-wheelchair user |
| WN | early 40s | Caregiver to wheelchair user (elderly) |
| AL | late 30s | |
| AZ | early 40s | Pregnant women |
| CC | late 60s | Elderly |
| AM | mid 30s | Person with temporary disability |
| MS | early 40s | Person with walking disability |
| **Total** | | **11 participants** |

*Source: (Author, 2025)*

The interview sessions were conducted online, in Malay (Bahasa Malaysia), until a saturation point was reached, where no new themes emerged. The sessions were later transcribed and translated using back-translation to ensure accuracy. The contents of the sessions were also referred back to the respondents during the analysis process in order to eliminate bias. The data collected were analyzed using ATLAS.ti, where 68 key phrases were axially coded into five main themes.

Second, to validate the findings from the semi-structured interviews, an on-site participant observation was conducted involving 20 first-time vulnerable users visiting the selected site of KLHQ Heritage Trail. According to Denscombe (2010), the participant observation method is beneficial as the researcher is directly involved in the field, enabling data collection in real-life situations and within the participants' natural setting. However, Cassell & Symon (2004) argued that participant observation may involves perception of the users and the observation findings can result in personal preferences. Therefore, in this research, the researcher adopted the participant-as-observer identity as suggested by Waddington (2004) to participate in the observation session in order to clarify any issues or personal perception of the participants to minimize biasness. The researcher also clearly explained her role and purpose during a briefing session prior to the site visit to ensure transparency and informed participation.

**Table 3**: Categories of observation participants

| **Observation Participants (first time visitor to selected site of case study)** | | |
|---|---|---|
| Pseudonym | Age range | Impairment category |
| P1 | 31 | Physical disability |
| P2 | 32 | Visual impairment |


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| | | |
|---|---|---|
| P3 | 45 | Physical disability |
| P4 | 31 | Visual impairment |
| P5 | 34 | Visual impairment |
| P6 | 25 | Physical disability |
| P7 | 27 | Visual impairment |
| P8 | 33 | Visual impairment |
| P9 | 38 | Physical disability |
| P10 | 31 | Physical disability |
| P11 | 35 | Visual impairment |
| P12 | 27 | Physical disability |
| P13 | 34 | Physical disability |
| P14 | 35 | Physical disability |
| P15 | 35 | Physical disability |
| P16 | 39 | Physical disability |
| P17 | 40 | Physical disability |
| P18 | 59 | Visual impairment |
| P19 | 30 | Physical disability |
| P20 | 33 | Physical disability |

*Source: (Author, 2025)*

**Case Study Selection: KLHQ Heritage Trail**

The Kuala Lumpur Headquarters (KLHQ) Heritage Trail was selected as the focal unit of analysis due to its unique status as the cultural and administrative birthplace of modern Kuala Lumpur. This is the most prominent trail, as it features a variety of significant heritage buildings along the route. Spanning a continuous 2.57 km loop through the gazetted historic core of downtown Kuala Lumpur, the trail encompasses 16 key heritage checkpoints, including Dataran Merdeka (Independent Square), the Sultan Abdul Samad Building, Jamek Mosque, and the Old General Post Office. This site represents a classic urban planning challenge which are protected under the National Heritage Act 2005 (Act 645). The buildings within and around the KLHQ Heritage Trail are featured as unique experiences in various official tourism websites as the Kuala Lumpur Tourism Bureau and Jabatan Wilayah Persekutuan (JWP) (Jabatan Wilayah Persekutuan, 2025). Concurrently, the trail serves as an active commercial and transit corridor with high daily pedestrian foot traffic, managed by the Kuala Lumpur City Hall (DBKL) and promoted globally for heritage tourism. Consequently, the KLHQ trail also acts as a highly representative micro-model for other post-colonial, high-density historic cities across Southeast Asia struggling to balance strict conservation guidelines with modern accessibility standards.

To systematically evaluate the on-site accessibility quality, the Heritage Trail Accessibility Checklist (HTAC) was developed as an audit instrument. The HTAC was constructed by adopting the statutory specifications detailed in the MS1184:2014 and the standard universal design checklist developed by

Department of Local Authority (JKT) into an observable, site appropriate audit format. To ensure validity, the draft checklist was evaluated by two universal design experts from Public Works Department (JKR) and one heritage conservator of National Heritage Department (JWN). The HTAC was tested prior to the observation session at the selected site by the author to further refine the items listed. During the observation session, the researcher acted as a 'participant-as-observer' capacity to minimize researcher bias and ensure participant comfort, while utilizing the HTAC to systematically document spatial dimensions (e.g., curb heights, ramp angles, path widths) and compliance status across the 16 checkpoints. The route map for Kuala Lumpur Heritage Trail KLHQ is depicted in Figure 1.

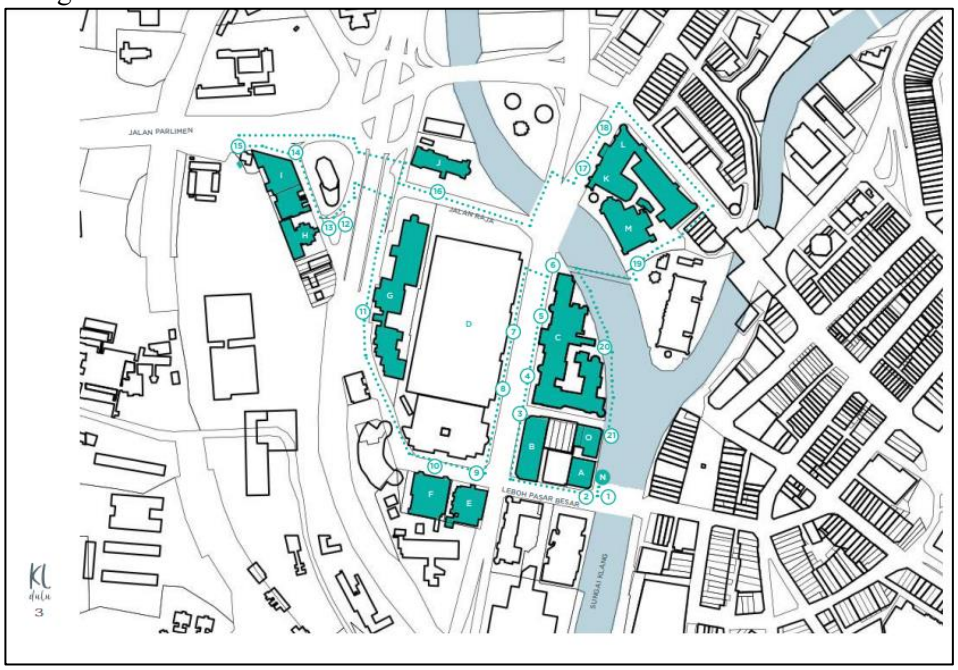



**Figure 1:** Route Map of Kuala Lumpur KLHQ
*Source:* (Dewan Bandaraya Kuala Lumpur, 2018)

## ANALYSIS AND DISCUSSION

### Findings on Semi-Structured Interviews

The thematic analysis of the interviews generated 68 key phrases concerning accessibility, which were categorized into five core themes: connectivity, usability, safety, information availability, and policy implementation. The interview analysis revealed interconnected and systemic accessibility issues as detailed below.


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***Connectivity (most critical)***

Connectivity was identified as the most critical issue, with almost all respondents detailing severe challenges with pathway conditions. The findings revealed uneven surfaces, broken tactile walking surface indicators (TWSI), and discontinuous pathways. Vulnerable users frequently had to share routes with active motor vehicle traffic due to high curbs, missing pedestrian crossings, and the absence of dedicated pedestrian lanes, causing immense danger. The respondents were quoted as:

> "*They (pathway) were done halfway through, portion by portion. There is no continuity*." (AL: Caregiver to wheelchair user)
> "*Not all users are familiar with the location, even I've stumbled here and there (due to the uneven surfaces)"* (AZ: Pregnant women)

> "*But the pathways near BSAS are quite rocky. Therefore, we had to be careful to avoid tripping over while walking (around the area)*." (AM: Person with temporary disability)

***Usability (critical)***

Usability challenges encompassed an overall lack of public amenities and family-friendly facilities, such as accessible public toilets and nursing rooms. Furthermore, respondents highlighted discomfort due to unpredictable weather, uncovered walkways, and the absence of shaded resting areas or seating along the lengthy trails. The lack of permanent food and beverage facilities nearby also impacted user experience.

> "*The buildings were nice, beautiful, yet the facilities for public were not available, such as toilets, shaded areas."* (HL: Parents with small children)
> "*The area has some seating, but they are in the open (not properly covered). The seating was only shaded by big trees (and surrounding buildings).*" (AL: Caregiver to wheelchair user).

***Safety (critical)***

Safety features were severely lacking. Respondents reported feeling unsafe navigating poorly maintained, dimly lit pathways and underground parking structures. Additionally, public seating intended for tourists was often occupied by homeless individuals, deterring vulnerable users.

> "*I don't feel safe to be around that area. No, I tried not to (go back home late at night). It was scarier at night. The police were not around much too.*

*Hmm, it was quite risky (to use the route). Well, the route is unsafe. Lack of safety features.*" (CC: Elderly)

"*Lack of maintenance will cause obstacles and people will avoid routes that are not well maintained, as these issues will create safety problems*." (AL: Caregiver to wheelchair user).

***Information Availability***

Wayfinding across the KLHQ trail was heavily criticized. Participants reported ineffective and poorly positioned signages, making independent navigation nearly impossible for first-time visitors or visually impaired individuals. The absence of on-site information centres and accessible write-ups regarding the heritage buildings compounded this issue.

"*Currently the route was quite unwelcoming (confusing), as visitors don't even know they can access the courtyard and stroll along the ground floor of BSAS. The wayfinding system was off too*." (HL: Parents with small children);

"*The stairs in BSAS are also quite confusing and their location are hidden, hard to find and navigate. The stairs are not visible. Only frequent users will be able to locate the stairs, other than the grand staircases at the front of the building*." (AL: Caregiver to wheelchair user).

***Legislation and Policy***

Respondents emphasized that bureaucratic restrictions under the National Heritage Act limit necessary physical alterations. A general lack of enforcement regarding Universal Design integration in heritage locations and limited budget allocations were also cited as primary barriers.

"*So, when we want to repair or renovate a particular warisan (heritage) building, it really depends on the act (National Heritage Act 2005). Therefore, it causes us to be restricted in a lot of things related to the act, we could not change it. Because the route itself is considered as part of the building's area, isn't it? So maybe we could not change it, I'm not sure*." (AM: Person with temporary disability)

"*The current amendment of UBBL to adhere to MS1184 were published in 2021, so the awareness of this were not adamant yet. for older buildings, there are many steps for us to take to touch, renovate or amend the buildings, as we need to adhere to Act 645 National Heritage Act, or some*


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*restrictive jurisdiction from the local authority*." (HL: Parents with small children)

**Findings on the Participant Observation**

The site observations robustly validated the interview findings and further revealed five key thematic issues: connectivity, usability, safety, information, and policy compliance. In terms of connectivity, several segments of the heritage trail were found to be physically discontinuous. For example, at Check Point 4 (Old General Post Office), the presence of mobile road barriers and steel poles fragmented pedestrian movement and disrupted the logical flow between heritage nodes. This discontinuity forced wheelchair, stroller and visually impaired users to divert onto main vehicular roads, significantly reducing walkability and network cohesion along the trail. They were diverted onto the active, multi-lane vehicular road, exposing them to direct collision risks.

Regarding usability, the pathway design was found to be poorly adapted for diverse user needs. At Check Point 6 (Independent Square), the obstruction of pedestrian crossings with multiple traffic lanes created confusion and difficulty in navigation, particularly for older persons and users with mobility limitations. The presence of street furniture placed without consideration of pedestrian desire lines further reduced overall spatial usability.

From a safety perspective, critical hazards were identified along key segments. Steel poles installed directly within tactile paving at Check Point 5 (Sultan Abdul Samad Building) and Check Point 7 (along Jalan Raja) posed serious risks for visually impaired users, undermining the function of accessibility aids and increasing the likelihood of collision or misdirection. The lack of segregation between pedestrian and vehicular movement further heightened risk exposure.

In relation to information, Check Point 15 (Masjid Jamek area) demonstrated a clear deficiency in wayfinding and interpretive signage. First-time visitors of elderlies, wheelchair and visually disabled users, were observed navigating the area without adequate guidance, resulting in uncertainty, hesitation, and inefficient movement patterns. The absence of clear and inclusive information systems significantly reduced the legibility of the heritage environment. Elderly and pregnant women are most vulnerable to environmental discomfort and a lack of resting infrastructure. The 2.57 km trail has long segments without any shade, benches, or public restrooms available to be used by the users.

Finally, policy compliance issues were evident across multiple checkpoints. The misalignment between on-ground conditions and established accessibility and urban design guidelines suggests gaps in the enforcement and implementation of inclusive urban policies. Visually impaired participants faced

many obstacles, such as steel poles installed directly in the middle of tactile paving, shown in Check Point 7 as non-compliance with the MS1184:2014. The inconsistent provision of barrier-free infrastructure indicates that existing standards are not fully integrated into site-level planning and management practices. These findings are summarised in Figure 2 and Table 4, illustrating the interrelated nature of these five themes in shaping the accessibility experience of vulnerable users along the heritage trail.

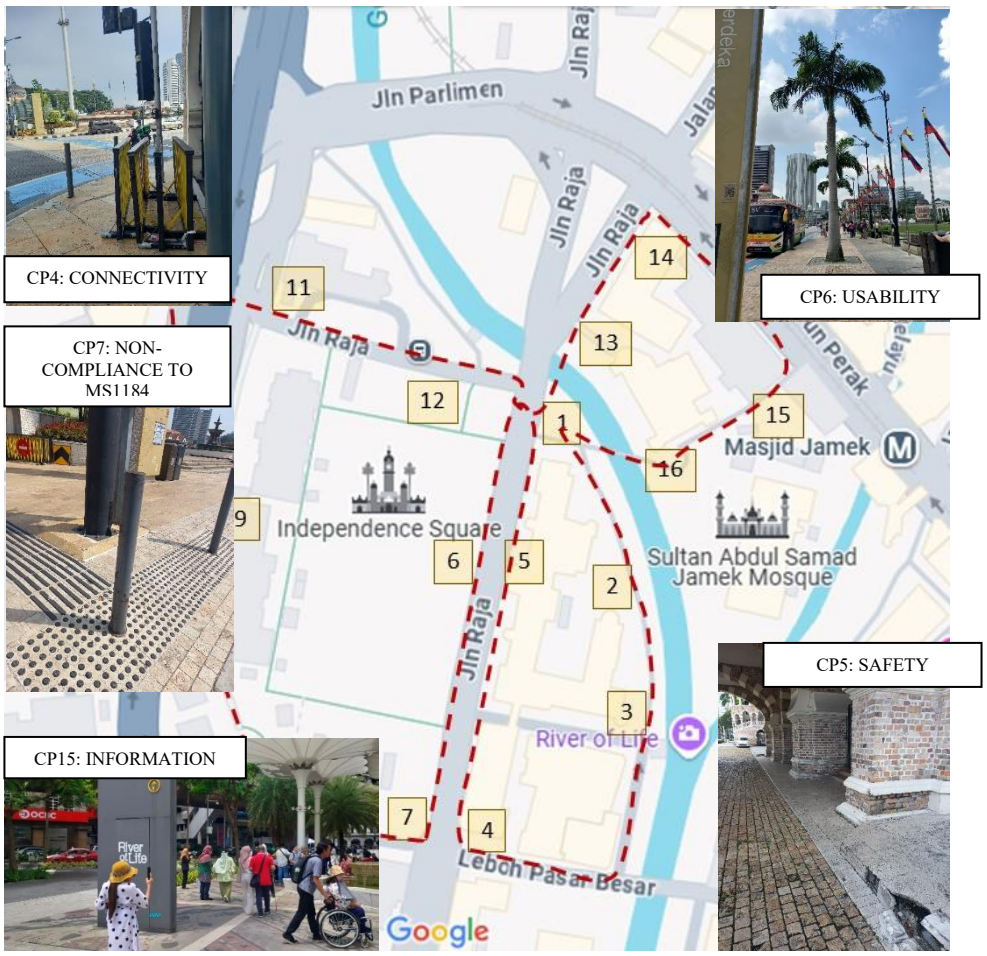



**Figure 2:** Accessibility findings during participant observation
*Source: (Authors, 2025)*

**Table 4**: Accessibility Themes, Key Challenges and Priority Action Level


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| Theme | Key Challenges | Priority Action Level |
|---|---|---|
| **Connectivity** | Uneven surfaces; shared paths with vehicles; unusable/obstructed TWSI; steep ramps; inaccessible sidewalks due to high curbs. | Priority 1: Immediate Safety Hazards (Urgent Intervention) |
| **Usability** | Lack of family-friendly facilities; inaccessible toilets; uncovered rest areas; lack of maintenance. | Priority 2: Mid-Term Usability & Path Adjustments |
| **Safety** | Poorly lit paths and parking; homeless people occupying public seating; broken tiles and uneven pathway. | Priority 1: Immediate Safety Hazards (Urgent Intervention) |
| **Information Availability** | Unclear wayfinding; limited/ineffective signage; unavailable on-site heritage information. | Priority 3: Long-Term Information & Amenity Gaps |
| **Policy Compliance** | Lack of enforcement for universal design and MS1184:2014; bureaucratic limits on heritage alteration. | Priority 3: Long-Term Planning and Strategic Coordination |

*Source: (Author's, 2025)*

## DISCUSSION

Accessibility to heritage trails is vastly impacted by connectivity, usability, safety, information and policy. The concept of "human-centred design" shall be adapted in the built environment to improve access to people of all ability (Myerson, 2007). This can be done by identifying elements that need to be improved (Australia ICOMOS. & International Council on Monuments and Sites., 2000;) National Heritage Act 2005, 2006) (Department of National Heritage, 2017). The integration of Universal Design within historic built environments is paramount for achieving sustainable heritage tourism. As demonstrated by the findings, the current accessibility quality of the KLHQ Heritage Trail fails to meet the fundamental standards required by the Social Model of Disability, leaving vulnerable users marginalized by disabling environmental designs rather than individual limitations.

Therefore, it is crucial for all stakeholders to take actions according to their jurisdiction. The proposed stakeholders' responsibility matrix is shown below in Table 5.

**Table 5**: Stakeholder's responsibility matrix

| Stakeholder Agency | Jurisdiction | Proposed Action |
|---|---|---|
| Dewan Bandaraya Kuala Lumpur (DBKL) | Public rights-of-way, pedestrian pathway maintenance, street furniture, crossing signals, and UBBL enforcement | Immediate removal of steel poles blocking tactile paving.<br>Levelling uneven paving stones.<br>Extending pedestrian crossing times at CP6. |

| Stakeholder Agency | Jurisdiction | Proposed Action |
|---|---|---|
| Jabatan Warisan Negara (JWN) | Statutory oversight of gazetted heritage sites and conservation guidelines under Act 645 | Drafting a 'Heritage Universal Design Guideline'.<br>Fast-tracking approvals for essential installation of universal design elements. |
| Tourism Agencies (e.g., JWP, KL Tourism Bureau) | Tourism marketing, trail curation, visitor distribution, and public awareness campaigns | Developing inclusive tactile and audio trail maps.<br>Incorporating accessibility ratings on official tourism portals. |
| Heritage Building Owners | Internal facility management, building entrances, universal restrooms, and step-free lobby access | Retrofitting entrance steps with compliant, reversible ramps.<br>Ensuring constant maintenance of universal toilets. |
| Infrastructure & Transit Providers | Public transit interfaces, LRT/MRT stations, and designated PwD parking spaces | Repairing broken elevators connecting parking to trail levels.<br>Enforcing strict towing of non-PwD vehicles in PwD bays |

*Source: (Author's, 2025)*

Resolving the tension between the National Heritage Act 2005 (which preserves historic fabric) and the PwD Act 2008 (which mandates accessibility) requires a paradigm shift from rigid physical modification to reversible, sympathetic universal design solutions. Achieving inclusive heritage trails requires stakeholders to systematically address all elements in the five identified attributes. First, connectivity must be resolved by prioritizing continuous, level, and dedicated pedestrian pathways over vehicular infrastructure. To preserve the original historical paving and structural facades, the use of modular, lightweight, and reversible composite ramps that sit on top of historic building fabrics shall be considered. Second, guidelines must dictate the sympathetic installation of modern accessibility features such as integrated 3D-tactile maps for wayfinding, shaded rest stops, and accessible ramps without stripping the authenticity of the cultural heritage (Lutfi A Rahaman; Nabilah Naharudin, 2024). This includes the deployment of low-energy technology and QR codes that stream real-time audio navigation and digital wayfinding directly to users' smartphones, ensuring inclusion while preserving strict heritage authenticity. Finally, legislative frameworks, such as the National Heritage Act 2005 and the Persons with Disabilities Act 2008, must be better harmonized to enforce Universal Design compliance as a mandatory, rather than voluntary, requirement in conservation management plans.


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## CONCLUSION

In conclusion, this research demonstrates that heritage trails within Kuala Lumpur's urban conservation areas remain largely inaccessible to vulnerable communities due to severe physical and systemic barriers. The conflicting priorities between preserving historical authenticity and implementing Universal Design (UD) principles have consistently marginalized users, ranging from people with disabilities to the elderly, pregnant women, and families with young children. Achieving truly inclusive heritage trails requires concerted, integrated action from all stakeholders. This means moving beyond fragmented bureaucratic roles to effectively harmonize legislation. By mandating these accessibility policies and fully adopting standards like MS1184:2014 in conservation guidelines, local authorities can provide barrier-free environments without compromising intrinsic cultural values. Ultimately, a human-centered urban design approach aligns directly with Sustainable Development Goal (SDG) 11, fostering equitable access, social inclusion, and sustainable community-based heritage tourism. Moving forward, future research must focus on formulating a detailed, standardized framework based on these five attributes to comprehensively guide local authorities and policymakers in managing and retrofitting heritage trails across Malaysia.

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## DISCLOSURE STATEMENT

The authors declare no competing interests.

This research has been approved for its application of research ethics clearance by Universiti Malaya Research Ethics Committee (UMREC) in accordance with the Universiti Malaya Research Ethics Guidelines with reference number of UM.TNC2/UMREC_2597.

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# TOWARDS SHARIA COMPLIANT MARKET SOUNDING PRACTICES IN PUBLIC-PRIVATE PARTNERSHIPS: EVIDENCE FROM INDONESIA

**Ali Sunandar[1], Zulhafiy Zolkipli[2], Noor Azree Mohd Hanifiah[3], Umi Kalsum Zolkafli@Zulkifly[4], Saipol Bari Abd Karim[5]**

[1,4,5]*Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[1]*Department of Civil Engineering, Faculty of Engineering,*
UNIVERSITAS MERCU BUANA
[2]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA
[3]*Department of Media and Communication Studies,*
*Faculty of Arts and Social Sciences,*
UNIVERSITI MALAYA

## Abstract

This study examines whether Sharia principles emphasising transparency and full disclosure can be operationalised within market sounding practices in Public-Private Partnership (PPP) schemes. The study adopts a qualitative research design based on semi-structured interviews with 21 expert stakeholders from government institutions, financial organisations, private investors, advisory bodies, and Sharia authorities. Data were analysed using thematic analysis to identify recurring patterns and to develop a conceptual framework. The findings reveal a strong convergence among stakeholders that transparency and full disclosure are fundamental requirements under Sharia and are consistent with principles of good governance in PPPs. However, practical limitations, including limited project readiness, institutional capacity constraints, and the need to preserve competitive innovation, restrict the feasibility of full disclosure at early stages. The study is limited to the Indonesian context and expert perspectives. Future research may incorporate comparative studies across jurisdictions and quantitative validation of impacts on investor participation. This study contributes to the emerging discourse on Sharia PPPs by proposing market sounding based on transparency and full disclosure as a foundational mechanism bridging Sharia principles and conventional PPP practices.

***Keywords***: Investor; Market sounding; Public-private partnership; Sharia PPP; Transparency

[1] Corresponding author. Email: alisunandar@mercubuana.ac.id

## INTRODUCTION

Public–Private Partnerships (PPPs) have emerged as a central mechanism for infrastructure delivery, particularly in developing economies seeking to bridge financing gaps while enhancing efficiency and innovation (Asian Development Bank, 2018; Sunandar & Indiyati, 2023; Sunandar et al., 2025d). In recent years, the expansion of Islamic finance has introduced new dimensions to PPP structuring, especially in jurisdictions such as Indonesia, where Sharia principles are increasingly integrated into public investment frameworks (KNEKS et al., 2024; Sunandar et al., 2025c). These principles emphasise transparency, full disclosure, fairness, and the avoidance of excessive uncertainty, collectively shaping the ethical and contractual foundations of Sharia compliant transactions (Imaduddin & Kassim, 2025; Sunandar et al., 2025a). Within this context, market sounding plays a critical preparatory role by facilitating early engagement between governments and potential investors, enabling the refinement of project assumptions and the assessment of market appetite (APMG International, 2026; Ministry of National Development Plan, 2023).

Despite its importance, conventional market sounding practices in PPPs often operate with selective disclosure. Governments typically share high level financial indicators, such as internal rates of return or general project parameters, while withholding detailed cost structures, profit margins, and underlying assumptions (APMG International, 2026; Ministry of National Development Plan, 2023). This approach is intended to preserve competitive tension and encourage innovation among bidders. However, such practices may not fully align with Sharia principles, which require clarity and mutual understanding of contractual elements to avoid ambiguity and informational asymmetry. The increasing interest in Sharia compliant PPPs therefore raises a fundamental question as to whether existing market sounding practices can be adapted to meet stricter requirements of transparency and full disclosure.

The existing literature on PPP governance has extensively examined issues such as risk allocation (Sunandar et al., 2024), contractual design (Feng et al., 2023), and sustainable frameworks (Alqahtani et al., 2024). Parallel scholarship in Islamic finance has explored Sharia compliance in financial instruments, including sukuk structures and profit sharing arrangements (Balative et al., 2025; Mahama & Yakubu, 2025). However, there remains limited intersection between these two strands of research, particularly in the context of early-stage PPP processes such as market sounding. Current studies tend to focus on financial structuring at later stages of project development, while overlooking how Sharia principles can be operationalised during market sounding between public authorities and investors (Imaduddin & Kassim, 2025; KNEKS et al., 2024; Sunandar et al., 2025c). This gap is significant because market sounding

shapes investor perceptions, influences project bankability, and establishes the foundation for subsequent contractual arrangements.

The problem addressed in this study lies in the tension between the need for comprehensive transparency under Sharia principles and the practical constraints of PPP market sounding. On one hand, full disclosure of financial elements, including cost structures, profit margins, and sharing ratios, is essential to ensure Sharia compliance and to build trust among stakeholders. On the other hand, premature disclosure may be constrained by incomplete project preparation, limited capacity among project owners, and the need to maintain flexibility and innovation during early project stages. This creates a critical governance challenge in determining the appropriate level and timing of disclosure within Sharia compliant PPP frameworks.

This study contributes to the literature by advancing an integrated perspective on Sharia compliant market sounding within PPPs. It provides empirical insights derived from expert stakeholders across government, financial institutions, private investors, and advisory organisations in Indonesia. By capturing both convergent and divergent perspectives, the study identifies practical pathways for embedding transparency and disclosure requirements without undermining the functional objectives of market sounding. In doing so, it bridges the conceptual gap between Islamic economic principles and conventional PPP practices, offering a nuanced understanding of how ethical requirements can be translated into operational mechanisms.

The originality of this study lies in its focus on market sounding as a critical yet underexplored stage of Sharia PPP governance. Rather than concentrating solely on contractual or financial instruments, the research highlights the importance of early-stage interactions in shaping Sharia compliance outcomes. It introduces the notion of a balanced disclosure approach, whereby core financial and project information is communicated transparently while retaining flexibility in areas subject to uncertainty or innovation. This approach contributes to the development of a more adaptive and context sensitive framework for Sharia PPP implementation.

The aim of this study is to examine the applicability of Sharia principles within market sounding practices in PPP schemes, drawing insights from Indonesia. The research objectives are as follows:

1. To identify the main themes concerning the applicability of Sharia principles within market sounding practices in PPP schemes in Indonesia.
2. To develop a conceptual framework for the application of Sharia principles within market sounding practices in PPP schemes in Indonesia.


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## RESEARCH METHODOLOGY

### *Data Collection*

Primary data were collected through semi-structured interviews with 21 expert participants, reaching a point of data saturation (Saunders et al., 2018). Each interview followed a common interview protocol consisting of open ended questions exploring the applicability of Sharia principles in PPP market sounding. Interviews lasted approximately 45 to 90 minutes, were conducted with participants' consent, audio recorded, and subsequently transcribed verbatim for analysis (Sunandar, Abd Karim, et al., 2026b). Participants represented a broad spectrum of stakeholders, including senior officials from government ministries, representatives from financial institutions, private investors, advisory organisations, and authorities (Sunandar, Andriyanti, et al., 2026a; Sunandar et al., 2025b). The selection of participants followed a purposive sampling strategy, drawing initially from members of the PPP Indonesia Office and complemented by snowball sampling to ensure that respondents possessed relevant expertise. A summary of all expert participants is presented in Table 1.

**Table 1:** Details of Experts

| Code | Organization |
|---|---|
| P1 | Ministry of Public Works |
| P2 | Ministry of Investment |
| P3 | National Committee for Islamic Economy and Finance |
| P4 | Ministry of National Development Planning |
| P5 | Ministry of Finance |
| P6 | Ministry of Public Works |
| P7 | Ministry of Transportation |
| P8 | Ministry of Transportation |
| P9 | National Public Procurement Agency |
| P10 | National Public Procurement Agency |
| P11 | Sharia Bank |
| P12 | PPP Financier Company |
| P13 | PPP Private Investment |
| P14 | PwC Indonesia |
| P15 | PPP Private Investment |
| P16 | PPP Private Investment |
| P17 | Sharia Bank |
| P18 | Sharia Bank |
| P19 | Indonesian Ulema Council (MUI) |
| P20 | Asian Infrastructure Investment Bank |
| P21 | Indonesian PPP Expert Association |

*Source: Author's Own Creation* (2026)

### *Data Analysis*

The data were analysed using thematic analysis to identify patterns and key themes emerging from the interviews. This method enables systematic coding and interpretation of qualitative data while remaining sensitive to context and meaning (Sunandar, Abd Karim, et al., 2026a; Sunandar, Andriyanti, et al., 2026b). Following Saldana (2021), the analysis involved familiarisation with the transcripts, first cycle open coding, category development through iterative comparison, and refinement into higher order themes. Coding was undertaken manually across all transcripts, and emerging themes were continuously reviewed against the original interview data to ensure consistency, credibility, and conceptual coherence. Finally, themes were refined and synthesised into a coherent interpretation that integrates multiple stakeholder perspectives. The resulting thematic structure informed the development of a conceptual framework for Sharia compliant market sounding, balancing normative requirements with practical implementation considerations.

## ANALYSIS AND DISCUSSION

### *Theme 1: Convergence on the Normative Imperative of Transparency in Sharia-Compliant Market Sounding*

The first prominent theme emerging from the data is the strong convergence among stakeholders regarding the normative necessity of transparency and full disclosure within market sounding practices. Across the interviews, participants consistently emphasised that the principles of transparency, clarity, and fairness are not only compatible with PPP practices but are also foundational requirements under Sharia. This convergence reflects a shared understanding that market sounding, as an early stage of engagement, should embody ethical and governance standards that minimise information asymmetry and promote trust between public authorities and private investors. While conventional PPP practices often adopt selective disclosure, the findings suggest that stakeholders perceive Sharia principles as reinforcing, rather than contradicting, the broader objectives of good governance. This theme is further elaborated through three interrelated categories, as summarised in Table 2.


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**Table 2:** Theme 1 Normative Imperative of Transparency

| Category | Coding | Source |
|---|---|---|
| **Alignment with Sharia principles** | transparency as obligation; full disclosure required; avoidance of uncertainty; compliance requirement | P1, P9, P16, P18, P19 |
| **Transparency as good governance** | alignment with GCG; fairness and accountability; equal information access; ethical conduct | P2, P7, P20, P21 |
| **Transparency to build trust** | reducing uncertainty; preventing disputes; informed decision making; investor confidence | P5, P8, P15, P21 |

*Source: Author's Own Creation* (2026)

The first category highlights the strong alignment between market sounding transparency and Sharia principles. Several participants explicitly stated that transparency and disclosure are not optional but constitute a fundamental requirement for Sharia compliance. As P19 explained, "the fundamental philosophy of Sharia is transparency," while P18 emphasised that transparency is "not just important, but mandatory." Similarly, P9 asserted that failure to disclose key financial information would render the process "non-compliant" with Sharia principles. This indicates that stakeholders perceive transparency not merely as a technical feature of market sounding, but as an essential condition for the legitimacy of Sharia-compliant PPPs.

The second category situates transparency within the broader framework of good governance. Participants such as P2 and P7 highlighted that transparency is already a central principle of PPP governance. P2 noted that "the principle of transparency is one of the main principles upheld in the development of PPP in Indonesia," while P7 stressed that "the agreement must be clear and transparent" and aligned this principle with good corporate governance and Islamic economics. Similarly, P20 argued that transparency and accountability are universally important, regardless of whether a project adopts a Sharia or conventional framework. P21 further suggested that transparency enhances the credibility of the market sounding process by ensuring that all participants have equal access to information. These perspectives indicate that Sharia principles reinforce existing governance norms rather than introducing entirely new requirements, thereby facilitating their integration into PPP practices.

The third category emphasises the role of transparency in building trust and improving investor engagement. Participants consistently noted that comprehensive disclosure reduces uncertainty and enables more informed decision making. P5 argued that "the government must disclose everything; nothing should be hidden," enabling investors to assess project viability using transparent assumptions. Likewise, P21 observed that transparency allows the market to make informed decisions so that investors "won't feel deceived or misled." Collectively, these insights demonstrate that transparency is not only a

normative requirement but also a practical mechanism for improving the effectiveness of market sounding.

### *Theme 2: Practical Constraints and Contextual Limitations in Implementing Full Disclosure*

Despite the strong normative support for transparency, the second theme reveals significant practical constraints that limit the full implementation of disclosure requirements during market sounding. Participants acknowledged that while Sharia principles advocate comprehensive transparency, the realities of PPP project preparation, institutional capacity, and market dynamics necessitate a more nuanced approach. These constraints highlight the tension between ideal principles and operational feasibility, particularly in early project stages characterised by uncertainty and evolving information. This theme is further elaborated through three categories, as presented in Table 3.

**Table 3:** Theme 2 Practical Constraints and Limitations

| Category | Coding | Source |
|---|---|---|
| **Limited project readiness** | incomplete data; lack of documentation; capacity constraints; early stage uncertainty | P2, P4, P10, P12 |
| **Need to preserve innovation** | competitive tension; non-disclosure of financial models; bidder differentiation; flexibility | P4, P14, P11, P12 |
| **Uncertainty in early stages** | evolving assumptions; undefined profit sharing; case by case application; provisional information | P3, P10, P11, P12 |

*Source: Author's Own Creation* (2026)

The first category relates to the limited readiness of project owners and institutions to provide comprehensive disclosure. P2 highlighted that project owners "may not necessarily be prepared to provide the required documents," reflecting institutional readiness challenges despite strong support for transparency. P4 noted that even in conventional PPPs, detailed cost structures are rarely disclosed, suggesting that existing practices may not yet support the level of transparency required under Sharia principles. Likewise, P10 questioned whether implementation should become "more detailed or more technical," indicating uncertainty regarding the practical scope of disclosure. P12 further emphasised that many stakeholders still lack a clear understanding of PPP mechanisms, which complicates efforts to introduce more rigorous transparency requirements. These findings suggest that institutional capacity is a critical determinant of transparency in market sounding.

The second category highlights the need to preserve innovation and competitive dynamics. Participants expressed concern that full disclosure of financial models and assumptions could undermine competition among bidders. As P14 explained, certain financial baselines are intentionally withheld because


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authorities expect bidders "will not just copy" government calculations, thereby preserving innovation and competition. Similarly, P4 observed that "not everything is disclosed" in conventional PPP market sounding, suggesting that Sharia implementation may require a different regulatory approach. P11 and P12 further suggested that disclosure should be adapted on a case-by-case basis, depending on the nature of the project and the level of market maturity. These perspectives indicate that transparency must be balanced against the need to maintain a competitive and dynamic bidding environment.

The third category addresses the inherent uncertainty of early-stage project development. P3 explained that the profit-sharing ratio "doesn't necessarily have to be included" during market sounding because project assumptions remain uncertain. P11 emphasised that implementation should be context specific, acknowledging that not all projects can provide the same level of detail. Similarly, P12 suggested that disclosure should focus on "the range of the margin" rather than precise financial figures during the early stages. These insights suggest that full disclosure may not always be feasible or meaningful during early stages, and that flexibility is required to accommodate uncertainty.

***Theme 3: Towards a Balanced and Adaptive Disclosure Framework***

The third theme synthesises the findings by proposing a balanced approach to transparency that reconciles Sharia principles with practical constraints. Rather than advocating absolute disclosure or maintaining conventional selective practices, participants emphasised the need for an adaptive framework that distinguishes between essential and flexible information. This approach seeks to ensure compliance with Sharia requirements while preserving the functional objectives of market sounding, including innovation, competition, and iterative project development. The key dimensions of this theme are summarised in Table 4.

**Table 4:** Theme 3 Practical Constraints and Limitations

| Category | Coding | Source |
|---|---|---|
| **Core information disclosure** | cost structures; profit margins; key assumptions; data transparency | P5, P9, P16, P18 |
| **Flexible disclosure elements** | indicative ranges; evolving details; staged disclosure; non-fixed ratios | P3, P11, P12, P14 |
| **Interactive and iterative process** | market feedback; dialogue; joint refinement; stakeholder engagement | P8, P2, P15, P21 |

*Source: Author's Own Creation* (2026)

The first category emphasises the importance of disclosing core information as a minimum requirement for Sharia compliance. Participants such as P5 and P9 stressed that essential financial information should always be

disclosed. P5 argued that "the source and formula of the calculations should also be disclosed," while P9 maintained that "everything must be clear, no secrets should be kept" to ensure Sharia compliance. P16 reinforced this by linking disclosure to the prevention of uncertainty and speculative behaviour. P18 further described transparency as mandatory, indicating that certain information cannot be withheld without compromising Sharia compliance. These perspectives suggest that a baseline level of disclosure is necessary to uphold ethical and contractual standards.

The second category introduces the concept of flexibility in disclosure. Participants acknowledged that not all information can or should be fixed during market sounding. P3 reiterated that profit sharing ratios are "not mandatory" during market sounding, whereas P14 argued that some internal financial models remain undisclosed to encourage bidder innovation, if transparency regarding project fundamentals is maintained. This indicates that transparency can be achieved through indicative ranges and evolving details rather than rigid specifications. Such flexibility allows market sounding to remain responsive to changing conditions while maintaining alignment with Sharia principles.

The third category highlights the importance of interaction and iterative engagement in achieving effective transparency. P8 noted that transparency "also requires feedback from the market," highlighting the importance of two-way communication. P2 noted that collaboration between government and stakeholders is essential for developing Sharia-compliant frameworks. P15 stressed the need for continuous refinement of data and assumptions to ensure accuracy and relevance. Likewise, P21 argued that honest disclosure enables investors to make informed decisions without feeling "deceived or misled." These insights suggest that transparency is not a static outcome but an ongoing process that evolves through stakeholder engagement.

### *Discussion and Conceptual Framework*

The first theme reveals a strong convergence on the normative imperative of transparency, which is well supported in both PPP and Islamic finance literature. Transparency has been widely recognised as a cornerstone of good governance, enhancing accountability, reducing information asymmetry, and strengthening investor confidence in PPPs (Ministry of National Development Plan, 2023; World Bank, 2017). Early disclosure and stakeholder engagement have been shown to improve project bankability and procurement outcomes (Hössl-Neumann & Torggler, 2021; Lombardo & Mucciarelli, 2019; Payne, 2024). In parallel, Islamic finance scholarship emphasises that full disclosure and clarity of contractual terms are essential to ensure validity and to avoid excessive uncertainty or gharar (Hamid et al., 2019; Zultaqawa et al., 2025). The findings of this study reinforce these perspectives, demonstrating that stakeholders


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perceive transparency not only as a governance requirement but also as a moral and religious obligation. This aligns with the argument that Sharia principles complement conventional governance frameworks by strengthening fairness and informed consent in economic transactions.

The second theme highlights practical constraints in implementing full disclosure, which is consistent with prior PPP research. Institutional capacity limitations, including insufficient technical expertise and incomplete project preparation, have been identified as key barriers to effective market sounding in developing economies (APMG International, 2026; Asian Development Bank, 2018). Furthermore, the literature on competitive procurement suggests that selective disclosure is often necessary to preserve bidder innovation and avoid standardised proposals that reduce value for money (Arijeloye et al., 2024; Mat Aron et al., 2024). The concern that full transparency may undermine competitive tension is therefore well established. In addition, uncertainty in early-stage project development has been widely acknowledged, with project parameters often evolving as more information becomes available (Dewulf & Garvin, 2020; Song et al., 2018). The findings corroborate these insights by showing that stakeholders recognise the limits of disclosure in contexts characterised by uncertainty, limited readiness, and the need for flexibility.

The third theme proposes a balanced and adaptive disclosure approach, which resonates with emerging perspectives in governance and stakeholder engagement. Importantly, the findings do not advocate universal or immediate full disclosure. Instead, they support proportionate transparency in which the scope of disclosure evolves according to project readiness, institutional capability, and the certainty of available information. In practice, this may be implemented through a staged disclosure process. During the initial market sounding stage, public authorities should disclose a minimum set of information comprising project objectives, procurement scope, indicative cost structures, funding sources, key financial assumptions, principal project risks, and the methodology underpinning financial calculations. Subsequent market sounding rounds may progressively refine project specific elements, including indicative profit-sharing ranges, preliminary financial projections, financing arrangements, and technical specifications, as additional information becomes available. Throughout this process, investor feedback should be systematically incorporated to refine project assumptions, while periodic Sharia review ensures that evolving disclosures remain consistent with the principles of transparency, fairness, and the avoidance of excessive uncertainty. This approach ensures that essential information is communicated from the outset while allowing project specific elements to evolve without compromising either market sounding effectiveness or Sharia compliance. From an Islamic perspective, such adaptability is consistent

with the principle of maslahah, which prioritises public interest and practical feasibility in applying Sharia rules (Abd Razak, 2020; Arifin, 2025).

Building on these discussions, this study develops a conceptual framework for Sharia compliant market sounding in PPPs. The framework consists of three interrelated dimensions. The first dimension is the normative foundation, grounded in Sharia principles of transparency, full disclosure, fairness, and the avoidance of uncertainty. The second dimension comprises contextual constraints, including institutional capacity, project readiness, competitive dynamics, and early-stage uncertainty. The third dimension represents the operational mechanism, defined as a balanced disclosure approach that differentiates between core information, such as cost structures and key assumptions, and flexible elements, such as indicative ranges and evolving details. These dimensions interact dynamically through iterative stakeholder engagement, enabling continuous refinement of project information. This integrated structure forms the basis of a practical and adaptive framework, as illustrated in Figure 1.

Overall, the framework offers a theoretically informed and empirically grounded contribution to the design of PPP processes that are both Sharia compliant and operationally effective. Unlike existing PPP market sounding frameworks, which primarily emphasise investor engagement and procurement efficiency, and unlike Islamic finance governance frameworks, which mainly focus on contractual compliance and financial instruments, the proposed framework integrates ethical transparency requirements with the operational realities of early stage PPP market sounding. It therefore introduces a balanced disclosure mechanism that distinguishes between mandatory core disclosures and context dependent flexible disclosures, providing practical guidance for implementing Sharia principles without compromising market sounding effectiveness.


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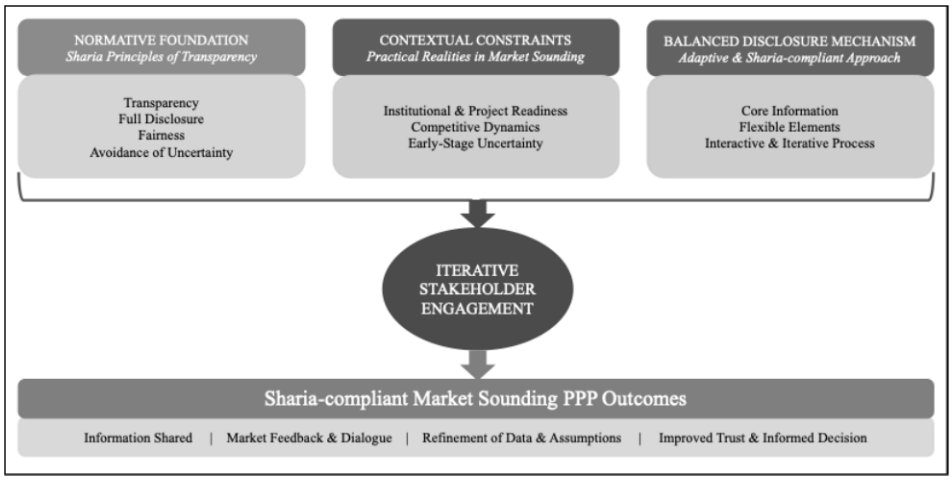



**Figure 1:** Conceptual Framework
*Source: Author's Own Creation* (2026)

## CONCLUSION

This study demonstrates that Sharia principles, particularly transparency, full disclosure, and fairness, are broadly compatible with market sounding practices in PPPs. The findings indicate a strong consensus among stakeholders that transparency constitutes both a governance requirement and a Sharia obligation. At the same time, the study identifies important practical constraints, including limited institutional capacity, early stage uncertainty, and the need to preserve competitive innovation. These factors necessitate a calibrated approach to disclosure rather than a rigid or universally applicable model of full transparency. Instead, Sharia compliant disclosure should be implemented progressively, taking into account project readiness, institutional capacity, and the maturity of available information.

The principal contribution of this research lies in the development of a balanced and adaptive disclosure framework for Sharia compliant market sounding. Although the framework is derived from empirical evidence in Indonesia, its conceptual foundations have broader relevance for Malaysia, Saudi Arabia and other Muslim majority countries with established PPP and Islamic finance ecosystems and improving infrastructure procurement practices within the built environment sector. For public authorities and PPP units, the framework supports the preparation of structured market sounding processes by distinguishing mandatory disclosures from information that may be refined as projects mature. For Sharia advisory bodies, investors, and financiers, the framework provides a practical basis for assessing disclosure adequacy,

strengthening stakeholder confidence, and facilitating more informed investment decisions throughout the early stages of PPP development.

Nevertheless, the study is subject to several limitations. It is confined to the Indonesian context and relies on qualitative data derived from expert perspectives, which may limit generalisability. Future research may extend this work through comparative studies across jurisdictions, as well as quantitative analyses examining the impact of implementing Sharia principles on investor participation, project bankability, and procurement outcomes.

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## DISCLOSURE

The authors declare that there is no conflict of interest associated with this research.

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# URBAN FLOOD PROJECT MANAGEMENT: UNCOVERING SOLUTIONS FOR KUALA LUMPUR

**Farhana Mohd Zaini[1], Zulkiflee Abdul-Samad[2*], Mohd Saidin Misnan[3], Chew Li Ying[4], Nik Fatma Arisya Nik Yahya[5]**

[1] *Centre of Studies for Quantity Surveying and Management (Quantity Surveying), Faculty of Built Environment,*
UiTM SHAH ALAM
[*2] *Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[3]*Department of Quantity Surveying,*
*Faculty of Built Environment and Surveying,*
UNIVERSITI TEKNOLOGI MALAYSIA
[4,5]*Department of Quantity Surveying,*
*Faculty of Engineering and Quantity Surveying,*
INTI INTERNATIONAL UNIVERSITY

## Abstract

Kuala Lumpur is the most developed city in Malaysia, facing heightened risks of flash floods due to rapid urbanisation and intense rainfall. This study evaluates the effectiveness of structural interventions in mitigating flash floods through qualitative methods, using semi-structured interviews with experts from the Department of Irrigation and Drainage (DID) and consultant engineers. Content analysis revealed that existing measures, including the JPS manual and guidelines (MASMA), retention and detention ponds, on-site detention systems, and rainwater harvesting tanks, contribute significantly to flood risk reduction but cannot fully resolve the problem. Experts highlighted the importance of consistent maintenance of current infrastructure while recommending innovative approaches to strengthen resilience. Proposed strategies include adopting sponge city concepts, developing coastal reservoirs, integrating green spaces in urban planning, and applying advanced practices from Singapore, such as underground tunnel systems. The findings underscore the need to complement MASMA with innovative structural measures to address persistent flood challenges more effectively. The study contributes to strengthening existing flood management frameworks in Malaysia and urges the DID and local authorities to consider their adoption in future urban flood resilience planning.

***Keywords***: Disaster risk reduction, Flash floods, Flood disaster, Mitigation plan, Structural measures, Developing countries.

[2] Corresponding author. Email: zulkiflee1969@um.edu.my

# INTRODUCTION

The world is currently facing severe impact from climate change, such as rising sea levels, droughts, typhoons, and floods (Said, Gapor, & Hamat, 2024). Floods have already caused widespread disruption, including damage to critical infrastructure such as railway tracks, bridges, roads, vehicles, and properties, often resulting in loss of life (Saad et al., 2024). The consequences extend beyond physical damage: communities are often cut off, delaying emergency response and restricting daily movement, which affects people, goods, and services alike.

Floods have become more frequent and severe, with devastating impacts on the environment, society, and economy (Aldardasawi & Eren, 2021). The urgency of enhancing flood resilience is growing, as buildings and infrastructure remain highly vulnerable to flood damage. However, current approaches are inadequate due to outdated materials, poor design standards, and a general lack of awareness and education within the construction industry. Despite efforts to communicate risk and promote preparedness, adoption of mitigation measures remains low (Abunyewah et al., 2018). While many cities are now investing in urban parks and open spaces to increase water retention and reduce flood risks (Ibrahim et al., 2020), such efforts must be part of a broader strategy.

Kuala Lumpur is one of the busiest cities in Malaysia, frequently affected by flash floods. This is due to the rapid development in the city, poor drainage maintenance, and unsuitable design, as reported by Samsuri et al. (2018). The government has implemented various initiatives to mitigate flood impacts, such as building the Stormwater Management and Road Tunnel (SMART Tunnel), stormwater drains, retention ponds, dams, and more, but these measures seem insufficient as floods persist. Therefore, the goal of this research is to assess the effectiveness of the structural measures and non-structural measures implemented in Kuala Lumpur in mitigating flash floods. Three research objectives are the following: (1) To examine the existing flood prevention strategies implemented in Kuala Lumpur, (2) To evaluate the effectiveness of these flood prevention strategies in mitigating flood risks, and (3) To explore potential improvements for enhancing flood prevention measures in Kuala Lumpur.

# LITERATURE REVIEW

## Flood Implications in Kuala Lumpur City Centre

One of the most common infrastructure-related consequences of flooding is the shutdown of roadways, particularly in low-lying areas. Vehicles attempting to pass through these inundated zones may become stranded or submerged, resulting in severe traffic congestion and extended travel delays (Al-Qadami et al., 2024). Apart from that, floodwater frequently damages or washes away business

premises and the merchandise within them. Such events disrupt business operations, and recovery depends heavily on the extent of losses and the time taken to restore capital (Maleki et al., 2022). Frequent flooding events can lead to significant economic losses, thus affecting business sustainability. Moreover, floods can inflict significant structural damage on buildings. The force of floodwaters can compromise building integrity; roofs may be torn off, walls may collapse or crack, and foundations may weaken. Wooden structures, in particular, may swell, warp, or decay after prolonged submersion. Flash floods are triggered by various factors and tend to be especially destructive near rivers or streams, often resulting in property loss and fatalities. In mountainous regions, intense rainfall can cause soil erosion and mudslides, further damaging infrastructure, homes, and roads, and heightening the risk to human life (Othman et al., 2023). In the commercial sector, the impact is equally devastating.

Beyond physical and economic damage, the social consequences of flooding are far-reaching. These impacts are generally classified into four key aspects: socio-economic, socio-political, socio-demographic, and psychological. Psychosocial effects refer to the mental health challenges faced by flood victims, including emotional distress, anxiety, depression, and grief. Victims often experience behavioral changes as a result of trauma (Zhong et al., 2018). Sociodemographic impacts include the loss of residential property and the forced relocation of affected individuals. Housing recovery typically unfolds in stages, and for many, the psychological toll can be long-lasting, especially for those who remain near flood-prone areas. Each monsoon season, these individuals relive the trauma through recurring anxiety and fear. Flooding also disrupts the broader social fabric of affected communities. Displacement and homelessness are common outcomes, with some victims facing temporary relocation while others are permanently uprooted (Odula, 2020). In such situations, individuals may be forced to stay with relatives or in emergency shelters, which can erode their sense of community and belonging. Tragically, floods can also result in the loss of life, triggering collective grief and disrupting social networks. Furthermore, community life often grinds to a halt. Children may miss school, adults may be unable to work or operate their businesses, and recreational or cultural events are often cancelled. This disruption can weaken community cohesion and lead to increased social stress. In extreme cases, unmet basic needs may give rise to interpersonal and communal conflict (Ullah et al., 2025). Lastly, floods can lead to financial strain and resource shortages, not only for affected individuals but also for surrounding regions. The temporary closure of public facilities like parks, community centers, and recreational venues limits opportunities for social engagement and affects the overall quality of life in the community.


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**The Structural Measures in Kuala Lumpur**

The severe flood that struck Kuala Lumpur's Business District in 1971 prompted the Malaysian government to begin seeking long-term solutions to the city's recurring flood problems. By the mid-1970s, a comprehensive flood mitigation master plan was developed. This plan included strategies such as stormwater ponding, pumped drainage, upstream water storage, and the enhancement of the Klang River's drainage capacity along with its key tributaries (Shahrulnizam et al., 2020). Several structural interventions were implemented to further reduce flood risks, including the construction of dams, floodwalls, levees, revetments, pump stations, and river deepening works (Martinez et al., 2020A major milestone in Kuala Lumpur's flood management was the launch of the Stormwater Management and Road Tunnel (SMART Tunnel) in 2004. Jointly developed by the Malaysian Highway Authority and the Department of Irrigation and Drainage, the RM1.9 billion project served a dual purpose: mitigating flood risk and easing traffic congestion in the city (Ibrahim et al., 2020). The tunnel, which passes through the challenging Kuala Lumpur Limestone Formation, spans 9.7 km in length. It includes a 3 km double-deck motorway and stretches from the Kampung Pandan roundabout to the Kuala Lumpur-Seremban Highway near the TUDM airfield in Sungai Besi. The SMART Tunnel primarily serves central Kuala Lumpur, which is the most congested area during working days (Monday to Friday). The areas include like Masjid Jamek, Jalan Tun Perak, Dataran Merdeka, Kampung Baru, Jalan Munshi Abdullah, and Jalan Tunku Abdul Rahman. There have been no flash floods caused by Klang River overflow in these areas since its opening (Samsuri et al., 2018).

Other than the SMART tunnel, retention ponds are commonly used to help manage stormwater. These ponds collect runoff from surrounding areas and release it slowly through a low-flow outlet to minimize environmental harm. Unlike detention ponds, which eventually dry out, retention ponds are designed to always contain some water, as their outlets are positioned higher. This distinction is critical when designing water management infrastructure (Curtis, 2024). Stormwater problems can be solved in part by installing retention ponds. Stormwater collected in these ponds drains off from the surrounding watershed and is released into the surrounding environment at a preset, slower pace through a low-flow aperture to prevent environmental damage. Similar to detention ponds, which are intended to allow water to flow out until they are entirely dry, retention ponds are made to always contain water. When it comes to building, this distinction means that retention ponds have higher outflow points that permit some water to stay in the pond always, while detention ponds have their orifices near the bottom of the pond. To date, multiple retention ponds have been constructed as initiatives towards flood measures, as presented in Table 1. These

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are among the initiatives taken by the Department of Drainage and Irrigation (DID) in Kuala Lumpur.

**Table 1**: List of Retention Ponds Developed by DID

| Name | Size (hectares) | Agency in charge | Status |
|---|---|---|---|
| Kampung Benteng | 6.6 | DID Director | - |
| Taman Sri Segambut | 4.2 | DID Director | - |
| Batu | 71.6 | FT Department Director-General | Alienated for development |
| Nanyang | 20.1 | DID Director | Flood mitigation project |
| Delima | 8.1 | DID Director | Approved for development |
| Taman Wahyu | 25.4 | DID Director | Approved for development |
| Kampung Puah | 2.3 | DID Director | - |
| Batu 4 1/2 | 0.9 | DID Director | Alienated for development |
| Midah | 17.5 | DID Director | - |
| Flat Sri Johor | 24.8 | FT Department Director-General | - |
| Taman Desa | 17.6 | Federal Territory Land Exco | Project cancelled |
| Taman Berembang | 13.4 | DID Director | - |
| Setapak Jaya | 4.5 | Federal Territory Land Exco | - |
| Boyan | 8.9 | Federal Territory Land Exco | - |
| Bohol | 37.8 | FT Department Director-General | Proposed for alienation |

*Source: Department of Drainage and Irrigation (2023)*

Dams are another essential component of flood control. Beyond their regular storage capacity, dams designed for flood mitigation have dedicated compartments for holding excess water (Xia & Chen, 2021). During heavy rain, dam operators can retain more water and release it gradually, lowering the downstream flood risk. Dams also help recharge groundwater and trap sediment behind their barriers. Outlets installed in the dam's structure control water discharge efficiently. As defined in the Malaysia Dam Safety Management Guideline (MyDAMS), a structure is classified as a dam if it stands at least 10 meters high with a storage volume of over 20,000 $m^3$ or over 5 meters in height with storage exceeding 50,000 $m^3$. In Malaysia, most dams are earth-fill types and are over 40 years old. These dams serve multiple roles, including water supply, irrigation, hydroelectric power generation, flood control, and sediment retention


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(Mohd, 2019). Batu Dam is a flood mitigation structure constructed in Kuala Lumpur at 44 meters high, which is the tallest dam in Malaysia.

An increasingly recognized solution for water management is the use of rainwater harvesting systems (RWHS). These systems are gaining popularity as a sustainable alternative to piped water and an effective method to manage stormwater. Studies have shown that RWHS provide significant environmental, economic, and technological benefits (Qi et al., 2019). Although Malaysia hasn't experienced a major water crisis recently, rainfall is unevenly distributed across regions and seasons. As such, integrating rainwater harvesting can help balance water availability and reduce the risk of flash floods. When widely adopted, these systems not only reduce reliance on treated water but also help manage urban runoff, reduce soil erosion, prevent pollutants from entering waterways, and mitigate flash floods. Promoting RWHS at a larger scale is therefore crucial for sustainable urban development.

## RESEARCH METHODOLOGY

A series of expert semi-structured interviews was conducted with engineers, specifically targeting consultant engineers and professionals from the Department of Irrigation and Drainage (DID) and engineering who are experts in flood management. These individuals were selected due to their direct involvement in the planning and implementation of structural flood mitigation measures from the early stages of the respective projects in Kuala Lumpur City. These sample selections fall under a non-probability sampling method and are categorized as a purposive sampling method. It is anticipated that the small sample size would be adequate since the majority of participants have extensive experience in flood mitigation strategies, with some having up to 43 years of expertise. A similar study related to experience respondents was found by Rahimin et al. (2026).

The interview recordings will be transcribed verbatim and manually translated into English before being analyzed using content analysis. Content analysis will be employed as the primary qualitative data analysis technique to identify themes and interpret the findings.

## ANALYSIS AND DISCUSSION

### Respondents' Profile

The results of the respondents' background are presented in Table 2. All selected respondents are civil engineers with relevant work experience or knowledge related to structural measures for flood mitigation in Kuala Lumpur. Two of the respondents are civil engineers from the Department of Irrigation and Drainage (DID) of Wilayah Persekutuan Kuala Lumpur, while the other two represent Engineering Consultancy Services. All respondents have over 20 years of

professional experience, with the most experienced being Respondent 3 (R3), who has 43 years in the field. This extensive experience makes them highly qualified to provide relevant insights into flood mitigation.

**Table 2**: Details of the respondents

| Participant | Designation | Working Experience (years) |
|---|---|---|
| R1 | Director | 32 |
| R2 | Assistant Director | 21 |
| R3 | Executive Director | 43 |
| R4 | Project Engineer | 33 |

*Source: Authors (2025)*

**Identification of the Flood Prevention Plan in Kuala Lumpur**

Table 3 presents the current flood prevention strategies implemented in Kuala Lumpur. The findings highlight that the Department of Irrigation and Drainage (DID) Manual and Guidelines, commonly known as MASMA, and the use of rainwater harvesting tanks are frequently cited as key flood mitigation measures within the Kuala Lumpur City Centre. The overarching goal of MASMA is to reduce the risk and severity of urban flooding during heavy rainfall events. Accordingly, developers must obtain approval from JPS prior to construction to ensure compliance with MASMA requirements. Before the implementation of MASMA, water from developments was typically discharged directly into rivers without adequate control measures. While previous literature, such as Abunyewah et al. (2018), categorizes MASMA primarily as a non-structural measure focused on policy and planning, These findings contradict previous literature that MASMA also incorporates structural elements by enforcing design standards that directly influence flood mitigation infrastructure. MASMA can also be regarded as part of emergency preparedness planning or overall flood management strategies within the Kuala Lumpur flood mitigation plan. Although it is not discussed in the existing literature, this represents a significant finding of the study, highlighting its contribution to the understanding of flood mitigation strategies.

Rainwater harvesting was also mentioned as a flood mitigation measure among the respondents. Specifically, respondents R3 and R4 emphasized the importance of promoting rainwater harvesting tanks in all households. These systems are designed to capture, store, and manage rainwater runoff for later use. Typically, rainwater is collected from rooftops and directed into storage tanks, where it can be reused for various non-potable purposes. Beyond effective water resource management, rainwater harvesting presents a sustainable and cost-efficient approach to reducing dependency on treated water supplies. It serves as


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a practical solution for enhancing household-level water conservation and contributes to broader environmental sustainability efforts.

In addition to MASMA and rainwater harvesting, detention ponds play a crucial role in managing peak stormwater runoff. During heavy rainfall, these ponds temporarily store excess water and release it gradually, thereby reducing the volume and velocity of water entering downstream drainage systems. This helps to mitigate the risks of flooding and erosion. In contrast, retention ponds are designed to permanently hold stormwater runoff on-site. Unlike detention ponds, retention ponds maintain a constant water level, allowing the water to either infiltrate into the ground or evaporate over time. This process not only supports groundwater recharge but also enhances water quality through the natural removal of pollutants. Respondent R1 emphasized the importance of a multi-faceted structural approach to flood mitigation in Kuala Lumpur. R1 added that "In Kuala Lumpur as a whole, the SMART system is only part of the structural measures that divert a portion of water from certain rivers. A more viable flood mitigation strategy requires a combination of multiple methods to provide comprehensive protection. For example, in developed areas, the river basin functions as a catchment where rainwater is impounded. Effective flood mitigation must cover all areas such as upstream, midstream, and downstream. At the upstream level, structures regulate and control water flow; at the midstream, measures such as detention, retention, and diversion are employed; while downstream, coastal bunding is used to manage water outflow." To conclude, R1 highlighted that all structural components like retention, detention, diversion, dams, and coastal bunds play a vital and interconnected role in managing flood risks across the entire river basin in Kuala Lumpur. These integrated measures are essential for controlling water flow and minimizing flood impacts throughout the catchment area.

On-Site Detention (OSD) systems were also another mitigation strategy mentioned by the experts, further strengthening localized stormwater management strategies. The primary objective of OSD is to control stormwater runoff by temporarily storing excess rainwater during heavy rainfall events. This stored water is then gradually released at a controlled rate into the stormwater drainage network or adjacent natural water bodies. By regulating the flow, OSD helps to reduce downstream flooding, prevent erosion, and improve water quality by allowing sediments and pollutants to settle before the water is discharged.
Building on this, respondent R1 highlighted that flood mitigation in Kuala Lumpur requires an integrated approach involving multiple structural measures. R1 explained,

> "In Kuala Lumpur as a whole, the SMART system is only part of the structural measures that divert a portion of water from certain rivers. A

> viable flood mitigation system must comprise multiple components to provide comprehensive protection. For instance, in a developed area that includes a river basin or catchment area, flood mitigation should cover upstream, midstream, and downstream levels." [R1]

R1 elaborated further, noting that

> "Upstream interventions help regulate and control water flow, while the midstream zone involves detention, retention, and diversion structures. Finally, the downstream area utilises coastal bunding to manage water discharge." [R1]

This holistic approach ensures that all areas of the river basin are adequately protected against flood risks. R1 emphasised that no single structural measure can effectively manage flood risks on its own. Instead, a combination of dams, detention and retention ponds, and diversion channels, particularly in the midstream sections of river basins, is essential for controlling and redirecting water flow during heavy rainfall.

**Table 3**: List of flood prevention plans in Kuala Lumpur

| Flood prevention plans/ respondents | R1 | R2 | R3 | R4 |
|---|---|---|---|---|
| JPS manual and guideline (MASMA) | ✓ | ✓ | | |
| Retention and Detention Pond | ✓ | | | ✓ |
| On-Site Detention (OSD) | ✓ | | | ✓ |
| Rainwater harvest tank | | | ✓ | ✓ |
| Total word frequency | ✓ | ✓ | | |

*Source: Authors (2025)*

**Effectiveness of the Flood Prevention Plan in Kuala Lumpur**

The findings indicate that there is no single flood mitigation strategy in Kuala Lumpur that can guarantee the complete prevention of flood disasters. However, structural measures have proven effective in significantly reducing the impact and severity of flooding. R1 & R2 have a similar opinion that the mitigation strategies must involve a combination of structural approaches, for example, dams and water retention, smart tunnels, and retention ponds, as each measure serves a distinct function and is suited to specific contexts. For instance, the SMART Tunnel is primarily designed to divert stormwater, ponds are constructed to store excess water, and dams function to control river flow. These structural solutions are not universally applicable; their effectiveness depends on factors such as geographical location, population density, and urban development


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intensity. In addition, R1 explained that the SMART Tunnel, while effective, is geographically limited to the city center, specifically benefiting impacted areas. As such, it has minimal impact outside its operational zone. This illustrates that no single measure can address flood risks citywide, and instead, a comprehensive, location-sensitive strategy is essential. Further insights were gathered from Table 4, where respondents R3 and R4 evaluated the efficiency of various structural measures used for stormwater management and flood mitigation in Kuala Lumpur.

(i) SMART Tunnel
R3 assigned a low efficiency rating, suggesting that the SMART Tunnel contributes minimally to overall stormwater management. This could reflect concerns about operational limitations, capacity constraints, or the belief that other interventions offer greater impact.

(ii) Dams
Dams received the highest effectiveness score. R3 highlighted their ability to store excess rainfall, regulate flow, and prevent downstream flooding. The rating reflects a broader global consensus on the importance of dams in water resource infrastructure.

(iii) Retention Ponds
R3 considered retention ponds moderately effective. These structures temporarily hold stormwater runoff, allowing pollutants to settle before discharge. Their effectiveness, however, may depend on design quality, maintenance, and site-specific factors such as catchment size and urban density.

Overall, R3's assessment indicates that dams are perceived as the most reliable structural solution, followed by retention ponds, with the SMART Tunnel viewed as having limited effectiveness in broader flood mitigation. Unlike R3, respondent R4 did not rate the SMART Tunnel, dams, or retention ponds, citing limited personal experience with these measures. However, R4 assigned a high effectiveness rating to general water retention strategies, underscoring her strong support for sustainable, decentralized approaches to flood control. Water retention techniques aim to retain stormwater on-site and enhance groundwater infiltration. These include practices such as green roofs, rain gardens, permeable pavements, and other forms of green infrastructure. R4's perspective reflects an understanding of the multi-functional benefits of these systems, including urban greening, water quality improvement, groundwater recharge, and flood reduction.

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**Table 4**: Most Effective Flood Measures in Kuala Lumpur

| Theme/Respondent | R1 | R2 | R3 | R4 |
|---|---|---|---|---|
| It must have a combination of a few approaches. | ✓ | ✓ | | |
| Different structural measures and locations serve different purposes. | | ✓ | | |
| Dam | | | ✓ | |
| Water Retention | | | ✓ | |
| Smart Tunnel | | | ✓ | |
| Retention pond | | | | ✓ |

*Source: Authors (2025)*

**Strategies in Enhancing the Flood Prevention Plan in Kuala Lumpur**

According to respondents R1 and R2, one of the key strategies to enhance Kuala Lumpur's flood prevention efforts is to continue implementing flood mitigation projects in areas still affected by recurring floods. For example, a project at Sungai Bunus has recently been completed, and the Department of Irrigation and Drainage (DID) is currently working on new initiatives at Sungai Kuyoh and other critical locations. R1 emphasised that a long-term, basin-wide flood mitigation strategy is necessary to ensure sustainable protection against future flooding. Similarly, respondent R2 highlighted that, over the next five years, a master plan is being developed for diversion projects along Sungai Klang and Sungai Kuyoh, which will further strengthen the city's stormwater management system.

Beyond local initiatives, R1 also recommended adopting international best practices, specifically the Sponge City concept, which originated in China. This urban planning approach aims to reduce flood risks by enabling cities to function like natural sponges, absorbing, storing, and purifying rainwater rather than allowing it to overwhelm drainage systems. Unlike traditional urban areas with impervious surfaces, sponge cities incorporate green infrastructure such as rain gardens, green roofs, permeable pavements, and bioswales. These features allow water to infiltrate into the ground, reduce surface runoff, and improve water quality. By slowing down water flow and enhancing infiltration, sponge city elements like wetlands, retention ponds, and vegetated swales can help prevent downstream flooding while also providing ecological and aesthetic benefits. Integrated drainage systems, which combine traditional infrastructure with nature-based solutions, are key to the sponge city model and offer a comprehensive strategy for increasing urban flood resilience.

In addition to this, respondent R2 identified coastal reservoirs as another promising structural measure. Coastal reservoirs, located near shorelines, use natural coastal formations such as bays or estuaries to store water without the need for extensive damming. These structures offer benefits including a reliable water


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supply, drought resilience, and potential for desalination, making them a strategic asset in managing both flood risks and water scarcity.

Respondent R4 added that increasing the allocation of green spaces in development plans is crucial for flood mitigation. She emphasised the importance of green lung projects and preserving trees and forests. Vegetated areas such as parks, gardens, and urban forests act as natural sponges, absorbing rainfall and reducing surface runoff. These spaces help to delay water discharge into drainage systems, thus preventing overload during heavy rains. Additionally, tree-lined streets and green zones contribute to soil stabilization, erosion control, and improved infiltration, further enhancing flood prevention capabilities.

From a maintenance perspective, respondents R3 and R4 stressed the need for strict enforcement of routine upkeep for existing infrastructure, particularly retention ponds. Regular maintenance including sediment removal, debris clearance, and pollution control is vital for preserving the pond's storage capacity and water quality. These actions help ensure that the infrastructure performs effectively during rain events and meets environmental regulations.

Lastly, R3 proposed constructing underground tunnels beneath roads and buildings, similar to systems used in Singapore. These drainage tunnels increase the capacity to channel stormwater away from urban surfaces, easing the burden on surface infrastructure and lowering the risk of urban flooding. Singapore's approach serves as a model for densely built cities like Kuala Lumpur, where space constraints require innovative, subterranean solutions. In conclusion, the insights from all four respondents underline that an effective flood mitigation plan for Kuala Lumpur must integrate ongoing structural projects, innovative international models like sponge cities, green infrastructure, regular maintenance, and adaptive planning. This holistic approach is essential to enhancing the city's resilience to future climate challenges and ensuring sustainable urban development. The result of this section was presented in Table 5.

**Table 5**: Strategies for reducing the flood impact in Kuala Lumpur

| Theme/Respondent | R1 | R2 | R3 | R4 |
|---|---|---|---|---|
| Maintain flood mitigation efforts. | ✓ | ✓ | | |
| Sponge City | ✓ | | | |
| Coastal Reservoir | | ✓ | | |
| Planning Provision for Green Areas | | | ✓ | |
| Carry out regular maintenance. | | | ✓ | ✓ |
| Structural measures in Singapore | | | ✓ | |

*Source: Authors (2025)*

## CONCLUSION

Flood mitigation strategies need to be improved since the flood's disaster has become a major problem in many countries. This research was guided by three key objectives: (1) to identify the current flood prevention plans in Kuala Lumpur, (2) to assess the effectiveness of these measures, and (3) to explore potential enhancements to further strengthen flood mitigation strategies. A semi-structured interview with the experts' engineers from the DID department discovers the current structural measures in Kuala Lumpur are dams, retention ponds, and the SMART Tunnel. Other measures such as green infrastructure and rainwater harvesting were also considered as prevention strategies. These findings align with prior studies (Ibrahim et al., 2020; Martinez et al., 2020) that the current implementation is integrated flood management. On the other hand, respondents highlighted that each structural measure plays a different role; their effectiveness varies depending on geographic location and implementation scale. Overall, it was found a combination of structural and non-structural solutions is necessary for comprehensive flood mitigation. Notably, some respondents considered dams to be the most effective, though this perception was recognized as subjective and context-dependent (Xia & Chen, 2021). Sustainable management practices such as rainwater harvesting further enhance the body of knowledge on urban flood resilience (Qi et al., 2019). These insights provided valuable directions for future improvements in Kuala Lumpur's flood management strategy.

The study contributes to both theory and practice by confirming the importance of integrated structural and non-structural measures and highlighting the relevance of emerging concepts such as the sponge city model, which offers a nature-based solution to the urban flooding challenge. It also clarifies misconceptions of MASMA's role, positioning it as a hybrid strategy encompassing both structural and emergency preparedness elements, thus extending the conceptual framework of flood mitigation planning in Kuala Lumpur.

Future research could incorporate quantitative data analysis and broader stakeholder engagement for a more comprehensive evaluation. Practically, this study implies that enhancing routine maintenance of existing infrastructure, expanding green urban spaces, and adopting international best practices such as coastal reservoirs and underground drainage tunnels are critical for improving flood resilience. Strategic planning should also emphasize basin-wide interventions across upstream, midstream, and downstream areas to ensure holistic management (Shahrulnizam et al., 2020).


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# ASSESSING THE FACTORS INFLUENCING PRIVATE VEHICLE OWNERS' INTENTION TO PAY PROPOSED CONGESTION FEES IN GEORGE TOWN, PENANG: A THEORY OF PLANNED BEHAVIOUR

**Julia Aqila Japry[1], Nitanan Koshy Matthew[2], Zakiah Ponrahono[3]**

[1,2,3] *Department of Environmental Management,*
*Faculty of Forestry and Environment,*
UNIVERSITI PUTRA MALAYSIA

## Abstract

Penang was identified as the most congested city in Malaysia in 2024, primarily due to the influx of tourists in George Town, which contributed to high greenhouse gas emissions. Therefore, the Penang State government proposed becoming the first state to implement a congestion fee. However, limited information was available regarding the stakeholders' intentions towards congestion fees. Accordingly, the research aimed to determine the relationship between attitude, subjective norms (SN), perceived behavioural control (PBC), and intention to pay a congestion fee. Questionnaires were utilised to collect responses from 440 respondents through stratified sampling in George Town, involving residents of Penang and domestic tourists. The results of multiple regression analysis indicated that the constructs of the Theory of Planned Behaviour (Attitude, SN, and PBC) had significant and positive relationships. These findings provided valuable insights for the State Government and the Traffic Enforcement and Investigation Department in designing effective congestion fee implementation strategies, which were aligned with the National Transport Policy 2021-2030 and SDG11 (Sustainable Cities and Communities).

***Keywords***: Congestion fee, Multiple Regression Analysis, Stratified Sampling, Theory of Planned Behaviour

[1] Corresponding author. Email: nitanankoshy@upm.edu.my

# INTRODUCTION

The rise in population and the increasing number of registered vehicles in major cities has been identified as key factors contributing to frequent traffic congestion (Kapoor, 2024). In 2024, George Town, the capital city of Penang, was reported to be the most congested city in Malaysia (The Sun, 2025). The growing population of Penang (Penang Institute, 2024) and the increasing number of vehicles entering George Town have contributed to overcrowding among both residents and tourists. This has resulted in persistent traffic congestion, extended travel times, and reduced traffic performance (Li-Sian et al., 2024).

During a session of the Dewan Rakyat, George Town was identified as a potential location for the initial implementation of congestion fees. Consequently, the Penang State Government proposed the introduction of congestion fees to address this ongoing issue (The Star, 2025). The implementation of this policy is still under consideration until alternative public transportation such as the LRT has been built (The Star, 2025). However, research on congestion fees in Malaysia, particularly in Penang, has remained limited. Identifying the factors that influence stakeholders' intention to pay is a critical initial step for accessing the feasibility of congestion fee policies (Ngah et al., 2020). Therefore, the Theory of Planned Behaviour was adopted as the primary theoretical framework for this study. This study aimed to determine the relationship between attitude, subjective norms (SN), perceived behavioural control (PBC), and the intention to pay a congestion fee.

# LITERATURE REVIEW

## Review of Past Studies Using TPB in Congestion Fees Research in Transportation

The successful implementation of congestion fees in major cities such as Singapore, London, Milan and Stockholm have attracted considerable research attention. The study by Cui et al. (2025) integrated TPB and the Norm Activation Model (NAM) to examine the public acceptance of congestion charges. The variables examined included awareness of consequences, attitudes, PBC, SN, personal norms, and behavioural intentions. Responses from 426 participants, collected through convenience sampling, were analysed using Structural Equation Modelling (SEM). The findings revealed that personal norms were significant factors influencing the acceptance of congestion fees.

Transportation-related issues have increasingly required attention to maximise environmental benefits and promote sustainable mobility practices. Consequently, the TPB has been extensively applied to examine and predict public behaviour and intentions regarding the transportation-related changes. In China, Li et al. (2025) investigated the factors influencing car owners' intention


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to adopt car-sharing practices using modified TPB variables. The variables examined included behavioural attitudes, novel experience, PBC, and SN. Data were collected from 399 respondents through stratified sampling and were analysed using SEM. The findings identified behavioural attitudes, PBC, and SN as significant factors influencing the public's intention to engage in car-sharing practices. Similarly, a study conducted by Angin et al. (2024) in Northern Cyprus determined intentions to use sustainable public transport. The study employed the core TPB variables, namely attitude, SN and PBC. The data obtained from 384 respondents through convenience sampling were analysed using Multiple Linear Regression. The results indicated that SN and PBC were significant variables.

## RESEARCH METHODOLOGY

### Study Area

The study area was located in George Town (5.4141° N, 100.3285° E), situated in the northeast region of Penang Island and serving as the capital city of Penang. The escalating influx of tourists, coupled with rising local vehicle registrations and growth in private vehicle ownership, has contributed to recurring traffic congestion. In order to address this issue, the Penang State Government proposed the implementation of a congestion fee (Nambiar, 2025). In addition, the Dewan Rakyat identified George Town as one of the cities for the preliminary implementation of the proposed congestion fee (The Star, 2025), thereby rendering it the most relevant location for this study.

### Questionnaire Design

This study employed a face-to-face questionnaire survey involving residents and domestic tourists who owned private vehicles and were aged 18 years and above. Both residents and domestic tourists were included as the proposed congestion fee applies to all vehicles entering George Town regardless of residency status, mirroring universal systems like Singapore Electronic Road Pricing (Government of Singapore, 2026). Both categories of stakeholders were included because they represent significant components of the total traffic volume causing the congestion; thus, including both groups are crucial to providing a realistic assessment of the policy's overall impact. Data collection was conducted between October 2025 and December 2025. The questionnaire was divided into six sections (A, B, C, D, E, and F). Section A comprised nine close-ended questions relating to respondents' sociodemographic characteristics, including gender, age, marital status, income, and education level. Sections B, C, D and E measured respondents' attitudes, SN, PBC, and intentions towards congestion fees, respectively, using a five-point Likert scale.

In this study, attitude is operationally defined as responses to the perceived benefits and costs of implementing the George Town congestion fee.

Subjective norm (SN) refers to the perceived social pressure regarding the fee, while perceived behavioural control (PBC) represents an individual's perceived control over their intention to accept it. Finally, intention measures their willingness to support the implementation of the congestion fee.

**Data Collection**

The sample size was calculated based on a population of 6.59 million, derived from the combined total population of Penang in 2023 (1.8 million) (Penang Institute, 2024) and the number of domestic hotel guests recorded in Penang during the same year (4.79 million) (Tourism Malaysia, 2024). The sample size calculation proposed by Krejcie and Morgan (1970) and Yamane (1973) yielded sample sizes of 385 and 400 respondents, respectively. The estimated sample size was determined to be 393 respondents based on the average of those two values. Assuming a 10% drop-out rate, the final sample size was calculated as 437 respondents (Sakpal 2010). Therefore, the target sample size for this study was rounded to 440 private vehicle owners in the Georgetown area.

A stratified random sampling technique was utilised to achieve an equal 50:50 distribution of the 440 participants. Specifically, local residents were randomly selected during weekdays in residential areas and recreational parks. Meanwhile, domestic tourists were randomly surveyed during weekends at popular attractions, such as the Penang Esplanade and Armenian Street. The equal sampling distribution proportion of this study follows a similar approach to those used in past studies by Ku & Mak (2017) and Ng et al. (2017). Additionally, an equal proportion ensures sufficient sample size for separate data analysis to make relevant comparisons.

**Questionnaire Validation**

The questionnaire was validated by five experts specialising in economic valuation research, environmental planning and management, and environmental education. Revisions were made based on the experts' feedback. The questionnaire was subsequently pre-tested among 15 road users in Malacca. Prior to the main survey, a pilot study was conducted involving 40 respondents in George Town to assess the reliability of the instruments. The Cronbach's alpha reliability test conducted using IBM SPSS Statistics produced scores of 0.448, 0.992, 0.879, 0.759 and 0.874 for awareness, attitude, SN, PBC, and intention, respectively. According to Pallant (2020), a minimum Cronbach's alpha value of 0.70 is required to establish acceptable reliability. Therefore, all constructs demonstrate acceptable reliability, except for awareness.


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### Data Analysis

Descriptive statistics were first used to analyse the data. Subsequently, multiple regression analysis was conducted via SPSS to determine how attitude, SN, and PBC influence private vehicle owners' intention to pay congestion fees in the city centre of George Town. The data analysed included the mean values obtained from calculations performed using SPSS Software.

## ANALYSIS AND DISCUSSION

### Sociodemographic Profiles

Table 1 presents the sociodemographic profiles of the respondents. The participation of residents and domestic tourists was relatively balanced between male and female respondents. Among residents, the largest age group was 26–35 years, comprising 69 respondents (31.4%). In contrast, the majority of tourists were aged 18–25 years, accounting for 96 respondents (43.6%). Overall, respondents aged 18–25 years constituted the largest age group, with 157 individuals (35.7%). More than half of the residents and tourists reported monthly incomes below RM2,500, with 128 respondents (33.2%) in each group. Consequently, the B40 represented the dominant income category in this study. Most resident respondents reported secondary school as their highest educational qualification, whereas the majority of tourists possessed higher educational qualifications. Overall, secondary school was the most frequently highest education level. Nonetheless, the cumulative number of respondents possessing pre-university, bachelor's, master's, and doctoral qualifications amounted to 280 respondents (63.6%), indicating a relatively high overall level of educational attainment.

**Table 1**: Sociodemographic Profiles of the Respondents

| Item | Resident | | Tourist | | Overall | |
|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % |
| **Gender** | | | | | | |
| Male | 107 | 48.6 | 110 | 50.0 | 217 | 49.3 |
| Female | 123 | 51.4 | 110 | 50.0 | 223 | 50.7 |
| **Age Group** | | | | | | |
| 18 - 25 years | 61 | 27.7 | 96 | 43.6 | 157 | 35.7 |
| 26 - 35 years | 69 | 31.4 | 58 | 26.4 | 127 | 28.9 |
| 36 - 45 years | 45 | 20.5 | 35 | 15.9 | 80 | 18.2 |
| 46 - 55 years | 19 | 8.6 | 23 | 10.5 | 42 | 9.5 |
| 56 years and above | 26 | 11.8 | 8 | 3.6 | 34 | 7.7 |
| **Marital Status** | | | | | | |
| Single | 87 | 39.5 | 120 | 54.5 | 207 | 47.0 |
| Married | 131 | 59.5 | 99 | 45.0 | 230 | 52.3 |
| Others | 2 | 0.9 | 1 | 0.5 | 3 | 0.7 |
| **Monthly Individual Gross Income** | | | | | | |
| Less than RM2,500 | 117 | 53.2 | 128 | 33.2 | 245 | 55.7 |
| RM2,501 - RM3,169 | 46 | 20.9 | 34 | 8.8 | 80 | 18.2 |
| RM3,170 - RM3,969 | 16 | 7.3 | 15 | 3.9 | 31 | 7.0 |

| Item | Resident | | Tourist | | Overall | |
|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % |
| RM3,970 - RM4,849 | 13 | 5.9 | 6 | 1.6 | 19 | 4.3 |
| RM4,850 - RM5,879 | 14 | 6.4 | 7 | 1.8 | 21 | 4.8 |
| RM5,880 - RM7,099 | 8 | 3.6 | 13 | 3.4 | 21 | 4.8 |
| RM7,100 - RM8,699 | 2 | 0.9 | 4 | 1.0 | 6 | 1.4 |
| RM8,700 - RM10,959 | 3 | 1.4 | 4 | 1.0 | 7 | 1.6 |
| RM10,960 - RM15,039 | - | - | 5 | 1.3 | 5 | 1.1 |
| More than RM15,039 | 1 | 0.5 | 4 | 1.0 | 5 | 1.1 |
| **Education Level** | | | | | | |
| Primary School | 14 | 6.4 | 2 | 0.5 | 16 | 3.6 |
| Secondary School | 89 | 40.5 | 55 | 14.2 | 144 | 32.7 |
| STPM/ Foundation/ Diploma/ Matriculation | 65 | 29.5 | 70 | 18.1 | 135 | 30.7 |
| Bachelor's Degree | 43 | 19.5 | 67 | 17.4 | 110 | 25.0 |
| Master's Degree | 9 | 4.1 | 24 | 6.2 | 33 | 7.5 |
| Doctor of Philosophy (PhD) | 0 | 0 | 2 | 0.5 | 2 | .5 |

## Visitation Characteristics

Table 2 highlights that the majority of the local respondents were road users residing on Penang Island, comprising 175 respondents (79.5%), while the remaining 45 respondents (20.5%) resided on Penang Mainland. The largest proportion of respondents, namely 106 individuals (48.2%), commuted to George Town daily for employment, educational, and recreational purposes. Most respondents were residents of George Town, which made commuting activities more frequent and necessary compared to those residing in other parts of Penang. Meanwhile, only seven respondents (3.2%) reported commuting to George Town once every few years. Some respondents attributed this pattern to a declining interest in travelling due to worsening traffic congestion, which was consistent with the findings of a previous study by Jaafar (2025).

**Table 2**: Visitation Characteristics among Residents

| Item | Frequency | Percentage |
|---|---|---|
| **Road User Category (n=220)** | | |
| Resident (Penang Island) | 175 | 39.8 |
| Resident (Penang Mainland) | 45 | 10.2 |
| **Frequency of Commuting to George Town (n = 220)** | | |
| Daily | 106 | 48.2 |
| Weekly | 63 | 28.6 |
| Monthly | 19 | 8.6 |
| Several times a year | 25 | 11.4 |
| Once every few years | 7 | 3.2 |

Table 3 indicates that most of the domestic tourists originated from Kedah, comprising 81 respondents (36.8%). In addition, most tourists, namely 166 respondents (75.4%), travelled to Penang using private vehicles. This contributed to many private vehicles in Penang, particularly during weekends and holiday periods. Furthermore, the largest proportion of tourists reported visiting George Town once every few years, accounting for 74 respondents (33.6%).


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**Table 3**: Visitation Characteristics among Domestic Tourists

| Item | Frequency | Percentage |
|---|---|---|
| **Road User Category (n=220)** | | |
| Domestic Tourist | 220 | 50.0 |
| **State of Origin (n = 220)** | | |
| Johor | 12 | 5.5 |
| Kedah | 81 | 36.8 |
| Kelantan | 14 | 6.4 |
| WP Putrajaya | 8 | 3.6 |
| WP Kuala Lumpur | 26 | 11.8 |
| Perak | 21 | 9.5 |
| Perlis | 7 | 3.1 |
| Sabah | 1 | 0.5 |
| Sarawak | 1 | 0.5 |
| Selangor | 35 | 15.9 |
| Terengganu | 3 | 1.4 |
| Negeri Sembilan | 11 | 5.0 |
| **Mode of Transportation (n=220)** | | |
| Public Transportation | 45 | 20.5 |
| Private Vehicles | 166 | 75.4 |
| Rented Vehicles | 6 | 2.7 |
| Air Travel | 3 | 1.4 |
| **Frequency of Visits to George Town (n = 220)** | | |
| Daily | 11 | 5.0 |
| Weekly | 16 | 7.3 |
| Monthly | 47 | 21.4 |
| A few times a year | 72 | 32.7 |
| Once every few years | 74 | 33.6 |

Table 4 shows that 220 respondents (50.0%) were domestic tourists, while residents of Penang Island and Penang Mainland accounted for 175 respondents (39.8%) and 45 respondents (10.2%), respectively. Overall, the largest proportion of respondents travelled to George Town daily, comprising 117 respondents (26.6%).

**Table 4**: Visitation Characteristics among Overall Respondents

| Item | Frequency | Percentage |
|---|---|---|
| **Road Users Category (n=440)** | | |
| Resident (Penang Island) | 175 | 39.8 |
| Resident (Penang Mainland) | 45 | 10.2 |
| Domestic Tourist | 220 | 50.0 |
| **Travel Frequency to George Town (n = 440)** | | |
| Daily | 117 | 26.6 |
| Weekly | 79 | 18.0 |
| Monthly | 66 | 15.0 |
| A few times a year | 97 | 22.0 |
| Once every few years | 81 | 18.4 |

## Attitude Towards the Congestion Fees

Table 5 presents the levels of attitude towards congestion fees. The first item, relating to the reduction of greenhouse gas emissions through the implementation

of a congestion fee, showed a medium level of attitude among residents, tourists, and the overall respondents. Residents and the overall respondents also demonstrated a medium level of attitude for the second item, which related to using congestion fees to ease traffic congestion, whereas tourists exhibited a high level of attitude. The third item, which assessed perception of congestion fees as a fair mechanism for managing road use, indicated a medium level of attitude across all respondent groups. This finding contrasted with a previous study, in which most respondents perceived such measures as unfair (Al-Mawajdeh, 2023). The fourth item, which examined whether congestion fees could reduce traffic congestion, showed a medium level of attitude among residents and the overall respondents, while tourists demonstrated a high level of attitude.

**Table 5**: Level of Attitude towards the Congestion Fee

| | Item | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | Total Mean | Level |
|---|---|---|---|---|---|---|---|---|---|
| Resident | Attitude Item 1 | 15.5 | 12.3 | 24.1 | 28.6 | 19.5 | 3.25 | 3.34 | Medium |
| | Attitude Item 2 | 12.3 | 10.5 | 24.5 | 34.5 | 18.2 | 3.36 | | Medium |
| | Attitude Item 3 | 11.8 | 12.3 | 24.5 | 32.3 | 19.1 | 3.35 | | Medium |
| | Attitude Item 4 | 12.7 | 11.8 | 22.3 | 32.3 | 20.9 | 3.37 | | Medium |
| Tourist | Attitude Item 1 | 8.2 | 6.8 | 28.6 | 33.2 | 23.2 | 3.56 | 3.64 | Medium |
| | Attitude Item 2 | 5.5 | 9.1 | 21.8 | 40.5 | 23.2 | 3.67 | | High |
| | Attitude Item 3 | 5.5 | 8.6 | 26.8 | 39.1 | 20.0 | 3.60 | | Medium |
| | Attitude Item 4 | 6.4 | 5.9 | 20.5 | 43.6 | 23.6 | 3.72 | | High |
| Overall | Attitude Item 1 | 11.8 | 9.5 | 26.4 | 30.9 | 21.4 | 3.40 | 3.48 | Medium |
| | Attitude Item 2 | 8.9 | 9.8 | 23.2 | 37.5 | 20.7 | 3.51 | | Medium |
| | Attitude Item 3 | 8.6 | 10.5 | 25.7 | 35.7 | 19.5 | 3.47 | | Medium |
| | Attitude Item 4 | 9.5 | 8.9 | 21.4 | 38.0 | 22.3 | 3.55 | | Medium |

*1 = Totally Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Totally Agree*
*Mean scores are interpreted as Low (1.00 – 2.33), Medium (2.34 – 3.66), and High (3.67 – 5.00).*
*Attitude Item 1 = I feel that paying a congestion fee would reduce greenhouse gas emissions.*
*Attitude Item 2 = I feel that paying a congestion fee can ease traffic*
*Attitude Item 3 = Paying a congestion fee is a fair way to manage road use.*
*Attitude Item 4 = Paying a congestion fee can help reduce traffic congestion in George Town, Penang.*

## Subjective Norm (SN)

Table 6 presents the levels of SN towards congestion fees. The first item, which examined the perceived importance of using public transportation instead of


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private vehicles among respondents' significant others, indicated a medium level of SN among residents, tourists and the overall respondents. This finding was consistent with studies by Hu et al. (2025). The second item, which assessed perceived approval from respondents' significant others regarding the payment of congestion fees, indicated a high level of SN among tourists, while residents and the overall respondents recorded medium levels. The third item, which examined family members' expectations that respondents supported congestion fees, indicated a medium level of SN across all groups. The fourth item, which assessed whether individuals whose opinions were valued would support congestion fees, showed a medium level of SN among residents and the overall respondents, whereas tourists reported a high level of SN.

**Table 6**: Level of Subjective Norms towards the Congestion Fee

| | Item | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | Total Mean | Level |
|---|---|---|---|---|---|---|---|---|---|
| Resident | SN Item 1 | 12.3 | 11.8 | 35.9 | 23.6 | 16.4 | 3.20 | 3.19 | Medium |
| | SN Item 2 | 10.0 | 15.9 | 38.2 | 25.0 | 10.9 | 3.11 | | Medium |
| | SN Item 3 | 6.8 | 16.4 | 37.7 | 28.2 | 10.9 | 3.20 | | Medium |
| | SN Item 4 | 7.7 | 14.5 | 33.6 | 33.2 | 10.9 | 3.25 | | Medium |
| Tourist | SN Item 1 | 7.3 | 12.7 | 36.4 | 28.2 | 15.5 | 3.32 | 3.33 | Medium |
| | SN Item 2 | 7.3 | 14.1 | 33.6 | 35.0 | 10.0 | 3.26 | | Medium |
| | SN Item 3 | 7.3 | 12,7 | 35.0 | 33.6 | 11.4 | 3.29 | | Medium |
| | SN Item 4 | 6.4 | 10.0 | 31.4 | 37.3 | 15.0 | 3.45 | | Medium |
| Overall | SN Item 1 | 9.8 | 12.3 | 36.1 | 25.9 | 15.9 | 3.26 | 3.26 | Medium |
| | SN Item 2 | 8.6 | 15.0 | 35.9 | 30.0 | 10.5 | 3.19 | | Medium |
| | SN Item 3 | 7.0 | 14.5 | 36.4 | 30.9 | 11.1 | 3.25 | | Medium |
| | SN Item 4 | 7.0 | 12.3 | 32.5 | 35.2 | 13.0 | 3.35 | | Medium |

*1 = Totally Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Totally Agree*
*Mean scores are interpreted as Low (1.00 – 2.33), Medium (2.34 – 3.66), and High (3.67 – 5.00).*
*SN Item 1 = Most people who are important to me think I should use public transportation instead of driving.*
*SN Item 2 = People important to me would approve of me paying the congestion fee.*
*SN Item 3 = My family expects me to support the congestion fee aimed at reducing traffic congestion.*
*SN Item 4 = I believe people whose opinions I value would support congestion pricing in Penang.*

## Perceived Behaviour Control (PBC)

Table 7 presents the level of PBC towards the congestion fee. The first item, which assessed respondents' confidence in using public transportation during peak hours if the congestion fees were introduced, indicated a medium level of PBC among residents, tourists, and the overall respondents. The second item showed high levels of PBC across residents, tourists, and the overall respondents, which was consistent with a previous study by Moulin et al. (2025). The third item, which examined the reduction of trip frequency to George Town if the congestion fee was perceived as too expensive, indicated that tourists demonstrated a high level of PBC, whereas residents and the overall respondents

exhibited medium levels. Meanwhile, the fourth item, which assessed the perceived ease of paying the congestion fee if it were affordable, indicated high levels of PBC among tourists and the overall respondents.

**Table 7**: Level of Perceived Control Behaviour towards the Congestion Fee

| | Item | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | Total Mean | Level |
|---|---|---|---|---|---|---|---|---|---|
| Resident | PBC Item 1 | 10.5 | 15.5 | 28.6 | 26.4 | 19.1 | 3.28 | 3.53 | Medium |
| | PBC Item 2 | 6.8 | 8.2 | 22.7 | 30.0 | 32.3 | 3.73 | | High |
| | PBC Item 3 | 9.1 | 14.1 | 26.4 | 23.6 | 26.8 | 3.45 | | Medium |
| | PBC Item 4 | 6.4 | 9.1 | 26.4 | 30.5 | 27.7 | 3.64 | | Medium |
| Tourist | PBC Item 1 | 10.9 | 11.4 | 26.4 | 32.7 | 18.6 | 3.37 | 3.67 | Medium |
| | PBC Item 2 | 5.5 | 3.6 | 23.6 | 37.3 | 30.0 | 3.83 | | High |
| | PBC Item 3 | 2.7 | 9.1 | 30.9 | 25.0 | 32.3 | 3.75 | | High |
| | PBC Item 4 | 5.0 | 4.5 | 28.6 | 30.9 | 30.9 | 3.78 | | High |
| Overall | PBC Item 1 | 10.7 | 13.4 | 27.5 | 29.5 | 18.9 | 3.33 | 3.61 | Medium |
| | PBC Item 2 | 6.1 | 5.9 | 23.2 | 33.6 | 31.1 | 3.78 | | High |
| | PBC Item 3 | 5.9 | 11.6 | 28.6 | 24.3 | 29.5 | 3.60 | | Medium |
| | PBC Item 4 | 5.7 | 6.8 | 27.5 | 30.7 | 29.3 | 3.71 | | High |

*1 = Totally Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Totally Agree*
*Mean scores are interpreted as Low (1.00 – 2.33), Medium (2.34 – 3.66), and High (3.67 – 5.00).*
*PBC Item 1 = I am confident that I would use public transportation during peak hours if the congestion fee were introduced.*
*PBC Item 2 = I would use private vehicles to travel to George Town during non-peak hours.*
*PBC Item 3 = If the congestion fee is too expensive, I will reduce trip frequencies to George Town.*
*PBC Item 4 = Paying the congestion fee would be easy for me if it were affordable.*

## Intention Towards the Congestion Fee

Table 8 presents the level of intention towards the congestion fee. The first item, which assessed the respondents' intention to support the implementation of a congestion fee, indicated a medium level of intention among residents, tourists, and the overall respondents. The second item, which examined respondents' determination to pay the congestion fee during peak hours, indicated a medium level of intention, consistent with a previous study by Axsen and Long (2025). The third item, which assessed support for the congestion fee if the revenue was allocated to public transport improvements, indicated a high level of intention among residents and the overall respondents. Tourists demonstrated a higher level of support, as improved public transportation was perceived to enhance efficiency and reliability while reducing future travel costs. Similarly, the fourth item, which assessed the perceived ease of paying the congestion fee if it were affordable, indicated a high level of intention among tourists and the overall respondents.


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**Table 8**: The level of Intention towards the Congestion Fee

| | Item | 1 (%) | 2 (%) | 3 (%) | 4 (%) | 5 (%) | Mean | Total Mean | Level |
|---|---|---|---|---|---|---|---|---|---|
| Resident | Intention Item 1 | 8.6 | 14.5 | 32.3 | 29.1 | 15.5 | 3.28 | 3.40 | Medium |
| | Intention Item 2 | 11.8 | 14.5 | 29.1 | 30.9 | 13.6 | 3.20 | | Medium |
| | Intention Item 3 | 7.7 | 8.6 | 27.7 | 31.4 | 24.5 | 3.56 | | Medium |
| | Intention Item 4 | 6.8 | 9.1 | 29.5 | 32.3 | 22.3 | 3.55 | | Medium |
| Tourist | Intention Item 1 | 5.9 | 9.5 | 30.0 | 35.9 | 18.6 | 3.52 | 3.62 | Medium |
| | Intention Item 2 | 7.3 | 13.6 | 28.6 | 35.5 | 15.0 | 3.37 | | Medium |
| | Intention Item 3 | 3.2 | 5.9 | 25.5 | 35.9 | 29.5 | 3.83 | | High |
| | Intention Item 4 | 5.5 | 5.9 | 23.6 | 39.5 | 25.5 | 3.74 | | High |
| Overall | Intention Item 1 | 7.3 | 12.0 | 31.1 | 32.5 | 17.0 | 3.40 | 3.51 | Medium |
| | Intention Item 2 | 9.5 | 14.1 | 28.9 | 33.2 | 14.3 | 3.29 | | Medium |
| | Intention Item 3 | 5.5 | 7.3 | 26.6 | 33.6 | 27.0 | 3.70 | | High |
| | Intention Item 4 | 6.1 | 7.5 | 26.6 | 35.9 | 23.9 | 3.64 | | High |

*1 = Totally Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Totally Agree*
*Mean scores are interpreted as Low (1.00 – 2.33), Medium (2.34 – 3.66), and High (3.67 – 5.00).*
*Intention Item 1 = I plan to support the implementation of the congestion fee in Penang.*
*Intention Item 2 = I will pay a congestion fee to enter George Town during peak hours.*
*Intention Item 3 = If the revenue is used to improve public transportation, I would support the implementation of a congestion fee in Penang.*
*Intention Item 4 = I would be more likely to support the introduction of a congestion fee in Penang to address traffic congestion.*

## Multiple Linear Regression Analysis

Prior to conducting the multiple linear regression (MLR) analysis, the underlying assumptions were tested. The results indicated that the independent variables did not suffer from multicollinearity, with all inter-variable correlations remaining below the 0.70 threshold. Furthermore, normality testing via skewness and kurtosis values confirmed that the regression residuals were normally distributed, with skewness values falling within the acceptable range of -1.0 to 1.0 and kurtosis values within -2.0 to 2.0. Additionally, the distribution of residual values aligned with the assumption of homoscedasticity.

Table 9 presents the results of the multiple linear regression analysis. According to Hankins et al. (2000), *R* refers to multiple correlation coefficient

whereas *R* square is defined as the percentage of variance in intention which is influenced by the TPB variables (attitude, SN and PCB). Estimation of explained variance in this study were identified by using adjusted *R* square. The TPB variables, namely attitude, SN, and PBC, were found to have significant positive relationships with intention among residents, tourists, and the overall respondents. Among residents ($R^2$ = 0.554), 55.4% of the total variance in intention was explained with strong linear relationship with the TPB variables, whereas among tourists ($R^2$ = 0.443), the TPB variables accounted for the lowest total variance, indicating moderate linear relationship at 44.3%. For the overall respondents, 50.3% of the total variance in intention was explained with strong linear relationship with the TPB variables. These findings suggested that the regression model for all respondent categories (residents, tourists, and the overall respondents) demonstrated an acceptable model fit (Tranmer et al., 2020).

**Table 9**: Results of the Multiple Linear Regression Analysis

| Item | R | R square | Adjusted R Square | Std. error of the estimate |
|---|---|---|---|---|
| Resident | 0.744 | 0.554 | 0.548 | 0.702 |
| Tourist | 0.666 | 0.443 | 0.436 | 0.697 |
| Overall | 0.709 | 0.503 | 0.499 | 0.703 |

*a.Predictors (Constant), Attitude, Subjective Norms, Perceived Control Behaviour*
*b.Dependent Variable: Intention*

Table 10 highlights the regression coefficient analysis for residents, tourists, and the overall respondents. The regression coefficient between intention and attitude ($b$=0.252, $p$<0.000) was significant, indicating that residents' intention increased by 0.252 for every one-unit increase in attitude. Similarly, the regression coefficient between intention and SN ($b$=0.409, $p$<0.000) was significant, with intention increasing by 0.409 for every one-unit increase in SN, representing the strongest effect among the TPB variables. The regression coefficient between intention and PBC ($b$=0.315, $p$<0.000) was also significant, with respondents' intention increasing by 0.315 for every one-unit increase in PBC. Overall, the TPB independent variables, namely attitude, SN, and PBC, exerted positive effects on the intention of resident respondents. Among these variables, SN ($\beta$=0.355) demonstrated the strongest influence, followed by attitude ($\beta$=0.273) and PBC ($\beta$=0.271). The greatest influence of SN among residents may be attributed to the direct effects of congestion fee implementation on their travel behaviour, public acceptance and support. The intention score was 1.123.

The regression coefficient between intention and attitude ($b$=0.351, $p$<0.000) among tourists was significant, indicating that intention increased by


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0.351 for every one-unit increase in attitude. Similarly, the regression coefficient between intention and SN ($b$=0.319, $p$<0.000) was also significant, with tourists' intention increasing by 0.319 for every one-unit increase in SN. However, the regression coefficient between intention and PBC ($b$=0.127, $p$=0.057) was not significant. Therefore, the TPB independent variables, namely attitude and SN, exerted positive effects on tourists' intention, with attitude ($\beta$=0.364) demonstrating the strongest influence, followed by SN ($\beta$=0.308). The stronger influence of attitude on tourists' intention may be attributed to the lack of social pressure in shaping their decision, as their support for the congestion fee is more likely to be influenced by personal preferences and perceptions of the anticipated outcomes or impact of the congestion fee implementation on their travel experience. The intention score was 1.603.

For the overall respondents, the regression coefficient between the intention and attitude ($b$=0.301, $p$<0.000) was significant, indicating that respondents' intentions increased by 0.301 for every one-unit increase in attitude. Similarly, the regression coefficient between intention and SN ($b$=0.364, $p$<0.000) was also significant, implying that respondents' intention increased by 0.364 for every one-unit increase in SN. The regression coefficient between intention and PBC ($b$=0.229, $p$<0.000) was likewise significant, with respondents' intention increasing by 0.229 for every one-unit increase in PBC. Therefore, the TPB independent variables, namely attitude, SN, and PBC, exerted positive effects on intention, with SN ($\beta$=0.332) demonstrating the strongest influence, followed by attitude ($\beta$=0.321) and PBC ($\beta$=0.199). The intention score was 1.34.

The positive relationship between attitude and intention observed in the regression model was consistent with the findings of Nguyen (2020) on entrepreneurial intention in Vietnam, in which attitude, SN, and PBC were positively associated with intention. Similarly, Gibson (2021), who examined the intention to conserve freshwater resources in the United States using TPB, reported comparable findings, demonstrating positive relationships between attitude, SN, PBC, and the dependent variable, namely intention. In conclusion, the findings indicated that attitude, SN, and PBC were significant predictors of intention and exhibited positive relationships across all regression models pertaining to residents, tourists, and overall respondents. These results were consistent with the findings of most previous studies and supported the propositions of the TPB theory by Ajzen (1991).

**Table 10**: Results of the Regression Coefficient Analysis

| Model | | Unstandardised Coefficients | | Standardised Coefficient | t | p-value. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| Resident | Constant | 0.147 | 0.211 | - | 0.697 | 0.487 |
| | Attitude | 0.252 | 0.053 | 0.273 | 4.769 | 0.000 |
| | Subjective Norms | 0.409 | 0.069 | 0.355 | 5.906 | 0.000 |
| | PBC | 0.315 | 0.064 | 0.271 | 4.949 | 0.000 |
| Tourist | Constant | 0.806 | 0.242 | - | 3.331 | 0.001 |
| | Attitude | 0.351 | 0.062 | 0.364 | 5.636 | 0.000 |
| | Subjective Norms | 0.319 | 0.070 | 0.308 | 4.544 | 0.000 |
| | PBC | 0.127 | 0.066 | 0.112 | 1.916 | 0.057 |
| Overall | Constant | 0.446 | 0.158 | - | 2.823 | 0.005 |
| | Attitude | 0.301 | 0.040 | 0.321 | 7.499 | 0.000 |
| | Subjective Norms | 0.364 | 0.049 | 0.332 | 7.395 | 0.000 |
| | PBC | 0.229 | 0.046 | 0.199 | 4.971 | 0.000 |

## CONCLUSION.

In overall, the analysis indicated that both residents and tourists exhibited medium to high levels of attitude, PBC, and intention towards congestion fees, whereas SN was recorded at a medium level. All the variables within the Theory of Planned Behavior (TPB) such as attitude, Subjective Norms and Perceived Behavior Control (PBC) are found to be significant with positive relationship with the intention to pay for the congestion fee in George Town, Penang. Since SN had the highest relative strength value among the TPB variables, SN was identified as the most influential factor affecting overall and residents' intention to pay the congestion fees, followed by attitude and PBC.

The implementation of a congestion fee is expected to impose an additional financial burden on all private vehicle users, particularly individuals within the B40 income group. To ensure social equity, specialised rebates should be integrated into the pricing mechanism for vulnerable groups such as students and senior citizens who commute daily within the city centre of George Town, Penang. In addition, substantial discounts targeting individuals residing inside the designated congestion fee zone could be implemented to mitigate the financial strain on daily commuters. Furthermore, targeted public transport subsidies for the B40 income group, covering buses and the future LRT system, would encourage a cost-effective behavioural shift from private vehicles to public transportation. The study recommends that the revenue generated from the congestion fee should be ring-fenced for specific uses, such as public transport upgrades, pedestrian facilities, cycling infrastructure, park-and-ride systems, and transparent fee management.


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## ETHICAL APPROVAL

This study was approved by the Ethics Committee for Research Involving Human Subjects (JKEUPM), Universiti Putra Malaysia (Reference No: UPM.TNCPI.800-2/1/7) on 26 January 2026 prior to the commencement of the study. The approval was valid from 26 January 2026 to 25 January 2027.

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# PLACE-BASED INTERPRETATION OF ORANG ASLI LIFE-COURSE HERITAGE

**Aisyah Abu Bakar[1], Nur Kaseh Wildany Mohd Hamzy[2], Siti Husna Awalluddin[3], Mariana Mohamed Osman[4]**

[1,2,3]*Department of Environmental Management, Faculty of Forestry and Environment,*
UNIVERSITI PUTRA MALAYSIA
[4] *Department of Urban and Regional Planning, Kulliyyah of Architecture and Environmental Design,*
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

## Abstract

This study reframes Orang Asli (OA) cultural practices as a life-course and spatial system within Intangible Cultural Heritage (ICH) Domain 3. It connects them to care settings, households, Adat institutions, burial boundaries and ancestral sites. Studies emphasise festive events, weakening recognition of continuity across life phases. The research combined interviews with OA knowledge holders and representatives with ethnographic, academic and heritage sources. Content analysis coded manifestations by social role, ritual purpose, symbolic meaning, participation pattern and community context. Inductive-deductive thematic analysis organised them into codes, facets and themes. Six experts assessed the framework using the Content Validity Index, informing four themes and sixteen facets. These cover early development, marital institutions, maternal care, adulthood, elderhood and ancestry. Spatial analysis produced four planning categories and eight cultural spaces for protection, learning, household formation, maternal care, subsistence, governance, burial and ancestry. The framework supports documentation, planning, assessment and community-led mapping of life-course heritage.

***Keywords*:** Orang Asli, Cultural Practices, Life-Course Transitions, Intangible Cultural Heritage, Cultural Landscape

[1] Corresponding author. Email: aisyah.ab@upm.edu.my

## INTRODUCTION

This paper forms part of continuing work to document and classify Orang Asli [OA] Intangible Cultural Heritage [ICH] across five ICH domains, with this paper focusing on Domain 3, Social Practices, Rituals and Festive Events.

Across OA communities, social practices unfold through life phases, social relations and ancestral continuity. Distinct from related papers on oral traditions, performing arts and ecological knowledge, this paper organizes social practices into a life-course framework. The study develops an expert-informed classification linking manifestations to social settings, learning environments, household spaces, maternal zones, livelihood areas, burial boundaries and ancestral sites for heritage documentation, planning and safeguarding.

## LITERATURE REVIEW

OA cultural practices form a lived system through which relationships, responsibilities and life transitions are regulated. Within ICH Domain 3, customs and ceremonies sustain collective identity while linking communal life with ecological settings and inherited knowledge (Abu Bakar et al., 2025a, 2025b; Shaari et al., 2024). Early life is shaped by protection, caregiving and experiential learning, while adolescence introduces behavioural expectations and bodily regulation (Chew et al., 2022; Syed Abdullah et al., 2022). Marriage involves readiness, negotiation, engagement, ceremonial validation and changes in residence and household roles (Abu Bakar et al., 2025a; Endicott, 2016; Yew et al., 2023). Pregnancy, childbirth and postpartum recovery are governed through taboos, informal support, confinement and dietary practices (Syed Abdullah et al., 2022; Ambak et al., 2026; Adnan et al., 2025). In later life, elders assume custodial responsibilities, while death and ancestral ceremonies maintain relations between the living and the deceased (Shaari et al., 2024; Zamzuri et al., 2024; Linggang et al., 2024).

These practices depend on the settings in which they occur. Caregiving and social learning unfold within household and communal environments. Marriage reorganizes residential and kinship space. Reproductive practices require protected maternal settings; and mourning or ancestral observance gives ritual meaning to communal places. In essence, spatial context shapes participation, privacy, authority and continuity. Heritage mapping can connect OA cultural practices with households, ceremonial grounds, ecological settings and ancestral sites rather than record them as isolated practices. Yet research remains focussed on single community and ceremonial practices, while digital materials are scattered and static (Zuhairi et al., 2020; Kamaruddin & Said, 2021; Sylaiou et al., 2020). A Domain 3 framework is needed to thematically analyze OA cultural practices while recognizing the cultural spaces that sustain them. The outcome supports stronger digital documentation, heritage planning, and community-led safeguarding.

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## METHODOLOGY

This paper belongs to a wider effort of documenting and classifying OA ICH across five ICH domains. Although the companion OA ICH papers follow parallel phases of data extraction, coding, thematic organization and expert validation, this study applies the process to Domain 3: Social Practices, Rituals and Festive Events, focusing on communal order, life-cycle practices, ritual obligations and customary continuity.

The corpus consisted of interview transcripts with OA knowledge holders and community representatives, supported by ethnographic writings, academic studies and heritage reports. Content analysis identified manifestations related to birth, childhood, marriage, pregnancy, healing, taboos, ancestral observances, festive events, household roles and *Adat* responsibilities. In this paper, social practices are translated as recurring communal actions that organize roles, relationships, obligations, transitions and culturally significant spaces. Each manifestation was examined according to social role, ritual purpose, symbolic meaning, participation pattern, life-stage relevance and community setting. The coded data were then organized through inductive-deductive thematic analysis into manifestation codes, facets and broader themes. The framework was evaluated using the Content Validation Index [CVI] to assess clarity, relevance, coherence and cultural appropriateness for Domain 3 practice-based heritage.

**Table 1:** Framework Development Stages

| Phase | Description of Process | Output |
|---|---|---|
| Stage 1: Data Extraction and Coding | Interview transcripts and documents were analyzed using content analysis in ATLAS.ti to identify OA ICH Domain 3 manifestations. Symbolic meaning, ritual form and social function were recorded. | Dataset of identified ICH manifestations, segmented corpus of data excerpts |
| Stage 2: Coding of ICH Manifestations under Domain 3 | Identified manifestations were assigned manifestation codes to organize recurring social practices, rituals, taboos, ceremonies and life-cycle practices. | Coded dataset of OA Cultural Practices under Life Phases |
| Stage 3: Categorization of Themes and Facets | Coded manifestations were grouped into facets and organized into themes using thematic analysis to refine conceptual groupings within each theme and facet. | Structured set of themes and corresponding facets |
| Stage 4: Framework Drafting | Themes and facets were structured into a conceptual framework, mapping relationships into a coherent visual matrix guided by theoretical reasoning. | Initial framework showing classification hierarchy |
| Stage 5: Iterative Refinement | The framework was reviewed against coded data using thematic analysis to improve clarity, consistency and reduce overlap between codes, facets and themes. | Refined ICH Domain 3 framework ready for validation |
| Stage 6: Validation Preparation | The framework was converted into a validation tool with definitions of themes and facets and manifestation codes as well as guidance for expert evaluation. | Validation package with framework and scoring sheets |
| Stage 7: Validation Study Execution | Experts evaluated the framework, and I-CVI and S-CVI were calculated to assess content validity. | Expert feedback and CVI scores |
| Stage 8: Framework Refinement | Validation results were used to revise labels, structure, and grouping for improved coherence. | Revised Framework of OA ICH Domain 3 |


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## Semi-Structured Interviews

The semi-structured interviews were arranged using an interview guide to cover key themes across communities while allowing participants to describe their social practices in a natural narrative flow. The guide covered settlement background, household and social relations, socio-demographic and socio-economic conditions, governance, environmental context and heritage continuity. The questions then explored social practices, rituals, festive events, life-cycle customs, taboos, healing practices, marriage arrangements, pregnancy care, birth practices, elder roles, communal duties and Adat obligations. Participants included *Tok Batin*, elders, committee representatives and village members from various OA subgroups. Personal names were coded, while role, subgroup and village location were retained.

**Table 2:** Profile of Orang Asli Interview Participants

| Code | Roles in Village | Subgroup | Village Name and Location |
|---|---|---|---|
| PO01 | Director, Cultural Institution | Mah Meri | Kampung OA Sungai Bumbun, Pulau Carey |
| PO02 | OA Youth Representative | Mah Meri | Kampung OA Sungai Bumbun, Pulau Carey |
| PO03 | Leader / *Tok Batin* | Jakun | Kampung OA Sungai Bot, Karak, Bentong |
| PO04 | Village Chairperson | Temuan | Kampung OA Cinta Manis, Karak, Bentong |
| PO05 | Leader / *Tok Batin* | Temuan | Kampung OA, Ulu Pareh, Karak, Bentong |
| PO06 | OA Representative | Temuan | Kampung OA, Ulu Pareh, Karak, Bentong |
| PO07 | Leader / *Tok Batin* | Jah Hut | Kampung OA Pian, Kuala Krau, Temerloh |
| PO08 | Leader / *Tok Batin* | Jah Hut | Kampung OA Pian, Kuala Krau, Temerloh |
| PO09 | Leader / *Tok Batin* | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO10 | Village Elder | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO11 | OA Representative | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO12 | Leader / *Tok Batin* | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO13 | OA Representative 1 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO14 | OA Representative 2 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO15 | OA Representative 3 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO16 | Leader / *Tok Batin* | Bateq | Kampung OA Kuala Atok, Jerantut |
| PO17 | Leader / *Tok Batin* | Semoq Beri | Kampung OA Sungai Tiang, Jerantut |
| PO18 | Leader / *Tok Batin* | Semai | Kampung OA Rening, Cameron Highlands |
| PO19 | Leader / *Tok Batin* | Semai | Kampung OA Kuala Boh, Cameron Highlands |
| PO20 | Leader / *Tok Batin* | Jakun | Kampung OA Gumum, Tasik Chini, Pekan |

**Table 3:** Coding Trail from Content Analysis to Theme Development

| | Coding Stage | Coding Output |
|---|---|---|
| 1 | Verbatim Transcription | PO14: *...zaman dulu, lubuk besar bawah jambatan jadi tempat orang menuba ikan. Orang lama percaya bila muncul Ikan Sebarau semasa menuba tandanya hujan dan kilat akan datang. Jadi kena balik, berteduh ka selamatkan diri…* |
| 2 | Transcript Excerpt | The participant explained that the river pool beneath the bridge was once used for poisoning fish, and that the appearance of *Ikan Sebarau* was believed to signal approaching rain and lightning, prompting people to leave for safety. |
| 3 | Condensed Meaning | The appearance of Hampala Barb during river fish-poisoning activity is interpreted as a warning sign of approaching rain and lightning. |
| 4 | Initial Codes | Animal Omen, Animal-based Environmental Warning |
| 5 | Final Code | Animal Interaction Folktales |
| 6 | Facet | Animal Folktales |
| 7 | Theme | Folktales, Legends, and Narrative Forms |

## Document Analysis

Document analysis extended the interview corpus by examining 403 academic, institutional, community and media sources on OA social practices. Sources were screened for subgroup context, practice-based evidence and Domain 3, life-course social practices relevance. Pertinent materials were condensed into meaning units, then coded into manifestation codes, facets and themes to support the classification of practice-based heritage (refer to Table 4).

**Table 4:** Document Sources and Screening Criteria

| No | Types | Sources | Inclusion Criteria | Exclusion Criteria |
|---|---|---|---|---|
| 1 | Peer Reviewed Articles | Mainly retrieved from MyCite, followed by Google Scholar, Scopus, ScienceDirect, JSTOR, DOAJ SpringerLink, Taylor & Francis Online | Evidence on OA social practices, life-cycle customs, rituals, family roles, birth, death, *Adat*, communal relations, and subgroup context. | No ICH or social practices evidence; focused only on development, education, health or socio-economy. |
| 2 | Conference Papers | Academic conference proceedings, seminar papers and heritage-related conference publications. | Relevant findings on OA social customs, communal events, life-stage practices, cultural change or heritage continuity. | Too brief, duplicated published articles, or did not provide usable evidence for coding. |
| 3 | Book Chapters | Edited academic books on Orang Asli, indigenous studies, anthropology, heritage and culture. | Subgroup-specific evidence on birth, childhood, and marriage customs, or *Adat*. | General discussion without insufficient detail for coding. |
| 4 | Books and Monographs | Ethnographic books, cultural monographs, Orang Asli studies and indigenous community publications. | Detailed descriptions of OA social norms and practices, ritual conduct, household roles, or community governance. | Outdated claims without cultural relevance, unclear source basis or no link to social practices. |
| 5 | Theses and Dissertations | University repositories, institutional libraries and postgraduate research databases. | Empirical or ethnographic findings on OA embodied expression or heritage transmission. | Unavailable full text, unrelated focus or no extractable cultural evidence. |
| 6 | Government Reports | Mainly JAKOA, with related government and agency reports. | Official information on OA subgroups, village context, and cultural activities | Administrative data only, irrelevant to ICH documentation. |
| 7 | UNESCO documents | UNESCO ICH documents, safeguarding guidelines and conceptual references. | Definitions, safeguarding principles and conceptual guidance relevant to ICH and social practices. | Unrelated to ICH concepts or documentation. |
| 8 | Museum Archives | Museum records, exhibition notes, archive descriptions and heritage documentation. | Descriptions of OA ritual objects, ceremony records, community customs or intangible meanings. | Records with unclear provenance and no identification of subgroups. |
| 9 | Community Publications | NGO materials, local publications, blogs, community websites and informal documentation. | Community accounts of OA birth, childhood, adolescent, marriage, and household customs or *Adat*. | Unverifiable claims, or unidentifiable community context. |
| 10 | Media Recordings | Audio and video documentaries, online news articles, and media features related to Orang Asli communities. | Recorded or reported rituals, ceremonies, life-cycle customs, communal events, social norms or heritage transmission. | Sensationalized reporting, unclear informant source or insufficient detail for coding. |


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## Multi-Phase Framework Development and Validation Workflow

Figures 1 and 2 summarize the two-stage framework process, showing initial source coding and thematic structuring, followed by expert validation, refinement, restructuring and final framework confirmation.

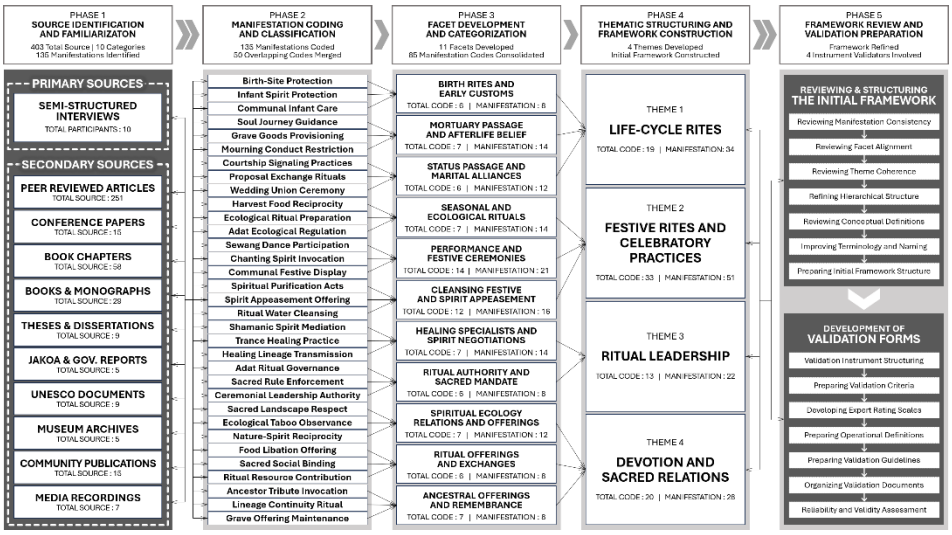



**Figure 1:** Initial Development and Construction of the ICH Domain 3 Framework

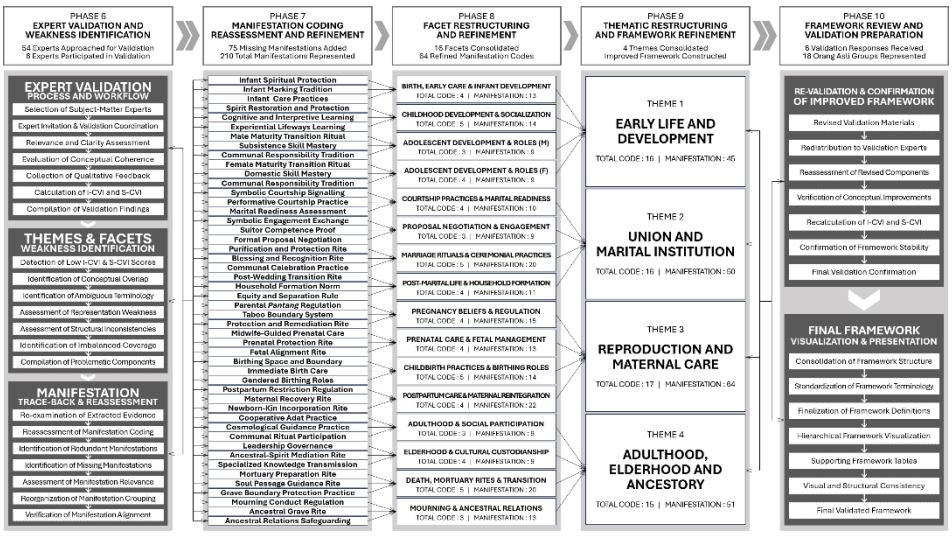



**Figure 2:** Expert Validation and Refinement of the ICH Domain 3 Framework

## RESULTS

The expert validation process involved six experts. To ensure confidentiality, validators were anonymized using coded identifiers (Expert 1 to Expert 6). Table 5 presents each expert's background, field of expertise, and feedback.

**Table 5:** Validators' Feedback and Corresponding Revisions

| Validator | Feedback | Corresponding Revision |
|---|---|---|
| **Expert 1**<br>Department of Orang Asli Development (JAKOA)<br>Expert in Indigenous welfare management and community support services | Suggested that Domain 3 manifestations should include culturally meaningful places, routes, landmarks, and spatial practices, as these shape the meaning of OA rituals, transitions, and ancestral relations. | Place-based elements were strengthened through manifestations such as river initiation, birth spaces, burial orientation, grave boundaries, and ancestral sites. Oral or performative elements were retained only when functioning as social practice, ritual conduct, or life-transition practice. |
| **Expert 2**<br>Department of Orang Asli Development (JAKOA)<br>Expert in Indigenous welfare management and community support services | Recommended that terms used better reflect lived OA practices rather than performative categories. Suggested that manifestations show actual modes of practice, regulation, narration, and transmission. | Generic performative framing was reduced. The framework now emphasizes practices, roles, restrictions, responsibility, transmission, and custodianship through examples such as infant care, pregnancy taboos, childbirth roles, marital duties, and mourning conduct. |
| **Expert 3**<br>GERIMIS Art Project (Cultural Organization)<br>Expert in Indigenous Knowledge, Cosmologies, and Eco-Critical Cultural Studies | Recommended that manifestations specify the relevant OA group, cultural context, ritual occasion, belief meaning, and indigenous terminology. | The revised tables include a Groups column and retain indigenous terms such as *Sewang, Kejak Mengejak, Melenggang Perut, Mandi Tepung, Buka Pantang, Tok Batin, Pawang,* and *Badi* at manifestation level. |
| **Expert 4**<br>Institute of Environment and Development, Universiti Kebangsaan Malaysia<br>Expert in Sustainable Livelihoods of Indigenous Communities, Heritage Conservation | Recommended that the framework be reorganized to better reflect Domain 3 cultural practices as either life-phase practices or cyclical/yearly events. Suggested including coming-of-age as a key life transition. | The framework was reorganized into four life-course themes: *Early Life Development, Union and Marital Institution, Reproduction and Maternal Care,* and *Adulthood, Elderhood and Ancestry*. Coming-of-age was incorporated under male and female adolescent development facets. |
| **Expert 5**<br>Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin<br>Expert in Indigenous people studies, Social Anthropology | Suggested that customary rituals and taboos related to nature be organized under relevant life phases, as they reflect OA belief systems, social regulation, and respectful conduct toward the environment. | The framework was reorganized into life-phase themes so taboo-based and customary rituals are distributed according to their cultural function. Pregnancy and birth taboos were placed under *Reproduction and Maternal Care*, while ecological and ancestral rituals were placed under *Adulthood, Elderhood and Ancestry*. |
| **Expert 6**<br>Kulliyyah of Sustainable Tourism and Contemporary Languages, International Islamic University Malaysia<br>Expert in Humanities, Linguistic and Literature, Malay Language and Literature | Recommended clarifying overlapping terms such as ritual, healing, customary regulation, and ceremonial practice, so Domain 3 manifestations are classified according to their role in OA social life. | The framework was reorganized by life phases and social functions. Healing practices were positioned as care, protection, or communal responsibility, while rituals and taboos were placed according to their role in birth, marriage, reproduction, mourning, and ancestral relations. |


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Table 6 presents the content validation summary for the initial framework, while Table 7 outlines the revised themes and facets.

**Table 6:** Content Validation Summary of the Initial Framework

| Themes | I-CVI | Facets | I-CVI | S-CVI |
|---|---|---|---|---|
| Life Transition Rites | 0.83 | Birth and Early Life Customs | 0.83 | 0.72 |
| | | Mortuary Passage and Afterlife Belief | 0.67 | |
| | | Status Passage and Marital Alliances | 0.67 | |
| Festive Rites and Celebratory Practices | 0.83 | Seasonal and Ecological Rituals | 0.67 | 0.78 |
| | | Performance and Festive Ceremonies | 0.83 | |
| | | Cleansing Festive and Spirit Appeasement | 0.83 | |
| Ritual Leadership | 0.83 | Healing Specialists and Spirit Negotiations | 0.83 | 0.75 |
| | | Ritual Authority and Sacred Mandate | 0.67 | |
| Devotion and Sacred Relations | 0.83 | Spiritual Ecology Relations and Offerings | 0.83 | 0.83 |
| | | Ritual Offerings and Exchanges | 0.83 | |
| | | Ancestral Offerings and Remembrance | 0.83 | |

**Table 7:** Revised Theme and Facets

| Themes | Facets |
|---|---|
| Early Life Development | Birth, Early Care and Infant Development |
| | Childhood Development and Socialization |
| | Adolescent Development and Roles (Male) |
| | Adolescent Development and Roles (Female) |
| Union and Marital Institution | Courtship Practices and Marital Readiness |
| | Proposal Negotiation and Engagement |
| | Marriage Rituals and Ceremonial Practices |
| | Post-Marital Life and Household Formation |
| Reproduction and Maternal Care | Pregnancy Beliefs and Regulation |
| | Prenatal Care and Fetal Management |
| | Childbirth Practices and Birthing Roles |
| | Postpartum Care and Maternal Reintegration |
| Adulthood, Elderhood and Ancestry | Adulthood and Social Participation |
| | Elderhood and Cultural Custodianship |
| | Death, Mortuary Rites and Transition |
| | Mourning and Ancestral Relations |

The earlier framework placed OA cultural practices under broad ritual categories, which made some life-course processes difficult to distinguish. The revised version reorganizes the framework around social progression: early life development, union and marital institution, reproduction and maternal care, and adulthood, elderhood and ancestry. This arrangement separates birth and infant care, childhood learning, adolescent roles, courtship, marriage, pregnancy, childbirth, elder custodianship, mortuary rites, and ancestral relations into clearer process-based groupings. The result is a stronger life-course structure that reflects how OA cultural practices are shaped by roles, responsibilities, transitions, and continuing relations between the living, the community, and ancestors.

**Table 8:** Revised Themes and Facets Definitions

| Themes & Definitions | Facets & Definitions |
|---|---|
| **Early Life Development**<br>*A socio-cultural system shaping early growth, protection, and role formation through embodied practices, caregiving, and experiential learning.* | **Birth, Early Care and Infant Development**<br>*Infant care practices that protect, imprint identity, and regulate wellbeing through bathing, herbal treatments, naming, and symbolic protection.* |
| | **Childhood Development and Socialization**<br>*Experiential learning through exploration, participation, and guidance to develop autonomy, social responsibility, and adaptive skills.* |
| | **Adolescent Development and Roles (Male)**<br>*Progressive acquisition of skills, responsibilities, and social expectations marking transition into recognized male roles.* |
| | **Adolescent Development and Roles (Female)**<br>*Embodied transition through social expectations, skill development, and role preparation marking entry into recognized female roles.* |
| **Union and Marital Institution**<br>*A relational system governing attraction, negotiation, union formalisation, and the formation of household and kinship responsibilities.* | **Courtship Practices and Marital Readiness**<br>*Expressive and symbolic practices of attraction, including performance, adornment, and non-verbal communication, signalling readiness for union.* |
| | **Proposal Negotiation and Engagement**<br>*Structured family-mediated processes involving assessment, exchanges, and demonstrations of responsibility to formalise marital intent.* |
| | **Marriage Rituals and Ceremonial Practices**<br>*Ritual enactments, cleansing, and symbolic acts that legitimise union, integrate families, and establish social recognition.* |
| | **Post-Marital Life and Household Formation**<br>*The organization of domestic roles, shared labour, residence patterns, and obligations that sustain marital and kinship structures.* |
| **Reproduction and Maternal Care**<br>*A biocultural system regulating pregnancy, childbirth, and postpartum recovery through taboos, care practices, and ritual protection.* | **Pregnancy Beliefs and Regulation**<br>*Taboos, behavioural restrictions, and symbolic practices governing parental actions to safeguard maternal and fetal wellbeing.* |
| | **Prenatal Care and Fetal Management**<br>*Monitoring, massage, ritual intervention, and midwifery guidance to position, protect, and prepare the fetus for birth.* |
| | **Childbirth Practices and Birthing Roles**<br>*Techniques, spatial arrangements, and gendered roles managing delivery, ensuring safety, and maintaining ritual and environmental control.* |
| | **Postpartum Care and Maternal Reintegration**<br>*Dietary control, bodily treatment, seclusion, and ritual acts supporting recovery, purification, and reintegration into daily life.* |
| **Adulthood, Elderhood and Ancestry**<br>*A continuity system linking adult participation, cultural custodianship, death transition, and enduring ancestral relations.* | **Adulthood and Social Participation**<br>*Active engagement in communal labour, ritual enactment, ecological interaction, and social regulation sustaining collective life.* |
| | **Elderhood and Cultural Custodianship**<br>*Transmission, regulation, and enactment of cultural knowledge, ritual practice, healing systems, and material traditions across generations.* |
| | **Death, Mortuary Rites and Transition**<br>*Body preparation, burial practices, spatial organization, and ritual processes guiding transition from life to the spiritual realm.* |
| | **Mourning and Ancestral Relations**<br>*Practices of mourning, remembrance, restriction, and offering that regulate relations between the living and ancestral spirits.* |

Tables 9–12 present the thematic classification of ICH manifestations. The examples are partly representative, with each theme comprising four facets, each facet three to five codes, and each code covering multiple ICH manifestations.


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**Table 9:** Theme 1 – Early Life Development

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Birth, Early Care and Infant Develop-ment** | Infant Spiritual Protection | **Protection Bath:** Sixth-day infant bath sprinkled with forest herbs toughens immunity and protects against predatory spirits. | ALL |
| | | **Black Soot Application:** Hearth charcoal/soot on infant to conceals scent, protecting against malevolent forest spirits. | Che/Bat/ Jai/Ter |
| | Infant Marking Tradition | **Role Imprinting:** Placenta hung in a tree-suspended miniature house; a pandanus leaf (girl)/ a wood stick (boy) placed in hand. | Sel/Mah |
| | | **Spiritual Identity Recasting:** Renaming the infant with lighter forest terms to reduce spiritual burden and unseen attraction. | ALL |
| | Infant Care Practices | **The *Duk* Immersion*:*** Infants carried in a *Duk* sling, learning forest rhythms and social interaction through constant contact. | ALL |
| | | ***Urut* and *Barut*:** Daily herbal oil massage hardens limbs, while abdominal wrapping expels wind and gives womb-like security. | Tem/Jak/ Sel/Mah |
| **Childhood Develop-ment and Sociali-zation** | Spirit Restoration and Protection | ***Memanggil Semangat:*** Elders strike the ground at the fright site and call the child's name to restore the soul. | ALL |
| | | **River Initiation:** Introducing a child to major river spirits through offerings for protection from drowning and illness. | Tem/Jak/ Sel/Mah |
| | Cognitive and Interpretive Learning | **Solved Puzzles:** Solved traditional puzzles by a child signifies mental acuity needed for advanced tracking skills later in life. | Jak/Tem/ Sel/Mah |
| | | **Dream Circle:** Morning dream-sharing tradition treats children's dreams as spiritual messages interpreted by elders. | Ter/Sem/ Che/Seq |
| | Experien-tial Lifeways Learning | **Forest Exploration:** Children are granted autonomy to learn forest limits through experience, with minimal risk restriction. | Bat/Jai/ Ter/Sem |
| | | **Alloparenting:** Children carry infants (relatives) in slings as natural social bonding to foster empathy and responsibility. | Bat/Jai/ Ter/Sem |
| **Adolescent Developme nt and Roles (Male)** | Male Maturity Transition Ritual | ***Kejak Mengejak***: Communal circumcision ritual with traditional dress, music, and symbolic bestowing of the *keris.* | Jat/Tem/ Jak/Sel |
| | | **Role in *Sewang* Dance**: Inner-circle participation, mastering *genrang* and lead vocals to drive the spiritual engine. | Ter/Sem/ Jat/Che |
| | Subsistence Skill Mastery | **Honey Harvesting (*Panjat*)**: Climbing *Tualang* trees at night for wild honey marks bravery and ability of resource provision. | Bat/Jai/ Ter/Sem |
| | | **Sumpit Mastery:** Mastery of blowpipe use and *Ipoh* poison preparation signifies maturity and skilled hunting capability. | Bat/Jai/ Ter/Sem |
| | Communal Respon-sibility Tradition | **First Kill Sharing**: Young hunter shares his entire first major kill with the community, signifying survival skill and maturity. | Bat/Jai/ Ter/Sem |
| | | **Ancestral Custodianship**: Assuming care of ancestral graves or *Moyang* mask carving marking the youth's custodial roles. | Mah/Jat/ Tem/Jak |
| **Adolescent Develop-ment and Roles (Female)** | Female Maturity Transition Ritual | **Menarche Isolation:** First-menstruation seclusion in a cooling designated house area marks safe transition into womanhood. | Ter/Sem/ Che/Seq |
| | | **Role in *Sewang* Dance**: *Teluq*-chorus participation and *centong* stamping to create interlocking rhythms as the rhythmic anchor. | Ter/Sem/ Jat/Che |
| | Domestic Skill Mastery | **Intricate Weaving:** Weaving mastery in *tempok, mengkuang* mats and *Sanggar* marks maturity and marriage readiness. | Mah/Tem /Jak/Ter |
| | | **Wild Yam Detoxification**: Precise *Ubi Gadong* slicing, soaking, and squeezing leaches toxins, marks trustworthiness. | Ter/Sem/ Bat/Jai |
| | Communal Respon-sibility Tradition | ***Semangat Padi***: Spiritual agriculturalists harvest, wrap, and store Mother Rice to entice nature spirits and abundance. | Tem/Jak/ Sem/Sel |
| | | ***Bidan* Initiation:** Midwife shadowing and locating female plants for bleeding and childbirth mark caregiving roles. | ALL |

**Note.** ALL = All or almost all ethnic groups practiced the manifestation; Abbreviations refer to Orang Asli subgroups: Kensiu (Ken), Kintaq (Kiq), Jahai (Jai), Mendriq (Men), Bateq (Bat), Temiar (Ter), Semai (Sem), Jah Hut (Jat), Che Wong (Che), Semoq Beri (Seq), Mah Meri (Mah), Temuan (Tem), Jakun (Jak), Semelai (Sel), Orang Kuala (Orl), Orang Seletar (Ors), and Orang Kanaq (Ork).

**Table 10:** Theme 2 – Union and Marital Institution

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Courtship Practices and Marital Readiness** | Symbolic Courtship Signalling | ***Pensol* Serenade:** Young men play the nose flute to signal presence and romantic interest without direct confrontation. | Ter/Sem/ Jat/Che |
| | | **Fragrant Adornment:** Tucking fragrant flowers/leaves behind ears or into hair to enhance charm and attract potential partner. | ALL |
| | Perfor-mative Courtship Practice | ***Main Jo-oh:*** Masked dance to invite ancestral spirits while allowing the young people to observe potential partners. | Mah/Jak /Sel |
| | | ***Sewang* Social Space:** All-night *Sewang* sparks attraction as youths displays stamina and grace through song and dance. | ALL |
| | Marital Readiness Assessment | ***Kerchang*:** Separating the Kerchang bamboo puzzle string symbolizes marital complexity, patience, and readiness. | Jak/Sel/ Tem |
| | | **Compatibility Audition:** The man stays at the woman's house for 3 days to undergo a form of audition by the woman's father. | Sem/Ter/ Jat/Jak |
| **Proposal Negotia-tion and Engage-ment** | Symbolic Engage-ment Exchange | **Needle and Thread Proposal:** Needle and thread sent in a *mengkuang* container; returned pierced signals acceptance. | Tem/Jak/ Sel |
| | | **Modest *Hantaran:*** Marriage intent is signalled through practical forest-based items, with a silver ring rather than gold. | ALL |
| | Suitor Compe-tence Proof | ***Adat Menunggu:*** Suitor proves responsibility to future in-laws by managing daily tasks and providing financial support. | Sem/Ter/ Jat/Jak |
| | | **Gift Exchange Proposal:** A custom handcrafted wooden comb (*sisir*) presented by suitor to signify domestic technical worth. | ALL |
| | Formal Proposal Negotiation | ***Merisik:*** A structured family-led poetic inquiry to assesses compatibility and confirm eligibility before formal proposal. | Jak/Tem/ Sel/Mah |
| | | ***Minang:*** Elder-led visit to the woman's family presents *hantaran*, sets engagement period, and marks her as promised. | Jak/Tem/ Sel/Mah |
| **Marriage Rituals and Ceremo-nial Practices** | Purification and Protection Rite | ***Circling a Mound:*** Bride circles a mound 7 times, followed by groom, seeking nature-spirit protection and household blessing. | Sel/Jak/ Tem |
| | | ***Kenduri Hum:*** Couple cleansed with rice scrubbing and three jars of flower-scented limewater poured over their heads. | Jat/Sel/ Jak/Tem |
| | Blessing and Recogni-tion Rite | ***Mohon Sembah:*** The bride and groom pay respect to the parents and the elders to signify continued devotion to their kin. | Tem/Jak/ Mah/Sel |
| | | ***Bersanding:*** Couple in traditional clothes sit on a *mengkuang* mat in *Rumah Adat* as Tok Batin officiates wedding. | Jak/Tem/ Mah/Sel |
| | Communal Celebration Practice | ***Gotong-Royong:*** Villagers divide ceremonial tasks and share meals to strengthen social bonds and kinship. | ALL |
| | | **Wedding *Sewang*:** Circle chant and rhythmic stomping dance to celebrate and seek longevity and ancestral-spirit protection. | ALL |
| **Post-Marital Life and Household Formation** | Post-Wedding Transition Rite | **3-Day Curfew:** 3-day post-ceremony curfew, spirit banishment and money-tossing protects newlyweds from harmful spirit. | ALL |
| | | **Wall Completion:** Couple completes pre-built house walls after officiation, symbolizing shared marital responsibility. | Jat/Che |
| | Household Formation Norm | **Uxorilocal Residence:** Long-standing norms that newlyweds initially reside with the bride's family to strengthen bonds. | ALL |
| | | **Household Roles:** Husbands lead hunting and heavy labour; wives lead gathering and basket fishing, with shared duties. | ALL |
| | Equity and Separation Rule | **Matrimonial Equity (Egalitarian):** Spouses share equal decision-making and freedom to separate if incompatible. | ALL |
| | | **Post-Marital Compensation:** Divorce and remarriage entail fault-based financial obligations and spouse-house entry fees. | Sem/Ter/ Jak/Tem |

**Note.** ALL = All or almost all ethnic groups practiced the manifestation; Abbreviations refer to Orang Asli subgroups: Kensiu (Ken), Kintaq (Kiq), Jahai (Jai), Mendriq (Men), Bateq (Bat), Temiar (Ter), Semai (Sem), Jah Hut (Jat), Che Wong (Che), Semoq Beri (Seq), Mah Meri (Mah), Temuan (Tem), Jakun (Jak), Semelai (Sel), Orang Kuala (Orl), Orang Seletar (Ors), and Orang Kanaq (Ork).


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**Table 11:** Theme 3 – Reproduction and Maternal Care

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Pregnancy Beliefs and Regulation** | Parental *Pantang* Regulation | **Paternal *Pantang*:** Father's restrictions (wood cutting, animal injuring, etc) during the 3rd trimester to ensure infant's safety. | Ork/Ter/ Jak |
| | | **Maternal *Pantang*:** Mother's restrictions and dietary taboos (watch other births, carving, eariting hot or sharp foods, etc). | Mah/Ter/ Ork/Jak |
| | Taboo Boundary System | **Liminal Boundary:** Liminal-time and place taboos protect vulnerable maternal-fetal spirits from disturbance. | Mah/Jak/ Ork/Ter |
| | | **Mimetic Taboo System:** Pregnancy taboos link parental actions to fetal outcomes, restricting behaviour to prevent harm. | Mah/Ork/ Ter/Jak |
| | Protection and Remedia-tion Rite | **Ancestral Protection Rite:** Prayers to ancestors and nature spirits protect mother and unborn child from spiritual harm. | Mah/Ter/ Sem/Ork |
| | | **Fishing Line Remediation:** Corrective rite uses fishing line and straightened hook to ease childbirth after taboo breach. | Ter |
| **Prenatal Care and Fetal Manage-ment** | Midwife-Guided Prenatal Care | **Early Engagement:** Midwife engagement from 3rd month guides due-date calculation, diet, and delivery preparation. | Jak/Mah/ Ter/Ork |
| | | **Monitoring Care:** Midwife-led care monitors maternal health, nutrition, and spiritual balance to protect the fetus. | Mah/Jak/ Sem/Ter |
| | Prenatal Protection Rite | ***Mandi Tepung:*** Flour bath and talismans applied during pregnancy to guard the mother and fetus from spirit disturbance. | Jak |
| | | **Thermal Wellbeing System:** Cooling-shading using *pancuur*, plants, and silver coin to avoid heat and agony for safe birth. | Sem/Jak/ Mah/Ter |
| | Fetal Alignment Rite | ***Melenggang Perut*:** 7-month rite uses coloured cloths to realign belly, position fetus, welcome soul, and mark nearing birth. | Mah |
| | | **Abdominal *Urut*:** Periodic gentle massage to position the baby correctly and prepares the path for the soul's eventual exit. | Jak/Mah/ Ter/Bat |
| **Childbirth Practices and Birthing Roles** | Birthing Space and Boundary | **Blood-Ground Barrier:** Home birth on woven pandanus mat with wood beneath, preventing blood seepage into ground. | Jak |
| | | **Birth Hut Seclusion:** Birth occurs in a secluded forest hut away from camp, specifically constructed for women-assisted labour. | Bat |
| | Immediate Birth Care | **Bamboo Cord Cutting:** Sharp bamboo splinter reflecting forest purity cuts the umbilical cord immediately after delivery. | Bat/Mah/ Jak |
| | | **Thermal Recovery Bathing:** Immediate cool mother bath and warm baby bath prevent fever and support recovery. | Bat/Mah/ Jak |
| | Gendered Birthing Roles | **Women-Led Childbirth:** Midwives and female assistants manage birth, maintaining women's authority in childbirth care. | Bat/Sem/ Jak |
| | | **Paternal Birth Support:** Fathers manage environmental-symbolic conditions without direct obstetric role. | Jak/Sel/ Ork/Ter |
| **Post-partum Care and Maternal Reinte-gration** | Postpartum Restriction Regulation | **Dietary Restriction:** Days 7–30 require household cooking and maternal diet restrictions on oil, salt, MSG, sugar, and meat. | Ter/Jak/ Ork |
| | | **Behavioural Restriction:** Mother eats alone (impurity), avoids river washing, heavy work, bathing (3 days), and praising baby. | Ter/Ork/ Jak/Mah |
| | Maternal Recovery Rite | **Post-partum Herbal Bath:** *Durian Belanda* and *Jambu Batu* leaves used in bath to treat flatulence and refresh the body. | Tem/Jak/ Sem/Mah |
| | | ***Buka Pantang*:** Post-confinement feast ends restrictions, with mother and midwife eating to mark societal reintegration. | Ter |
| | Newborn-Kin Incorpo-ration Rite | **Placenta as Kin:** Placenta is washed and buried nearby house, with a 7-day lamp or guarded birth-site fire for several days. | Mah/Bat/ Sel/Jak |
| | | **Naming Rites:** Nature-based naming and baby sale-retrieval to correct unsuitable pre-name followed by feast and purification. | Mah |

**Note.** ALL = All or almost all ethnic groups practiced the manifestation; Abbreviations refer to Orang Asli subgroups: Kensiu (Ken), Kintaq (Kiq), Jahai (Jai), Mendriq (Men), Bateq (Bat), Temiar (Ter), Semai (Sem), Jah Hut (Jat), Che Wong (Che), Semoq Beri (Seq), Mah Meri (Mah), Temuan (Tem), Jakun (Jak), Semelai (Sel), Orang Kuala (Orl), Orang Seletar (Ors), and Orang Kanaq (Ork).

**Table 12:** Theme 4 – Adulthood, Elderhood and Ancestry

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Adulthood and Social Participation** | Cooperative *Adat* Practice | **Behaviour Regulation:** Taboos, norms, and moral expectations regulate social order and acceptable conduct. | Sem/Sel |
| | | **Harvest Procession:** Collective food preparation and sharing reinforce cooperation, reciprocity and social responsibility. | Sem/Sel/ Ter |
| | Cosmological Guidance Practice | **Ritual Setup:** Constructing natural-material spirit spaces and wearing plant-based attire to embody ecological identity. | Sem/Ter/ Mah/Bat |
| | | **Dream Awareness:** Dreams are attended and recalled to guide rituals and songs, grounding practice in cosmological authority. | Sem/Ter/ Bat/Che |
| | Communal Ritual Participation | **Healing Rituals:** Participants rhythmically strike Kelundang wood/bamboo while Bomoh heals and chants to restore health. | Sem/Ter/ Jak/Mah |
| | | **Sea Appeasement:** Participants perform sea-themed dance to seek sea-spirit protection and reflect marine dependence. | Ors/Orl/ Mah |
| **Elderhood and Cultural Custodianship** | Leadership Governance | **Tok Batin Authority:** Tok Batin mediates disputes, liaises with authorities, and guides adat to ensure cultural continuity. | Tem |
| | | **Ritual Governance:** *Tok Halak, Tok Sidang* and *Pawang* lead, sanction, and enact rituals through trance and spirit invocation. | Ter/Sem |
| | Ancestral-Spirit Mediation Rite | **Ancestral Rites:** *Pawang* and *Adat* council lead coastal offerings, music, and invocations to honour ancestors. | Mah |
| | | **Spirit Mediation:** *Putao* (shamans) lead 6-night séance singing *Nopoh Bukau* in to ask supernatural beings for abundance. | Che |
| | Specialized Knowledge Transmission | **Healing Lineage:** *Bomoh* transmit ritual and ethnomedicine through apprenticeship and inheritance to preserve knowledge. | Sel/Jak/ Che |
| | | **Mask Craftsmen:** Elder artisans craft ceremonial wooden masks, sustaining spiritual meaning and material-cultural links. | Mah/Jat |
| **Death, Mortuary Rites and Transition** | Mortuary Preparation Rite | **Funerary Rites:** Body washing and shrouding ensure safe transition; status-based burial reflects spiritual hierarchy. | Sem/Ter/ Bat |
| | | **Burial Provisioning:** Body is positioned and interred with grave goods to support afterlife journey and spiritual beliefs. | Sem/Ter/ Bat |
| | Soul Passage Guidance Rite | **Soul Guidance by Spirit Invocation:** *Sewang* dance and offerings invoke spirits to guide souls and protect the living. | Sem/Ter |
| | | **Afterlife Orientation:** Sun or spirit-path burial orientation guides the soul's journey and ensures spiritual passage. | Sem/Ter |
| | Grave Boundary Protection Practice | **Grave Marking:** Natural burial markers blend with the environment, supported by protective grave structures. | Ors |
| | | **Across River Burial:** Burial across rivers creates a natural boundary that prevents the spirit from returning to the living. | Sem/Ter |
| **Mourning and Ancestral Relations** | Mourning Conduct Regulation | **7-Day Rite:** Communal meal, prayers, and ritual acts formally mark the closure of mourning and transition back to normal life. | Sem/Ter |
| | | **Mourning Restrictions:** Dance, music, adornment, and deceased naming are restricted for respect and non-disturbance. | Sem/Ter/ Bat |
| | Ancestral Grave Rite | **Grave Offering:** Grave-visiting with offerings, libations, and ritual acts to guide spirits and sustain ancestral ties. | Mah/Jat |
| | | **Grave Care:** Grave maintenance practice involving cleaning, care, and libations to guide, protect, and remember the spirit. | Mah/Sem |
| | Ancestral Relations Safeguarding | **Badi Belief:** Taboos are observed to avoid *Badi*, a spiritual danger from tragic deaths causing illness and disturbance. | Sem/Ter/ Bat |
| | | **Ancestral Continuity:** Annual ancestral festivals and offerings sustain reciprocal ties and guide conduct via ancestral presence. | Mah/Sem |

**Note.** ALL = All or almost all ethnic groups practiced the manifestation; Abbreviations refer to Orang Asli subgroups: Kensiu (Ken), Kintaq (Kiq), Jahai (Jai), Mendriq (Men), Bateq (Bat), Temiar (Ter), Semai (Sem), Jah Hut (Jat), Che Wong (Che), Semoq Beri (Seq), Mah Meri (Mah), Temuan (Tem), Jakun (Jak), Semelai (Sel), Orang Kuala (Orl), Orang Seletar (Ors), and Orang Kanaq (Ork).


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The transition from the ICH manifestation classification (Tables 9-12) to the cultural spaces (Tables 10-11) was made by reading each life-phase code as a practice tied to setting, boundary or social use of space. Tables 9–12 show a progression from birth and childhood to marriage, reproduction, elderhood, death and ancestral relations. Within this progression, spatial cues appear throughout the examples. Infant baths, soot marking and placental care require protected care settings. River initiation, forest exploration, honey harvesting, weaving and midwife shadowing locate learning in domestic, forest and communal environments. Courtship, engagement, bersanding, uxorilocal residence and household roles identify spaces of union and household formation. Pregnancy pantang, birthing huts, postpartum restrictions and newborn-kin incorporation mark maternal and newborn spaces. Later codes such as *Tok Batin* authority, ritual governance, healing lineage, mortuary preparation, burial orientation, grave care and *Badi* belief extend the framework into *Adat*, custodial, burial and ancestral spaces.

Table 13 was developed from these recurring spatial cues. Instead of treating cultural practices only as life-cycle events, the table reorganizes them into planning-oriented spaces: early protection care, youth role learning, marriage-household formation, maternal-newborn care, subsistence-domestic practice, *Adat* governance, mortuary boundary and ancestral mourning. Table 14 then returns these spaces to the manifestation codes, showing which practices depend on which cultural settings. This conversion helps planning interpretation by identifying spaces that may require protection, access control, community use, ritual continuity or sensitivity during settlement planning and development decisions.

**Table 13:** Planning-Oriented Cultural Space Framework

| Layers | Code | Cultural Spaces | Definition |
|---|---|---|---|
| Early Life and Role Formation | **A** | Early Protection Care Space | Spaces safeguarding fetal-newborn, infant, and child wellbeing, identity, and protection. |
| | **B** | Youth Role Learning Space | Spaces for childhood learning, adolescent transition, skill formation, and responsibility. |
| Union and Maternal Care | **C** | Marriage Household Formation Space | Spaces for courtship, engagement, marriage rituals, residence, and household formation. |
| | **D** | Maternal Newborn Care Space | Spaces for pregnancy, childbirth, postpartum recovery, protection, and reintegration. |
| Domestic, Communal and Custodial | **E** | Subsistence Domestic Practice Space | Spaces for domestic skills, subsistence work, food sharing, and livelihood practice. |
| | **F** | Adat Governance Custodianship Space | Spaces for *adat* regulation, leadership, ritual authority, and knowledge transmission. |
| Mortuary and Ancestral Continuity | **G** | Mortuary Burial Boundary Space | Spaces for body preparation, burial orientation, grave marking, and spirit boundaries. |
| | **H** | Ancestral Mourning Relation Space | Spaces for mourning conduct, offerings, grave care, and ancestral continuity. |

**Table 14:** Spatial Interpretation of ICH Manifestation Codes

| Themes | Facets | Manifestation Codes | Cultural Spaces (Coded) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H |
| Early Life Development | Birth, Early Care & Infant Development | Infant Spiritual Protection | / | | | / | | | | |
| | | Infant Marking Tradition | / | | | / | | | | |
| | | Infant Care Practices | / | | | | | | | |
| | Childhood Dev. & Socialization | Spirit Restoration and Protection | / | / | | | | / | | |
| | | Cognitive & Interpretive Learning | | / | | | | / | | |
| | | Experiential Lifeways Learning | | / | | | / | | | |
| | Adolescent Development & Roles (M) | Male Maturity Transition Ritual | | / | | | | / | | |
| | | Subsistence Skill Mastery | | / | | | / | | | |
| | | Communal Responsibility Trad. | | / | | | / | / | / | / |
| | Adolescent Development & Roles (F) | Female Maturity Transition Ritual | | / | | | | / | | |
| | | Domestic Skill Mastery | | / | | | / | | | |
| | | Communal Responsibility Trad. | | / | | / | / | / | | |
| Union and Marital Institution | Courtship & Marital Readiness | Symbolic Courtship Signalling | | | / | | | | | |
| | | Performative Courtship Practice | | | / | | | / | | |
| | | Marital Readiness Assessment | | | / | | | / | | |
| | Proposal–Engagement Negotiation | Symbolic Engagement Exchange | | | / | | | / | | |
| | | Suitor Competence Proof | | | / | | / | / | | |
| | | Formal Proposal Negotiation | | | / | | | / | | |
| | Marriage Rituals & Ceremonies | Purification and Protection Rite | | | / | | | / | | |
| | | Blessing and Recognition Rite | | | / | | | / | | |
| | | Communal Celebration Practice | | | / | | / | / | | |
| | Post-Marital Household Formation | Post-Wedding Transition Rite | | | / | | / | / | | |
| | | Household Formation Norm | | | / | | / | | | |
| | | Equity and Separation Rule | | | / | | | / | | |
| Reproduction and Maternal Care | Pregnancy Beliefs & Regulation | Parental *Pantang* Regulation | / | | | / | | / | | |
| | | Taboo Boundary System | / | | | / | | / | | |
| | | Protection and Remediation Rite | / | | | / | | / | | |
| | Prenatal Care & Fetal Management | Midwife-Guided Prenatal Care | / | | | / | | / | | |
| | | Prenatal Protection Rite | / | | | / | | / | | |
| | | Fetal Alignment Rite | / | | | / | | / | | |
| | Childbirth & Birthing Roles | Birthing Space and Boundary | / | | | / | | / | | |
| | | Immediate Birth Care | / | | | / | | | | |
| | | Gendered Birthing Roles | | | | / | | / | | |
| | Postpartum Care & Mat. Reintegration | Postpartum Restriction Regulation | / | | | / | | / | | |
| | | Maternal Recovery Rite | | | | / | | / | | |
| | | Newborn-Kin Incorporation Rite | / | | | / | | / | | |
| Adulthood, Elderhood and Ancestry | Adulthood & Social Participation | Cooperative Adat Practice | | | | | / | / | | |
| | | Cosmological Guidance Practice | | | | | | / | | |
| | | Communal Ritual Participation | | | | | / | / | | |
| | Elderhood & Cultural Custodianship | Leadership Governance | | | | | | / | | |
| | | Ancestral-Spirit Mediation Rite | | | | | | / | | / |
| | | Specialized Knowledge Transm. | | | | | / | / | | |
| | Mortuary Rites & Transition | Mortuary Preparation Rite | | | | | | | / | |
| | | Soul Passage Guidance Rite | | | | | | | / | / |
| | | Grave Boundary Protection Prac. | | | | | | | / | |
| | Mourning & Ancestral Relations | Mourning Conduct Regulation | | | | | | / | | / |
| | | Ancestral Grave Rite | | | | | | | / | / |
| | | Ancestral Relations Safeguarding | | | | | | / | | / |


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## DISCUSSION

A life-course reading shifts the analysis of OA cultural practices from separate rituals to an ordered sequence of birth, adolescent, union, reproduction, adulthood, death and ancestral continuity. This reorganization responds to expert concerns about overlap among the original ritual, authority and festive categories. Although the initial themes received I-CVI values of 0.83 and S-CVI values between 0.72 and 0.83, the revised four-theme structure provides clearer distinctions among practices while preserving their continuity across life phases.

Place is central to OA cultural practices continuity. Infant care and childhood socialization occupy protected domestic, riverine, forest and communal settings. Courtship, marriage and household formation involve gathering areas, ceremonial spaces and residential arrangements. Pregnancy, childbirth and postpartum recovery depend on maternal-care settings, seclusion boundaries and controlled access. In later life, *Adat* governance, knowledge transmission, mortuary rites and ancestral relations extend cultural practice into communal institutions, burial grounds and remembrance sites.

Tables 13 and 14 consolidate the spatial relationships into eight heritage-mapping spaces. Care settings, learning environments, household spaces, maternal zones, livelihood areas, *Adat* institutions, burial boundaries and ancestral sites are thereby recognised as interconnected cultural infrastructure. This interpretation supports settlement planning, heritage inventories, development screening and community-led mapping by identifying where continuity, access, protection and spatial sensitivity must be considered.

## CONCLUSION

OA cultural practices are most coherently understood as a life-course system linking personal transition with family, community and ancestral responsibility. The four-theme, sixteen-facet framework captures this progression from early care and socialization to marriage, reproduction, custodianship, mortuary transition and continuing ancestral relations. Its principal planning value lies in making the spatial settings of the cultural practices visible. Domestic areas, rivers, forests, ceremonial grounds, household environments, maternal-care spaces, *Adat* institutions, burial areas and ancestral sites together form a culturally structured landscape. Recognizing these settings can strengthen heritage inventories, settlement planning, and community-based documentation.

The framework provides a basis for future site-level mapping through a long-term and sustainable collaboration with OA communities, covering the identification of practice locations, movement routes, customary boundaries and culturally sensitive areas. Local access conditions, seasonal use, custodianship responsibilities and levels of information disclosure should be documented under community guidance, with appropriate precautions for sacred or restricted community knowledge.

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# CULTURAL SPACES SUSTAINING ORANG ASLI NATURE–CULTURE KNOWLEDGE AND WISDOM

**Aisyah Abu Bakar[1], Nurul Amirah Laili[2], Siti Husna Awalluddin[3], Mariana Mohamed Osman[4]**

[1,2,3]*Department of Environmental Management,*
*Faculty of Forestry and Environment,*
UNIVERSITI PUTRA MALAYSIA
[4] *Department of Urban and Regional Planning,*
*Kulliyyah of Architecture and Environmental Design,*
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

## Abstract

This paper maps landscapes, rivers, celestial settings, healing areas and household spaces sustaining Orang Asli (OA) knowledge under Intangible Cultural Heritage (ICH) Domain 4. Evidence remains scattered across practices, beliefs and environmental settings, limiting interpretation as a coherent, place-based nature–culture system. The study combined interviews with OA knowledge holders and representatives with ethnographic sources, literature and heritage reports. Content analysis identified manifestations by knowledge function, setting, cultural meaning, practice and community context. Inductive-deductive thematic analysis organised them into codes, facets and themes. Six experts assessed the framework using the Content Validity Index, informing four themes and sixteen facets. These cover ecological landscapes, riverine systems, celestial-cosmological knowledge, therapeutics, healing and foodways. Spatial interpretation generated five conceptual layers and ten cultural spaces, including routes, customary territories, renewal landscapes, species habitats, river networks and sacred water sites. The framework supports landscape mapping, conservation zoning, river protection, resource safeguarding and culturally sensitive development control.

***Keywords***: Orang Asli, Indigenous Knowledge, Nature–Culture Systems, Intangible Cultural Heritage, Cultural Landscape

[1] Corresponding author. Email: aisyah.ab@upm.edu.my

## INTRODUCTION

This paper is positioned within a broader initiative to catalogue and organize Orang Asli [OA] Intangible Cultural Heritage [ICH] across five ICH domains, with this study devoted specifically to Domain 4, Knowledge and Practices, concerning Nature and Universe.

OA knowledge and wisdom in Peninsular Malaysia is shaped through forests, rivers, celestial cycles, medicinal resources and household practices. Distinct from OA ICH papers on oral traditions, performing arts and social practices, this paper examines ecological, hydrological, celestial-cosmological and therapeutic-foodway knowledge as connected nature-culture systems. The study develops an expert-informed framework for translating knowledge manifestations into cultural landscapes to support environmental stewardship, heritage mapping, and safeguarding.

## LITERATURE REVIEW

OA knowledge and wisdom develop through sustained engagement with forests, rivers and ecological cycles, where observation, belief and practice guide subsistence, healing and resource management (Diansyah et al., 2022; Haq et al., 2023). Land is understood through use rather than as an abstract mapped surface. Movement, foraging and cultivation rely on remembered routes, landmarks and customary tenure, while forests are differentiated by access rules, taboos and permitted activities (Dong et al., 2022; Wook et al., 2020). Ecological knowledge also informs seasonal decision-making and respectful relations with non-human beings (Tharmabalan, 2023). Cosmological understanding is embedded in ritual timing, lunar observation and spiritual interpretations of environmental balance, although it is less explicitly documented than observable practices (Jaafar, 2021; Sinthumule, 2023). Healing knowledge is more visible, particularly through medicinal plants, wild foods and preventive care, which connect health to everyday use of natural resources (Abdullah et al., 2021; Jessen et al., 2022).

Navigational and hydrological knowledge further demonstrates how environment and culture are interwoven. Rivers support movement, settlement and resource access (Praveena et al., 2025; Abdul Wahab & Manaf, 2020). Together, forests, rivers, cultivation areas, gathering routes, healing-resource sites and sacred locations function as cultural spaces where knowledge is learned and applied. Heritage mapping can help relate physical features to customary boundaries, seasonal use, access patterns, ecological functions and spiritual meanings. Existing studies tend to examine ethnobotany, healing and land use separately, with less attention given to their connections with cosmological and water-related knowledge (Kamaruddin & Said, 2021; Tharmabalan, 2023). A Domain 4 framework is needed to thematically explore OA knowledge subtypes and recognizing ecosystems as cultural spaces, strengthening documentation, heritage planning, and community-led safeguarding.

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## METHODOLOGY

This paper draws from continuing research that documents and classifies OA ICH across five domains. While the companion papers apply related stages of extraction, coding, thematic analysis and expert validation, this study adapts the process to Domain 4: Knowledge and Practices Concerning Nature and the Universe. Its focus is on ecological knowledge, riverine understanding, botanical use, healing, foodways, celestial interpretation and cosmological relationships.

The corpus comprised interview transcripts with OA knowledge holders and community representatives, supplemented by ethnographic records, academic publications and heritage reports. Content analysis was used to identify knowledge-based manifestations connected to forests, rivers, plants, animals, weather, water systems, healing resources, food practices, seasonal indicators and spiritual-ecological meanings. In this paper, knowledge is translated as practical, environmental and cosmological understanding that guides resource use, movement, care, ritual timing and human–nature relations. Each manifestation was coded by knowledge function, ecological setting, cultural meaning, associated practice and community context. The coded materials were then organized through inductive-deductive thematic analysis into manifestation codes, facets and themes. OA cultural and heritage experts assessed the framework using the Content Validation Index [CVI] for clarity, relevance, coherence and cultural suitability.

**Table 1:** Framework Development Stages

| Phase | Description of Process | Output |
|---|---|---|
| Stage 1: Data Extraction and Coding | Interview transcripts and documents were analyzed using content analysis in ATLAS.ti to identify OA ICH Domain 4 manifestations. Knowledge function, cultural meaning and environmental context were recorded. | Dataset of identified ICH manifestations, segmented corpus of data excerpts |
| Stage 2: Coding of ICH Manifestations under Domain 4 | Identified manifestations were assigned manifestation codes to organize recurring ecological and cosmological knowledge, foodways, and healing practices. | Coded dataset of OA Knowledge and Wisdom |
| Stage 3: Categorization of Themes and Facets | Coded manifestations were grouped into facets and organized into themes using thematic analysis to refine conceptual groupings within each theme and facet. | Structured set of themes and corresponding facets |
| Stage 4: Framework Drafting | Themes and facets were structured into a conceptual framework, mapping relationships into a coherent visual matrix guided by theoretical reasoning. | Initial framework showing classification hierarchy |
| Stage 5: Iterative Refinement | The framework was reviewed against coded data using thematic analysis to improve clarity, consistency and reduce overlap between codes, facets and themes. | Refined ICH Domain 4 framework ready for validation |
| Stage 6: Validation Preparation | The framework was converted into a validation tool with definitions of themes and facets and manifestation codes as well as guidance for expert evaluation. | Validation package with framework and scoring sheets |
| Stage 7: Validation Study Execution | Experts evaluated the framework, and I-CVI and S-CVI were calculated to assess content validity. | Expert feedback and CVI scores |
| Stage 8: Framework Refinement | Validation results were used to revise labels, structure, and grouping for improved coherence. | Revised Framework of OA ICH Domain 4 |


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## Semi-Structured Interviews

The semi-structured interviews used an open thematic guide to encourage participants to explain knowledge practices in their own order and narrative style. The guide began with settlement background, household context, social organization, livelihood conditions, governance, environmental surroundings and heritage continuity. Following this flow, the questions then explored OA nature-culture knowledge covering forest and river knowledge, plant and animal uses, healing resources, food practices, water-related practices, weather indicators, celestial observation, seasonal signs, sacred ecological meanings and human–nature relationships. Participants included *Tok Batin*, elders, committee representatives and village members from various OA subgroups. Names were coded, while role, subgroup and village location were retained.

**Table 2:** Profile of Orang Asli Interview Participants

| Code | Roles in Village | Groups | Village Name and Location |
|---|---|---|---|
| PO01 | Director, Cultural Institution | Mah Meri | Kampung OA Sungai Bumbun, Pulau Carey |
| PO02 | OA Youth Representative | Mah Meri | Kampung OA Sungai Bumbun, Pulau Carey |
| PO03 | Leader / *Tok Batin* | Jakun | Kampung OA Sungai Bot, Karak, Bentong |
| PO04 | Village Chairperson | Temuan | Kampung OA Cinta Manis, Karak, Bentong |
| PO05 | Leader / *Tok Batin* | Temuan | Kampung OA, Ulu Pareh, Karak, Bentong |
| PO06 | OA Representative | Temuan | Kampung OA, Ulu Pareh, Karak, Bentong |
| PO07 | Leader / *Tok Batin* | Jah Hut | Kampung OA Pian, Kuala Krau, Temerloh |
| PO08 | OA Representative | Jah Hut | Kampung OA Pian, Kuala Krau, Temerloh |
| PO09 | Leader / *Tok Batin* | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO10 | Village Elder | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO11 | OA Representative | Che Wong | Kampung Kuala Enggang, Temerloh |
| PO12 | Leader / *Tok Batin* | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO13 | OA Representative 1 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO14 | OA Representative 2 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO15 | OA Representative 3 | Semelai | Kampung OA Pelawan, Pos Iskandar, Bera |
| PO16 | Leader / *Tok Batin* | Bateq | Kampung OA Kuala Atok, Jerantut |
| PO17 | Leader / *Tok Batin* | Semoq Beri | Kampung OA Sungai Tiang, Jerantut |
| PO18 | Leader / *Tok Batin* | Semai | Kampung OA Rening, Cameron Highlands |
| PO19 | Leader / *Tok Batin* | Semai | Kampung OA Kuala Boh, Cameron Highlands |
| PO20 | Leader / *Tok Batin* | Jakun | Kampung OA Gumum, Tasik Chini, Pekan |

**Table 3:** Coding Trail from Content Analysis to Theme Development

| | Coding Stage | Coding Output |
|---|---|---|
| 1 | Verbatim Transcription | PO08: *…bila musim hujan panas, kita ambil daun hijau, mana-mana daun hijau pun boleh. Ludah sikit pada daun tu, letak dekat telinga supaya tak kena demam. Satu keluarga lah pakai daun pelindung…* |
| 2 | Transcript Excerpt | The participant explained that during alternating rainy and hot weather, green leaves are spat on and placed near the ear as a protective practice to prevent fever, with the practice observed by the whole family. |
| 3 | Condensed Meaning | Green leaves are used as protective botanical items to prevent fever during seasonal weather changes. |
| 4 | Initial Codes | Protective Leaf, Seasonal Fever Prevention, Botanical Protection |
| 5 | Final Code | Plant-Part Therapeutics |
| 6 | Facet | Materia Medica and Therapeutic Resources |
| 7 | Theme | Therapeutics, Healing and Foodways Knowledge |

## Document Analysis

Document analysis supported the interview data through a review of 403 academic, institutional, community and media sources on OA knowledge systems. Sources were selected for subgroup context, knowledge-based evidence and ICH Domain 4 relevance. Relevant content was condensed into meaning units and coded into manifestation codes, facets and themes for classifying ecological and cosmological knowledge heritage (refer to Table 4).

**Table 4:** Document Sources and Screening Criteria

| No | Types | Sources | Inclusion Criteria | Exclusion Criteria |
|---|---|---|---|---|
| 1 | Peer Reviewed Articles | Mainly retrieved from MyCite, followed by Google Scholar, Scopus, ScienceDirect, JSTOR, DOAJ SpringerLink, Taylor & Francis Online | Evidence on OA ecological knowledge and wisdom, medicinal and foodways knowhow, celestial and cosmological knowledge, or subgroup context. | No ICH or OA knowledge evidence; focused only on development, education, health or socio-economy. |
| 2 | Conference Papers | Academic conference proceedings, seminar papers and heritage-related conference publications. | Relevant findings on OA ethnobotany and healing knowledge, subsistence practices, or knowledge transmission. | Too brief, duplicated published articles, or did not provide usable evidence for coding. |
| 3 | Book Chapters | Edited academic books on Orang Asli, indigenous studies, anthropology, heritage and culture. | Subgroup-specific evidence on ecological wisdom, celestial and cosmological knowledge. | General discussion without insufficient detail for coding. |
| 4 | Books and Monographs | Ethnographic books, cultural monographs, Orang Asli studies and indigenous community publications. | Detailed descriptions of OA ecological, healing, foodways ethnobotany, forest mobility, or cosmological knowledge. | Outdated claims without cultural relevance, unclear source basis or no link to knowledge. |
| 5 | Theses and Dissertations | University repositories, institutional libraries and postgraduate research databases. | Empirical or ethnographic findings on OA traditional ecological celestial and cosmological knowledge. | Unavailable full text, unrelated focus or no extractable cultural evidence. |
| 6 | Government Reports | Mainly JAKOA, with related government and agency reports. | Official information on OA subgroups, village context, and cultural programs. | Administrative data only, irrelevant to ICH documentation. |
| 7 | UNESCO documents | UNESCO ICH documents, safeguarding guidelines and conceptual references. | Definitions, safeguarding principles and conceptual guidance relevant to ICH knowledge and wisdom. | Unrelated to ICH concepts or documentation. |
| 8 | Museum Archives | Museum records, exhibition notes, archive descriptions and heritage documentation. | Descriptions of OA ecological lifeways objects, tools and materials with intangible meanings. | Records with unclear provenance and no identification of subgroups. |
| 9 | Community Publications | NGO materials, local publications, blogs, community websites and informal documentation. | Community accounts of forest and river practice and mobility, healing and foodways and resource use. | Unverifiable claims, or unidentifiable community context. |
| 10 | Media Recordings | Audio and video documentaries, online news articles, and media features related to Orang Asli communities. | Recorded or reported ecological knowledge, forest, river, healing and foodways knowledge and heritage transmission. | Sensationalized reporting, unclear informant source or insufficient detail for coding. |


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## Multi-Phase Framework Development and Validation Workflow

Figures 1 and 2 map the framework development process across two stages, from source coding and thematic structuring to expert validation, refinement, restructuring, and final framework confirmation.

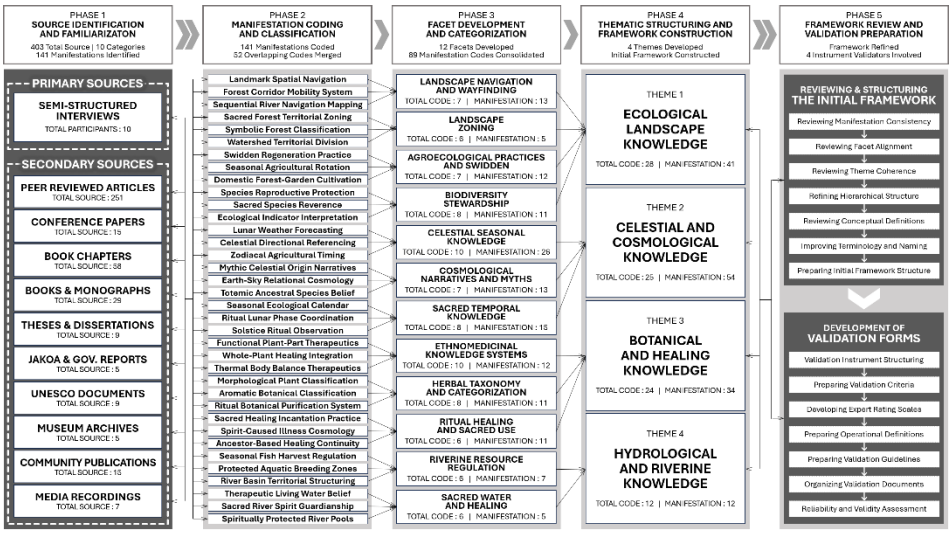



**Figure 1:** Initial Development and Construction of the ICH Domain 4 Framework

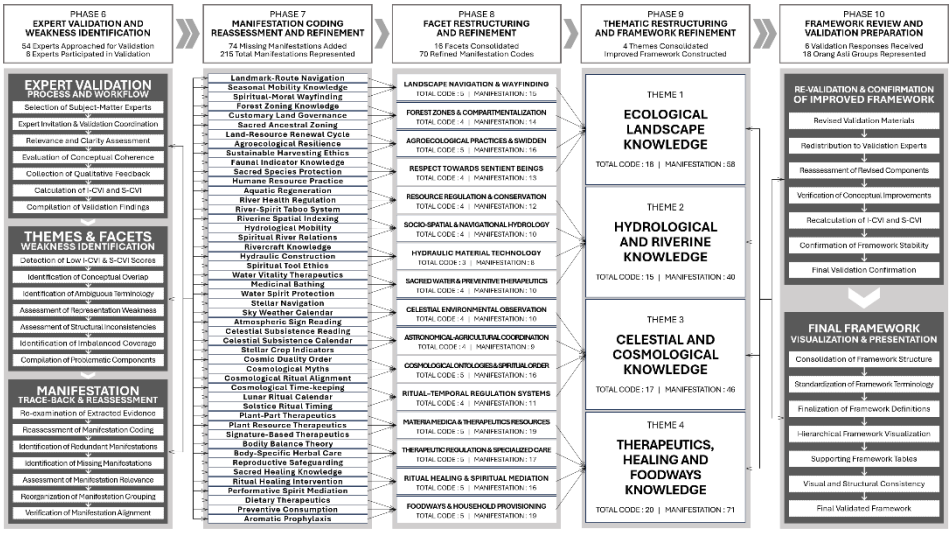



**Figure 2:** Expert Validation and Refinement of the ICH Domain 4 Framework

## RESULTS

Six experts were involved in validating the framework. Their identities were protected through coded identifiers, listed as Expert 1 to Expert 6. Table 5 summarizes each expert's background, expertise, and feedback.

**Table 5:** Validators' Feedback and Corresponding Revisions

| Validator | Feedback | Corresponding Revision |
|---|---|---|
| **Expert 1**<br>Department of Orang Asli Development (JAKOA)<br>Expert in Indigenous welfare management and community support services | Suggested that Domain 4 manifestations give stronger attention to routes, directions, landmarks, and culturally meaningful places, as OA environmental knowledge is often stored through movement, place memory, and spatial experience. | *Landscape Navigation and Wayfinding* was retained and strengthened through landmark-route navigation, *Jok* mobility, and spiritual-moral wayfinding. River-based spatial knowledge was also expanded under Socio-Spatial and Navigational Hydrology through toponymic mapping, watershed zoning, flood navigation, and portage routes. |
| **Expert 2**<br>Department of Orang Asli Development (JAKOA)<br>Expert in Indigenous welfare management and community support services | Recommended clarifying whether *Batek Jok* mobility and customary land are group-specific, as OA ecological knowledge, travel practices, and land relations vary across groups. | *Jok* mobility was positioned under *Landscape Navigation and Wayfinding, and* customary land knowledge was refined under *Forest Zones and Compartmentalization.* A 'Groups' column was added to specify relevant OA subgroups. |
| **Expert 3**<br>GERIMIS Art Project (Cultural Organization)<br>Expert in Indigenous Knowledge, Cosmologies, and Eco-Critical Cultural Studies | Recommended more Domain 4-specific documentation, including relevant OA group, cultural context, indigenous terms, materials, celestial indicators, and belief meanings. | The revised manifestation tables include a 'Groups' column. Indigenous terms such as *Jok, Maganu Totuo, Tagal, Lubuk Larangan, Saka, Pancur, Celau, Penunggu, Jampi, Pantang*, and *Mai-Ten-Yul* were retained at manifestation level. |
| **Expert 4**<br>Institute of Environment and Development, Universiti Kebangsaan Malaysia<br>Expert in Sustainable Livelihoods of Indigenous Communities, Heritage Conservation | Recommended clarifying the position of *Cosmological and Mythological Knowledge* within Domain 4, as cosmological worldviews may overlap with ecological knowledge. | *Celestial and Cosmological Knowledge* was reorganized into four clearer facets, distinguishing knowledge related to environmental prediction, subsistence timing, cosmological belief systems, and ritual calendars, reducing overlaps with ecological knowledge. |
| **Expert 5**<br>Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin<br>Expert in Indigenous people studies, Social Anthropology | Suggested that customary rituals be considered as part of OA knowledge because they reflect respectful relations with nature, belief systems, and ecological ethics. | Ecological ritual and ethical resource-use knowledge were refined under *Ecological Landscape Knowledge*, particularly *Forest Zones and Compartmentalization* and *Respect Towards Sentient Beings*. |
| **Expert 6**<br>Kulliyyah of Sustainable Tourism and Contemporary Languages, International Islamic University Malaysia<br>Expert in Humanities, Linguistic and Literature, Malay Language and Literature | Recommended clarifying overlapping classification terms, especially where ritual, healing, ecological, and cosmological knowledge intersect, so Domain 4 manifestations are classified by knowledge function rather than surface practice. | The revised framework classifies manifestations by knowledge function, expanding *Botanical and Healing Knowledge* into *Therapeutics, Healing and Foodways Knowledge* and refining hydrological knowledge through material technology, spatial navigation, and preventive therapeutics. |


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Table 6 presents the content validation summary for the initial framework, while Table 7 outlines the revised themes and facets.

**Table 6:** Content Validation Summary of the Initial Framework

| Themes | I-CVI | Facets | I-CVI | S-CVI |
|---|---|---|---|---|
| Ecological Landscape Knowledge | 0.83 | Landscape Navigation and Wayfinding | 1.00 | 0.92 |
| | | Landscape Zoning | 0.83 | |
| | | Agroecological Practices and Swidden | 1.00 | |
| | | Biodiversity Stewardship | 0.83 | |
| Celestial and Cosmological Knowledge | 0.83 | Celestial Seasonal Knowledge | 1.00 | 0.89 |
| | | Cosmological Narratives and Myths | 0.83 | |
| | | Sacred Temporal Knowledge | 0.83 | |
| Botanical and Healing Knowledge | 0.83 | Ethnomedicinal Knowledge System | 0.83 | 0.89 |
| | | Herbal Taxonomy and Categorization | 0.83 | |
| | | Ritual Healing and Sacred Use | 1.00 | |
| Hydrological and Riverine Knowledge | 0.83 | Riverine Resource Regulation | 0.83 | 0.75 |
| | | Sacred Water and Healing | 0.67 | |

**Table 7:** Revised Theme and Facets

| Themes | Facets |
|---|---|
| Ecological Landscape Knowledge | Landscape Navigation and Wayfinding |
| | Forest Zones and Compartmentalization |
| | Agroecological Practices and Swidden |
| | Respect Towards Sentient Beings |
| Hydrological and Riverine Knowledge | Resource Regulation and Conservation |
| | Socio-Spatial and Navigational Hydrology |
| | Hydraulic Material Technology |
| | Sacred Water and Preventive Therapeutics |
| Celestial and Cosmological Knowledge | Celestial Environmental Observation |
| | Astronomical-Agricultural Coordination |
| | Cosmological Ontologies and Spiritual Orders |
| | Ritual–Temporal Regulation Systems |
| Therapeutics, Healing and Foodways Knowledge | Materia Medica and Therapeutics Resources |
| | Therapeutic Regulation and Specialized Care |
| | Ritual Healing and Spiritual Mediation |
| | Foodways and Household Provisioning |

The initial framework showed acceptable agreement, but some facets still combined different types of knowledge within the same category. Ecological practice, riverine knowledge, cosmological belief, healing resources, and foodways needed clearer boundaries without losing their interconnections. The revised framework therefore separates ecological landscape knowledge, hydrological and riverine knowledge, celestial and cosmological knowledge, and therapeutics, healing and foodways knowledge. This gives clearer attention to spatial orientation, forest governance, swidden renewal, river regulation, hydraulic knowledge, celestial observation, ritual time, medicinal resources, and household provisioning. The final structure presents OA wisdom as a nature-culture system in which environmental practice, belief, resource use, healing, and everyday wellbeing remain closely connected.

**Table 8:** Revised Themes and Facets Definitions

| Themes & Definitions | Facets & Definitions |
|---|---|
| **Ecological Landscape Knowledge**<br>*A holistic environmental literacy system integrating spatial orientation, land governance, and sustainable subsistence with a moral worldview to ensure communal survival.* | **Landscape Navigation and Wayfinding**<br>*The mental and physical systems used to organize spatial memory and navigate the landscape using environmental cues and traditional routes.* |
| | **Forest Zones and Compartmentalization**<br>*The customary classification of terrestrial spaces into functional and symbolic regions to regulate resource access and safeguard territorial continuity.* |
| | **Agroecological Practices and Swidden**<br>*The systematic management of soil, crops, and forest cycles that prioritizes long-term ecological health and subsistence sufficiency.* |
| | **Respect Towards Sentient Beings**<br>*The ethical framework and behavioral protocols governing human interaction with non-human life to maintain the spiritual and biological forest hierarchy.* |
| **Hydrological and Riverine Knowledge**<br>*A socio-technical and spiritual system governing the management, navigation, and therapeutic use of aquatic ecosystems.* | **Riverine Resource Regulation and Conservation**<br>*The customary governance of aquatic life through ecological monitoring and social restrictions to ensure sustainable resource regeneration.* |
| | **Socio-Spatial and Navigational Hydrology**<br>*The mental and physical mapping of river systems as primary anchors for territorial organization and seasonal mobility.* |
| | **Hydraulic Material Technology**<br>*The applied engineering and craftsmanship used to manipulate water flow and construct specialized riverine tools and transport.* |
| | **Sacred Water and Preventive Therapeutics**<br>*The spiritual and medicinal application of water from specific sources to restore vitality and maintain harmony with aquatic guardians.* |
| **Celestial and Cosmological Knowledge**<br>*An integrated knowledge system that synchronizes human activities, agricultural cycles, and spiritual governance with celestial movements and mythic origins.* | **Celestial Environmental Observation Systems**<br>*The systematic interpretation of atmospheric and stellar phenomena to provide predictive indicators for environmental change and navigational guidance.* |
| | **Astronomical-Agricultural Coordination Systems**<br>*The practical application of celestial timing to regulate the production, harvesting, and management of food resources.* |
| | **Cosmological Ontologies and Spiritual Orders**<br>*The foundational belief systems and mythic narratives that define the relationship between the cosmic realm and earthly existence.* |
| | **Ritual–Temporal Regulation Systems**<br>*The management of communal time through sacred cycles and ceremonial markers to maintain synchronization with cosmic rhythms.* |
| **Therapeutics, Healing and Foodways Knowledge**<br>*A holistic knowledge system integrating natural resources, bodily care, food practices, and spiritual mediation to sustain health and community wellbeing.* | **Materia Medica and Therapeutics Resources**<br>*The specialized knowledge regarding the properties and preparation of natural substances into complex healing agents.* |
| | **Therapeutic Regulation and Specialized Care**<br>*The application of indigenous physiological theories to provide targeted medical interventions across diverse life stages and social roles.* |
| | **Ritual Healing and Spiritual Mediation**<br>*The sacred dimension of healing involving metaphysical diagnosis and ceremonial practices to resolve the spiritual root causes of affliction.* |
| | **Foodways and Household Provisioning**<br>*The inherited knowledge of food selection, preparation, preservation, and household provisioning for sustenance and everyday wellbeing.* |

Tables 9–12 organise the ICH manifestations into a thematic framework. The examples shown provide partial representation only, since each theme comprises four facets, each facet contains three to five codes, and each code may include various manifestations.


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**Table 9:** Theme 1 – Ecological Landscape Knowledge

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Landscape Navigation and Way-finding** | Landmark-Route Navigation | **Natural Feature Mapping:** Natural landmarks (ridges, trees, river bends, etc.) cognitively structure landscape memory. | ALL |
| | | ***Jok* Mobility:** Customary forest route through forest corridors shaped by inherited ecological experience and familiarity. | Bat/Jai/ Men/Ken |
| | Seasonal Mobility Knowledge | **Seasonal Ecological Naming:** Classification of temporal cycles structured around ecological and climatic transitions. | Bat/Sem/ Ter/Tem |
| | | **Migration Tracking:** Animal migration patterns and ecological cues are interpreted for seasonal mobility planning. | Bat/Sem/ Ter/Jat |
| | Spiritual-Moral Wayfinding | **Spiritual Path:** Forest pathways are distinguished between permissible and restricted routes through spiritual meanings. | ALL |
| | | **Moral Orientation:** Spatial movement requires ethical mindfulness of unseen forces disrupting ecological harmony. | ALL |
| **Forest Zones and Compart-menta-lization** | Forest Zoning Knowledge | **Forest Classification:** Classificatory system of forest landscapes via symbolic, ecological, or functional distinctions. | Bat/Sem/ Ter/Che |
| | | **Fallow Land Regeneration:** Reclassification of forest areas from active cultivation to regenerative phase to restore fertility. | Sem/Ter/ Tem/Jak |
| | Customary Land Governance | **Communal Land Governance:** Management of forest access through customary rules to prevent resource overuse or conflict. | Sem/Tem /Jak/Sel |
| | | **Land Encroachment:** Engagement with external actors to negotiate forest boundaries and defend customary territories. | ALL |
| | Sacred Ancestral Zoning | **Sacred Forest Zoning:** Specific forest areas are spiritually inhabited and sacred; hence approached with moral discipline. | ALL |
| | | **Ancestral Territory:** Forest boundaries are morally inherited through ancestral links and spiritual territorial belonging. | Sem/Tem /Jak/Sel |
| **Agro-ecological Practices and Swidden** | Land-Resource Renewal Cycle | **Seasonal Rotation:** Forest productivity, crop maturity, and soil recovery are managed through seasonal ecological cycles. | Sem/Ter/ Tem/Jak |
| | | **Land-Human Lifecycle Parallelism:** The belief that human life and land regeneration follow parallel cyclical rhythms. | Sem/Ter/ Bat/Jai |
| | Agroeco-logical Resilience | **Crop Diversity:** Systematic diversification of crop species for food security, soil stability, and pest and climatic resilience. | Sem/Tem /Jak/Jat |
| | | **Domestic Agroforestry:** Home gardens mirror forest structure through multi-layered vegetation for food and medicinal use. | Tem/Jak/ Sem/Mah |
| | Sustainable Harvesting Ethics | ***Maganu Totuo*:** Crops and forest resources are harvested according to species maturity and reproductive stage. | ALL |
| | | **Subsistence Principle:** Subsistence ethics prioritize cultivating sufficient for rather than over accumulating surplus. | ALL |
| **Respect Towards Sentient Beings** | Faunal Indicator Knowledge | **Avian Seasonal Transition**: Bird presence signals ecological transition, climatic change, and ecosystem health. | Bat/Sem/ Ter/Jat |
| | | **Faunal Regulation:** Long-term observation of species-specific habits and reproductive timing to avoid disrupting regeneration. | ALL |
| | Sacred Species Protection | **Totemic Species Reverence**: Certain species embody ancestral spirits and require reverent, morally guided treatment. | ALL |
| | | **Dragonfly Catching Taboo**: Dragonflies are spiritually linked to ecological balance; hence harming them is tabooed. | Sem/Ter/ Che/Seq |
| | Humane Resource Practice | ***Sumpitan*:** Close-range precision, quick and quiet practice using a blowpipe and plant-based darts to avoid sufferings. | Sem/Ter/ Bat/Jat |
| | | **Botanical Pest Stewardship:** Plant-based pest control protects crops while reducing harm to sentient life. | Sem/Tem /Jak/Jat |

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**Table 10:** Theme 2 – Hydrological and Riverine Knowledge

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Riverine Resource Regulation and Conser-vation** | Aquatic Regenera-tion | **Spawning Cycles (*Tagal*):** Fish breeding seasons are observed to regulate harvesting and ensure population regeneration. | Sem/Tem /Jak/Bat |
| | | ***Lubuk Larangan*:** The communal practice of declaring specific deep river pools off-limits to fishing to preserve breeding stock. | Sem/Tem /Jak/Bat |
| | River Health Regulation | **Aquatic Health Indicators:** Moss density, water clarity, and other environmental markers indicate river ecosystem health. | Bat/Jai/ Sem/Tem |
| | | **Downstream Etiquette:** Bathing and waste disposal are regulated to keep water clean for downstream communities. | Che/Jat/ Sem/Ter |
| | River-Spirit Taboo System | **Covenant with Crocodile**: Crocodiles are believed to protect rivers when humans respect specific fishing taboos. | Sel/Jak |
| | | **The Noise Taboo (Celau):** Excessive noise or mockery near water triggers supernatural storms and dangerous flash flooding | ALL |
| **Socio-Spatial and Naviga-tional Hydrology** | Riverine Spatial Indexing | **Toponymic Mapping**: Sequential river names and narratives form a mental spatial index (river spine) for forest navigation. | ALL |
| | | **Watershed Zoning:** The division of ancestral forest territories based on the natural drainage areas of river tributaries (*Saka*). | Sem/Ter/ Jak/Tem |
| | Hydro-logical Mobility | **Flood Cycle Navigation:** Seasonal flood patterns guide safe transport, river crossing, and resource collection. | Jak/Sel/ Tem/Sem |
| | | **Portage Route:** Forest corridors connecting river basins are identified and maintained for trade and resource movement. | Sel/Jak/ Tem/Mah |
| | Spiritual River Relations | **Ancestral Presence in Pools:** Ancient deep river pools are understood as dwelling places of protective ancestral spirits. | Sel/Jak/ Tem/Jat |
| | | **River-Soul Connection:** An individual's life-force is spiritually linked to the health and flow of their birth river. | Ter/Sem/ Bat/Jai |
| **Hydraulic Material Techno-logy** | Rivercraft Knowledge | **Hydro-Acoustic Knowledge:** Interpretation of water sounds to identify hidden rocks, depth changes or fish-breeding grounds. | Jak/Sel/ Ors/Tem |
| | | **Riparian Buoyancy:** Expertise in lightweight, water-resistant timbers for constructing durable and balanced dugout canoes. | Orl/Ors/ Jak/Sel |
| | Hydraulic Construc-tion | **Bamboo Aqueduct (*Pancur*):** Engineering practice of gravity-fed split bamboo water systems to supply water to villages. | Sem/Ter/ Jat/Che |
| | | ***Empang* Construction:** Temporary construction of river weir using stones and rattan to channel fish into traditional traps. | Jat/Sem/ Jak |
| | Spiritual Tool Ethics | **Tool-Spirit Respect:** River tools (boats, traps, etc) possess spirits that require respectful treatment for successful use. | Sel/Jak/ Orl/Tem |
| | | **Material Sanctity:** Bamboo for water transport must be harvested during specific lunar phases to ensure spiritual purity. | Tem/Sem /Jak/Jat |
| **Sacred Water and Preventive Thera-peutics** | Water Vitality Thera-peutics | **Thermal Healing**: Knowledge of specific mineral and spiritual properties of hot springs to treat skin and joint ailments. | Sem/Tem /Jak/Jat |
| | | **Water Vitality:** Running river water is believed to carry cool energy that neutralizes the heat of physical illness. | Ter/Sem/ Bat/Che |
| | Medicinal Bathing | **Aquatic Pharmacopeia:** Water-dwelling plants and roots harvested for essential ingredients in medicinal healing baths. | Jak/Tem/ Sel/Sem |
| | | **Ritual Lustration**: The ceremonial bathing in purified or floral water to restore spiritual harmony and wash away misfortune. | ALL |
| | Water Spirit Protection | **Spirit Offering:** Ritual offerings placed at river confluences or lakes for protection, safe passage, and successful foraging. | Sel/Mah/ Jak/Tem |
| | | **Spring Guardianship:** Every freshwater spring is protected by a spiritual guardian (*Penunggu*) who grant permission for use. | Che/Bat/ Jai/Men |

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**Table 11:** Theme 3 – Celestial and Cosmological Knowledge

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Celestial Environmental Observation Systems** | Stellar Navigation | ***Biduk* Navigation:** Stellar patterns are used to guide movement and migration decisions according to climatic conditions. | Sel/Jak/ Tem/Orl |
| | | ***Balatek* Navigation:** Celestial reference guide directional movement across landscapes and changing seasonal conditions. | Sem/Ter/ Bat/Jat |
| | Sky Weather Calendar | ***Bapak Langit* Calendar:** Sky signs as timing - cloud colour, rainbow arcs, and wind signs for coming rains or droughts. | ALL |
| | | **Lunar Halo Weather Indicator:** Lunar rings are recognized as atmospheric signs indicating possible impending rainfall. | ALL |
| | Atmospheric Sign Reading | **Sky Colour Interpretation:** Atmospheric colour shifts are read to identify seasonal transitions and environmental changes. | ALL |
| | | **Wind-Spirit Movement:** Wind pattern changes are understood as signs of spiritual presence and movement. | ALL |
| **Astronomical Agricultural Coordination Systems** | Celestial Subsistence Reading | **Celestial Indicators:** The reading of celestial signs to recognize seasonal onset (begin/shift) or environmental change | ALL |
| | | **Stellar Subsistence:** Star patterns guide agricultural, hunting, and seasonal subsistence decisions. | Sem/Ter/ Bat/Jai |
| | Celestial Subsistence Calendar | **Lunar-Guided Planting:** Planting activities are coordinated according to waxing and waning lunar phases. | Sem/Ter/ Tem/Jak |
| | | **Celestial Food Management:** Food storage and consumption are actively regulated according to celestial-seasonal timing. | Sem/Ter/ Jak/Sel |
| | Stellar Crop Indicators | ***Periantan Penungguyan*:** *Peyh, Jekat*, and *Keranchong* constellations signal the paddy waiting or guiding season. | Sem/Ter/ Tem/Jat |
| | | ***Lunga* and *Lerek***: *Lunga* (Pleiades) signals fruit loosening, while *Lerek* (Orion's Belt) signals fruits ripening in March. | Bat/Jai/ Sem/Ter |
| **Cosmological Ontologies and Spiritual Orders** | Cosmic Duality Order | **Celestial Duality:** A systemic understanding of celestial bodies as complementary opposites that maintain universal balance. | ALL |
| | | **Earth–Sky Dualism:** Earth and sky are conceptualized as interdependent realms shaping existence, relations, and order. | ALL |
| | Cosmological Myths | **Cosmological Folklore:** Sun, moon, and star narratives transmit cosmological worldview, social and ecological ethics. | ALL |
| | | ***Sura Alam* Mythology:** Cosmic-origin myths connect celestial beings with earthly fertility and cosmological order. | Sem/Ter/ Tem/Jak |
| | Cosmological Ritual Alignment | **Trance-Dance Rituals:** Trance performances are understood to align communal spiritual states with seasonal rhythms. | Ter/Sem/ Bat/Jai |
| | | **Animal-Mimetic Rituals:** Subsistence rituals interpret animal behaviours as signs of celestial timing and life-cycle processes. | ALL |
| **Ritual-Temporal Regulation Systems** | Cosmological Timekeeping | **Lunisolar Timekeeping:** Long-term timekeeping system integrates solar positions and lunar cycles for temporal tracking. | Sem/Ter/ Tem/Sel |
| | | **Zodiac Year Cycle System:** Zodiacal yearly cycles provide a temporal structure for ritual timing and seasonal planning. | Tem/Jak/ Sel/Mah |
| | Lunar Ritual Calendar | **Five-Day Ritual Calendar:** Crescent moon marks new cycle of planting while full moon linked to fertility rituals. | Bat/Jai/ Sem/Ter |
| | | **Moon-Phase Timing:** Twelve-month lunar cycle knowledge is used to calculate timing for communal rituals. | ALL |
| | Solstice Ritual Timing | **Hari *Moyang* Solstice Ritual:** Solstice-timed ritual observance marks ancestral remembrance and ceremonial order. | Mah/Tem /Jak/Sel |
| | | **Hari *Genggulang* Solstice Ritual:** Community ceremony follows solstice-based timing to regulate sacred temporality. | Sem/Ter/ Jat/Che |

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**Table 12:** Theme 4 – Therapeutics, Healing and Foodways Knowledge

| Facets | Codes | Examples of Manifestation | Groups |
|---|---|---|---|
| **Materia Medica and Therapeutics Resources** | Plant-Part Therapeutics | **Multi-Part Plant:** Knowledge of different plant parts and their specific therapeutic use for particular ailments. | ALL |
| | | **Plant-Part Use:** Roots, bark, leaves, fruits, seeds, resin, and latex are prepared separately for specific illness treatments. | ALL |
| | Plant Resource Therapeutics | **Localized Bamboo:** Ethnobotanical and community-specific bamboo knowledge for restorative and health-related uses. | Sem/Ter/ Jat/Che |
| | | **Whole-Plant Use:** Entire plants gathered and used as integrated healing substances for stamina, strength, and wellbeing. | Bat/Jai/ Men/Ken |
| | Signature-Based Therapeutics | **Plant Signatures:** Morphological mimicry (shape and colour) dictate that leaves and roots regulate bodily heat and balance. | ALL |
| | | **Animal Signatures:** Vitality mimicry (behaviour) dictate that bones and bezoars restore strength and specialized immunity. | Sem/Tem /Jak/Bat |
| **Therapeutic Regulation and Specialized Care** | Bodily Balance Theory | **Theory of Hot vs. Cold:** Health depends on balancing bodily hot and cold states through botanical and dietary treatment. | ALL |
| | | **Theory of *Bayik*:** Pain is 'trapped wind' or 'stagnant breath', needing massage (*urut)* and wind-expelling botanicals. | Sem/Ter/ Tem/Jak |
| | Body-Specific Herbal Care | **Gender-Specific Herbs:** Herbal resources and treatments are prepared according to gendered bodily needs and social roles. | Sem/Tem /Jak/Mah |
| | | **Age-Specific Herbs:** Gentle herbal treatments are prepared according to childhood illnesses and age-specific bodily needs. | ALL |
| | Reproductive Safeguarding | ***Pantang*:** Postnatal restrictions protect 'porous' (vulnerable) mothers from forest spirits, omens, and harmful exposure. | ALL |
| | | ***Mai-Ten-Yul*:** A state of spiritual entanglement where the unborn child (*Yul*) follows (*Ten*) the parents' (*Mai*) movement. | Ter/Sem/ Che/Jat |
| **Ritual Healing and Spiritual Mediation** | Sacred Healing Knowledge | ***Jampi*:** Hereditary verbal healing knowledge uses sacred recitations to invoke protective and restorative power. | ALL |
| | | **Spiritual Diagnosis:** Illness is understood as disorder caused by spirit entities, taboos, or soul displacement. | ALL |
| | Ritual Healing Intervention | **Ritual Offering:** Offerings are presented to spirits to seek protection, restore harmony, and support spiritual intervention. | ALL |
| | | **Ritual Scent:** Aromatic botanicals purify ritual space, strengthen sacred efficacy, and support healing processes. | Sem/Ter/ Tem/Sel |
| | Performative Spirit Mediation | **Healing Chant and Percussion:** Vocal and spiritually rhythmic performances invoke healing and spiritual assistance. | Ter/Sem/ Bat/Jai |
| | | **Ancestor Veneration Ritual:** Healing continuity is believed to be sustained through ceremonial relations with ancestors. | Mah/Tem /Jak/Sel |
| **Foodways and Household Provisioning** | Dietary Therapeutics | **Nutraceutical Selection:** Species-selected wild-harvested foods are as blood cleansers or digestive aids in daily diet. | ALL |
| | | **Bitter-Tonic Blood Cleansing:** Foraged bitter plants are added to household meals as daily systemic tonics to purify blood. | ALL |
| | Preventive Consumption | **Seasonal Prevention:** Specific roots or tubers that must be consumed during seasonal changes to strengthen immunity. | Bat/Sem/ Ter/Tem |
| | | **Avoidance of *Kempunan*:** Provisioned foods are shared or tasted communally to prevent vulnerability and illness. | ALL |
| | Aromatic Prophylaxis | **Prophylactic Smudging:** *Kemenyan* or aromatic botanicals are burned to repel insects and illness-causing miasmas. | Sem/Ter/ Tem/Jak |
| | | **Aromatic Prophylaxis:** Pungent plants are worn or hung around the house to block sickness-bearing spirits. | ALL |

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The shift from Tables 9–12 to Table 13 is based on the environmental settings through which OA knowledge is practiced and sustained. Table 9 shows ecological knowledge moving through landmarks, Jok routes, forest zones, customary territories, swidden areas, sacred species habitats and harvesting sites. These codes indicate spaces of mobility, governance, renewal and species stewardship. Table 10 adds the riverine dimension, where spawning pools*, lubuk larangan*, watershed divisions, flood routes, portage paths, aqueducts, boats, springs and bathing places become part of hydrological memory and water-based practice. Table 11 introduces celestial and cosmological settings through sky observation, stellar navigation, lunar timing, agricultural calendars, ritual cycles and cosmological order. Table 12 grounds therapeutic and foodway knowledge in medicinal collection areas, healing settings, ritual treatment spaces, household storage, food sharing and preventive consumption.

Table 13 translates these knowledge settings into five layers of cultural spaces: place memory and forest governance, ecological renewal and species stewardship, riverine systems and water heritage, celestial timing and cosmological order, and healing resource and household wellbeing. The ten cultural spaces were therefore drawn from how the manifestation codes relate to land, rivers, species, sky, healing resources and household practice. Table 14 applies these spaces to each code, allowing the framework to support customary landscape mapping, conservation zoning, river corridor protection, sacred water management, medicinal resource safeguarding and culturally sensitive development control.

**Table 13:** Planning-Oriented Cultural Space Framework

| Layers | Code | Cultural Spaces | Definition |
|---|---|---|---|
| Place Memory and Forest Governance | **A** | Landmark-Route Memory Corridor | Corridors linking landmarks, forest paths, mobility routes, and wayfinding memory. |
| | **B** | Customary Forest Territory Area | Forest areas governed by customary access, ancestral claims, and territorial restrictions. |
| Ecological Renewal and Species Stewardship | **C** | Swidden Agroforestry Renewal Landscape | Cultivation landscapes sustaining fallow cycles, crop diversity, harvesting, and regeneration. |
| | **D** | Sentient Species Habitat Area | Habitats sustaining animal indicators, sacred species, taboos, and ethical restraint. |
| Riverine Systems and Water Heritage | **E** | River Corridor and Pool Network | River networks linking tributaries, pools, watersheds, crossings, and mobility routes. |
| | **F** | Sacred Water and Hydraulic Site | Water sites for springs, bathing, aqueducts, weirs, boats, and technologies. |
| Celestial Timing and Cosmological Order | **G** | Celestial Observation Ground | Open grounds for sky observation, weather reading, navigation, and timing. |
| | **H** | Cosmological Ritual Timing Site | Ritual sites structured by cosmological belief, sacred temporality, and ceremonial calendars. |
| Healing Resource and Household Wellbeing | **I** | Medicinal Resource and Healing Area | Resource areas for medicinal collection, preparation, treatment, and ritual healing. |
| | **J** | Foodway Provisioning Household Setting | Household settings supporting food selection, storage, sharing, and preventive protection. |

**Table 14:** Spatial Interpretation of ICH Manifestation Codes

| Themes | Facets | Manifestation Codes | Cultural Spaces (Coded) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G | H | I | J |
| Ecological Landscape Knowledge | Landscape Navigation & Wayfinding | Landmark-Route Navigation | / | | | | | | | | | |
| | | Seasonal Mobility Knowledge | / | | | / | | | | | | |
| | | Spiritual-Moral Wayfinding | / | / | | | | | | | | |
| | Forest Zones & Compartmentalization | Forest Zoning Knowledge | | / | / | | | | | | | |
| | | Customary Land Governance | | / | | | | | | | | |
| | | Sacred Ancestral Zoning | | / | | | | | | / | | |
| | Agroecological Practices & Swidden | Land-Resource Renewal Cycle | | | / | | | | | / | | |
| | | Agroecological Resilience | | | / | | | | | | / | / |
| | | Sustainable Harvesting Ethics | | | / | | | | | | | / |
| | Respect tow. Sentient Beings | Faunal Indicator Knowledge | | | | / | | | | | | |
| | | Sacred Species Protection | | | | / | | | | / | | |
| | | Humane Resource Practice | | | / | / | | | | | | |
| Hydrological and Riverine Knowledge | Riverine Resource Reg. & Conserv. | Aquatic Regeneration | | | | / | / | | | | | |
| | | River Health Regulation | | | | | / | | | | | |
| | | River-Spirit Taboo System | | | | / | / | | | / | | |
| | Socio-Spatial & Navigational Hydrology | Riverine Spatial Indexing | / | / | | | / | | | | | |
| | | Hydrological Mobility | / | | | | / | | | | | |
| | | Spiritual River Relations | | | | | / | | | / | | |
| | Hydraulic Material Technology | Rivercraft Knowledge | | | | | / | / | | | | |
| | | Hydraulic Construction | | | | | / | / | | | | |
| | | Spiritual Tool Ethics | | | | | | / | | / | | |
| | Sacred Water & Preventive Therapeutics | Water Vitality Therapeutics | | | | | | / | | | / | |
| | | Medicinal Bathing | | | | | | / | | | / | |
| | | Water Spirit Protection | | | | | / | / | | / | | |
| Celestial and Cosmological Knowledge | Celestial Env. Observation Systems | Stellar Navigation | / | | | | | | / | | | |
| | | Sky Weather Calendar | | | | | | | / | | | |
| | | Atmospheric Sign Reading | | | | | | | / | / | | |
| | Astronomical-Agricultural Coord. Syst. | Celestial Subsistence Reading | | | / | | | | / | | | |
| | | Celestial Subsistence Calendar | | | / | | | | / | | | / |
| | | Stellar Crop Indicators | | | / | | | | / | | | |
| | Cosmological Ontologies & Spiritual Ord. | Cosmic Duality Order | | | | | | | | / | | |
| | | Cosmological Myths | | | / | | | | | / | | |
| | | Cosmological Ritual Alignment | | | | / | | | / | / | | |
| | Ritual–Temporal Reg. System | Cosmological Timekeeping | | | | | | | / | / | | |
| | | Lunar Ritual Calendar | | | / | | | | / | / | | |
| | | Solstice Ritual Timing | | | | | | | / | / | | |
| Therapeutics, Healing and Foodways Knowledge | Materia Med. & Therapeutics Resources | Plant-Part Therapeutics | | | | | | | | | / | |
| | | Plant Resource Therapeutics | | | | | | | | | / | |
| | | Signature-Based Therapeutics | | | | / | | | | | / | |
| | Therapeutic Regulation & Spec. Care | Bodily Balance Theory | | | | | | | | | / | / |
| | | Body-Specific Herbal Care | | | | | | | | | / | |
| | | Reproductive Safeguarding | | | | | | | | / | / | / |
| | Ritual Healing & Spiritual Mediation | Sacred Healing Knowledge | | | | | | | | / | / | |
| | | Ritual Healing Intervention | | | | | | | | / | / | |
| | | Performative Spirit Mediation | | | | | | | | / | / | |
| | Foodways & Household Provisioning | Dietary Therapeutics | | | | | | | | | / | / |
| | | Preventive Consumption | | | | | | | | | / | / |
| | | Aromatic Prophylaxis | | | | | | | | / | / | / |


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## DISCUSSION

The validation results indicate a sound initial structure, with theme-level I-CVI values of 0.83 and S-CVI values ranging from 0.75 to 0.92. Nevertheless, expert feedback identified areas requiring sharper functional separation, particularly where ecological, cosmological, hydrological and healing knowledge intersected. The revised framework distinguishes four knowledge systems: (i) Ecological Landscape Knowledge, (ii) Hydrological and Riverine Knowledge, (iii) Celestial and Cosmological Knowledge, and (iv) Therapeutics, Healing and Foodways Knowledge. This structure clarifies how OA knowledge and wisdom operate through navigation, forest governance, resource renewal, water management, celestial timing, healing practice and household provisioning.

The results further show that such knowledge and wisdom are inseparable from environmental settings. Landmarks, *Jok* routes, customary territories, swidden areas, species habitats, rivers, pools, springs, observation grounds, medicinal collection areas and household spaces function as places of learning, regulation and practice. Tables 13 and 14 translate these relationships into five heritage-mapping layers and ten cultural spaces.

This spatial reading strengthens the planning relevance of the framework. The framework informs customary landscape mapping, conservation zoning, river-corridor protection, sacred-water management, medicinal-resource safeguarding and development control. Rather than treating ecosystems as neutral backgrounds, the framework recognizes them as active cultural spaces where ecological knowledge, belief, technology and wellbeing are sustained. Application should therefore be community-led and sensitive to customary access, seasonal use and restricted knowledge.

## CONCLUSION

This study is positioned within continuing work to document and structure OA ICH, addressing specifically Domain 45, Knowledge and Practices, concerning nature and the universe. The findings show that knowledge encapsulates what is known, applied, observed, managed, and transmitted as practical expertise. The study proposed an expert-informed framework that divides OA knowledge and wisdom into four themes, sixteen facets, and matching manifestation codes. This structure clarifies OA knowledge across ecology and landscape, hydrology and waterways, celestial and cosmology, and therapeutics and foodways. The key contribution lies in converting these knowledge systems into spatial planning categories. Forest routes, customary lands, river networks, swidden landscapes, and species habitats form a culturally structured environment. Realizing this spatial attribution strengthens heritage inventories and community-based documentation. The framework establishes a conceptual starting point for cultural spaces, rather than a final spatial inventory. Future site-specific mapping should be improved through sustained OA community input and validation.

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# FARMERS' KNOWLEDGE, ATTITUDES AND PRACTICES ON OPEN BURNING REGULATION: A CASE STUDY OF SEKINCHAN, SELANGOR

**Mariani Ariffin[1] and Nur Auni Syafiqah Othman[2]**

[1,2] *Department of Environmental Management,*
*Faculty of Forestry and Environment,*
UNIVERSITI PUTRA MALAYSIA

## Abstract

Despite a regulatory prohibition under the Environmental Quality Act 1974, open burning persists in Malaysia. Enforcement challenges are particularly evident in agricultural areas because seasonal farming cycles often involve farmers burning crop residues to clear land. Certain open burning activities, including smallholder cultivation, are permitted under specified conditions. This study explores farmers' knowledge, attitudes, and practices regarding the regulatory controls and the local community's perception of the issue in Sekinchan, Selangor. Employing a mixed-methods approach, the study combined quantitative surveys involving 144 respondents with qualitative interviews and field observations. The data were subsequently triangulated to enhance validity. The findings indicate that farmers have a high level of knowledge of the legal prohibition. They are also willing to participate in government awareness initiatives. However, interview and observational findings suggest that actual compliance with procedural and environmental requirements remains inconsistent. Economic considerations, time constraints, limited access to practical alternatives, and entrenched cultural norms continue to influence farmers' behaviour. The findings indicate gaps between regulatory awareness and implementation. Therefore, integrated enforcement strategies and feasible agricultural alternatives are required to support sustainable environmental governance, agricultural land management, and context-sensitive environmental planning in Selangor.

***Keywords***: Open burning, Environmental regulation, Paddy farming, Knowledge–Attitude–Practice (KAP), Sustainable agriculture

[1] Corresponding author. Email: marianiho@upm.edu.my

## INTRODUCTION

Any fire, combustion, or smouldering that occurs in the open air without being directed there through a chimney or stack is considered open burning. It has widespread impacts on human health and air quality (Taweesan et al., 2025), which may extend to neighbouring countries, as reflected in the near-annual transboundary haze in Southeast Asia. To tackle this burning issue and in line with regional commitments, Malaysia incorporated Section 29A into the Environmental Quality Act 1974 (EQA). The provision establishes a general prohibition against open burning on any premises or land. This reflects Malaysia's firm regulatory stance on controlling open burning. The issue is so serious in the country that the legislature amended the EQA in 2024 to impose more stringent penalties. Currently, any person found guilty of contravening the open burning prohibition is liable to a minimum fine of MYR25,000 and a maximum of MYR1 million. The person may also be imprisoned for a term not exceeding five years.

Recognising the operational needs of certain sectors, the Malaysian authority designated several activities as not prohibited open-burning activities (the declared activities), subject to specified conditions. The declared activities include animal and plant disease control, authority fire training, religious rites, and certain agricultural activities. This regulatory structure serves as a balancing mechanism within the legal framework, reconciling environmental protection objectives with socio-economic and cultural considerations. However, the existence of such permitted open burnings also poses practical and interpretive challenges for enforcement, especially in agricultural contexts.

The study aims to examine farmers' knowledge, attitudes and practices (KAP) regarding open-burning regulation. It also analyses community perceptions of farmers' KAP and identifies socio-economic and institutional factors that affect compliance. By linking behavioural insights with regulatory frameworks, the study contributes to a more nuanced understanding of environmental governance in agricultural settings. It would inform more effective and locally responsive management strategies.

## LITERATURE REVIEW

### Permitted Controlled Open Burning

The EQA prohibition on open burning supports Malaysia's and ASEAN's reduction in crop-burning policy, which aims to reduce air pollution and mitigate the harmful effects of haze from smallholders (ASEAN, 2024). However, the EQA, through the Environmental Quality (Declared Activities) (Open Burning) Order 2003, allows certain declared activities. They are legally exempt from the open burning prohibition, provided they comply with strict procedural conditions. One such declared activity is the burning of paddy stalks before replanting. For

this activity, the regulations require compliance with several conditions (Department of Environment, 2020). First, the paddy stalks must be dried for at least seven days before burning. Second, burning may only be carried out during dry weather between 1:00 p.m. and 5:00 p.m. Third, the burning must be closely monitored and controlled. Fourth, it must not cause a nuisance to nearby residents. Fifth, the resulting smoke must not interfere with traffic, and adequate warning signs must be provided where burning occurs near major roads. Finally, prior notification must be given to the nearest police station. These requirements seek to balance traditional agricultural practices with environmental protection and public safety. Effective regulation of controlled open burning, including declared activities, and ensuring compliance with these conditions are essential for sustainable land management, particularly in environmentally sensitive areas such as peatlands (Sawal & Tsai, 2016).

**Perceptions on Open Burning Prohibition**

Perceptions of the open burning prohibition vary across stakeholder groups. Urban residents and haze-prone communities generally view it as necessary for public health, but farmers may see the prohibition as disruptive to traditional practices or livelihoods (Costanza & Moody, 2011). Farmers often prefer open burning because of its cost and time efficiency, especially when alternatives are unaffordable or unavailable (MARDI, 2019). Socioeconomic factors, including income, education, and land tenure, further influence stakeholders' views on open burning and their willingness to comply with regulatory controls (Aminrad et al., 2013). To transition farmers away from open burning, ASEAN (2024) states that awareness and incentive programmes should be provided, along with encouragement to adopt alternative disposal methods such as composting, mulching, and mechanised clearing.

**Knowledge, Attitudes, and Practices (KAP)**

The KAP framework provides a lens for understanding the relationship among knowledge, attitudes, and behaviour in environmental compliance. Studies on sustainable agriculture indicate that farmers' KAP are shaped by socio-environmental conditions, agricultural experience, and policy interventions. For instance, Liao et al. (2022) found that farmers' perceptions of environmental degradation and agricultural policies significantly influence their attitudes and adoption of sustainable farming practices. In contrast, studies in Malaysia indicate a persistent knowledge-practice gap, in which individuals understand regulations but continue environmentally harmful practices due to convenience, cultural norms, or cost (Ariffin, M., & Wan Yacoob, 2017). In agriculture, farmers may, in principle, comply with prescribed activity requirements but often prioritise efficiency and tradition over environmental or legal considerations


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(Costanza & Moody, 2011). Attitudes shaped by trust in government, perceived fairness of enforcement, and social norms strongly influence whether knowledge translates into compliance (Aminrad et al., 2013). Misunderstanding or inconsistent application of exemptions can lead to confusion and selective compliance. The KAP framework thus helps identify gaps among awareness, attitudes, and behaviour (Ariffin & Wan Yacoob, 2017). This would inform the government about targeted interventions such as awareness programs, subsidies for alternatives, and participatory enforcement.

**Literature Gaps**

Research on stakeholder perceptions and experiences, particularly among farmers, villagers, and local authorities, remains limited (Mustafa et al., 2017). In addition, the legal exemptions applicable to declared activities are poorly understood, leading to confusion and inconsistent compliance. Few studies have employed qualitative or mixed-method approaches to capture the socio-cultural, economic, and institutional factors influencing compliance. This leaves the underlying motivations and constraints largely unexplored. Furthermore, aspects such as infrastructure limitations, community awareness, and enforcement capacity that affect open-burning practices have not been studied comprehensively. Moreover, few studies integrate legal regulatory frameworks with behavioural analyses of farmers' knowledge, attitudes, and practices (Ariffin & Wan Yacoob, 2017), which leaves important gaps in understanding how policy measures translate into on-the-ground compliance in agricultural communities. Addressing these gaps is crucial to inform more effective environmental governance and policy implementation.

**Detection and Impacts of Unlawful Open Burning**

Due to its dispersed and sometimes concealed nature, unlawful open burning is difficult to monitor. The authority detection methods include public complaints, ground inspections, satellite imagery, and spikes in PM2.5 or air pollution index readings (DOE, 2020). Open burning releases PM, CO, NOx, and $SO_2$, which may lead to respiratory illnesses, eye irritation, and stress, particularly among vulnerable populations such as children and senior citizens (Zikri Zahari et al., 2016; Costanza & Moody, 2011). Open burning also contributes significantly to particulate air pollution, particularly PM10, which is commonly associated with regional haze episodes in Malaysia. Studies have shown that although land-use changes may influence local air quality, extensive agricultural open burning remains a major contributor to elevated particulate concentrations during haze events (Zikri Zahari et al., 2016). Other than that, farmers benefit economically from burning, but they also face legal risks and long-term soil degradation.

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Meanwhile, enforcement agencies face challenges due to limited resources, personnel, and surveillance capacity.

## RESEARCH METHODOLOGY

Earlier studies on open burning, waste management, and environmental behaviour in Malaysia have largely relied on either quantitative or qualitative approaches with limited methodological integration (Ariffin & Wan Yacoob, 2017; Badrum & Mapa, 2021). Such approaches constrain a comprehensive understanding of stakeholder perceptions and the structural factors underpinning persistent non-compliance. It is essential to bridge this gap in designing context-sensitive enforcement mechanisms and adaptive environmental policies.

The current study, therefore, employs a mixed-methods design that integrates quantitative surveys with qualitative interviews and field observations to capture both measurable patterns and contextual explanations. The quantitative survey collects data on farmers' KAP regarding the open-burning regulatory controls. Meanwhile, interviews with local community representatives offer contextual insights and deeper explanations of farmers' observed behaviours and the challenges they face. Structured field observations were conducted to document open-burning activities, complementing survey and interview data. The use of multiple data sources enabled methodological triangulation, allowing findings from different methods to complement and validate one another (Denzin, 1978). This enhances the reliability and depth of the analysis (Creswell & Plano Clark, 2011).

Sekinchan, Selangor was selected as a study area for its significant agricultural activity, particularly paddy cultivation. As one of Malaysia's major rice-producing areas, Sekinchan experiences seasonal agricultural cycles that often involve burning crop residues for land clearing and pest control, making it highly relevant for the study. In addition, Sekinchan presents an important regulatory and planning context. The coexistence of intensive farming activities with residential settlements creates enforcement complexities.

### Quantitative Research

For quantitative research, a structured, closed-ended Likert-scale questionnaire was used to collect standardised data on farmers' KAP levels. The questionnaire was divided into several sections with items developed based on prior studies and regulations on open burning. The research instrument was validated through expert review using the Content Validity Index (CVI) to assess the relevance, clarity, and suitability of the questionnaire items. This was followed by a pilot study involving 20 farmers to evaluate the instrument's clarity and internal consistency. Reliability was assessed using Cronbach's alpha. The questionnaire comprised 19 items across three constructs, namely Knowledge ($\alpha = 0.620$),


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Attitude ($\alpha = 0.613$), and Practice ($\alpha = 0.679$), with an overall reliability coefficient of 0.679. Given the exploratory nature of the study and the small pilot sample, these values were considered acceptable for establishing the instrument's internal consistency (Hair et al., 2019). The questionnaire was subsequently retained for the main survey.

Based on the Krejcie and Morgan (1970) table, a sample of 144 respondents was drawn from a population of 2,886 farmers in the study area. Village heads and the Penghulu assisted in identifying farmers actively engaged in paddy cultivation. Questionnaires were then distributed purposively among eligible farmers until the target sample size of 144 respondents was achieved. Data were analysed using SPSS, employing descriptive statistics, namely frequencies, percentages, means, and standard deviations, to summarise farmers' KAP regarding open-burning regulations. Since the study aimed to identify general trends rather than test hypotheses, descriptive analysis was used to capture key patterns relevant to policy and intervention planning. Although Likert-scale responses are ordinal, the mean and standard deviation were used to summarise overall response trends and facilitate interpretation across multiple items, consistent with approaches adopted in previous KAP studies (Liao et al., 2022). Given the exploratory nature of the study, using mean scores was considered appropriate for identifying general response patterns among respondents.

**Qualitative Research**

The qualitative component involved semi-structured interviews with local community members residing in the study area. Participants were selected through purposive sampling, with random selection applied among adult residents to obtain diverse perspectives. Despite efforts to obtain additional participants, only four residents consented to the interviews. They comprised an equal number of males and females from different professional backgrounds. The participants were selected as community representatives residing near agricultural areas and were considered capable of providing contextual insights into local open-burning practices and their impacts.

The interviews were intended to complement, rather than generalise, the quantitative findings. As the qualitative component was designed to provide contextual explanations rather than achieve data saturation, a small number of strategically selected community representatives was considered sufficient for methodological triangulation. An interview guide comprising open-ended questions was developed to explore participants' perceptions of farmers' knowledge, attitudes, and practices regarding open burning. Interviews were transcribed verbatim and analysed using thematic analysis.

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Additionally, structured non-participant observation was conducted to complement the survey and interview data. Observations were scheduled during and immediately after the paddy harvesting season, when crop-residue burning is most likely to occur under local agricultural practices. This timing enabled the study to capture open-burning activities during the period when occurrence is expected to be highest. To ensure consistency and intra-observer reliability, a standardised checklist was used to systematically record instances of open burning and assess whether site conditions complied with the requirements for declared activities. Data obtained from the observation checklist were analysed using descriptive and frequency-based approaches. Observations were conducted on five occasions using the same standardised checklist to maintain consistency across sessions. Environmental features, such as the distance between paddy fields and adjacent roadways or residential areas, were summarised descriptively to provide contextual understanding of the study area.

**Limitations**

The current study has several limitations. It included only four resident interviews and five observation sessions, which may not capture all perspectives or seasonal variations. Furthermore, survey responses were self-reported and may therefore be subject to social desirability bias, whereby respondents overstate compliance with environmental regulations. To minimise this limitation, survey findings were triangulated with interviews and field observations. Future studies may employ inferential statistical analyses to examine the influence of demographic characteristics on compliance behaviour across different farming communities. Despite these limitations, the current study combined quantitative and qualitative data through methodological triangulation, thereby enhancing the credibility and validity of the findings by cross-checking evidence across multiple methods. This reduced bias and increased confidence in the study's conclusions (Creswell & Plano Clark, 2011).

## ANALYSIS AND DISCUSSION

This section presents the study's findings and interprets them in relation to the research objectives. The results are structured to first describe farmers' quantitative survey data on their KAP. It is followed by insights from qualitative interviews with residents that provide a contextual understanding of community perceptions and concerns. Field observational data are then presented to validate and complement the survey and interview findings. Finally, the section integrates the three data sources through triangulation to highlight any consistent patterns or divergences.


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## Farmers' Level of Knowledge, Attitudes and Practices (KAP)

The socio-demographic profile of the respondents shows that the majority were male (93.1%), while female respondents accounted for only 6.9%. Most respondents had SPM as their highest educational qualification (75.4%). About 9.8% held STPM, or a diploma, and only 0.9% held a degree. A small proportion (13.9%) stated other forms of education. As for age, the largest groups were 56 years and above (29.9%) and 46-55 years (28.5%). This is followed by those aged 36-45 (20.8%), 26-35 (13.9%), and 18-25 (6.9%). Regarding personal income, 45.8% earned no more than RM3,000 per month, 16.7% earned between RM3,001 and RM6,000, 2.8% earned between RM6,001 and RM10,000, and the rest reported no personal income.

**Table 1:** Farmers' KAP Overall Scores

| Domain | Mean | Standard Deviation |
|---|---|---|
| **Knowledge** | 4.03 | 0.78 |
| **Attitudes** | 4.20 | 0.69 |
| **Practices** | 4.11 | 0.73 |

The study's findings reveal that respondents demonstrated a strong overall knowledge of open burning (M = 4.03, SD = 0.73) with consistently high mean scores across all measured items. They showed a clear understanding of the definition of open burning (M = 4.16, SD = 0.76) and were aware of its environmental impact, particularly its contribution to local and regional haze (M = 3.91, SD = 0.90). The respondents were generally knowledgeable about the need to inform the authority before burning (M = 3.92, SD = 0.85). However, the relatively higher SD indicates variability in farmers' understanding of the matter. Besides that, knowledge of the permissible conditions for burning was higher and more consistent (M = 4.13, SD = 0.73). While general safety concepts were well understood, familiarity with specific procedural requirements, such as creating firebreaks, showed slightly greater variability (M = 3.92, SD = 0.79). The relatively uniform knowledge levels among respondents likely reflect their similar educational backgrounds. The results highlight that although respondents are generally well-informed, ongoing education is needed to address gaps in technical and procedural knowledge and ensure comprehensive awareness.

Regarding attitudes, the respondents generally hold positive attitudes toward open-burning regulations and responsible behaviour, with a high overall mean score (M = 4.20, SD = 0.69). This indicates strong support for management,

monitoring, and public awareness efforts. There was a broad consensus on the importance of regulation and education about the harmful effects of open burning (M = 4.28, SD = 0.65), but willingness to participate in workshops showed some variability (M = 4.13, SD = 0.879). In addition, attitudes toward procedural compliance, such as notifying authorities (M = 4.09, SD = 0.72) and following regulatory control (M = 4.24, SD = 0.62), were also favourable. The relatively uniform positive responses likely reflect the sample's demographic similarities. The overall findings indicate strong support for responsible practices and legal enforcement.

Other than that, the study found that respondents reported relatively positive self-perceptions of their practices (M = 4.11, SD = 0.73). The relatively high self-reported practice scores suggest that respondents generally perceived themselves as complying with safe burning practices. However, triangulation with interview and observational findings revealed inconsistencies between reported practices and on-site compliance with procedural and environmental requirements. Most respondents reported that they generally followed safety measures, such as avoiding burning during poor air quality or unfavourable weather (M = 4.29, SD = 0.57). Many respondents also expressed support for non-burning alternatives when feasible (M = 4.08, SD = 0.61). However, some variability exists in practices such as avoiding burning near residential areas (M = 4.06, SD = 0.804) and adopting alternative waste management methods (M = 4.11, SD = 0.73). While efficiency concerns sometimes lead to less desirable behaviours, the study found that overall self-reported compliance with safe burning techniques appeared relatively positive. The findings suggest relatively positive self-perceptions of compliance among respondents, although qualitative and observational findings indicate that on-site compliance remains partial.

**Local Community's Perception of Farmers' KAP**

Interview findings indicate that the community generally perceived farmers as having a good understanding of the requirements and risks associated with open burning. Most interviewees reported that farmers are aware of key practical conditions before burning, such as maintaining a safe distance from residential areas and considering weather conditions, including wind direction and speed. This suggests that farmers' understanding is primarily focused on immediate safety and harm prevention.

Farmers were also perceived to be aware of the environmental and health impacts of open burning, particularly respiratory effects on nearby residents. Despite this awareness, interviewees reported that open burning continues due to economic considerations and the long-standing use of burning as a traditional waste management practice. These findings suggest that


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awareness alone does not necessarily translate into full procedural compliance with open-burning controls.

Interviewees further indicated that farmers' willingness to reduce open burning is constrained by practical and financial considerations. Although alternatives such as reusing or selling paddy straw are recognised, they are generally viewed as costly, labour-intensive, and impractical, making open burning the most efficient and affordable option. Attitudes towards the ban are therefore mixed. Support depends largely on clear guidelines and government assistance, particularly for small-scale farmers, while opposition is driven by economic constraints and established farming practices. Farmers were also reported to prefer education-based and targeted enforcement over punitive measures.

Finally, interviewees highlighted that open burning is a seasonal practice occurring mainly after the harvesting period. Although farmers generally consider weather conditions to minimise the spread of fire and smoke, adherence to prescribed timing requirements remains inconsistent and depends on harvesting schedules and straw conditions. Safety measures were also reported to be largely informal and based on experience.

**Field Observation**

Field observations indicate that open burning is neither frequent nor continuous within the study area. Across five site visits, only one instance of active burning was observed. However, the presence of ash residues and burn scars in several spots suggests that open burning still occurs periodically. The limited number of observed incidents may have been influenced by factors such as weather conditions, enforcement activities, or farmers' awareness of environmental regulations. During the observed incident, paddy straw was burned in an open field after harvesting. The proximity of the burning site to nearby roads and residential areas raised concerns regarding compliance with recommended buffer distances, as smoke exposure may affect both road users and residents. It potentially poses risks to traffic safety and respiratory health. Observations also indicated that environmental conditions, such as wind direction, may not have been fully considered prior to burning. Furthermore, limited fire safety precautions and the absence of warning signs suggested inconsistencies between on-site practices and regulatory requirements. The findings suggest that open burning in Sekinchan occurs only occasionally. Compliance with safety measures, smoke management, and buffer distance requirements remains partial.

**Triangulation of Findings and Discussion**

The study's findings from surveys, interviews, and structured observations collectively indicate that open burning in Sekinchan is an occasional but

intentional activity. It is shaped by both regulatory awareness and socio-cultural practices. Survey results show that farmers have a high level of knowledge of the prohibition on open burning under the EQA and the permitted exemptions for small-scale agricultural burning. They express positive attitudes towards regulatory compliance in principle when supported by government awareness programs. However, self-reported practices were generally positive, although interview and observational findings suggest that on-site compliance with procedural requirements and environmental safeguards remains inconsistent. Economic considerations, time constraints, and cultural norms were identified as major barriers. Interviews with residents corroborate these findings, highlighting that while farmers generally understand the legal framework, enforcement challenges and the perceived convenience of burning contribute to the continued practice of open burning.

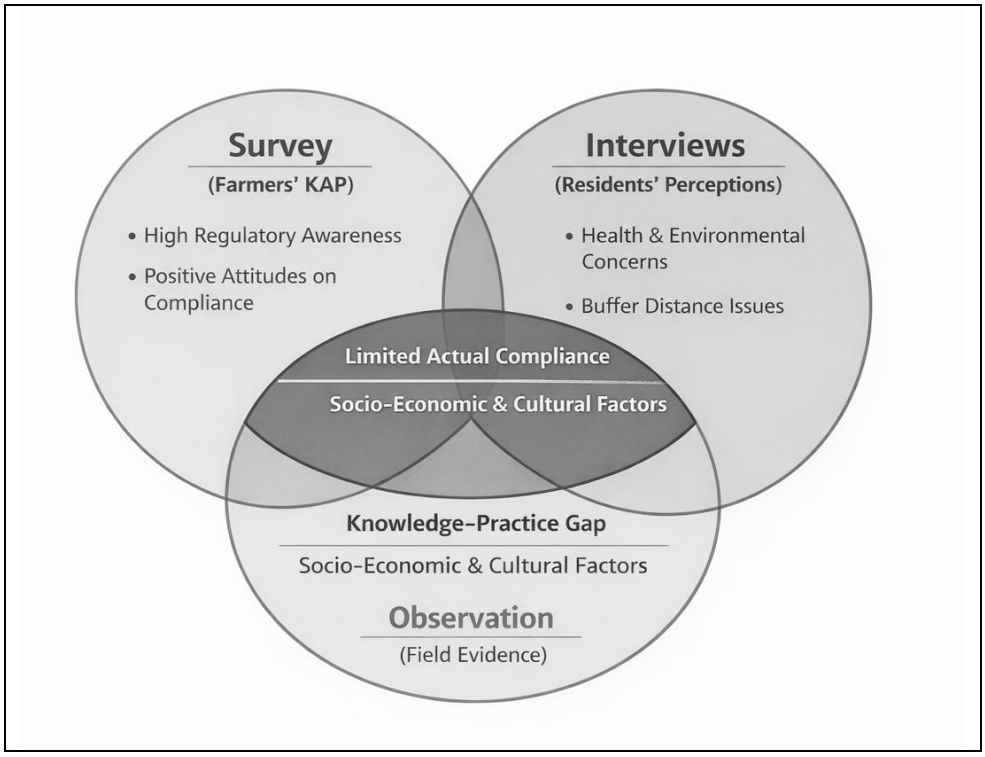



**Figure 1**: Triangulation of Findings on Open Burning in Sekinchan, Selangor

Interviewees also emphasised health and environmental concerns, particularly regarding exposure to smoke and proximity to residential areas. The proximity of burning activities to residential areas also increases the risk of fire


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spread. Structured observations complement these perspectives. The observations revealed that open burning is infrequent but strategically timed, often after harvest periods. Some disregard for recommended buffer distances, wind conditions, and fire safety measures was also noticed. Together, the three methods indicate a gap between regulatory awareness and consistent procedural compliance. While regulatory awareness is relatively high, adherence to procedural, safety, and environmental precautions is inconsistent. This reflects the complex interplay of socio-economic, cultural, and environmental factors influencing open-burning practices.

The findings show that farmers continue open burning not because they lack knowledge but due to structural and financial limitations. Respondents demonstrated good knowledge and positive attitudes towards environmental protection, consistent with Ariffin and Wan Yacoob (2017). However, this awareness does not always translate into compliance. The gap between regulatory awareness and actual compliance suggests that knowledge alone is insufficient to change behaviour when practical constraints and external influences remain significant. Similarly, Akahoshi et al. (2024) found that institutional and social barriers hinder the implementation of crop-residue burning control policies, indicating that regulatory measures alone are insufficient to reduce open burning practices.

Economic barriers were identified as the primary factor sustaining open burning. Although respondents expressed a willingness to adopt alternatives, such as straw commercialisation and decomposing agents, these options were perceived as costly and labour-intensive. This finding is consistent with Rosmiza et al. (2019), who reported that open burning remains the cheapest and fastest method of land preparation for paddy farmers in Malaysia. Likewise, Mustafa et al. (2017) argued that a complete ban is impractical without institutional and financial support. The present findings further show that logistical constraints, limited access to straw markets, and the economic vulnerability of small-scale paddy farmers continue to impede the adoption of alternative residue-management practices (Asli & Rahman, 2023).

Apart from that, the knowledge-practice gap identified in this study appears to be influenced by local cultural factors. Such factors include the normalisation of open burning within the farming community, long-standing agricultural traditions, and peer influence among farmers. They contribute to the farmer's persistence in burning practices despite awareness of regulatory restrictions and environmental impacts. MARDI (2019) reported similar observations on paddy residue waste management in Selangor. The findings of this study also align with earlier research by Na Talang et al. (2024) and Erbaugh et al. (2024). Both studies showed that cultural traditions and long-established

farming practices continue to influence farmers' decisions to engage in open burning despite awareness of its environmental impacts.

In terms of regulatory strategies, the findings corroborate Mustafa et al. (2017) assessment of the EQA which imposes significant penalties but faces practical enforcement challenges. As indicated by survey results and interview input, there is a greater community preference for educational programs and awareness-based initiatives over punitive actions. Additionally, the study confirms earlier findings that open burning in Malaysia is perpetuated by economic realities rather than ignorance (Ariffin & Wan Yacoob, 2017; Rosmiza et al., 2019; Mustafa et al, 2017). Integrated solutions that incorporate financial incentives, accessible alternatives, and context-sensitive enforcement are needed to close the gap between farmers' knowledge and practice. A strict ban is unlikely to result in long-term compliance without support systems.

From a planning perspective, the findings support the designation of appropriate agricultural buffer zones between paddy fields and residential areas, the establishment of community-based monitoring mechanisms, and the provision of centralised paddy-residue collection or processing facilities. Integrating these measures into local land-use planning would reduce conflicts between agricultural production and environmental protection.

## CONCLUSION

This study highlights the complex dynamics of open burning in Sekinchan, Selangor. It demonstrates that farmers generally have a high level of knowledge of the legal prohibition under the EQA and the provisions governing permitted controlled burning for small-scale agriculture. Nevertheless, compliance with procedural and environmental requirements remains inconsistent. Triangulation of survey, interview, and observational data revealed a persistent gap between regulatory awareness and on-site compliance, influenced by socio-economic constraints, cultural norms, and environmental factors such as the proximity of paddy fields to residential areas. Field observations further showed that open burning occurs infrequently but deliberately after the harvesting season to clear agricultural residues, with only partial adherence to safety procedures and smoke management requirements. Residents' perceptions also highlighted concerns regarding health impacts and enforcement challenges.

The findings highlight the need for more integrated and context-sensitive environmental governance strategies to address open burning. These include targeted awareness programmes, practical alternatives to burning, and improved enforcement measures that take local socio-cultural realities into account. Addressing these factors is essential to bridge the gap between regulatory knowledge and actual compliance, thereby supporting sustainable


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crop-residue management and environmental protection in Malaysia's rice-growing regions.

From a planning perspective, the findings support policy measures such as subsidies for straw-management technologies, cooperative straw markets, farmer training programmes, and strengthened monitoring during the harvesting season. They also highlight the importance of integrating agricultural buffer zones, community-based monitoring mechanisms, and paddy-residue collection or processing facilities into local land-use planning and environmental governance frameworks. Such integrated measures would help reduce conflicts between agricultural production and environmental protection while promoting long-term compliance with open-burning regulations.

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# SOCIAL ENTREPRENEURSHIP AS A CATALYST FOR LOCAL ECONOMIC RESILIENCE: A PESTELE ANALYSIS OF A SCHOOL-BASED FARMING PROJECT

**Radieah Mohd Nor**

*School of Social Sciences,*
UNIVERSITI SAINS MALAYSIA

## Abstract

This study aims to evaluate the socioeconomic viability and planning implications of a social entrepreneurship model through a rabbit farming project at SMITI Sains Bahrul Ulum, Penang, utilizing an analytical PESTELE diagnostic framework. Employing a mixed-methods design, data were extracted from operational financial records, surveys involving 23 students and 14 school staff, and qualitative thematic analysis. The findings prove that the model is financially viable, generating a net profit of RM1,736.30 in its first cycle, which successfully triggered secondary economic spillover effects for the local community. From a social aspect, the acceptance level among educators was highly positive (mean 4.07); however, the students' moderate practical skills (mean 3.64) necessitate the establishment of structured mentor-mentee workshops. Furthermore, spatial and operational analyses revealed that space constraints (40' x 60') and a low breeding rate (50%) restricted maximum profit, thus requiring smart technology interventions. Nevertheless, environmental sustainability was achieved through a circular economy system utilizing livestock waste. By implication, to ensure the replicability of this model, the study urges local authorities to formulate more flexible zoning policies to allow the integration of community economic activities within institutional zones.

***Keywords***: Community economic development, social entrepreneurship, analytical PESTELE analysis, spatial policy planning, socioeconomic sustainability

Corresponding author. Email: radieah@usm.my

## INTRODUCTION

Community-based economic development through social entrepreneurship approaches is increasingly recognized as a catalytic strategy for building socioeconomic resilience and sustainability at the local level (Elsen, 2018). In the Malaysian context, the concept of social entrepreneurship, particularly those mobilized at the educational institution level, is gaining increasing attention from policymakers and academics. Private educational institutions, such as the People's Religious Schools (*Sekolah Agama Rakyat* or SAR), frequently face financial constraints that hinder smooth operations and the development of student facilities. To reduce complete dependence on tuition fees and public contributions, a social entrepreneurship model based on broiler rabbit farming was pioneered at the Sekolah Menengah Integrasi Teras Islam (SMITI) Sains Bahrul Ulum, Penang. This model aims not only to generate self-sustaining school finances but is also integrated with the surrounding residents to create a secondary economic chain (micro-economy) within the local community. This aligns directly with the role of small-scale industries at the community level in building wealth and diversifying the residents' sources of income (Masyhuri, 2024; Subhe, 2023).

However, social entrepreneurship initiatives in areas with educational institution status are rarely analysed from the perspective of planning theory and spatial analysis. Schools planning to implement commercial farming activities within educational institution zones typically face constraints from land use zoning guidelines by local authorities, as well as limited infrastructural space. Meanwhile, environmental instruments such as PESTELE (Political, Economic, Social, Technological, Environmental, Legal, and Ethical) are frequently utilized in decision-making studies and complex project management (Srdjevic, Bajcetic, & Srdjevic, 2012). However, in the context of existing studies, it often serves merely as a listing tool without translating the analysis into strategic findings or policy formulation.

Therefore, this study shifts the focus from descriptive discussions on fund management to a more rigorous empirical and analytical socioeconomic and spatial assessment framework. The main objective of this study is to evaluate the socioeconomic viability of the community economic development project based on social entrepreneurship at SMITI Sains Bahrul Ulum using an analytical PESTELE diagnostic framework.

This study employs methodological rigor by assessing the project's viability using transparent empirical data, specifically through the extraction of actual on-site financial metric records and the findings from the school community's perception survey. Through this data integration approach, this paper aims not only to prove the effectiveness and sustainability of the social entrepreneurship model but also to analyse the spatial challenges and the


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management of agricultural facilities within educational zones. This in-depth analysis is highly critical for proposing a policy replication framework to planners and policymakers to support the relaxation of spatial zoning for suitable community economic generation activities within educational institution areas.

## LITERATURE REVIEW

Community economic development through the lens of social entrepreneurship is now recognized as a critical paradigm shift in the discourse of local socioeconomic sustainability, where it emphasizes collective participation to build an economic system that not only pursues profit but also benefits society as a whole (Acquier et al., 2017; Newman, 1986). Although the practice of delivering social value has long existed, academic and policy discourse regarding this concept particularly involving educational institution-based initiatives in Malaysia is gaining widespread attention for solving community problems innovatively (Daud Fhiri, Abdullah, & Ahmad, 2018; Kadir & Sarif, 2016). Therefore, to position this study within the appropriate academic foundation and to justify the research gap, this literature review section is structured to focus the discussion on four main themes: (i) community economic development and social entrepreneurship, (ii) educational institution-based social entrepreneurship models, (iii) spatial planning and policy ecosystem implications, and (iv) the analytical application of PESTELE analysis.

### Community Economic Development and Social Entrepreneurship

The concept of a community-based economy emphasizes local community participation, sustainability, as well as collective ownership and decision-making in driving economic activities (Newman, 1986). This approach aims to build an economic system that pursues not only physical growth but also social equity and mutual benefit for the broader society (Acquier, Daudigeos, & Pinkse, 2017). In this context, social entrepreneurship has evolved as a primary catalytic mechanism. Unlike traditional businesses that are centered on individual financial profit, social entrepreneurship is propelled by an innovative intent to create social value and address the fundamental problems of society (Dees, 1998; Kadir & Sarif, 2016).

The integration of these two concepts, particularly through small-scale enterprises and community entrepreneurship, has proven capable of enhancing socioeconomic resilience, diversifying income profiles, and generating a multiplier effect within the local community (Subhe, 2023; Yustika, 2019). A sustainable community economy directly stimulates the creation of local value chains, thereby reducing the community's dependence on external markets (Elsen, 2018).

**Educational Institution-Based Social Entrepreneurship Models**

Strong fundamental financial management is a critical element in ensuring the smooth operation of any institution, especially private educational institutions such as the Sekolah Agama Rakyat (SAR or literally translate People's Islamic Religious Schools). Issues of funding shortages and weak financial governance often hinder the delivery of education, infrastructure maintenance, and student welfare in these institutions. Recognizing this fact, the integration of commercial agricultural projects, such as broiler rabbit farming, into the school ecosystem acts as an innovative social entrepreneurship instrument to generate the institution's financial independence (Mohd Nor, 2022).

More significantly, the placement of social entrepreneurship projects in educational centers serves as a two-pronged approach in empowering the human capital of the younger generation. Community involvement in economic activities at the institutional level can instill practical skills, build leadership, foster an entrepreneurial mindset, and ensure they play a role in community wealth creation (Daud Fhiri, Abdullah, & Ahmad, 2018; Economic Planning Unit, 2015).

**Spatial Planning and Policy Ecosystem Implications**

The viability of institution-based community economic models is not only influenced by internal operational capacity but is highly dependent on the external planning ecosystem, particularly the spatial planning support and policies of local authorities. Urban planning literature asserts that land use transitions and zoning guidelines have an absolute influence on the feasibility and cost structure of a local economic project (Long et al., 2021).

Local authorities and local government institutions play a very important role, either as facilitators or barriers to the survival of these grassroots initiatives (Amanah et al., 2021; Liu et al., 2022). Without policy flexibility that allows the adaptation of institutional spaces for economic generation purposes, such as modular agricultural structures, efforts to replicate or expand this social innovation will face legal restrictions (van Doren et al., 2020).

**Analytical Application of PESTELE Analysis**

To evaluate and structure the strategic plan of a community project involving various stakeholders, the PESTELE (Political, Economic, Social, Technological, Environmental, Legal, and Ethical) framework is one of the most comprehensive diagnostic instruments. This analysis is typically used to assess external environmental factors capable of supporting or threatening the growth of an organization (Srdjevic, Bajcetic, & Srdjevic, 2012).

However, a weakness of most previous studies is merely using PESTELE as a listing tool. In this study, a paradigm shift is made by translating


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the PESTELE framework into an analytical instrument. Empirical data are mapped into the PESTELE elements to identify not only the on-the-ground challenges but also to analytically break down this information into strategic planning policy implications to support future stability (Srdjevic, Bajcetic, & Srdjevic, 2012)

## RESEARCH METHODOLOGY

### Research Design

This study applies a mixed-methods case study design. This qualitative and quantitative case study approach is highly suitable for capturing complex social processes, in addition to understanding how socioeconomic empowerment is built within actual field contexts (Creswell, 2014). To structure the evaluation, the PESTELE (Political, Economic, Social, Technological, Environmental, Legal, and Ethical) diagnostic framework was used as the primary analytical basis. The PESTELE model is widely recognized as a comprehensive strategic planning instrument to identify external and internal environmental factors that can support or threaten the resilience and sustainability of a community project (Srdjevic, Bajcetic, & Srdjevic, 2012).

### Sample Selection and Study Location

The study was conducted at Sekolah Menengah Integrasi Teras Islam (SMITI) Sains Bahrul Ulum, located in Mengkuang Titi, Kubang Semang, Penang. A non-probability purposive criterion sampling technique was employed to select a total sample of 37 participants, comprising 14 school staff (teachers and administrators) and 23 students.

- **School Staff Sampling ($n = 14$)**
  Total population/census sampling was applied to all academic teachers and administrative personnel who were directly involved in the project steering committee, daily operational supervision, financial record-keeping, and PdPc co-curricular integration. Staff with no administrative or supervisory roles in the rabbit farming project were excluded.
- **Student Sampling ($n = 23$)**
  Criterion-based purposive sampling was used to select students actively enrolled in the school's social entrepreneurship and agricultural co-curricular module. These students participated directly in the hands-on daily operations, including feeding, cage sanitation, breeding monitoring, and harvesting/slaughtering. Students outside this specialized module were excluded to eliminate response bias from non-participants.

This sampling strategy ensured that all respondents possessed firsthand operational experience and direct engagement required to rigorously assess the socioeconomic and pedagogical dimensions of the initiative (Ahmad & Wilkins, 2025).

**Table 1:** Survey Instrument Constructs, Measurement Scale, and Reliability Analysis

| Target Group | Measured Sub-Constructs | No. of Items | Measurement Scale | Cronbach's Alpha ($\alpha$) |
|---|---|---|---|---|
| **Students** ($n = 23$) | • Basic Knowledge & Awareness<br>• Attitude & Career Interest<br>• Practical & Handling Skills<br>• Entrepreneurial Mindset | 25 | 5-Point Likert Scale<br><br>*(1 = Strongly Disagree to 5 = Strongly Agree)* | 0.789 *(Good)* |
| **Staff & Teachers** ($n = 14$) | • Project Perception & Suitability<br>• Management & Operational Stability<br>• Educational & Pedagogical Impact<br>• Economic & Community Potential | 25 | 5-Point Likert Scale<br><br>*(1 = Strongly Disagree to 5 = Strongly Agree)* | 0.928 *(Excellent)* |

*Source: Authors' Questionnaire Survey Data*

## Data Collection

To ensure a robust data triangulation process, data collection in this study was carried out simultaneously through three (3) main instruments:

### *Document Analysis (Financial Records)*

The assessment of economic viability (the Economic element in PESTELE) was extracted directly from the operational report database and the actual financial cash flow records for the project's first cycle. This involves the documentation of raw material costs, slaughtering operations, and sales revenue metrics.

### *Questionnaire (Quantitative Instrument and Constructs)*

The quantitative survey instrument was structured using a 5-point Likert scale, ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). To ensure measurement validity and internal consistency, two distinct self-administered questionnaires were tailored for students and school staff, measuring specific sub-constructs:


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- **Student Survey Instrument ($\mathbf{n = 23}$, 25 items)**
  Measured four core constructs: (i) Basic Knowledge & Awareness of rabbit farming operations (e.g., nutrition, breeding cycles); (ii) Attitude, Interest & Time Commitment towards agricultural careers; (iii) Practical Handling Skills (e.g., livestock management, sanitation, slaughtering); and (iv) Entrepreneurial Mindset & Economic Value Perception. Internal consistency reliability yielded a high Cronbach's alpha ($\alpha = 0.789$).
- **Staff & Teacher Survey Instrument ($\mathbf{n = 14}$, 25 items)**
  Measured four core constructs: (i) Project Perception & Institutional Suitability (e.g., non-disruption of teaching and learning/PdPc, school image enhancement); (ii) Management & Operational Stability; (iii) Educational & Pedagogical Impact (experiential hands-on learning value); and (iv) Economic & Community Spillover Potential. Internal consistency reliability yielded an excellent Cronbach's alpha ($\alpha = 0.928$).

***Open-Ended Survey (Qualitative)***
To identify operational challenges and sustainability strategies (Technological and Environmental elements), open-ended survey responses were distributed to teachers and administrators to gather critical views regarding space constraints, biosecurity risks, and facility management.

**Data Analysis**
In line with the use of mixed-methods, data analysis was conducted through two dimensions, namely qualitative and quantitative analysis.

***Quantitative Analysis***
Data from the questionnaires were analysed using statistical software to produce a descriptive analysis, specifically determining the average metrics or Mean Scores. These mean scores are used to represent the percentage of agreement and the level of mastery of each target group towards the evaluated sub-constructs.

***Qualitative Analysis (Thematic Analysis)***
Data in the form of text responses from open-ended questions were analysed using a thematic analysis approach to break down the raw data into meaningful patterns, issues, and recommendations. This thematic coding process was adapted in line with the interactive qualitative data analysis model framework (Miles, Huberman, & Saldaña, 2014). Through this method, five (5) core themes were extracted, which include the effectiveness of experiential learning, the strength of project management and support, operational challenges and resource constraints, recommendations for improvement and innovation, and entrepreneurial and economic potential. These five themes serve as data

triangulation as they support the numerical data (quantitative) with text responses (qualitative themes) to strengthen the arguments.

In the final phase, all numerical data (cash flow profits and mean scores) as well as these qualitative themes were integratively mapped into the PESTELE diagnostic framework. This analytical mapping enables the study to shift its focus from merely reporting financial figures to generating a critical discourse on the Spatial Planning Policy required by local authorities to support such social entrepreneurship

## ANALYSIS

### Economic (E) and Social (S) Dimensions: Value Creation and Human Capital Empowerment

From the perspective of economic viability (E), financial records prove that this social entrepreneurship model generated a net profit of RM1,736.30 in its first cycle. This economic feasibility is also strongly supported by the qualitative analysis results through Theme 5 (Entrepreneurial and Economic Potential), where teachers view the project as having significant potential to generate school income through a variety of downstream products. This perspective is evidenced by a respondent's quote stating, *"Rabbits can be sold and by-products such as fertilizer can be used or sold, serving as an entrepreneurial (opportunity) for the students"*.

However, this economic success must be evaluated alongside social acceptance (S). Qualitative analysis through Theme 1 (Effectiveness of Experiential Learning) indicates that educators are highly positive regarding the pedagogical impact of this project. The majority of respondents emphasized that it fulfills the requirements of authentic learning, as voiced by a respondent: *"It provides an opportunity for students to experience the reality of managing the livestock farming world"*. Nevertheless, an analytical paradox exists when these data are triangulated with student responses. Although teachers perceive it as effective (Theme 1), quantitative data reveals that students' practical skills are only at a moderate level (mean 3.64). This situation is supported by the findings of Theme 3 (Operational Challenges and Resource Constraints), where teachers themselves acknowledge the existence of challenges regarding student commitment, stating, "*There are indeed students who have no interest in venturing into this field"*. This proves that the mere provision of physical infrastructure is insufficient without being supported by continuous skills guidance modules.


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**Table 2:** Financial Breakdown and Profitability Metrics for the First Production Cycle

| Category | Item Description | Quantity / Volume | Unit Price (RM) | Total Amount (RM) |
|---|---|---|---|---|
| Gross Revenue (A) | Live Breeding Rabbits (*Arnab Hidup*) | 5 heads | RM 150.00 / head | RM 750.00 |
| | Fresh Rabbit Meat (*Daging Arnab*) | 63.96 kg | RM 30.00 / kg | RM 1,918.80 |
| Total Gross Revenue | | | | **RM 2,668.80** |
| Operational Costs / OPEX (B) | Pellet Feed (Type 702P) | 10 bags | RM 49.50 / bag | RM 495.00 |
| | Pellet Feed (Type PHL128) | 10 bags | RM 43.75 / bag | RM 437.50 |
| Total Operational Cost | | | | **RM 932.50** |
| Net Operational Profit (A - B) | First Harvest Cycle (3–4 Months) | | | RM 1,736.30 |
| Financial Viability Indicators | Operating Profit Margin | $\frac{\text{Net Profit}}{\text{Total Revenue}} \times 100\%$ | | **65.06%** |

*Source: Authors' Field Operational Financial Records*

To rigorously validate the economic sustainability of the model, Table 2 itemizes the exact operational cash flow recorded during the project's initial harvest cycle (spanning 3 to 4 months). Capital expenditure (CAPEX) for primary infrastructure—including the $40' \times 85'$ shelter facility, 240 modular cages, and initial breeding stock (60 females, 10 males)—was capitalized via the social innovation research grant.

On an operational level, the project generated a gross revenue of RM 2,668.80, derived from the direct sale of 5 live breeding rabbits (RM 750.00) and 63.96 kg of processed carcass meat (RM 1,918.80). Total variable operating expenses (OPEX) were strictly confined to feed supplies (20 bags of specialized pellets costing RM 932.50). This yielded a net operational profit of RM 1,736.30 per production cycle, translating to an operational profit margin of 65.06%. Because labor was integrated into student experiential learning and staff co-curricular oversight, fixed overhead expenses remained negligible, confirming that the operational model is financially self-sustaining for subsequent cycles.

**Technological (T) and Environmental (E) Elements: Operational Challenges and Sustainability Practices**

The achievement of this project's economic goals is also constrained by on-the-ground operational challenges (Technological Element). Based on the findings in Theme 3 (Operational Challenges and Resource Constraints), in addition to the issue of student interest, the primary constraint limiting maximum profit generation is the low breeding productivity rate (around 50%) as well as the risk

of animal diseases. This was emphasized by a respondent: *"The low productivity level of the breeding rabbits prevents the project's profit from being maximized"*.

To resolve these operational gaps within the limited pen facility space (40'x85') for 240 cages accommodating 60 female breeders and 10 male breeders including future offspring, smart technology intervention is the answer. The findings from Theme 4 (Recommendations for Improvement and Innovation) suggest a transition from manual farm management to digitalization. According to the respondents, among the resolutions that require immediate adaptation include, *"The use of modern technology such as digital record systems (and) automated feeding/watering"*.

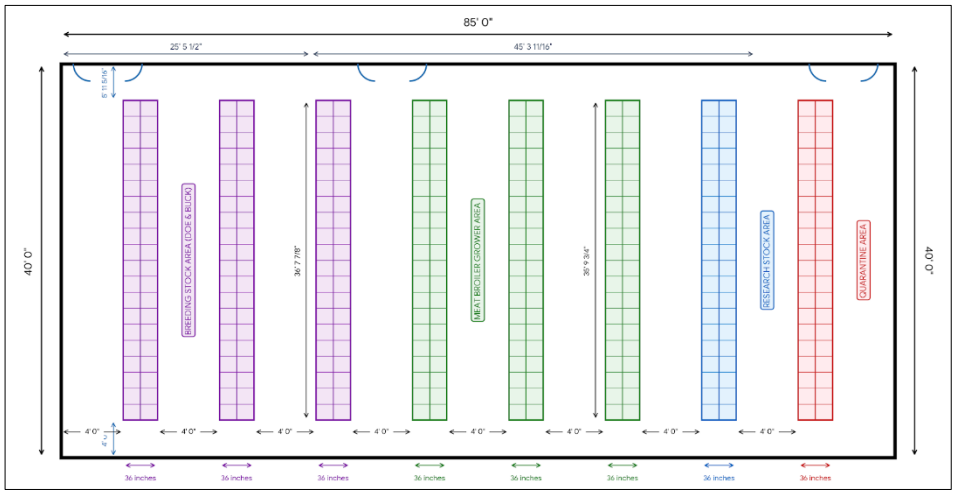



**Figure 1:** Spatial Layout and Functional Zoning Plan of the Rabbit Farming Facility ($40' \times 85'$)
*Source: Authors' Spatial Layout Mapping*

Furthermore, in line with the Environmental (E) dimension, the recommendation in Theme 5 to process rabbit waste as fertilizer also proves that sustainability practices through a circular economy are not only environmentally friendly but are capable of reducing the school's agricultural input purchasing costs. Clear qualitative evidence supporting the circular economy model is directly grounded in open-ended survey feedback from school staff and official grant operational records. Rather than treating livestock waste as an environmental disposal burden, the project implements an on-site waste-to-resource management framework where rabbit manure and urine are systematically repurposed as organic fertilizer for the school's vegetable garden. This closed-loop practice is validated by qualitative feedback under Theme 5 (Entrepreneurial and Economic Potential), where a teacher respondent (R5)


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emphasized that *"Rabbits can be sold, and by-products such as fertilizer can be used [for the school garden] or sold, serving as an entrepreneurial opportunity for students."*

Operationally, solid waste (feces) and liquid waste (urine) collected daily from pen trays are channelled directly into the school's composting area rather than being discharged into municipal public drainage systems. This zero-waste discharge protocol mitigates local environmental health risks, including potential odour nuisances and vector breeding, thereby aligning with the Environmental Quality Act 1974. Furthermore, applying organic compost directly to the school's vegetable plots substitutes commercial synthetic fertilizer inputs, effectively lowering operational expenditures while cultivating student awareness of sustainable agricultural value chains.

**Political (P), Legal (L), and Ethical (E) Elements: Strategic Networks and Spatial Policy Implications**

The resilience of the social entrepreneurship model in this institution is highly dependent on external institutional support elements (Political and Governance Elements). The qualitative analysis forming Theme 2 (Project Management Strength and Support) reveals that this project remains sustainable due to the existence of a strategic network involving Universiti Sains Malaysia (USM) and the Department of Veterinary Services. The importance of this cross-sector collaboration is directly acknowledged by the school community: *"The main strength of this project is the cooperation with USM and Veterinary (Services), and it is suitable to be carried out within the school area..."*. This external expertise network acts as the backbone to resolve the gap in student skills, as suggested in Theme 4, namely the need to establish *"... mentors among experienced breeders to guide the school"*.

To enable this social entrepreneurship initiative to be replicated on a large scale to other educational institutions, it requires flexibility in local planning policies. The resilience of the social entrepreneurship model in this institution cannot be realized without governance and legal support (P and L). The analysis reveals that the primary strength factor of this project depends on the strategic network (Theme 2), specifically the collaboration between the school and external parties such as USM, the Department of Veterinary Services, and the Kedah Broiler Rabbit Cooperative. This multi-entity support network is crucial for transferring technical expertise (Amanah et al., 2021) and ensuring compliance with financial management ethics (Ahmad Baharum, Hwa, & Mohd Salleh, 2025), considering that this project was developed through social fund contributions.

To enable this initiative to be scaled and replicated to other schools as a model of financial independence (Theme 5), it requires local planning policy

interventions. Policy analysis finds that the integration of micro-scale commercial agricultural structures into areas with educational institution status will typically face approval constraints and land use zoning guidelines from local authorities. In practice, the project at SMITI Sains Bahrul Ulum currently operates within a regulatory grey area without formal planning permission. However, driven by the urgent need for Community Economic Development (CED) and financial self-sufficiency, the school initiated this project informally through strong grassroots community collaboration.

Therefore, as a contribution to the field of spatial planning, this study proposes that urban planners develop more flexible zoning guidelines. As a contribution to the field of spatial planning, this study proposes that urban planners develop more flexible zoning guidelines. This policy relaxation should allow community-based agricultural structures to operate legally within institutional zones, provided that they comply with strict public biosecurity controls and regulations.

The resilience of the social entrepreneurship model in this institution cannot be realized without governance and legal support (P and L). The analysis reveals that the primary strength factor of this project depends on the strategic network (Theme 2), specifically the collaboration between the school and external parties such as USM, the Department of Veterinary Services, and the Koperasi Arnab Pedaging Kedah (Kedah Broiler Rabbit Cooperative). This multi-entity support network is crucial for transferring technical expertise (Amanah et al., 2021) and ensuring compliance with financial management ethics (Ahmad Baharum, Hwa, & Mohd Salleh, 2025), considering that this project was developed through social fund contributions.

**Operational Reality vs. Proposed Regulatory Blueprint**

In practice, as an exploratory pilot initiative, the rabbit farming project at SMITI Sains Bahrul Ulum operated through informal grassroots mechanisms rather than obtaining statutory municipal planning approvals. Operational compliance was maintained via direct advisory support from the strategic network (USM ARASC and the Department of Veterinary Services) for animal welfare and health, alongside internal consent from the School Management Board. Environmental management was handled organically by redirecting waste into the school's garden plot as compost.

However, to transition this pilot from an informal grassroots project into a scalable, legally recognized social entrepreneurship model that can be replicated across other educational institutions, a comprehensive regulatory blueprint spanning five structural pillars is necessary:


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- **Statutory & Animal Welfare Alignment (Legal)**
  Formalizing operations under the Animal Welfare Act 2015 (Act 772) regarding cage dimensions and density and ensuring meat processing follows MS 1500 Halal slaughtering standards.
- **Institutionalized Health & Biosecurity (Health)**
  Establishing formal protocols with the Department of Veterinary Services for routine biosecurity monitoring and implementing strict cold-chain hygiene compliance for processed meat packaging.
- **Environmental Standard Operating Procedures (Environmental)**
  Standardizing the closed-loop circular economy practices to ensure manure processing mitigates odor and fly vectors, complying with the Environmental Quality Act 1974 (Act 127) requirements without causing local public nuisances.
- **School Administration Protocols (School)**
  Institutionalizing student involvement strictly within formal co-curricular hours with mandatory safety equipment (PPE), ensuring core academic teaching and learning (PdPc) priorities remain uncompromised.
- **Local Authority Licensing (Local Authority)**
  As a core contribution to spatial planning, this study advocates for a 'Conditional Planning Permission' mechanism by local authorities. This policy flexibility must allow micro-scale, community-based commercial agricultural structures to operate legally within institutional land use zones, provided they comply with the aforementioned health and biosecurity regulations.

**Table 3:** Synthesis of PESTELE Diagnostics, Empirical Findings, and Spatial Planning Implications

| PESTELE Elements | Empirical Findings (Quantitative & Qualitative Thematic Analysis) | Spatial Planning and Policy Implications |
|---|---|---|
| **Economic** | • Generated a net profit of RM1,736.30 in the first cycle of operation with a sales value of RM2,668.80.<br>• Triggered a multiplier effect for the community through secondary economic chains (Theme 5), such as the sale of rabbit satay and burger patties by the residents. | • Mixed Land Use Policy - Justifies the need for local planning policies to view educational institution zones not only as academic hubs but also as legitimate incubator hubs for micro/community economic generation. |
| **Social** | • Educators' acceptance was highly positive (Mean 4.07) and effective for hands-on learning (Theme 1).<br>• Existence of a skills paradox: Students' mastery of practical skills was only at a moderate level (Mean 3.64), and interest in farming careers was low (Mean 3.39) due to time constraints (Theme 3). | • Inclusive Training Space Provision - Planning policies must support the provision of appropriate physical support infrastructure for structured mentor-mentee programs with industry experts within the school area. |

| PESTELE Elements | Empirical Findings (Quantitative & Qualitative Thematic Analysis) | Spatial Planning and Policy Implications |
|---|---|---|
| **Technological** | • Manual operations were inefficient in limited space (a 40'x60' pen accommodating 240 cages for 60 female breeders and 10 male breeders).<br>• The breeding productivity rate of pregnant rabbits was very low (around 50%) (Theme 3).<br>• Resolutions require smart technology interventions such as digital record systems and automated feeding (Theme 4). | • Smart Infrastructure Integration - The necessity for the installation and integration of smart/modular technology structures to maximize yield in compact spaces. |
| **Environmental** | • Sustainable livestock waste management through the implementation of a circular economy (Theme 5).<br>• Organic waste (rabbit feces and urine) is not discarded; instead, it is processed and reused as organic fertilizer for the school's vegetable garden project. | • Biosecurity and Landscape SOPs - Requires spatial planners to establish facility design standards equipped with a centralized solid waste management system at the project site to ensure zero environmental pollution (public biosecurity). |
| **Political, Legal & Ethical** | • Project sustainability highly depends on a strategic network of various stakeholders (Theme 2), involving USM, the Department of Veterinary Services, and community cooperatives.<br>• Ethical-based financial management transparency that complies with funding guidelines. | • Zoning Flexibility & Conditional Approval - Urging local authorities to amend zoning policies by granting flexibility (e.g., Conditional Planning Permission) so that these community-driven micro-scale commercial activities, which often operate in regulatory grey areas, can be legally replicated in any area with educational institution status. |

*Source: Authors' Primary Research Data & PESTELE Synthesis*

## DISCUSSION

Based on the PESTELE diagnostic analysis, the findings of this study reveal several critical implications for the viability of the educational institution-based community economic development model. This discussion encompasses four main axes: the empowerment of the local economy, the reality of the youth skills mismatch, the integration of technology in sustainability practices, and the need for flexibility in spatial planning policies.

**Community Economic Empowerment Through Social Entrepreneurship**

From the perspective of economic viability, this broiler rabbit farming model proves that educational institutions such as the SAR have great potential to


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operate as economic generation centers. The success in generating a net profit of RM1,736.30 in the first cycle aligns with the view of Subhe (2023), who asserts that small-scale enterprises and industries act as engines for job creation, broaden income diversification, and stimulate local economic growth through the multiplier effect at the grassroots level.

In the context of the project at SMITI Sains Bahrul Ulum, the resulting secondary economic chains such as the sale of satay and burger patties by residents directly contribute to reducing reliance on a single source of income. This phenomenon is supported by the studies of Umam (2024) and Sayed Nordin et al. (2025), which found that local resource-based agro-industrial innovation not only increases commodity value-added but also serves as a robust medium of social transformation to empower community economic resilience. Through this approach, the main goal of social entrepreneurship is successfully realized, which is to innovatively create social value while providing continuous solutions to local socioeconomic problems (Daud Fhiri, Abdullah, & Ahmad, 2018).

**Skills Mismatch and Youth Development**

Although this initiative recorded a highly positive level of social acceptance from educators, the analysis reveals the existence of a pedagogical paradox among the youth (students). Their level of theoretical knowledge improvement was recorded at a high level, yet their mastery of practical skills and interest in making agriculture a career were merely at a moderate level.

This situation clearly illustrates the existence of the skills mismatch issue that often plagues the youth labor market in Malaysia, where possessed qualifications do not align with the practical competencies demanded in the field (Said & Jamaludin, 2018). In line with the vision to drive rural youth involvement through the Community Base Integrated Farming (CBIF) concept, continuous support and a mentoring ecosystem are highly critical (Ab Rahman et al., 2018). The direct transfer of expertise through mentor-mentee module interventions or industry-based training (coaching and monitoring) must be implemented. This practical guidance is capable of fostering confidence and agency in the youth, proving that they have the actual capacity to bring about social change and generate financial sustainability (Daud Fhiri et al., 2018; Salkowitz, 2010).

**Smart Technology Integration and Circular Economy Sustainability**

Through the analysis of the environmental (E) and technological (T) dimensions, the operations of this project faced breeding productivity restrictions that limited maximum profit. This tactical weakness indicates that reliance on manual farm management methods must be ceased; instead, a rapid transition to the use of smart technology innovations such as automation systems, digital management

records, and genetic monitoring is urgently needed (Neethirajan, 2023; Saiz-Rubio & Rovira-Más, 2020).

Despite facing technical challenges, the model in this school deserves to be highlighted as a reference for sustainability due to its practical success in implementing a circular economy. Organic waste, such as rabbit feces, has been reprocessed into organic fertilizer for the school garden. This approach of treating waste as a new agricultural resource directly minimizes the impact of ecological damage while simultaneously generating operational cost-reduction value (Purnamasari et al., 2026; Cobo, Dominguez-Ramos, & Irabien, 2018). This independent, community resource-based management also supports the eco-social transformation framework, where waste recycling and local food production build community resilience against global uncertainties (Elsen, 2018).

**Spatial Planning Policy Implications and Integrated Networks**

The most significant contribution of this study pertains to urban planning practices and local government policies. The study concludes that the sustainability of the social entrepreneurship model at SMITI Sains Bahrul Ulum is successfully maintained through the existence of a strategic network involving collaboration among the school, USM, the Department of Veterinary Services, and local cooperatives. This cross-sector network proves that multi-stakeholder collaboration is the strongest foundation for transferring technical expertise and ensuring the independence of community empowerment programs (Umam, 2024; Emerson et al., 2012).

To enable this social entrepreneurship framework to be replicated on a large scale in other locations, proactive intervention from local authorities and urban planners is imperative. Local government administrative structures act as absolute determinants that can either facilitate or hinder the survival of such grassroots projects through their land use policies (Liu et al., 2022; van Doren et al., 2020). Therefore, as an implication for spatial planning theory, local authorities are advised to review and formulate more flexible zoning guidelines. The success of this community-driven effort highlights a significant gap in current spatial planning policies. It demonstrates that local authorities must introduce zoning flexibility. Rather than penalizing such grassroots innovations that currently lack formal approvals, urban planners should formulate a 'Conditional Planning Permission' framework. This spatial policy flexibility must allow community-based integrated agricultural structures to operate legally within institutional zones, provided that compliance with strict public biosecurity regulations remains a priority. This infrastructural policy support aligns with efforts to integrate community agriculture as part of a master plan for poverty mitigation and food security (Amanah et al., 2021; Long et al., 2021).


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**Replicability and Spatial Adaptation Across Rural, Semi-Urban and Urban Contexts**

To evaluate the scalability of this school-based social entrepreneurship model across diverse geographic and socio-spatial landscapes, the operational framework must be contextualized according to rural, semi-urban and urban educational environments. While the pilot case at SMITI Sains Bahrul Ulum demonstrates viability within a semi-urban/rural setting, replication in other institutional contexts requires distinct spatial and technological adaptations.

- **Rural School Contexts**
  Rural educational institutions possess abundant physical land footprints and experience low spatial friction with residential neighbors, making them ideal for horizontal facility expansion ($40' \times 60'$). In this context, replicability is highly feasible by integrating livestock farming directly with large-scale agricultural crop plots through closed-loop composting systems. However, the primary operational constraints in rural areas stem from technical breeding knowledge gaps, lower breeding efficiency (~50%), and logistics distances to bulk commercial buyers. To overcome these challenges, rural replication must be anchored by strong technical partnerships with community cooperatives such as the Kedah Broiler Rabbit Cooperative and the Department of Veterinary Services to maintain flock productivity.
- **Semi-Urban School Contexts**
  In semi-urban environments such as the SMITI Sains Bahrul Ulum case site, schools operate under moderate land availability while benefiting from immediate proximity to localized micro-markets and food vendors (e.g., satay and patty stalls). Replicability in semi-urban contexts hinges on managing spatial buffer zones and preventing nuisance factors (odor and vector risks) near adjacent residential neighborhoods. Facility design should utilize semi-closed modular structures with mesh screening and bio-slurry waste fermentation to neutralize odor before application to school gardens. This achieves an optimal balance between micro-scale meat production and direct community supply chains.
- **Urban School Contexts**
  Urban schools face severe land scarcity, strict municipal zoning guidelines, and zero tolerance for public nuisances. Replicability in urban environments necessitates a paradigm shift from volume-driven horizontal farming toward compact vertical farming systems. Urban schools can adopt multi-tiered, climate-controlled indoor vertical cages equipped with automated waste-flushing mechanisms to eliminate odor. Although initial capital expenditure (CAPEX) for urban setups is higher, the project focus shifts strategically from mass meat production toward high-value educational STEM incubators,

experiential bio-learning and localized organic fertilizer production for urban rooftop gardens.

By adapting the facility footprint and operational focus to these geographic realities, local authorities and school administrators can utilize this model as a flexible, context-sensitive tool for local economic resilience and sustainable agricultural education.

## CONCLUSION

This study concludes that the community economic development model based on social entrepreneurship through the rabbit farming project at SMITI Sains Bahrul Ulum is proven to be empirically viable. From an economic perspective, this initiative successfully generated self-sustaining financial viability through a net profit of RM1,736.30 in its first cycle and triggered secondary economic chains that directly benefit the local community through the sale of downstream products (Subhe, 2023; Yustika, 2019). However, social analysis reveals the existence of a pedagogical paradox and a skills mismatch among students, which demands more structured practical skills guidance interventions (Said & Jamaludin, 2019). Despite operational constraints such as a low breeding rate and space limitations that require smart technology adaptations (Saiz-Rubio & Rovira-Más, 2020), this model still successfully practiced sustainable circular economy practices by optimizing livestock waste as organic fertilizer (Cobo, Dominguez-Ramos, & Irabien, 2018; Koul, Yakoob, & Shah, 2022).

As a primary contribution to spatial planning and local government policy literature, this study asserts that the survival of grassroots social innovation initiatives is highly dependent on the support of a multi-entity strategic network ecosystem (Amanah et al., 2021). To realize the potential of replicating this model on a larger scale to other schools, this study urges policymakers, particularly local authorities, to review and restructure spatial zoning guidelines more flexibly. Recognizing that current institutional zoning rigidly restricts such activities, a policy shift towards Conditional Planning Permission is crucial. A spatial policy shift that allows the integration of micro-scale commercial agricultural activities within areas designated as educational institutions will not only resolve land use conflicts. A spatial policy shift that allows the integration of micro-scale commercial agricultural activities within areas designated as educational institutions will not only resolve land use conflicts but also elevate social entrepreneurship as a core strategy in holistically driving food security and local socioeconomic resilience.

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# INTEGRATING WAQF MU'AQQAT AND EQUITY CROWDFUNDING FOR THE SUSTAINABLE DEVELOPMENT OF IDLE WAQF LAND

**Ainul Syahidah Shaari[1] & Muhammad Shahrul Ifwat Ishak[1,2]**

[1]*Faculty of Business and Management,*
[2]*Islamic Social Finance Research Centre,*
UNIVERSITI SULTAN ZAINAL ABIDIN

## Abstract

In Malaysia, it was reported that an estimated 17% of waqf lands remains undeveloped in 2024 due to financial and managerial constraints. Agricultural use of idle waqf land could generate up to RM18,000 per hectare annually, reflecting significant unrealised economic value. Hence, it results in substantial opportunity costs, including lost financial sustainability and socio-developmental capacity of waqf institutions. In this context, developing idle waqf land for sustainable agriculture strengthens food security and socio-economic outcomes. It also can support local economic development by creating employment across the agricultural value chain. Overall, productive waqf land utilisation promotes income generation, rural livelihoods, and inclusive development. Therefore, this study aims to develop a sustainable financing model using equity crowdfunding to support the development of idle waqf land through sustainable agricultural initiatives. To achieve these objectives, this study adopts a qualitative research approach through a comprehensive analysis of relevant literature and semi-structured interviews with selected experts and practitioners from State Islamic Religious Councils (SIRCs), agricultural agencies, and land-related authorities. It was found that an alternative financing is crucially needed for waqf land development. Thus, equity crowdfunding can be proposed as a means of sustainable financing. However, to adapt into waqf land, it is suggested equity crowdfunding is integrated with waqf *muaqqat* (temporary waqf). This study contributes to the country economy agenda by developing idle land and providing venture capital for the agriculture sector business. At the same time, it aligns with Financial Sector Blueprint 2022-2026 in terms of advancing digitalisation of the financial sector and value-based finance through Islamic finance leadership Islamic finance. Finally, this model support Capital Market Masterplan 2026-2030 by encouraging development of innovative Islamic social finance products and frameworks, including waqf-linked investment for social and climate objectives.

***Keywords***: Waqf land; Equity Crowdfunding; Islamic Finance, Urban development.

[2] Corresponding author. Email: shahrulifwat@gmail.com

## INTRODUCTION

The potential of waqf land as a sustainable social and economic resource remains largely untapped. In Malaysia, a large percentage of waqf land is currently idle or underutilized, contributing little to social welfare or community development. Many of these lands are underutilized due to budgetary restrictions, unsuitable locations, administrative obstacles, a lack of professional knowledge, a lack of public awareness and trust, and the complexities of waqf administration (Abd. Jalil, 2020; Ali Azizan et al., 2021). Limited funding sources and reliance on traditional donations frequently limit the ability of waqf institutions to perform large-scale development projects, particularly in industries such as agriculture that need significant upfront investment. According to data from the Department of Waqf, Zakat and Haj (JAWHAR) states that as of July 2024, about 4,198 waqf land lots out of 23,364 total lots (about 18%) were vacant, meaning that 4,265 hectares out of 20,782 (almost 17%) are still unused. This circumstance indicates not only an economic inefficiency, but also a neglected opportunity to achieve waqf's original goals of promoting social development, community welfare, and sustainable economic activities.

The biggest barrier to developing idle waqf land is a lack of adequate investment capital (Abd. Jalil, 2020; Ali Azizan et al., 2021; Alam et al., 2024). Traditional waqf management is mainly reliant on donations or institutional money, which can often be insufficient to support large-scale agricultural or development projects. Furthermore, the regulations regarding permanent waqf make it administratively difficult to launch and administer projects effectively. As a result, idle waqf land remains to deliver little benefit to both the organizations overseeing the waqf and the community as a whole. The implications of failing to solve this issue are far-reaching. Economically, idle waqf lands do not provide returns sufficient to support future development or social activities (Ishak et al., 2024, Ab Rahman & Thaidi, 2026). Socially, the community is denied possible welfare benefits, such as job possibilities and access to locally produced food (Ishak et al., 2024). Abandoned lands may become degraded, reducing their long-term worth and potential for sustainable agriculture. Failure to develop these lands not only causes economic inefficiencies but also prohibits waqf institutions from achieving their broader socioeconomic goals. Productive agricultural development on waqf land has the potential to improve food security, create employment opportunities, and improve the community well-being (Ishak et al., 2024). As a result, the present situation underutilization of waqf land is a squandered chance to maximize the socioeconomic benefits of waqf assets. Collectively, these missed opportunities represent a significant loss of resources that could have been used to support national and community development, as well as the achievement of the United


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Nations Sustainable Development Goals (SDGs), particularly in areas such as zero hunger and sustainable communities.

To address these challenges, this study proposes the integration of equity crowdfunding as a financing mechanism for the development of idle waqf land, complemented by the adoption of waqf *muaqqat* (temporary waqf). Equity crowdfunding permits multiple investors to provide funds to development projects while distributing profits according to Shariah-compliant guidelines. This technique decreases reliance on individual donors or institutional money, allowing for the mobilization of larger resources for agricultural projects. Waqf *muaqqat,* on the other hand, provides more flexibility in land management by permitting temporary endowment for specific projects while simplifying operational monitoring. Once the prescribed period has expired or the stated situation has been met, waqf *muaqqat* stipulates that the waqf asset should be returned to the waqif or his faraid recipients (Al-Ansori, 1993; Al-Gharyani, 2002; Tahir, 2009; KAPF, 2014; AAOIFI, 2022; Mahmud et al., 2023). Together, these processes provide a practical and ethical foundation for converting idle waqf land into productive usage.

Many factors contribute to the effectiveness of this strategy. Financially, equity crowdfunding provides access to a variety of financial sources, allowing development projects to be completed even with modest individual contributions. Waqf *muaqqat* simplifies project implementation by eliminating administrative complexity and offering a planned but adaptable approach to land management. Socially and ethically, the integration of these systems is consistent with Shariah values, encouraging profit-sharing rather than interest-based financing while providing actual advantages to the community (Bakar, R., & Rosli, M. F. (2026). Furthermore, this technique is scalable, allowing for replication on other vacant waqf sites across the country or area, and it has the potential to attract young Muslim investors interested in ethical and socially responsible investments. This study resolves existing financial and operational restrictions by mobilizing idle waqf land for sustainable agriculture, while also contributing to community development, environmental sustainability, and the broader goals of Islamic social financing. Existing studies discuss waqf land development, Islamic crowdfunding, or sustainable agriculture separately. However, there is limited research that integrates these elements into a comprehensive framework that facilitates the development of idle waqf land for sustainable agriculture through equity crowdfunding mechanisms.

## LITERATURE REVIEW

### Utilisation of Waqf Land for Socio-Economic Development

Waqf land is an Islamic endowment of property or land for charitable, educational, or religious reasons. The asset itself cannot be sold and is no longer

private (Johari, 2022). However, the ownership permanently belongs to the people. It is administered by Islamic law, and the earnings or usages are intended for the benefits of society. Based on beneficiaries, waqf can be classified into two types: waqf am (public endowment), which benefits the general public, and waqf *khas* (specific endowment), which benefits specific individuals or groups. These kinds of waqf are determined on the purpose of the donor when he donated a certain asset. Similarly, these two waqf groups share comparable concerns such as financial constraints to plan and perform additional economic activity on waqf properties (Ali Azizan et al., 2021; Alam et al., 2024), waqf land is not strategically located or too remote, the land size is small that made them less desirable for residential or commercial projects and in Malaysia, the management of waqf lands is overseen by numerous state religious councils (Ali Azizan et al., 2021). Abd. Jalil (2020) also stated several issues and challenges of waqf practice including legal conflict, lack of understanding about waqf governance among Muslims, idle assets and land, management inefficiencies, incomplete data and illegal invasion of waqf properties (Abd. Jalil, 2020).

Thus, it can be concluded that the need for effective fund management strategies, a supportive regulatory framework, and increased public awareness, all of which require coordinated efforts from government agencies, financial institutions, and stakeholders to ensure the development and sustainability of waqf projects (WB & IsDB, 2025). Mat Hassan et al. (2021) highlight the need for continuous campaigns and promotional initiatives to enhance public awareness and participation in waqf. They further emphasise the importance of strengthening internal governance within State Islamic Religious Councils (SIRCs), particularly through improvements in management systems such as updated databases, ICT infrastructure upgrades, recruitment of professional expertise, and the enhancement of organisational structures.

In general. these waqf lands can be divided into five primary purposes, which are mosque, Islamic religious school, cemetery and general (Ali Azizan et al., 2021; Alam et al., 2024). Waqf land plays a significant economic and social role in communities. Economically, it generates income through leasing, agriculture, and commercial operations, which helps to alleviate poverty and promote local development. Land is required for agricultural activities. Farmers, particularly landless farmers, will have greater accessibility to additional agricultural land, allowing them to boost their production capacity, promote food security, promote farmer livelihoods, and economic stability (Ishak et al., 2024). Food security is defined as a condition in which all individuals have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life (Asli & Rahman, 2023). In contrast, the government's approach to food security is described as a strategy of complete reliance on domestic production without dependence on external food


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sources (Asli & Rahman, 2023). Socially, waqf land promotes education, healthcare, and community services, while boosting social solidarity and sustained flow of income for waqf institutions, allowing them to fund numerous charitable and social welfare programs (Ishak et al., 2024). Despite Malaysia's well-established waqf management policies, many waqf lands are still vacant or underutilized, which results in lost potential for socioeconomic growth. As of July 2024, around 18% of waqf land lots were idle, and 17% of hectares remained underutilized (JAWHAR, 2024).

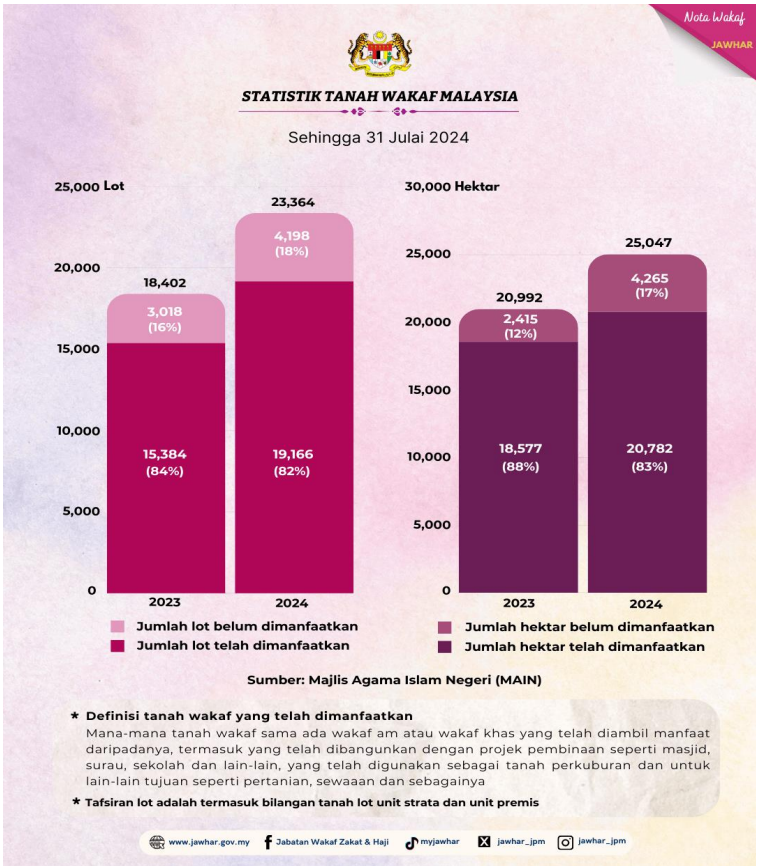



**Figure 1:** The Statistic of Waqf Land in Malaysia
*Source: JAWHAR 2024*

Based on previous studies, a typology of idle waqf land can be developed to categorise abandoned or underutilised waqf land according to several characteristics. These include land size, geographical location,

development suitability, accessibility, and legal or other development-related constraints. The typology can be summarised as follows:

**Table 1:** Typology and development of characteristics of Idle Waqf Land

| Characteristics | Literature-derived observation | Sources |
|---|---|---|
| Land size | Land varies considerably in size. Individual size may less attractive for commercial or residential projects. While, oversized size can cost a lot. | Ali Azizan et al. (2021); Abd. Jalil (2020) |
| Location | Idle waqf land exists in urban, peri-urban and rural locations, resulting in different development opportunities and constraints. | Ali Azizan et al. (2021); Abd. Jalil (2020) |
| Development sustainability | The area with a favourable climate, suitable soil conditions, and topography can support agricultural development. | Buang (2001) |
| Access | Improved road access and better land consolidation can support the development of small and scattered fields for crop production. | Anem (2009) |
| Waqf constraints | The purpose and endorsement of waqf *am* and waqf *khas* are different. | Mahamood (2025); Mat Hassan et al. (2021) |

Table 1 indicates that idle waqf land is not a homogenous resource. Its potential differs depending on land size, location, development sustainability, access and its constraints. Existing agricultural programmes show that waqf land of different size can be productively utilised when appropriate development arrangements are implemented. For example, MAIDAM (2025) has facilitated the cultivation of okra and eggplant on 0.4 hectares of waqf land in Kampung Gelugur Kayu Tinggi, Terengganu, generating an estimated gross income of approximately RM5,000 per month for the farmer. The annual rental fee for the land is RM 400. This project shows how waqf can strengthen the ummah's economy by producing cash crops.

Similarly, Perbadan Wakaf Selangor (2024) demonstrated that Saudagar Nanas Agrofarm, through Barakah Agribiz Enterprise, has leased 6.3 acres of waqf land managed by PWS in Dengkil, Sepang, for pineapple cultivation targeting high-income generation and market demand in the Klang Valley. These cases illustrate the utilisation of waqf land through different land scales and development arrangements. Therefore, the proposed typology provides an important initial basis for assessing the characteristics and development potential of idle waqf land before determining the most suitable land use, development model and financing mechanism.


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**Financing Mechanisms for Waqf Land and Agricultural Development**

Maulida and Rusydiana (2024) proposed the Integrated Waqf Environment Model (IWEM) as a sustainable, Shariah-compliant financial tool for developing agricultural innovation in the age of Smart Agriculture 5.0. IWEM integrates Islamic social finance and environmental goals, offering a structured approach to support farmers and research institutes using a waqf-based system. A combined effort of waqf and smart agriculture solves several critical issues, including difficult access to financial resources, poor technological adoption among small-scale farmers, and lack of policy support. The study demonstrated that waqf instruments can provide robust, debt-free funding for sustainable agricultural systems when they are appropriately regulated and supported by permitting laws, particularly when paired with risk-sharing agreements and digital tools.

Majid (2021), in his paper, introduced Salam-Muzara'ah Linked Waqf (SMW) which is a Sharia-compliant financial model that combines social finance and commercial into a single financing scheme designed to help Baitul Maal wat Tamwil (BMT) solving the agriculture sector's problems. The commercial agreement employed in SMW is *salam* (advanced payment) financing, which provides advance payment to small farmers to overcome their limited accessibility, and *muzara'ah* (agriculture venture) contract, which allows the cultivation of idle waqf land to deal with insufficient agricultural land caused by land conversion. The Islamic social finance tool applied to this model is the implementation of return of cash waqf and waqf land provided to farmers as a subsidy and *hibah* (gift) to offset risk during the planting season. To minimize the risks that accompany *salam* financing, SMW is meant to address the problem by utilizing profits from the cash waqf fund.

Afroz et al. (2019) developed Integrated Waqf Environmental Protection Model (IWEP) that seeks to directly incorporate the cash waqf to support farmers who are having difficulty adjusting to climate change. This model can assist the government in cutting costs associated with agricultural development. This study has led to the development of many viewpoints. Firstly, it advances Malaysia's agricultural development by encouraging funding to support farmers. Second, the study indicated that attitude, awareness, subjective norm, perceived difficulty, and knowledge all influence the intention to use a model. This study found that the decision of low-income farmers to adopt the IWEP model is heavily affected by family members, neighbours, and friends. Third, the study was able to create the theoretical framework by adopting and modifying pertinent literature (measured items) to address the paucity of material in the Malaysian context. Hence, cash funds are an extremely effective tool for fundraising.

In the study of Allah Pitchay et al. (2018), the proposed cooperative-waqf model intends to solve the liquidity crisis that waqf institutions are facing

and to encourage uniformity among cash waqf contributors. The suggested model improves the satisfaction of waqf institutions and donors. Donor trust will increase as a result of membership privileges. Additionally, the prestige of waqf organizations will be enhanced by steady cash waqf collection and the growth of waqf assets. Additionally, the CWM is anticipated to mitigate waqf institutions' reliance on government support and allow governments to reallocate funds to addressing society's basic needs at a relatively cheaper cost. Since the CWM promotes money circulation among all members of society rather than just the wealthy, it has the potential to make a significant contribution to society. Increasing the flow of public income can solve the issues that capitalists have caused in society.

**An Overview of Equity Crowdfunding (ECF)**

Equity crowdfunding (ECF) has emerged as an innovative financing mechanism that enables businesses and projects to gather capital from a large number of investors through digital platforms (Ishak, 2025). Compared to traditional financing methods that rely mainly on banks or institutional investors, equity crowdfunding permits individuals to jointly invest modest amounts of capital in exchange for equity participation (Hornuf & Schmitt, 2016; Butticè & Vismara, 2022; Mazzocchini & Lucarelli, 2023). In many countries, equity crowdfunding is becoming widely known as a viable alternative financing source for projects that cannot obtain conventional financing. Equity crowdfunding in Europe began with platforms like Crowdcube (United Kingdom) and Seedmatch (Germany), which launched their first successful campaigns in 2011 (Hornuf & Schmitt, 2016). Crowdfunding is the third most popular source of external funds for German entrepreneurs, trailing only bank and venture capital (Blaseg et al., 2021).

According to Mazzocchini & Lucarelli (2023), the purpose of equity crowdfunding is to accumulate a predefined amount of cash within a specific timeframe, which means that the project must be able to attract and convince a sufficient number of crowd-investors in order to collect the intended funds. Investors must make choices in a highly risky environment, with a significant amount of uncertainty, and possible returns (if any) will be realized only in the long run (Aderemi & Ishak, 2023). Thus, the key problem of information asymmetries between lenders and borrowers is brought into play by the signals entrepreneurs send to convince the crowd. The digitalization of Web-based equity crowdfunding platforms can increase the chances for entrepreneurs and investors to connect and share information. As a result, this approach minimizes the distance between them, fostering trust, and allowing the mitigation of information asymmetries (Butticè & Vismara, 2022; Mazzocchini & Lucarelli, 2023).


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Incorporating equity crowdfunding into waqf land development projects makes it feasible to raise money from the general public to fund profitable endeavors like sustainable agriculture. The development of waqf land relies not only on government support but also on active public participation (Mat Hassan et al., 2021). Equity crowdfunding offers a flexible and scalable financing alternative by distributing risk among a large pool of small investors, making it more acceptable as the risk is less concentrated. This approach is particularly suitable for financing idle waqf lands for sustainable agricultural development. To adapt with the waqf asset, crowdfunding can be designed in the form of waqf *muaqqat* (temporary waqf).

**The Concept of Waqf *Muaqqat* and Its Legal Framework in Malaysia**

In general, based on the duration of the waqf, waqf can be categorized into two types: waqf *muabbad* (perpetual waqf) and waqf *muaqqat* (Ab Rahman, 2026). In the past, waqf *muabbad* has supported a number of socioeconomic areas, including public infrastructure, education, and healthcare (Mohsin & Muneeza 2020). To improve flexibility and promote wider involvement in waqf activities, modern scholars and practitioners have also researched several types of waqf frameworks. Waqf *muaqqat*, a temporary endowment in which the waqf asset is dedicated for a predetermined amount of time before being returned to the original owner (Mahmud et al., 2023), is one such type. Waqf *muaqqat*, in contrast to waqf *muabbad*, permits donors to make asset contributions for a specific amount of time while continuing producing benefits for the general welfare. The study thoroughly examines the opinions of the Maliki school, which is the primary advocate of waqf *muaqqat.*

According to Al-Ansori (1993), the waqf asset reverts to the *waqif* or his *faraid* (family) beneficiary upon his demise in the event of the waqf's termination or end of waqf period. According to the aforementioned opinion, if the waqf time limit expires, the waqf asset will be returned to waqif, if he is still living, or to his *faraid* recipient upon his passing. This opinion is also supported by other modern Maliki scholars such as Al-Gharyani (2002) and Tahir (2009), where Al-Gharyani (2002) emphasized that when someone contributes his asset to the poor for ten (10) years, after the period the waqf asset reverts to the *waqif* or his *faraid* beneficiary. KAPF (2014) further stated the waqf asset will be handed to the *waqif* if he is still alive or to his *faraid* beneficiary if he is dead if the waqf period is ended. This opinion is also backed by a few Shariah authorities, such as AAOIFI (2022).

Given these benefits, incorporating waqf *muaqqat* into new financing methods like equity crowdfunding can create a possible approach to collect funds for the development of idle waqf lands. By integrating waqf *muaqqat* with collective investment platforms, it could be possible to construct long-term

development models that boost agricultural productivity while providing socioeconomic advantages to the community.

In terms of regulatory framework, Malaysia has a unique system for managing waqf property. According to federal constitution, SIRC are recognised as the sole trustees responsible for managing waqf property in their respective states. Currently, nine of 14 states have established specific waqf enactments, while the remaining five states are expected to introduce similar legislation in the future.

**Table 2**: Legal status of waqf *muaqqat* across the states

| Jurisdiction | Section | Enactment |
|---|---|---|
| Federal Territories | Rule 24: Waqf *Muaqqat* | Kaedah-Kaedah Pentadbiran Undang-Undang Islam (Wilayah-Wilayah Persekutuan) (Wakaf) 2025 |
| Terengganu | Section 18: Waqf *irsod*, waqf muabbad, waqf *muaqqat*, waqf *musya'* or waqf *musytarak*. | Enakmen Wakaf Terengganu 2016 (Enakmen 1) |
| Sarawak | Section 2(1) | Ordinan Majlis Islam Sarawak, 2001 (Bab 41) |
| Johor | Rule 17: Waqf Muabbad and waqf *Muaqqat*. | Kaedah-Kaedah Wakaf 1983 (J.P.U.51.) |
| Selangor | Section 2(1) | Enakmen Wakaf (Negeri Selangor) 2015 (Enakmen 15) |
| Pulau Pinang | Section 2(1) | Enakmen Pentadbiran Agama Islam (Negeri Pulau Pinang) 2004 (Enakmen 4/2004) |
| Perlis | Section 2(1) | Enakmen Pentadbiran Agama Islam 2006, Perlis (Enakmen 4) |
| Melaka | Section 2(1) | Enakmen Wakaf (Negeri Melaka) 2005 (Enakmen 5) |
| Sabah | Section 2(1) | Enakmen Wakaf (Negeri Sabah) 2018 (En. 7/2018) |

Since waqf falls under state jurisdiction, the absence of a uniform legal framework has made the administration and development of waqf matters somewhat complex. As a result, the legal recognition and regulation of Waqf *muaqqat* vary across Malaysian states. Terengganu and the Federal Territories expressly recognise waqf *muaqqat*, while Johor provides an earlier example through its subsidiary legislation (Mahamood, 2025). Therefore, the implementation of waqf *muaqqat* should consider both the conditions permitted under Islamic law and the specific legal, administrative, and institutional requirements of the relevant state authorities.


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## METHODOLOGY

In general, this study adopts a qualitative research approach. According to Hsieh & Shannon (2005) qualitative research involves a systematic categorization technique, such as patterns, coding or themes in dealing with data interpretation. The finding and result can create a depth of understanding in which quantitative research method may not be practical due to relying on numerical approaches (Johnson et al., 2006). As this study aims to propose an integration between waqf *muaqqat* and equity-based crowdfunding, it was achieved through qualitative analyse on literature and interviewing experience of experts. As for literature, synthesis on waqf, equity-based crowdfunding and blended financing were conducted while for interview, through semi-structured on purposive sampling was applied to ensure the research objectives were achieved. Then, the data was analysed based on thematic analysis since its finding was presented in the form of themes. Nowell et al., (2017) views that this approach is practical since it emphasizes on individuals' viewpoints by compaing between parallels and discrepancies, in producing insights. The sample of interviewees can be listed as follows:

**Table 3**: List of interviewees

| List of interviewees | Area of expertise | Area of Malaysia |
|---|---|---|
| IV 1 | Waqf | Northern Peninsular Malaysia |
| IV 2 | Crowdfunding | Central Peninsular Malaysia |
| IV 3 | Crowdfunding | Central Peninsular Malaysia |
| IV 4 | Waqf | East Malaysia |
| IV 5 | Waqf | Northern Peninsular Malaysia |
| IV 6 | Waqf | Central Peninsular Malaysia |
| IV7 | Waqf | Southern Peninsular Malaysia |
| IV8 | Waqf | East Coast Peninsular Malaysia |
| IV9 | Crowdfunding | Central Peninsular Malaysia |
| IV10 | Waqf | East Coast Peninsular Malaysia |
| IV11 | Agriculture | East Coast Peninsular Malaysia |
| IV12 | Land | East Coast Peninsular Malaysia |

As shown in Table 2, the interviewees comprised 12 individuals selected from waqf, agricultural, and land-related entities across various regions in Malaysia. Following data collection, the interview data were systematically analysed using an inductive approach to develop and propose a waqf *muaqqat* model.

## FINDINGS AND DISCUSSION

### The Limitation of Funding

All experts agreed that funding is considered as the main challenge in developing waqf land in Malaysia. Currently, JAWHAR is among the active funders supporting waqf land development through the budget allocated by the federal government. However, according to IV6, funding from JAWHAR is limited. As waqf is considered part of the third sector, waqf institutions should also mobilise funds from the public. In response to this view, the majority of interviewees argued that donation-based crowdfunding alone would not be sufficient to address the funding challenge. Another alternative is financing from banking institutions. However, many interviewees were reluctant to accept this option, as it could burden SIRC with repayment obligations. An exception may be equity-based financing, which was viewed as a more suitable alternative.

To propose equity financing, banking institutions, including Islamic banking operate within a complex risk environment, where various types of risks arising from their core activities. According to Kisman (2020), the risks faced by banks can be categorised into financing risk (Islamic banks), credit risk (conventional banks), market risk, liquidity risk, operational risk, legal risk, compliance risk, reputation risk, and strategic risk. Besides, debt-based financing modes such as *murabahah* (mark-up sale) and *tawarruq* (monetization) are more commonly practiced by Islamic banks worldwide compared to equity-based financing grounded in *musharakah* (full partnership) and *mudharabah* (partnership). While both associated with high risk, they have a significant potential to contribute to economic growth and development when effectively implemented (Maikabara, 2019; Ishak et. al, 2025). Although *musharakah* promotes equitable profit-sharing, the requirement to share losses in proportion to capital contribution exposes financial institutions to considerable risk. Consequently, *musharakah* and *mudharabah*, as equity-based financing modes, are often given lower priority due to several challenges, including high risk exposure, implicit capital protection concerns, information asymmetry, the need for specialised expertise, and limited public awareness of equity financing (Maikabara, 2019).

In this regard, waqf-based agricultural projects, which are inherently uncertain and lack collateral assets. Islamic banks rarely offer *musharakah* financing without requiring strong risk mitigation measures such as collateral or guarantees, which function to protect the bank's capital despite the theoretical risk-sharing nature of the contract (Maikabara, 2019). Financing risk in *mudharabah* contract occurs when the bank has fulfilled its obligation by delivering the asset, yet the client fails to meet the agreed payment terms (Kisman, 2020). Consequently, Islamic banks either avoid these financing structures or impose stringent risk mitigation measures, thereby constraining their


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applicability in the development of idle waqf land. Since equity crowdfunding provides a more flexible and scalable alternative by spreading risk across many small investors, this makes it more acceptable as the risk becomes less concentrated, particularly suitable to finance idle waqf lands for sustainable agriculture.

Meanwhile, government grants or subsidies seem ideal but in reality, there are many issues such as limited budget allocation, extreme competition, often one-off funding, not sustainable, bureaucratic delays and political influence. To address this issue, as outlined in the Capital Market Masterplan (2026-2030) developed by Securities Commission Malaysia (SC), the government focuses on promoting market-based financing such as equity, venture capital, bond, derivatives and digital platforms like equity crowdfunding and Peer-to-Pear (P2P) lending instead of traditional bank loans. This masterplan aims to reshape the capital markets to become more inclusive, sustainable and forward-looking. In addition, Bank Negara Malaysia promotes alternative financing avenues, including non-debt-based solutions such as blended finance, equity crowdfunding, venture capital, and private equity (BNM, 2022). These mechanisms complement traditional financing by offering more diverse and potentially resilient sources of funding for the economy. Ultimately, it is crucial for the financial sector to absorb, rather than amplify, economic shocks and vulnerabilities. Reducing excessive reliance on debt is therefore essential to achieving this objective.

**The Potential of Equity Crowdfunding through the Adoption of Waqf *Muaqqat***

All interviewees expressed positive views towards the proposed concept of equity crowdfunding for the development of idle waqf land, particularly due to the limited availability of funding opportunities. However, several Shariah issues were raised. For example, in the case of waqf *muaqqat*, donors should not receive an amount exceeding their original contribution, as this may raise concerns regarding an interest-based loan. To address this issue, a hybrid funding model could be proposed, whereby both donors and investors channel their funds into the project.

By incorporating equity crowdfunding into waqf land development projects makes it feasible to raise money from the general public to fund profitable endeavors like sustainable agriculture. Equity crowdfunding offers a flexible and scalable financing alternative by distributing risk among a large pool of small investors, making it more acceptable as the risk is less concentrated. This approach is particularly suitable for financing idle waqf lands for sustainable agricultural development.

In this regard, waqf *muaqqat* may serve as a practical framework for creating collaborations among waqf institutions, investors, and project developers. Waqf *muaqqat* allows land or financial resources to be utilized for productive projects such as agricultural development while maintaining the original waqf principles. According to Mahamood (2025), the concept of waqf *muaqqat* provides various benefits for contemporary waqf development. Using waqf *muaqqat* may encourage people and institutions to participate in waqf activities without permanently abandoning ownership of their assets. This flexibility could motivate increased engagement from investors, landowners, and institutions in projects that seek to provide socioeconomic advantages. Furthermore, waqf *muaqqat* can help in creating innovative financial frameworks that integrate charity goals with long-term economic operations. The proposed model can be illustrated as follows:

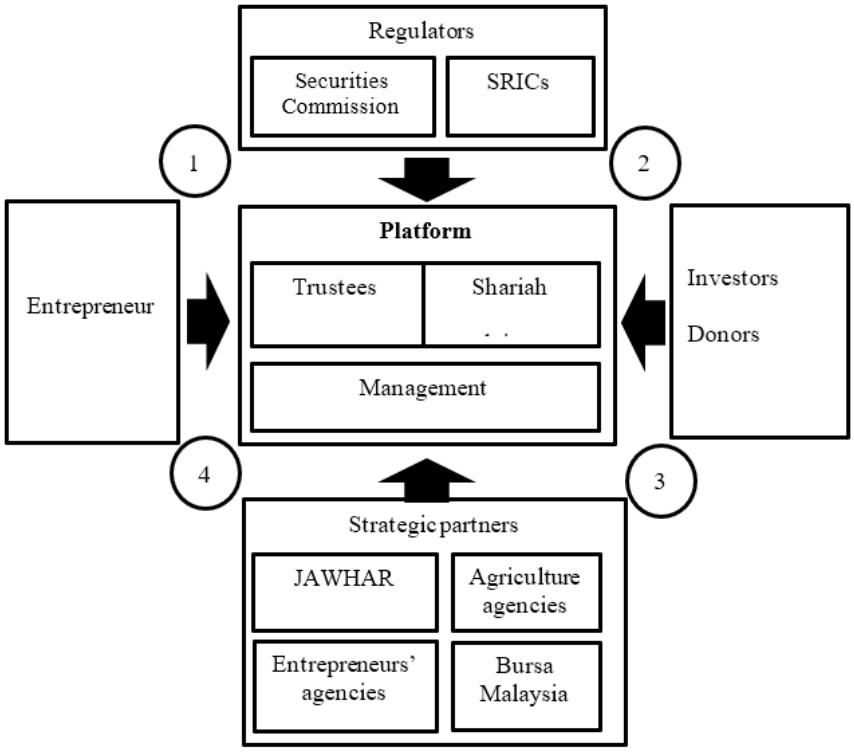



**Figure 2:** The proposed model


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Explanations:

**Funding flow**

1. An entrepreneur applies to the platform to raise funds for a business project.
2. The platform evaluates the project and invites the entrepreneur to pitch the idea. If the project meets the required criteria, the platform prepares the necessary agreements and initiates the fundraising campaign. At this stage, the Shariah advisory plays a crucial role in screening the project and agreements to ensure Shariah compliance. Trustees are also vital entity to monitor the management and to protect of waqf objectives.
3. Investors and donors contribute their funds to the project.
4. If the fundraising target is achieved, the platform disburses the total amount of funds in accordance with the agreed terms. Upon completion of the project, the entrepreneur returns the fund to donors and distributes the profits to the investors.

**Regulatory framework**

The SC is responsible for establishing rules and enforcing regulations relating to the capital market, including equity crowdfunding. Therefore, the platform needs approval from SC for launching the project. At the same time, since the platform uses the term waqf, it has to apply from SIRC for approval, depending on where the project is located.

**Strategic partners**

Since this model could be risky due to the concept of equity and the sector of agriculture, it requires coloration. Although waqf fall under the state government's jurisdiction, strategic coordination and co-operation efforts are necessary to enhance the practice of these institutions. In this regard, JAHWAR can play its role in coordinating for this initiative. In addition, Bursa Malaysia is needed to support how to raise fund in systematic ways. At the same time, entrepreneur agencies like TEKUN, MARA can be involved, together with agro-agencies like Jabatan Pertanian Malaysia (DOA), MARDI, FAMA, and Pertubuhan Peladang (PPK).

**Table 4**: List of potential agricultural support agencies

| Agency | Role |
|---|---|
| Jabatan Pertanian Malaysia (DOA) | Assess agricultural suitability, technical advice, crop selection, farming practices, training, MyGAP |
| MARDI | Agricultural technology, R&D, crop production techniques, technical expertise |
| FAMA | Market access, marketing, market information, contract farming, potential buyers |
| Pertubuhan Peladang (PPK) | Farmer networks, agricultural inputs, infrastructure support, training and production coordination |

**Advantages and challenges for model**

In the context of developing idle waqf land, waqf *muaqqat* may serve as a practical framework for creating collaborations among waqf institutions, investors, and project developers. Waqf *muaqqat* allows land or financial resources to be utilized for productive projects such as agricultural development while maintaining the original waqf principles. According to Mahamood (2025), the concept of waqf *muaqqat* provides various benefits for contemporary waqf development. Using waqf *muaqqat* may encourage people and institutions to participate in waqf activities without permanently abandoning ownership of their assets. This flexibility could motivate increased engagement from investors, landowners, and institutions in projects that seek to provide socioeconomic advantages. Furthermore, waqf *muaqqat* can help in creating innovative financial frameworks that integrate charity goals with long-term economic operations.

The funding begins with investors who provide financial capital through an equity crowdfunding platform. The crowdfunding platform functions as an intermediary that mobilises funds from multiple investors for the development of idle waqf land. Under the proposed framework, the SIRC contributes idle waqf land through a waqf *muaqqat* mechanism, allowing the land to be utilised temporarily for productive agricultural activities while preserving its waqf status. Investors contribute capital through the equity crowdfunding platform, whereas the entrepreneurs manage project implementation and agricultural operations.

The integration of waqf *muaqqat* and equity enables a Shariah-compliant financing structure where profits generated from agricultural activities are distributed between SIRC and investors according to a pre-agreed ratio. At the same time, the framework contributes to community development by creating employment opportunities, improving agricultural productivity, and generating social returns for waqf beneficiaries. The proposed framework benefits the community through multiple interconnected mechanisms. The introduction of waqf *muaqqat* enables the activation of idle waqf land for productive use, ensuring that underutilised assets are transformed into economically and socially beneficial resources.

However, it remains unclear how investors would be interested in participating. In fact, if they contribute their funds through waqf *muaqqat,* some investors may allocate the entire contribution, including the profit, to waqf. Others may be driven by charitable objectives but prefer to retain a portion of the returns for personal or institutional use. Some investors may be primarily driven by financial returns while remaining supportive of socially impactful initiatives (Hasan et al., 2024).

Thus, this structure promotes ethical profit-sharing and effective risk management among investors, promoting fairness and transparency in project


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returns. Through equity crowdfunding, the framework enhances financial inclusion by allowing small and retail investors to participate in waqf-based agricultural development, which was previously limited to larger institutional investors. At the operational level, farm activities contribute directly to the community by generating employment opportunities and supporting skills development, particularly in the agricultural sector. Finally, the SIRC share ensures that a portion of the returns is allocated to social programmes and broader waqf-related activities, reinforcing the cycle of social welfare and sustainable community development.

In addition, agriculture can give productive use to idle waqf land while generating economic and social value. Land that is currently unutilised can potentially be converted into productive agricultural assets. However, not every waqf land parcel is agriculturally suitable. Suitability depends on land topography, size and shape of the land, climate and crop suitability (Buang, 2001), flood risk, drought risk and more.

Larger and well-connected parcels can support more commercially viable agricultural activities and allow better use of machinery and infrastructure. Some waqf land may be small, fragmented or difficult to access. A parcel may exist on paper but still be commercially unattractive because it is too small or lacks proper road access (Anem, 2009). Individual plots may be too small to be attractive for commercial or residential development (Ali Azizan et al., 2021). However, a larger size can significantly increase the cost (Abd. Jalil, 2020). Agricultural development needs essential infrastructure such as roads, irrigation, electricity, drainage and water supply. If waqf land lack these essential infrastructures, providing them would require additional capital.

Selecting crops according to market demand and feasibility of land cultivation (Ishak et. al, 2025) are crucial in order to improve the economic viability of the project. Agriculture is exposed to price fluctuations, pests, diseases (Ishak et. al, 2025) and seasonal conditions like flood and drought. Producing a crop does not automatically mean that it will generate sufficient revenue. The project also may face yield and production risk (Ishak et. al, 2025) probably due to extreme weather, pests and diseases. To sum up, agricultural development can transform idle waqf land into productive assets and generate sustainable economic value. But it is also exposed to production, climate, market and cost-related risks. Therefore, these factors should be assessed before project implementation to ensure that the proposed financing model is both agriculturally feasible and financially sustainable.

## CONCLUSION

This study proposes a blended financing framework that integrates waqf *muaqqat* with crowdfunding to support sustainable development of idle waqf land,

particularly within the agricultural sector. The framework is expected to contribute to multiple stakeholders in different dimensions. From a societal perspective, the integration of waqf-based financing and equity crowdfunding has the potential to stimulate local economic development by supporting start-ups and small social enterprises, while also creating employment opportunities across the agricultural value chain, including production, processing, and distribution activities. This study enriches the existing body of knowledge on Islamic social finance, particularly in the areas of zakat, waqf, and crowdfunding, by proposing a structured conceptual framework for blended financing mechanisms.

At the governmental level, the proposed framework may help alleviate fiscal pressure by providing an alternative Shariah-compliant financing mechanism to support small and medium enterprises and rural development initiatives. In the industrial context, the framework empowers micro-entrepreneurs by enhancing their operational autonomy, creativity, and accountability, thereby contributing to the development of agro-based supply chains and strengthening agricultural sector growth. From an environmental perspective, the framework encourages socially responsible entrepreneurship that not only seeks economic returns but also promotes positive social and environmental outcomes.

Overall, this study provides a conceptual contribution that highlights the potential of integrating Islamic social finance instruments with crowdfunding mechanisms to achieve sustainable and inclusive development outcomes, while also aligning with key national and international policy agendas such as the MADANI Economy framework, MyDIGITAL, Sustainable Development Goal 8, the National Entrepreneurship Policy, SEMy2030, and the Value-Based Intermediation principle.

Finally, the study is not without limitations, particularly due to its conceptual nature and the absence of empirical validation at this stage, which suggests avenues for future research. Firstly, the proposed framework has not yet been tested within real-world decision-making or implementation contexts related to idle waqf land development and equity crowdfunding mechanisms. As such, the components and relationships outlined in the framework remain theoretical and represent a hypothetical construct that requires further empirical validation.

Future research is encouraged to conduct case studies or practice-based investigations involving relevant stakeholders such as waqf institutions, policymakers, equity crowdfunding platform operators, investors, and agricultural planners. Such studies would be valuable in assessing the practicality, feasibility, and effectiveness of the proposed framework in real implementation settings. In particular, further work could examine how the integration of Islamic social finance and crowdfunding mechanisms functions within actual governance


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and financing processes, and the extent to which it enhances decision-making, accountability, and sustainability outcomes in waqf land development.

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# MOSQUE TOURISM AND URBAN CULTURAL IDENTITY: A SUSTAINABLE PLANNING FRAMEWORK FOR MALAYSIAN CITIES

**Tengku Fatimah Muliana Tengku Muda[1], Siti Fatimah Salleh[2], Zurita Mohd Yusoff[3], Siti Khatijah Ismail[4], Rahimah Embong[5]**

[1,2,3,4,5]*Faculty of Islamic Contemporary Studies,*
UNIVERSITI SULTAN ZAINAL ABIDIN, MALAYSIA

## Abstract

This article examines mosque tourism as a spatial and cultural mechanism shaping urban cultural identity in Malaysian cities. Focusing on Kuala Terengganu, Melaka, George Town, and Putrajaya, it investigates how mosques function beyond religious institutions to contribute to urban placemaking, heritage representation, and tourism development. Using a qualitative comparative case study approach integrating documentary analysis, visual and spatial analysis, and semi-structured expert interviews, the study identifies three interrelated dimensions: heritage-embedded identity formation, Islamic placemaking, and governance-driven urban integration. Findings show that mosque tourism contributes to urban identity formation, but its expression varies across contexts. Melaka and George Town reflect layered multicultural heritage identities shaped by historical continuity, while Kuala Terengganu demonstrates organic Malay-Islamic spatial identity rooted in traditional settlement patterns. In contrast, Putrajaya represents a planned symbolic Islamic identity shaped through state-led urban design. Islamic placemaking is found to be central in shaping spatial experience and urban legibility, while governance fragmentation may constrain the effective integration of mosque tourism into urban planning systems. The study proposes a conceptual model positioning mosque tourism as a strategic component of urban identity systems rather than a standalone tourism product and highlights the need for integrated planning frameworks that align heritage conservation, tourism governance, and urban design to support sustainable urban cultural development in Malaysia.

***Keywords***: Mosque Tourism, Urban Cultural Identity, Islamic Placemaking, Sustainable Urban Planning, Heritage Cities

[1] Corresponding author. Email: tg_fatimah@unisza.edu.my

## INTRODUCTION

In recent decades, the relationship between tourism, heritage conservation, and urban identity has become increasingly significant within the discourse of sustainable city planning. Contemporary cities are no longer evaluated solely through economic productivity or physical infrastructure, but also through their ability to preserve cultural distinctiveness, strengthen place identity, and create meaningful urban experiences for residents and visitors alike. In this context, cultural tourism has emerged as an important planning instrument capable of enhancing urban vitality while simultaneously reinforcing local heritage values. Malaysian cities, particularly those with strong historical and Islamic civilisational backgrounds, possess considerable potential to position religious and cultural landmarks as strategic components of sustainable urban development. Among these landmarks, mosques occupy a unique position because they function not merely as places of worship, but also as symbols of historical continuity, social cohesion, architectural identity, and cultural representation within the urban landscape.

Globally, mosque tourism has gained increasing recognition as part of religious and cultural tourism, particularly within Muslim-majority countries seeking to diversify tourism products while maintaining cultural authenticity. Unlike conventional tourism attractions, mosque tourism integrates spiritual values, architectural appreciation, heritage interpretation, and intercultural engagement. Mosques frequently become focal points of urban imagery due to their symbolic visibility, strategic spatial location, and historical significance within city formation processes. In many Islamic cities, mosques serve as landmarks that shape urban orientation, communal activities, and socio-cultural interactions. This multidimensional role aligns closely with the broader concept of Islamic placemaking, which emphasises the integration of spirituality, public life, environmental harmony, and cultural identity in urban spaces. Recent studies have also demonstrated that mosques increasingly function as community hubs capable of supporting tourism engagement, educational activities, and social sustainability within urban settings (Baydoun et al., 2025; Harun et al., 2020).

Within the Malaysian context, mosque tourism presents substantial yet underutilised opportunities for sustainable urban and tourism planning. Malaysia possesses a diverse mosque landscape ranging from traditional Malay vernacular mosques to monumental contemporary Islamic architecture. Cities such as Kuala Terengganu, Melaka, George Town, and Putrajaya demonstrate distinctive forms of mosque representation shaped by historical evolution, governance priorities, colonial encounters, and modern nation-building narratives. For instance, Kuala Terengganu reflects the integration of traditional Malay-Islamic identity within riverine urbanism; Melaka represents the integration of Malay, Javanese, Chinese, and colonial influences within historic mosque architecture; George


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Town demonstrates multicultural urban structure through the integration of heritage mosques within its UNESCO World Heritage urban landscape; while Putrajaya projects a contemporary Islamic urban identity through monumental state-led planning and iconic mosque architecture. Collectively, these cities provide valuable comparative contexts for understanding how mosque tourism contributes to urban cultural identity formation and sustainable city branding.

Despite the growing visibility of mosque tourism in Malaysia, existing studies largely focus on architectural appreciation, religious significance, visitor experiences, or heritage conservation independently, with relatively limited attention given to the integration between mosque tourism and urban planning governance. Current literature also tends to examine mosques as isolated tourism attractions rather than as interconnected elements within broader urban cultural systems (Utaberta et al., 2021; Merina & Pratama, 2023; UNWTO, 2018). Consequently, there remains a significant research gap concerning how mosque tourism can be systematically incorporated into sustainable city planning frameworks capable of balancing tourism development, heritage preservation, public space enhancement, environmental sustainability, and cultural identity protection. This issue is particularly critical in rapidly urbanising Malaysian cities where commercialisation, modern redevelopment pressures, and tourism-oriented transformations increasingly threaten local identity and historical urban character.

Furthermore, the growing discourse on sustainable tourism emphasises the necessity of culturally responsive planning approaches that prioritise authenticity, community participation, and heritage continuity rather than purely economic tourism growth. In this regard, mosque tourism offers a potentially sustainable tourism model because it naturally combines cultural education, spiritual appreciation, heritage conservation, and public engagement. However, achieving such sustainability requires coordinated governance involving municipal authorities, tourism agencies, religious institutions, heritage departments, and local communities.

Accordingly, this article examines the relationship between mosque tourism and urban cultural identity through the lens of sustainable urban planning in selected Malaysian cities, namely Kuala Terengganu, Melaka, George Town, and Putrajaya. The study aims to develop a sustainable planning framework that integrates mosque tourism, Islamic placemaking, heritage conservation, and urban governance within the broader agenda of culturally sustainable city development. By analysing the planning characteristics, heritage narratives, tourism functions, and governance structures associated with mosque landscapes in these cities, the article seeks to contribute both theoretically and practically to the growing discourse on religious tourism and urban cultural planning in Malaysia. More importantly, the study aspires to provide policy-oriented insights

for city authorities, planners, heritage managers, and tourism stakeholders in strengthening mosque-based urban identity while ensuring balanced and sustainable urban transformation.

## LITERATURE REVIEW

The relationship between religious heritage, urban identity, and tourism development has increasingly become a focal point in contemporary urban planning discourse. In many global cities, cultural heritage is no longer treated as a static conservation object but as a dynamic urban resource that contributes to place-making, economic diversification, and social cohesion. Within this evolving paradigm, mosques represent a particularly significant typology of religious architecture that transcends their primary spiritual function to become symbolic, spatial, and cultural anchors within the urban fabric. In the Malaysian context, mosque landscapes reflect a layered historical narrative shaped by Malay-Islamic civilisation, colonial interventions, and post-independence nation-building processes, making them central to discussions on urban cultural identity and sustainable tourism planning.

### Mosque Tourism as an Emerging Dimension of Cultural and Religious Tourism

Religious tourism has been widely recognised as one of the most resilient and expanding segments of global tourism, driven by both spiritual motivations and cultural curiosity. Mosque tourism, in particular, has emerged as a distinctive sub-domain that combines religious heritage interpretation, architectural appreciation, and intercultural engagement. Unlike pilgrimage-centric travel, mosque tourism accommodates a broader spectrum of visitors, including non-Muslim tourists who are interested in Islamic art, architecture, and urban history. Studies highlight that mosque tourism contributes to destination attractiveness through its spatial symbolism, aesthetic value, and embedded narratives of Islamic civilisation, particularly in Southeast Asian contexts where Islam is deeply integrated into local culture and governance systems (Bahauddin & Zakaria, 2022; Othman et al., 2025).

In Malaysia, mosque tourism is increasingly associated with well-known architectural landmarks such as the Crystal Mosque in Kuala Terengganu, Masjid Sultan Salahuddin Abdul Aziz Shah in Shah Alam, and the Putra Mosque in Putrajaya, which function as both active religious institutions and iconic tourism attractions. These mosques demonstrate how religious spaces can be strategically integrated into urban tourism circuits without compromising their spiritual integrity, provided that appropriate governance and interpretive frameworks are in place (Othman et al., 2025). However, the integration remains


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uneven, with many mosques still underutilised as part of formal tourism planning strategies despite their high cultural and architectural value.

**Urban Cultural Identity and the Role of Mosques in Place-Making**

Urban cultural identity is constructed through the interaction of physical form, historical continuity, collective memory, and symbolic representation embedded within the cityscape. Within this framework, mosques play a crucial role as both functional and symbolic elements that shape the identity of Muslim-majority cities. Beyond their religious significance, mosques often serve as spatial landmarks that structure urban orientation, define skyline aesthetics, and anchor community life.

In heritage cities such as Melaka and George Town, mosques are embedded within multicultural urban landscapes that reflect centuries of trade, migration, and cultural exchange. Research on these cities demonstrates that sense of place is closely linked to intangible heritage elements such as community attachment, historical continuity, and lived cultural experience, all of which are reinforced through heritage sites including mosques (Bakri et al., 2021). These urban environments illustrate how religious heritage coexists with diverse cultural layers, thereby reinforcing Malaysia's identity as a pluralistic yet historically Islamic-influenced society.

Similarly, Kuala Terengganu represents a Malay-Islamic urban morphology where mosque distribution and spatial organisation reflect traditional settlement patterns and environmental adaptation. Studies on Kuala Terengganu's urban structure reveal that Islamic values are deeply embedded within its planning principles, influencing not only mosque placement but also the broader organisation of urban life (Latip et al., 2020). In contrast, Putrajaya presents a planned administrative city where mosque architecture is deliberately designed as a symbolic expression of Islamic modernity and national identity, illustrating how state-led planning can actively construct urban cultural meaning through monumental religious architecture.

**Sustainable Tourism, Heritage Conservation and Planning Challenges**

Sustainable tourism frameworks emphasise the need to balance economic development with cultural preservation, environmental protection, and community wellbeing. Within heritage cities, this balance is particularly delicate, as tourism development can simultaneously support conservation efforts while also generating pressures such as commodification, overcrowding, and loss of authenticity. The challenge in mosque tourism lies in ensuring that religious spaces retain their sanctity while being accessible and meaningful to visitors.

Recent scholarship on heritage urban quarters highlights that visitor perception is strongly influenced by the integration of built environment quality, interpretive

systems, and cultural narratives, all of which shape emotional and aesthetic responses to place (Zainol et al., 2013; Liu et al., 2024). In this regard, mosques require careful planning approaches that incorporate interpretation tools, visitor management systems, and community engagement strategies to ensure that tourism development aligns with local cultural values.

Furthermore, governance plays a critical role in mediating between tourism objectives and heritage preservation. Studies on heritage management in Malaysian cities indicate that fragmented planning structures often limit the effectiveness of integrating cultural heritage into broader urban development strategies (Xiang & Mohamad, 2023). This is particularly evident in mosque tourism, where coordination between religious authorities, local governments, and tourism agencies is often insufficiently aligned, leading to underdeveloped tourism potential and inconsistent visitor experiences.

Comparative analysis across Malaysian cities such as Kuala Terengganu, Melaka, George Town, and Putrajaya remains underexplored in planning literature, despite their distinct yet complementary representations of mosque-based urban identity. This gap highlights the need for a more holistic planning framework that positions mosque tourism not merely as a cultural attraction but as a strategic urban planning component embedded within sustainability, governance, and placemaking principles.

Accordingly, this study positions mosque tourism as a multi-dimensional urban planning instrument that contributes to sustainable urban cultural identity through the integration of heritage conservation, Islamic placemaking, and tourism governance. By doing so, it seeks to bridge the gap between cultural tourism studies and urban planning practice, offering a framework that is both theoretically grounded and practically applicable to Malaysian city contexts.

## RESEARCH METHODOLOGY

This study adopts a qualitative comparative case study approach to examine the relationship between mosque tourism, urban cultural identity, and sustainable urban planning governance in Malaysian cities. This approach is appropriate for examining socio-cultural, spatial, and symbolic processes that are interpretive and context-dependent (Creswell & Poth, 2018; Yin, 2018). The study focuses on Kuala Terengganu, Melaka, George Town, and Putrajaya, selected through purposive theoretical sampling to represent distinctive mosque-based urban contexts. Kuala Terengganu represents Malay-Islamic coastal urbanism, where mosques are closely associated with traditional settlement patterns and community life (Latip et al., 2020). Melaka represents a multicultural heritage context in which mosques reflect Malay, Chinese, Javanese, and colonial


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influences (Samat et al., 2014; Yaman et al., 2022). George Town represents a pluralistic heritage city where mosques are embedded within a multicultural historic urban fabric, while Putrajaya represents a planned Islamic administrative city characterised by state-led Islamic urban representation. The selection enables comparison across four urban contexts, from organic Malay-Islamic and multicultural heritage settings to pluralistic heritage and planned Islamic environments, allowing examination of how historical and planning conditions shape mosque tourism and urban cultural identity.

Data were collected through documentary analysis, visual and spatial analysis, and semi-structured expert interviews. Documentary sources included urban plans, tourism policy documents, heritage conservation reports, official planning publications, and relevant academic literature. Following Bowen (2009), these materials were reviewed and coded according to mosque functions, planning policies, heritage narratives, institutional responsibilities, and tourism integration. Visual and spatial analysis examined architectural documentation, maps, and photographic records according to mosque location and spatial context, architectural and symbolic characteristics, relationships with the surrounding urban fabric, and connections with heritage and tourism spaces. Visual evidence was interpreted alongside documentary sources to strengthen spatial and contextual interpretation (Dariyadi et al., 2022). Semi-structured interviews were also conducted with two PLANMalaysia officers selected for their professional knowledge of urban planning and mosque development. They were coded as EXP01, Head of Physical Planning and Land Use Unit, and EXP02, Town and Country Planning Officer. The interviews addressed mosque provision, land allocation, development approval, institutional responsibilities, standard design requirements, and implementation processes. Interview evidence was used to clarify and corroborate institutional and planning processes identified through documentary analysis.

Data were analysed using thematic analysis and cross-case comparative analysis. Thematic coding identified recurring patterns concerning mosque tourism, Islamic placemaking, heritage conservation, and urban governance (Braun & Clarke, 2006). Cross-case synthesis was then used to identify similarities and differences among the four cities and to explain how mosque tourism contributes to urban cultural identity across different planning contexts (Yin, 2018). Methodological validity was strengthened through data and theoretical triangulation. Data triangulation integrated documentary, academic, visual, spatial, tourism-related, and interview evidence, while theoretical triangulation drew on urban cultural identity, placemaking, Islamic urbanism, and sustainable tourism governance perspectives. The interview component is limited to two planning professionals and does not directly represent mosque administrators, tourists, local communities, or heritage and tourism authorities.

Nevertheless, combining expert interviews with documentary, visual, spatial, and comparative evidence provides appropriate triangulation for the exploratory nature of the study. Overall, the methodology integrates comparative case analysis, documentary and visual-spatial evidence, expert interviews, and thematic interpretation to examine mosques as cultural, spatial, and symbolic urban assets. This approach supports the development of a planning-oriented framework for sustainable urban governance and mosque tourism.

## ANALYSIS AND DISCUSSION

The analysis demonstrates that mosque tourism in Malaysian cities operates beyond a conventional heritage or religious tourism category, functioning instead as a multi-dimensional urban planning instrument that shapes cultural identity, spatial meaning, and governance structures. Across Kuala Terengganu, Melaka, George Town, and Putrajaya, mosque tourism consistently emerges as both a symbolic and functional anchor of urban identity. However, its expression varies significantly according to historical trajectories, planning regimes, and urban morphology. Rather than treating each city as an isolated case, the findings are organized thematically through three interrelated dimensions: heritage-embedded identity formation, Islamic placemaking dynamics, and governance-driven urban integration.

### Mosque Tourism as Heritage-Embedded Urban Identity Construction

The first finding indicates that mosque tourism plays a critical role in embedding historical continuity within contemporary urban identity. In Melaka and George Town, mosques are deeply embedded within UNESCO-recognised heritage landscapes, where their significance extends beyond religious function to encompass narratives of trade, migration, and multicultural interaction. These mosques function as living heritage markers, reflecting layered historical processes shaped by Malay-Islamic civilisation, colonial encounters, and plural cultural exchanges. This aligns with the historic urban landscape approach, which emphasises identity formation through accumulated cultural layering rather than isolated architectural artefacts (UNESCO, 2011; Bandarin & van Oers, 2012).

In Kuala Terengganu, mosque tourism reflects a different form of identity construction grounded in Malay-Islamic coastal civilisation. Here, mosques are integrated into settlement patterns shaped by riverine geography, traditional economies, and community-based governance systems, reinforcing the spatial embeddedness of cultural identity (Gün, A., 2025; Latip et al., 2020). In contrast, Putrajaya represents a deliberately constructed urban identity, where mosque tourism is instrumentalised to express modern Islamic governance through monumental architectural symbolism. This contrast highlights two


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dominant identity logics: organic heritage formation versus planned symbolic production of identity. This distinction is also reflected in contemporary urban planning practice. An interview with PLAN Malaysia officers indicated that mosque planning is guided by population thresholds, site allocation, and the provision of appropriate land for Islamic religious facilities. This suggests that mosque development is not considered in isolation, but is embedded within broader urban planning and land-use considerations (EXP01, personal communication, December 20, 2024)



(a) Malay-Islamic coastal identity within Kuala Terengganu's riverine and waterfront landscape of Crystal Mosque



(b) Monumental Islamic architecture of Putra Mosque within Putrajaya's planned urban landscape



(c) Mughal influences, Moorish elements and British Colonial features at Kapitan Keling Mosque, Georgetown



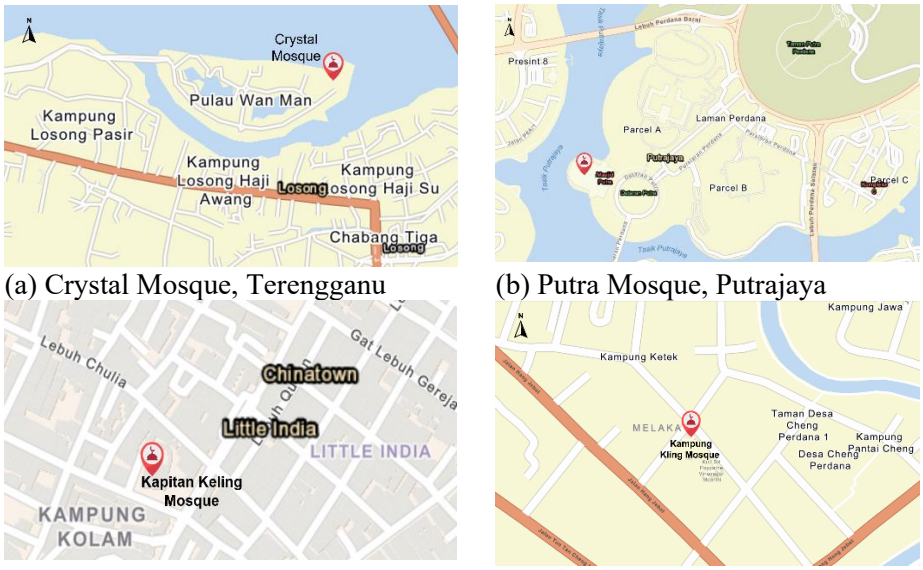
(d) Architectural fusion of Sumatran, Chinese, Hindu, and Melaka Malay influences at Masjid Kampung Kling

**Figure 1:** Comparative Architectural Expressions of Mosque-Based Urban Cultural Identity across the Four Case-Study Cities
*(Sources: (a) Discovery Terengganu (2026); (b) Tourism Malaysia (2026); (c) Kapitan Keling Mosque (2026); (d) Discover Malaysia UNESCO (2026)*

## Islamic Placemaking and Spatial Experience of the City

The second theme demonstrates that mosque tourism contributes to Islamic placemaking by shaping spatial legibility, urban experience, and the relationship between religious landmarks and their surrounding urban environments. Across

the four cities, mosques function as spatial anchors that contribute to visual orientation and the organisation of surrounding urban activities. In Melaka and George Town, mosques are embedded within dense historic urban fabrics where religious, commercial, and cultural activities coexist within relatively compact spatial settings. This reflects placemaking principles that emphasise human-scale interaction and experiential urban quality (Jacobs, 1961; Project for Public Spaces, 2020). In Kuala Terengganu, mosques operate as community focal centres closely connected to waterfronts and traditional kampung structures, reinforcing everyday social cohesion and collective identity. In Putrajaya, Islamic placemaking is highly formalised, where mosque placement is strategically designed as part of a monumental urban composition. While visually dominant, this approach reflects a top-down spatial logic rather than an organically evolved public-space system. These contrasting spatial configurations are illustrated in Figure 2, which situates the selected mosques within their respective waterfront, heritage, multicultural, and planned administrative urban contexts.




(a) Crystal Mosque, Terengganu

(b) Putra Mosque, Putrajaya

(c) Kapitan Keling Mosque, George Town

(d) Kampung Kling Mosque, Melaka

**Figure 2:** Spatial Context of Selected Mosque Tourism Environments
*(Source: DOSM Stats GeoPortal)*

The spatial evidence further demonstrates that mosque-based placemaking is context-dependent rather than uniform across Malaysian cities.


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The Crystal Mosque occupies a distinctive riverine and waterfront setting, while the Putra Mosque is embedded within Putrajaya's formally planned administrative landscape. In George Town and Melaka, Kapitan Keling Mosque and Masjid Kampung Kling are situated within denser historic urban fabrics, reflecting closer spatial relationships between religious heritage and surrounding cultural activities. These variations demonstrate how mosque location and surrounding urban morphology contribute to differentiated forms of mosque-based urban identity. Collectively, Islamic placemaking in Malaysia operates along a spatial continuum ranging from organic socio-cultural spatiality in Kuala Terengganu, through hybrid multicultural heritage spatiality in Melaka and George Town, to institutional-symbolic spatiality in Putrajaya. This continuum provides an analytical bridge for understanding how mosque tourism produces differentiated urban experiences across varied planning contexts. These differences reflect distinct socio-spatial and governance logics shaped by different urban planning models. To synthesise these variations, Table 1 presents a comparative typology of mosque tourism and urban cultural identity across the four cities.

**Table 1**: Comparative Typology of Mosque Tourism and Urban Cultural Identity Across Malaysian Cities

| CITIES | KUALA TERENGGANU | MELAKA | GEORGE TOWN | PUTRAJAYA |
|---|---|---|---|---|
| Type | Organic Malay-Islamic coastal city | Multicultural heritage city | Plural heritage urban fabric | Planned Islamic administrative city |
| Mosque Role | Community anchor | Heritage node | Cultural connector | Symbolic landmark |
| Tourism Mode | Local-cultural experience | UNESCO heritage tourism circuit | Living multicultural tourism | State-led symbolic tourism |
| Identity Formation | Malay-Islamic urban continuity | Layered historical identity | Multicultural coexistence | Institutional Islamic modernity |
| Planning Logic | Community based spatial structure | Heritage regulation & tourism overlay | Conservation & urban diversity | Master-planned top-down planning |

These variations indicate that mosque tourism cannot be approached through a uniform planning model. Rather, its integration into urban planning should respond to the historical, spatial, cultural, and governance characteristics of each city. The comparative typology therefore provides the analytical basis for developing a context-sensitive planning framework that integrates heritage identity, Islamic placemaking, and governance coordination.

**Governance Fragmentation and Planning Integration Challenges**

The third theme highlights a persistent governance challenge in the form of institutional fragmentation across local planning authorities, tourism agencies, religious institutions, and heritage bodies. Although these institutions perform distinct statutory and administrative functions, their responsibilities intersect in the planning, conservation, management, and tourism utilisation of mosque precincts. This fragmentation limits the systematic integration of mosques into urban tourism circuits and city branding strategies, resulting in inconsistent spatial and experiential outcomes.

This institutional complexity is also evident in contemporary mosque development practice. Mosque development involves multiple institutional actors, including federal planning agencies, local authorities, state religious departments, and the Public Works Department (JKR). Responsibilities for land allocation, development approval, standard design, and project implementation are distributed across these different institutional levels (EXP02, personal communication, December 20, 2024). This multi-agency arrangement demonstrates that mosque development is not governed by a single institution but operates through interconnected planning, religious, technical, and administrative structures. While such institutional specialisation reflects differentiated responsibilities, it also highlights the importance of effective inter-agency coordination in integrating mosque development within broader urban planning and tourism strategies. Taken together, the documentary, comparative, and interview evidence indicates that governance fragmentation is associated with differentiated institutional mandates and responsibilities across planning, religious, tourism, and heritage-related functions.

In Melaka and George Town, governance complexity is intensified by overlapping heritage regulations, municipal planning frameworks, and tourism management structures. While these cities benefit from strong heritage branding, mosque tourism is often embedded within broader tourism narratives without dedicated planning mechanisms. In Kuala Terengganu, comparative evidence suggests that governance remains centred on religious institutions, ensuring preservation of sanctity but limiting tourism activation and spatial optimisation. In Putrajaya, governance is more centralised and state-driven, enabling spatial coordination but prioritising symbolic representation over lived community


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engagement. This pattern supports broader urban governance literature which argues that fragmented institutional arrangements weaken the effectiveness of heritage-based urban development and sustainable tourism integration (UNWTO, 2018; Timothy & Nyaupane, 2009). It also underscores the need for integrated governance models that align urban planning, cultural heritage management, and tourism development within a unified strategic framework.

**Conceptual Integration: Toward a Mosque-Based Urban Identity Planning Model**

The findings indicates that mosque tourism in Malaysian cities operates as an integrated urban system comprising three interdependent dimensions; heritage identity construction, Islamic placemaking, and governance coordination. These dimensions do not function independently. Rather, their interaction determines the extent to which mosque tourism contributes to the formation of sustainable urban cultural identity. Heritage identity construction provides the historical and symbolic foundation through which mosques anchor urban memory and cultural continuity. Islamic placemaking translates this heritage into spatial and experiential form, shaping how cities are physically experienced, navigated, and interpreted. Governance coordination, in turn, determines whether these cultural and spatial values are effectively integrated into urban planning and tourism systems or remain fragmented across institutional boundaries.

The comparative analysis suggests that cities demonstrating stronger alignment among these three dimensions, particularly where heritage continuity is reinforced through inclusive placemaking and supported by coordinated governance thus exhibit more coherent and resilient urban cultural identities. In contrast, where institutional fragmentation is evident, mosque tourism tends to oscillate between two extremes: either becoming overly symbolic within state-driven monumental planning or remaining underutilised within heritage contexts with limited spatial activation. This therefore reframes mosque tourism not as an isolated tourism product, but as a strategic planning mechanism embedded within urban identity systems. It highlights the need to view mosques as integrated urban infrastructure that simultaneously supports cultural continuity, spatial experience, and governance alignment in Malaysian cities.

**Planning and Policy Implications**

The findings of this study suggest that mosque tourism should be repositioned within Malaysian urban policy as a strategic component of city identity and spatial planning, rather than being treated as a peripheral tourism product. Across Kuala Terengganu, Melaka, George Town, and Putrajaya, mosques function as active urban anchors that shape cultural identity, tourism experience, and spatial legibility. However, their integration into planning systems remains fragmented,

with limited coordination between urban planners, tourism authorities, and religious governance institutions. This fragmentation constrains the potential of mosques to function as cohesive elements within sustainable urban development frameworks. A key policy direction is the formal integration of mosque tourism into statutory urban planning instruments, including local plans and tourism master plans. This would enable mosques to be systematically integrated within heritage trails, cultural corridors, and surrounding urban spaces, rather than operating as isolated destinations. Such integration is particularly relevant in heritage cities like Melaka and George Town, where mosque-based narratives can strengthen UNESCO-recognised urban heritage landscapes, and in Kuala Terengganu, where mosque networks reflect continuity of Malay-Islamic settlement patterns. The study also highlights the importance of strengthening governance coordination across planning, tourism, and religious authorities. A more structured inter-agency framework is required to ensure that mosque tourism development aligns with both heritage conservation objectives and urban growth strategies. Without such coordination, mosque tourism risks being reduced to promotional activity rather than a managed component of urban cultural planning. This aligns with broader sustainable tourism governance principles that emphasise institutional integration and policy coherence (UNWTO, 2018). In addition, mosque precincts should be reconceptualised as Islamic placemaking environments, where spatial design, accessibility, and public realm quality are treated as planning priorities. This includes improving enhancing surrounding public spaces, and ensuring that mosque environments remain socially inclusive while preserving their spiritual function. In Putrajaya, this would support a shift from purely monumental representation toward more experiential and community-engaged urban spaces, while in traditional cities it would reinforce everyday cultural and social use of mosque environments. Finally, the study emphasizes the need for a shift from attraction-oriented tourism planning to identity-oriented urban governance. Mosque tourism should not be managed solely for visitor numbers or branding value, but as part of a broader strategy for sustaining urban cultural identity and place distinctiveness. This requires planners to recognise mosques as living cultural infrastructure that simultaneously supports spirituality, tourism experience, and urban meaning-making. Such an approach strengthens the long-term resilience of Malaysian cities in maintaining their cultural identity amid rapid urban transformation. Mosque tourism planning should also balance visitor needs with the primary religious function of mosques. Planning and management should therefore consider worshipper needs, sacredness, appropriate visitor etiquette, crowd management, gender-sensitive access, and community acceptance to ensure that tourism activities remain compatible with religious practices and local values. Operationally, the proposed framework involves five planning components; (i)


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key actors comprising planning, religious, tourism, and heritage authorities; (ii) planning instruments such as local plans and tourism master plans; (iii) spatial guidelines for mosque precincts and surrounding urban spaces; (iv) heritage controls to safeguard cultural character and religious authenticity; and (v) monitoring indicators focusing on heritage conservation, spatial integration, visitor management, and inter-agency coordination.

## CONCLUSION

This study demonstrates that mosque tourism is not merely a form of religious or heritage tourism, but an urban phenomenon that contributes to cultural identity, Islamic placemaking, and planning governance. Across Kuala Terengganu, Melaka, George Town, and Putrajaya, mosques function as symbolic and spatial anchors, although their roles vary according to historical and planning contexts. Melaka and George Town reflect layered multicultural heritage identities, Kuala Terengganu represents Malay-Islamic traditions embedded in community and riverine settings, while Putrajaya expresses a more formalised, state-planned Islamic identity. The findings further indicate that the contribution of mosque tourism to urban identity is constrained by fragmented governance and limited integration across planning, tourism, religious, and heritage institutions. Mosque tourism should therefore be repositioned as part of urban cultural infrastructure, supported by coordinated planning mechanisms that integrate heritage conservation, placemaking, tourism management, and urban governance. Such integration can strengthen cultural continuity, place identity, and sustainable tourism while preserving the religious significance of mosques. The study therefore provides a planning-oriented perspective for positioning mosques as active components of sustainable urban identity and governance in Malaysian cities.

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# DEVELOPING A COMMUNITY-BASED WATER RESOURCE SECURITY FRAMEWORK FOR RURAL MALAYSIA: INTEGRATING GREEN TECHNOLOGY AND SOCIAL CAPITAL PERSPECTIVES

**Abang Mohd Razif Abang Muis[1], Abdul Khair Beddu Asis[2], Mohd Sohaimi Esa[3], Mohd Remy Rozaimi Mohd Arif Zainol[4], Septian Aji Permana[5]**

[1,2,3]*Centre for the Promotion of Knowledge and Language Learning,*
UNIVERSITI MALAYSIA SABAH
[1]*Faculty of Social Sciences and Humanities,*
UNIVERSITI MALAYSIA SARAWAK
[4]*School of Civil Engineering, Engineering Campus,*
UNIVERSITI SAINS MALAYSIA
[5]*Faculty of Teacher Training and Education,*
UNIVERSITAS PGRI YOGYAKARTA

## Abstract

Access to safe and reliable water remains a persistent challenge for rural communities in Malaysia, where infrastructural limitations, spatial constraints, and governance fragmentation continue to undermine water security. While technological solutions have been widely promoted, their long-term effectiveness in rural contexts is often constrained by limited community ownership and weak institutional coordination. This paper develops a Community-Based Water Resource Security Framework (CBWSF) that integrates social capital, place-responsive green technology, and institutional coordination. This study used a structured integrative synthesis of peer-reviewed scholarship, Malaysian planning evidence, and national policy documents to derive and connect five dimensions: institutional governance, social capital, green technology, spatial and environmental context, and sustainability monitoring. The framework distinguishes four recurring terrain-settlement configurations (interior highland, riverine floodplain, coastal peat-lowland, and island or stilt settlement) and links each to source, technology, and governance choices. It also translates the National Water Resources Policy and Rural Development Policy 2030 into operational community-level planning actions. The paper contributes a policy-connected implementation logic for rural water planning rather than an empirically validated causal model. Its propositions should therefore be tested through comparative case studies and longitudinal performance assessment.

***Keywords:*** Water resource security; community-based planning; social capital; green technology; rural development

[1] Corresponding author. Email: amrazif@ums.edu.my, amrazif@gmail.com

## INTRODUCTION

Water resource security is a planning concern because reliable access depends on the interaction of source availability, water quality, infrastructure, affordability, governance, and the capacity to maintain services. Globally, rural populations continue to lag behind urban populations in safely managed drinking-water access (World Health Organization, 2023). In Malaysia, treated piped-water access is high overall but remains uneven between states and between urban and rural strata; this indicator should not be conflated with the more demanding international definition of safely managed drinking water (National Water Services Commission, 2022). The residual deficit is concentrated in places where conventional network extension is difficult and where failures have disproportionate consequences for health, livelihoods, and spatial equity.

Rural Malaysia combines climate exposure with demanding physical geography. Drought and intense rainfall can alter source reliability and turbidity, while dispersed settlements, river dependence, steep interiors, peat lowlands, and islands raise capital and maintenance costs (Fulazzaky et al., 2023; Sarbatly et al., 2023). Institutional fragmentation compounds these constraints: responsibilities for resource governance, service provision, rural development, land, and local planning are distributed across agencies and levels of government (Tuah et al., 2022). A uniform infrastructure response is therefore unlikely to be technically appropriate or institutionally sustainable.

Community-based planning offers a complementary response by combining local knowledge, collective responsibility, and external technical support. Evidence across rural water systems shows that participation can improve source protection, monitoring, maintenance, and legitimacy, but only when communities receive durable institutional backing and when roles are explicit (Aashiq et al., 2020; Lockwood & Smits, 2011; Souter et al., 2024). Green technologies can reduce energy and network dependence, yet their performance remains contingent on siting, water quality, operator capability, and access to parts.

This paper develops a Community-Based Water Resource Security Framework (CBWSF) for rural Malaysia. It asks how social capital, green technology, spatial conditions, and institutional arrangements can be organised within a single planning logic, and how that logic corresponds to Malaysia's National Water Resources Policy (NWRP) and Rural Development Policy (RDP) 2030. The contribution is conceptual and planning-oriented: it specifies dimensions, relationships, and decision points that can guide diagnosis and subsequent empirical testing.

## LITERATURE REVIEW

### Rural Water Insecurity as a Planning and Development Challenge

Rural water insecurity is produced by interacting environmental, spatial, socio-economic, and institutional conditions. Climate variability affects quantity and raw-water quality, while groundwater availability varies markedly across settings (Hosea & Khalema, 2021; MacDonald et al., 2021). In Malaysia, climate change increases pressure on resource management and demands more adaptive planning (Fulazzaky et al., 2023). Sabah's rural-water experience further demonstrates that terrain and geographical distance are primary barriers to extending conventional systems, strengthening the case for decentralised and context-specific options (Sarbatly et al., 2023).

Infrastructure alone does not secure service. Rural schemes often deteriorate when financing, spare parts, operator support, water-quality surveillance, or maintenance responsibilities are insufficient (Alvarado et al., 2022; Lockwood & Smits, 2011; Souter et al., 2024). Water-security assessments also show the value of multidimensional indicators rather than a single supply measure (Abdullah et al., 2024; Vieira et al., 2020). The planning problem is consequently one of spatial inequality, lifecycle management, and institutional coordination rather than construction alone.

These conditions require planners to connect settlement form and environmental sensitivity with service standards, implementation capacity, and local governance. A place-based framework should reveal which constraint is binding, who controls the relevant decision, and how performance will be monitored after handover.

### Governance, Institutions, and Decentralised Water Management

Centralised and fragmented governance can weaken responsiveness because authority, finance, and operational knowledge are separated. Sarawak's infrastructure-planning experience illustrates coordination and implementation challenges in remote areas (Tuah et al., 2022). Comparative research likewise shows that decentralisation works only when local institutions have recognised authority, clear accountability, technical assistance, and dependable escalation routes (Prachanda Pradhan et al., 2022; Yu, 2014).

Community management should therefore be understood as co-production rather than state withdrawal. Public agencies retain responsibility for standards, capital support, surveillance, and corrective intervention; village institutions contribute contextual knowledge, day-to-day oversight, and collective action. Leadership ethics and accountability are relevant to this allocation of responsibility, while technical education must combine competence with stewardship (Bennett et al., 2018; Ismail et al., 2025; Kahsay et al., 2023; Kamaruding et al., 2026). The practical implication is a nested governance


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arrangement: a representative local committee operates the system under a written agreement, district actors provide technical and administrative support, and state agencies maintain regulatory oversight. Such an arrangement reduces ambiguity without transferring unreasonable risk to volunteers.

**Community-Based Planning and the Role of Social Capital**

Social capital explains why similarly designed schemes can produce different outcomes. Bonding ties support mutual help within a settlement; bridging ties connect groups across communities and organisations; and linking ties provide access to authorities, expertise, and finance (Carmen et al., 2022; Putnam, 1995). Rural-water studies associate these relationships with participation, rule compliance, monitoring, and maintenance (Aashiq et al., 2020; Rasool et al., 2024; Simarmata et al., 2024). Social capital is not automatically inclusive. Dense networks can reproduce exclusion unless committee design, decision records, grievance channels, and representation requirements protect less powerful users. Sabah research on mutual assistance and intergroup harmony indicates that local networks can mobilise support across social boundaries, but these capacities should be translated into transparent institutional rules. Scholarship on local wisdom similarly supports treating community knowledge as a planning resource to be documented and critically assessed rather than romanticised (Muis & Sintang, 2026; Van Huynh et al., 2020).

**Green Technology and Sustainable Rural Water Infrastructure**

Decentralised green technologies including rainwater harvesting, gravity-fed supply, slow sand or biofiltration, and low-energy treatment can serve settlements for which conventional network extension is costly (Kumar & Choudhury, 2024; Shivaraju et al., 2024). Malaysian evidence on roof-collected rainwater highlights the need for quality control, while research on Sarawak peat water demonstrates that difficult raw-water chemistry requires treatment suited to local conditions rather than generic selection (Frichot et al., 2021; Rahman et al., 2023).

Technology is therefore a socio-technical choice. Source yield, raw-water quality, terrain, energy, storage demand, operator skill, consumables, and replacement parts must be evaluated together. Training and digital documentation may strengthen monitoring, but technology should support, not substitute for, local accountability and human judgement (Beal et al., 2023; Ismail et al., 2025; Li, 2024; Muis et al., 2026).

Existing studies establish the importance of governance, participation, local knowledge, and appropriate technology, but commonly examine them separately. Bennett et al., (2018), Folke et al., (2007) and Muis (2025) advances a local-wisdom-based water-management model; the present paper differs by specifying an integrated planning architecture in which social capital mediates

technology stewardship, spatial diagnosis constrains technology choice, and policy alignment defines institutional support. The unresolved conceptual task is to connect these elements to an operational sequence and explicit monitoring responsibilities.

### Theoretical Foundations

Putnam's (1995) social capital theory provides the principal explanatory lens. Bonding, bridging, and linking relations are treated as distinct resources that can enable collective action, coordinate users, and connect rural communities to formal institutions. The framework does not assume that social cohesion is sufficient or uniformly beneficial; its effect depends on inclusive rules, accountability, and access to material and technical support. The CBWSF embeds social capital within a socio-technical planning system. Spatial conditions define feasible sources and infrastructure; institutions allocate authority and resources; green technology provides a service mechanism; and social relationships influence selection, operation, maintenance, and adaptation. Water security is the outcome of these interactions, assessed through reliability, quality, accessibility, and institutional sustainability.

## RESEARCH METHODOLOGY

### Conceptual Framework Development

This study uses a structured integrative conceptual synthesis to develop a planning framework rather than to estimate an empirical effect. The design follows guidance for theory-synthesis conceptual articles and integrative literature reviews, in which previously separate constructs are connected through explicit organising logic (Jaakkola, 2020; Snyder, 2019). The unit of analysis is the conceptual proposition linking a planning condition, an enabling mechanism, and a water-security implication. The evidence corpus was assembled purposively from peer-reviewed research and official Malaysian documents cited throughout the paper; it was not a preregistered or exhaustive systematic review and no claim of comprehensive coverage is made. This boundary is important because the method supports conceptual integration and analytical transferability, not bibliometric inference or population-level generalisation.

First, sources were retained when they informed at least one of four domains: rural water security outcomes; community governance and social capital; decentralised or green water technology; or rural spatial planning. Priority was given to peer-reviewed empirical or review studies, authoritative policy documents, and Malaysian or comparable rural contexts. Sources unrelated to water planning or unable to support the proposition for which they were cited were excluded. For each retained source, the relevant actor, constraint,


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mechanism, outcome, and contextual condition were identified. Concepts were then coded deductively into availability, quality, accessibility, reliability, governance, collective capacity, technology fit, spatial constraint, and lifecycle monitoring. Apparent contradictions were treated as conditional differences, for example, community management performing differently depending on the level of technical support, rather than averaged into a universal claim. Relationships among these concepts were compared across the four domains. Recurring dependencies, such as institutional support for community maintenance and terrain constraints on technology choice, were retained as framework linkages, while isolated associations were not treated as causal evidence (Binder et al., 2013; McGinnis & Ostrom, 2014).

Second, the synthesis was grounded in rural Malaysia using water access data, sectoral planning evidence, and national policy. Contextual interpretation considered settlement dispersion, terrain, hydrology, raw water quality, institutional mandates, and rural development priorities. The official policy texts were read for objectives, core areas, thrusts, responsible actors, and implementation implications; the open-data indicator was interpreted according to its stated definition. Documentary interpretation was used to preserve policy meaning and historical context (Blasio & Sorice, 2016; Esa et al., 2025; Nugroho et al., 2015), while local-wisdom research informed the treatment of situated knowledge (Fallys et al., 2022; Muis, 2025; Muis & Sintang, 2026).

Third, the concepts were organised into five interacting dimensions: institutional governance, social capital, green technology, spatial and environmental context, and sustainability monitoring. A proposed linkage was included only when it had a plausible planning mechanism, support in the reviewed literature, and a corresponding diagnostic or implementation question. The dimensions were checked against three design criteria: conceptual distinctness, practical observability, and relevance to a planning decision. Redundant elements were consolidated, and policy correspondence was assessed only where the official wording provided a defensible match (Connell & Daoust-Filiatrault, 2018; Macmillan et al., 2016; Rudolf et al., 2017). **Figure 1** presents the resulting architecture. The procedure yields an analytically transparent framework, not an empirically validated model. It cannot establish effect sizes, causal direction, or relative weights among dimensions. Those questions require comparative field application, stakeholder validation, and longitudinal measurement; the framework's present purpose is to structure that research and planning process.

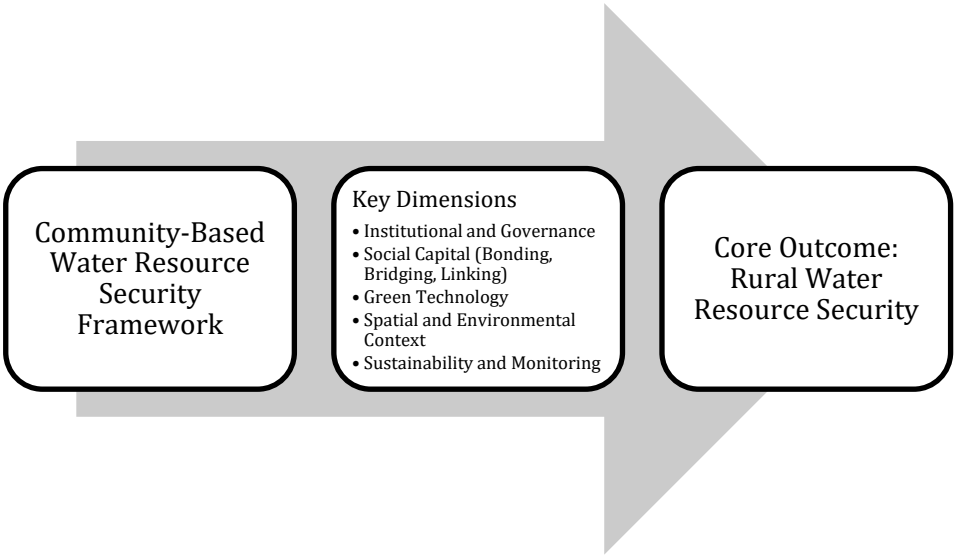



**Figure 1:** Community-Based Water Resource Security Framework (CBWSF).

## ANALYSIS AND DISCUSSION

### The Community-Based Water Resource Security Framework (CBWSF)

The CBWSF treats rural water security as an outcome of five interacting dimensions. It begins with a spatial and service diagnosis, selects a feasible source and technology, assigns institutional and community responsibilities, and establishes monitoring and escalation. No dimension is sufficient by itself: technically sound infrastructure may fail without maintenance, strong local cooperation may be ineffective without formal support, and policy alignment may remain symbolic without place-specific design. The framework is iterative because performance evidence can require redesign of technology, rules, finance, or support arrangements.

### Core Dimensions of the CBWSF

#### *Institutional and Governance Dimension*

Institutional effectiveness requires an explicit division of responsibilities among water authorities, rural development agencies, district and local actors, and village organisations. Each scheme should identify the asset owner, operator, funding source, water-quality surveillance body, maintenance schedule, and escalation route. This converts participation from consultation into accountable co-production (Lockwood & Smits, 2011; Souter et al., 2024; Tuah et al., 2022).


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### *Social Capital Dimension*

Bonding capital supports routine cooperation; bridging capital broadens representation and exchange; and linking capital connects communities to technical, financial, and regulatory resources. The planning task is to cultivate all three through inclusive committee rules, recorded decisions, transparent contributions, and scheduled contact with external agencies (Carmen et al., 2022; Prachanda Pradhan et al., 2022).

### *Green Technology Dimension*

Green technology is selected through fitness for context rather than novelty. Rainwater harvesting may suit islands or peat lowlands, gravity-fed systems may suit protected upland catchments, and modular treatment may suit riverine settlements, provided storage, quality control, energy, operator competence, and supply chains are adequate (Frichot et al., 2021; Kumar & Choudhury, 2024; Sarbatly et al., 2023).

### *Spatial and Environmental Dimension*

Settlement dispersion, slope, flood exposure, peat conditions, salinity, catchment size, and access routes determine the feasibility and lifecycle cost of water options. These variables should be mapped before design because they shape source yield, treatment demand, construction logistics, maintenance access, and vulnerability to disruption. The assessment scale should match the decision: district mapping can screen settlement types and hazards, whereas scheme design requires site-level source, elevation, access, and water-quality data. Figure 2 is therefore an analytical transect, not a georeferenced inventory of all rural settlements.

### *Sustainability and Monitoring Dimension*

Monitoring should combine service indicators (downtime, quantity, basic quality, user access, maintenance completion, and expenditure) with community feedback. Simple records can support adaptive management and district-level escalation; digital tools may improve continuity where connectivity and data governance are adequate (Muis et al., 2026). Monitoring remains a shared public-community responsibility rather than an unfunded local obligation.

## Spatial and Topographical Constraints of Distantly Located Rural Settlements

In this paper, 'distantly located' refers not only to kilometres from an urban centre but to functional remoteness created by terrain, hydrology, access conditions, and weak network connectivity. **Figure 2** distinguishes four idealised but recurring configurations. Sabah evidence identifies terrain variation and geographical

distance as major rural-supply constraints, supporting decentralised solutions where network expansion is impractical (Sarbatly et al., 2023).

Interior highland settlements in the Crocker Range, interior Sabah, and upper Sarawak face steep slopes, difficult road access, and turbidity at upland intakes; gravity-fed systems may be feasible where catchments are protected. Riverine and floodplain settlements along corridors such as the Rajang, Baram, Kinabatangan, and Segama have accessible surface water but experience variable quality, inundation, and linear dispersion, favouring raised intakes, elevated storage, and modular treatment.

Coastal peat-lowland settlements confront acidic, highly coloured raw water, saline intrusion, and unstable ground; Sarawak treatment research confirms that peat-water chemistry materially affects technology choice (Rahman et al., 2023). Island and stilt settlements have limited catchment and groundwater options and may depend on communal rainwater storage or transported supply. These types can overlap; their purpose is diagnostic, linking the dominant spatial constraint to source choice, treatment, storage, access, and the CBWSF governance leverage point.

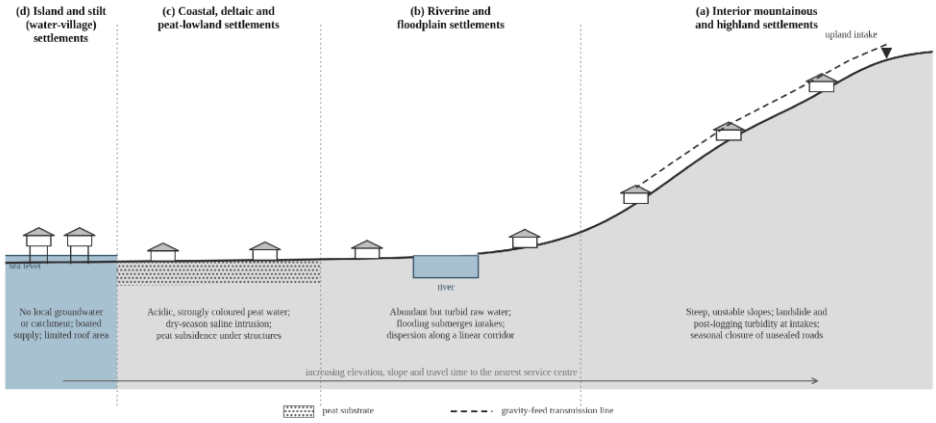



**Figure 2:** Idealised terrain transects of rural Malaysia.

## Operational Logic of the Framework

Operationally, planners apply the CBWSF in six linked steps: (1) diagnose service deficits and terrain-settlement conditions; (2) identify feasible sources and risks; (3) assess community networks, representation, and capability; (4) select technology using lifecycle and operator criteria; (5) formalise roles, finance, maintenance, and escalation; and (6) monitor service and adapt. **Table 1** converts the five dimensions into planning questions and outputs.


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**Table 1:** Key Dimensions of the CBWSF and Planning Relevance.

| Framework Dimension | Key Elements | Planning Relevance |
|---|---|---|
| Institutional and Governance | Local authorities, water agencies, coordination mechanisms | Infrastructure planning, service delivery, policy alignment |
| Social Capital | Trust, networks, community participation | Community-based planning and governance |
| Green Technology | Rainwater harvesting, biofiltration, low-energy systems | Sustainable infrastructure solutions |
| Spatial and Environmental Context | Settlement pattern, land use, topography | Place-based and rural planning |
| Sustainability and Monitoring | Maintenance systems, feedback mechanisms | Long-term resilience and adaptive planning |

## Discussion: Planning, Policy, and Theoretical Implications

### *Implications for Rural Planning Practice*

The CBWSF reframes rural-water planning from a standard asset-delivery exercise to a place-based service system. Its diagnostic sequence helps planners avoid two recurrent errors: selecting technology before understanding terrain and water quality and transferring facilities before defining support and maintenance. Application should produce a spatial diagnosis, technology options appraisal, inclusive governance agreement, lifecycle plan, and monitoring protocol.

### *Institutional and Policy Relevance*

The framework complements the Water Sector Transformation agenda and national development planning by specifying a community-scale delivery mechanism. Its most direct policy anchors are the National Water Resources Policy and the Rural Development Policy 2030, launched in 2019. The CBWSF does not replace statutory mandates; it connects their principles to scheme-level decisions.

### *Alignment with the National Water Resources Policy and the Rural Development Policy*

NWRP organises national action around water resource security, sustainability, partnerships, and capacity building. The CBWSF translates these areas into source integrity and risk diagnosis, stakeholder role allocation, community-agency partnerships, operator capability, and monitoring. Its spatial dimension supports NWRP's concern with resource integrity and disaster risk, while the institutional and social capital dimensions operationalise inclusive shared governance (Ministry of Natural Resources and Environment, 2012).

RDP envisions prosperous, inclusive, sustainable, and holistic rural development by 2030. The CBWSF contributes through comprehensive infrastructure, effective delivery and governance, human capital development, environmental stewardship, and integrated settlement planning (Ministry of Rural

Development, 2019). **Table 2** makes the correspondence explicit and identifies a practical output for each framework dimension.

The policies create a clear planning mandate but do not by themselves prescribe how a remote settlement should match terrain, technology, community capability, and inter-agency support. The CBWSF addresses that operational gap. Its place-based and adaptive logic also aligns with the Thirteenth Malaysia Plan 2026-2030's emphasis on resilient infrastructure and more balanced territorial development (Economic Planning Unit, 2025).

**Table 2:** Correspondence between the CBWSF, National Water Resources Policy, and Rural Development Policy

| CBWSF dimension | Corresponding NWRP core area and thrust | Corresponding RDP thrust | Operational planning implication |
|---|---|---|---|
| Institutional and governance | Core Area 3 (Partnership): Thrust 7, stakeholder inclusiveness and engagement; Thrust 8, shared water resources governance | Effective delivery system and governance | Formal allocation of roles between state water authorities, district offices, and village institutions, recorded in a written operation and maintenance agreement |
| Social capital | Core Area 4: Thrust 9, capacity building and awareness, including joint programmes with higher learning institutions and non-governmental organisations; Core Area 3: Thrust 7 | Quality human capital; prosperous rural living | Constitution of a village water committee with inclusive membership, supported by a recurring training cycle rather than a single handover briefing |
| Green technology | Core Area 1: Thrust 3, use of alternative water resources and sources | Comprehensive and advanced infrastructure | Technology selected against the terrain-settlement typology in Figure 2, with spare parts obtainable within the district |
| Spatial and environmental | Core Area 1: Thrust 2, water resources integrity; Core Area 2: Thrust 6, conservation and protection, including sensitivity mapping in physical planning | Sustainable biodiversity and environment; integrated housing, regional development, and rural settlement planning | Catchment sensitivity mapping and siting rules incorporated into district and local plans before scheme design |
| Sustainability and monitoring | Core Area 1: Thrust 1, water intelligence; Thrust 4, water-related disaster risk reduction, preparedness, and response | Effective delivery system and governance | Simple community-recorded indicators reported to district level, with a defined escalation route when performance falls |

### *Theoretical Contributions*

The theoretical contribution is a conditional account of social capital in rural infrastructure planning. Social capital is positioned neither as a substitute for public capacity nor as an inherently positive community attribute. It becomes productive when institutional support, inclusive rules, and technically appropriate assets convert relationships into reliable collective action. The framework's further contribution is to make spatial context a boundary condition: the same


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social and institutional capacity may require different technologies and support arrangements across highland, riverine, peat-lowland, and island settings. Three propositions follow for empirical testing. First, bonding capital should improve routine operation only when rules and responsibilities are explicit. Second, bridging and linking capital should be more strongly associated with recovery from technical or climate disruption because they provide access to external resources. Third, the relationship between participation and service reliability should be mediated by technology-terrain fit and maintenance support. These propositions distinguish the framework from a descriptive list of desirable factors.

## CONCLUSION

This paper develops a Community-Based Water Resource Security Framework that connects institutional governance, social capital, green technology, spatial context, and sustainability monitoring. The framework makes explicit that durable rural service depends on relationships among these dimensions rather than on infrastructure provision alone. For planning practice, the CBWSF provides a sequence for diagnosing terrain-settlement constraints, appraising sources and technology, allocating roles, and monitoring service. Its mapping to NWRP and RDP 2030 demonstrates how national principles can be translated into community-scale outputs while preserving public accountability. Figure 2 and Tables 1-2 provide concise tools for initial application. The framework remains conceptual. Future research should test its propositions across contrasting Malaysian settlement types using comparative case studies, participatory validation, and longitudinal indicators of water quality, reliability, access, cost, maintenance, inclusion, and institutional response. Such evidence is necessary before causal or performance claims can be made.

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## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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# INSTITUTIONAL DYNAMICS IN SUSTAINABLE TOURISM VILLAGE MANAGEMENT: THE ROLE OF YOUTH AGENCY AND "CAPACITY TO ASPIRE" IN ALAMENDAH, INDONESIA

**Ina Helena Agustina[1], Astri Mutia Ekasari[2], Gina Puspitasari Rohman[3], Muhammed Rafi[4], Azhar Assankutty[5], Riswandha Risang Aji[6], Hazmi Fadhilah Ahmad[7], Safarnaddin[8]**

[1,2,3,6 ,7,8]*Urban and Regional Planning,*
UNIVERSITAS ISLAM BANDUNG, INDONESIA
[4,5] *Department of Commerce and Management Studies,*
MES KALLADI COLLEGE, INDIA

## Abstract

Alamendah Village in Rancabali District, Bandung Regency, has emerged as a prominent tourism destination, distinguished by its effective management under the stewardship of the local younger generation. This study analyzes the institutional ecosystem of Alamendah Tourism Village—a recipient of the Indonesian Tourism Village Award (ADWI)—to elucidate how local actors navigate the transition of the tourism village as an alternative economic source for the community. The objective of this research is to formulate a model of "youth agency" as a catalyst for sustainable Halal tourism. Adopting a constructivist paradigm, the research employed a five-stage phenomenological approach, ranging from phenomenon comprehension to theoretical synthesis. Data were accrued via in-depth interviews (n=15) and participatory observation in Rancabali District, Bandung Regency, and analyzed using NVivo 12 to ensure methodological rigor. To substantiate this qualitative narrative with observable physical evidence, the analysis further incorporates a longitudinal GIS-based spatial assessment of tourism-accommodation growth across four benchmark years (2010, 2015, 2020, and 2025). The findings reveal that Alamendah's success is driven by endogenous youth agency characterized by three institutional dimensions: Entrepreneurial Creativity, where youth diversify products based on ecological assets; Organizational Capacity, functioning as an intermediary for "Integrated Rural Development"; and Social Cohesion, facilitated by higher educational attainment. Theoretically, this study validates Appadurai's concept of "Capacity to Aspire" as a tangible institutional force, empirically corroborated by a 680 per cent increase in tourism accommodation units between 2010 and 2025 whose spatial diffusion directly traces the corridors curated by youth-led institutional governance.

***Keywords***: Institutional Framework, Sustainable Tourism, Youth Agency, Capacity to Aspire, Rural Revitalization, Halal Tourism, Spatial Analysis, Land-Use Governance.

[1] Corresponding author. Email: inahelena66@gmail.com; ina.helena@unisba.ac.id

# INTRODUCTION

The development of tourism villages aims to drive economic growth by highlighting cultural, natural, and local uniqueness as primary attractions. Rural tourism has emerged as a strategic engine for economic revitalization in the Global South, offering a viable pathway to alleviate poverty and mitigate rapid urbanization (Anríquez & Stamoulis, 2007). In Indonesia, this strategy is institutionalized through the "Desa Wisata" (Tourism Village) program, epitomized by the prestigious Indonesian Tourism Village Award (ADWI). However, the sustainability of such initiatives often remains precarious. Despite robust infrastructure investment, the success of village development is ultimately determined by the social capital possessed by the community. This social capital is constructed by the "institutional order"—namely the rules, norms, and organizations that govern interaction (Binswanger-Mkhize & McCalla, 2008).

Alamendah Tourism Village in Bandung Regency presents an intriguing "deviant case" regarding institutional success. Unlike villages dependent on external Foreign Direct Investment (FDI) or top-down government instructions, Alamendah has integrated traditional agrarian livelihoods with a modern tourism economy through internal social cohesion, supported by Bandung Regent Regulation No. 6 of 2020 concerning Halal Tourism. This regulation provides direction for embedding Halal principles within village tourism governance.

Despite this practical success, there remains a paucity of literature explicitly linking Institutional Theory with Youth Agency in the context of Indonesian rural tourism. This study aims to bridge this gap by deconstructing Alamendah's institutional system. It posits that the primary driver of resilience is not solely government policy, but the "Capacity to Aspire" (Appadurai, 2007) cultivated among local youth. This capacity acts as a navigational tool, enabling the community to bridge the gap between current village development and future projections of sustainable prosperity. To move beyond narrative claims alone, the study further triangulates this institutional account with a longitudinal spatial analysis of physical land-use change, thereby anchoring the concept of youth agency in observable transformations of the village landscape.

# RESEARCH METHODOLOGY

## Research Design and Philosophical Paradigm

This study adopts a qualitative constructivist paradigm, utilizing a phenomenological approach to explain institutional dynamics. This perspective was selected to capture the "lived experiences" of local actors, investigating the processes and agency behind the village's success rather than merely measuring quantitative outputs. This qualitative core is complemented by a supplementary

quantitative spatial (GIS) analysis of land-use change, employed not to test hypotheses but to triangulate and materially substantiate the institutional processes narrated by informants.

## Study Area and Site Selection

Fieldwork was conducted in Alamendah Village, Rancabali District, Bandung Regency, West Java. This location was selected through purposeful sampling as it represents a successful model of "endogenous development." Having received the ADWI award, the village is geographically situated in a highland tea plantation area, bordering Margamulya (North) and Ciwidey (South), making it a strategic locus for agrotourism integration, as delineated in the administrative map presented in Figure 1.

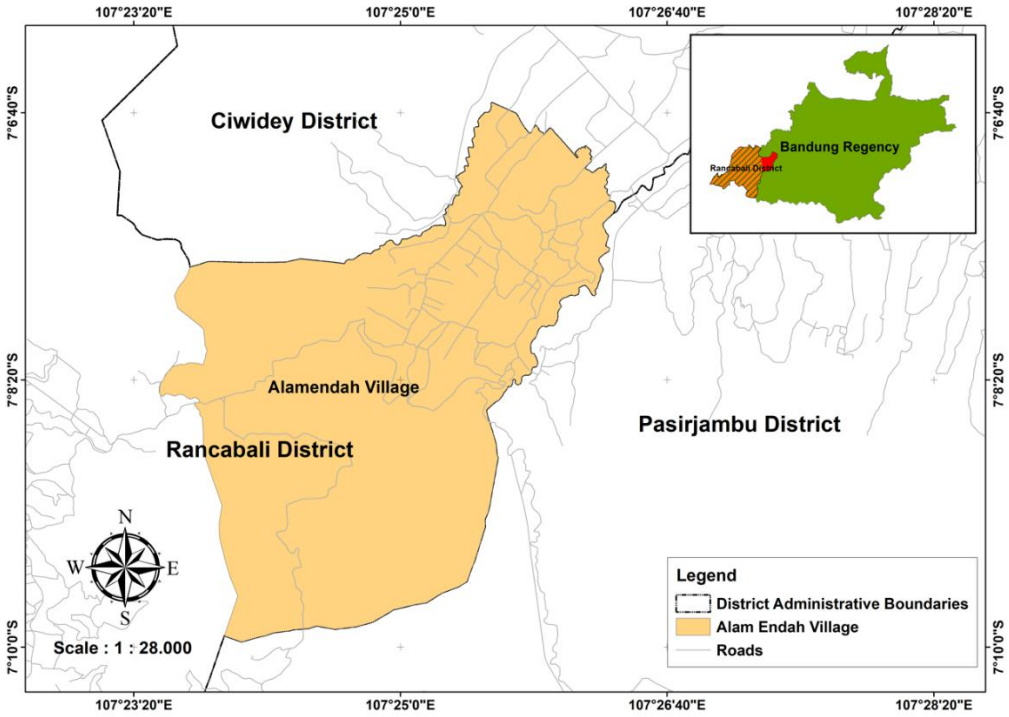



**Figure 1:** Administrative Map of Alamendah Village, Rancabali District, Bandung Regency
*Source: Authors' GIS analysis (2026), based on Rancabali District administrative boundary data and village monographic records*


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## Data Collection Techniques

To ensure rigor and data saturation, the study employed triangulation:

- In-depth Semi-structured Interviews: Conducted with stakeholders identified through snowball sampling (n=15). Participants included Village Officials (for the regulatory landscape), Youth Leaders/Local Figures (specifically key actors identified as 'Kang X' and 'Teh Y'), and Community Elders (for social acceptance).
- Participatory Observation: Researchers immersed themselves in daily village activities for three months, observing the management of attractions (e.g., Bird Watching, Agro-trekking) and the operations of local groups (Pokdarwis).
- Document Review: Analysis of the Village Medium-Term Development Plan (RPJMDes) and ADWI assessment documents.
- Spatial and Land-Use Data: Point-location data on tourism accommodation units for four benchmark years (2010, 2015, 2020, and 2025) were compiled from village monographic records and ADWI documentation, verified through field observation, and mapped using Geographic Information Systems (GIS) following the facility-mapping approach of Fan and Subrina (2025) to visualize the physical footprint of institutional governance.

## Analytical Framework

Data were analyzed using a thematic analysis framework supported by NVivo 12 Pro software to ensure auditability and systematic coding. The analysis proceeded through three coding layers: Open Coding (identifying initial concepts), Axial Coding (grouping concepts into categories), and Selective Coding (establishing core themes). The step-by-step analysis flow is visualized in Figure 2. To strengthen the credibility of the institutional claims emerging from this thematic coding, the qualitative results were subsequently triangulated with a quantitative spatial analysis of land-use change, detailed in the Discussion section.

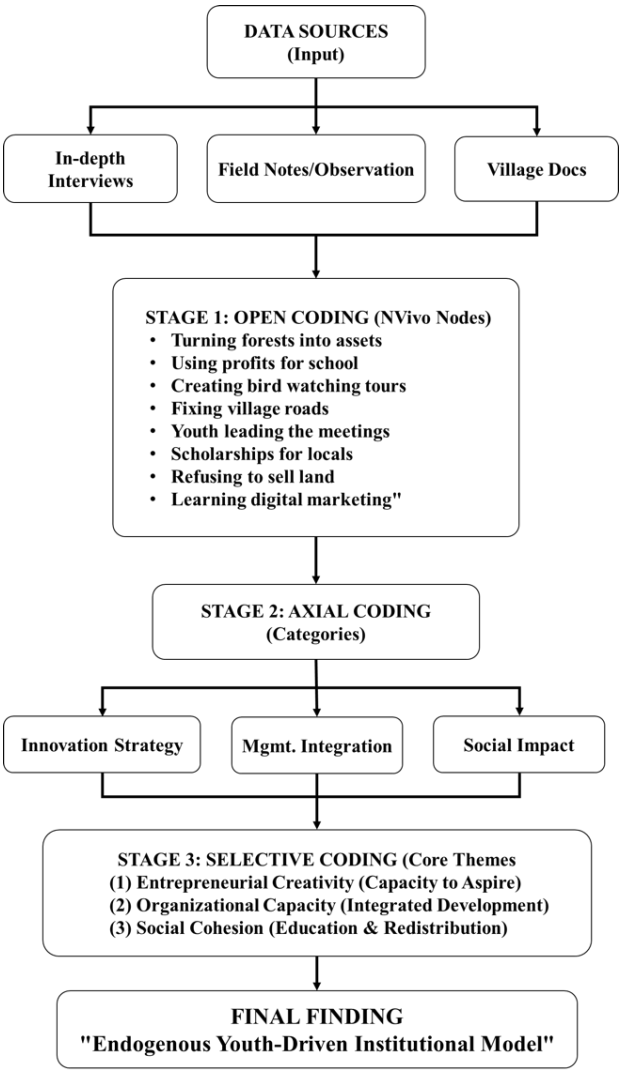



**Figure 2:** Thematic Analysis Framework using NVivo 12
*Source: Authors (2026)*

## RESULTS AND DISCUSSION

The interpretation of phenomena in Alamendah Village reveals that institutional resilience relies heavily on local youth agency. This agency manifests in three interconnected dimensions: Business Creativity, Organizational Capability, and Social Cohesion.


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## Results

### *Local Youth and Business Creativity*

Findings indicate that local youth groups, led by figures such as Kang X (pseudonym) and Teh Y (pseudonym), have successfully diversified the rural economy. Unlike traditional models that rely passively on landscape views, these youths have engineered specific tourism products tailored to local potential, such as Bird Watching and Plantation Trekking. This diversification represents a cognitive shift. As expressed by Kang X in an interview regarding the transition from agriculture to ecotourism:

> *"Previously, we only saw the forest as a source of timber or land to plant potatoes. But then we realized, if we cut down the trees, the money comes only once. If we sell the 'Bird Watching' experience, the trees remain, the birds remain, and the income flows forever. We match our village's nature with what city people long for."* (Interview with Youth Leader, 2024).

This statement empirically validates Appadurai's (2007) concept of "Capacity to Aspire." It demonstrates that aspiration is not a fixed trait but a "navigational capacity" nurtured through practice. The youth navigate the "dense combination of nodes and pathways" between their agrarian present and a tourism-oriented future. By transforming "dormant assets" into economic value, they connect dreams with viable pathways, making Alamendah a competitive Tourism Village.

### *Organizational Capability for Integrated Rural Development*

The second finding is the sophisticated Organizational Capability of the youth. Youth groups do not operate in a vacuum; they function as a bridge for "Integrated Rural Development" (Binswanger-Mkhize & McCalla, 2008). Data shows that youth manage the intersection of education, infrastructure, and environmental sustainability. Teh Y, a key organizational figure, highlighted this integration:

> *"We don't just run a business. Profits from the glamping sites and trekking guides go partly into the village treasury. We use it to repair roads and support school activities. If the village is messy, tourists won't come. So, tourism manages the village, and the village supports tourism."* (Interview with Pokdarwis Member, 2024).

This aligns with the assertion that rural development components cannot be treated independently (Baldock et al., 2001; Nemez, 2005). Alamendah youth have implemented an integrated strategy where tourism profits cross-

subsidize public goods, fostering an entrepreneurial cycle (Chambers & Conway, 1991). This finding addresses a common failure in rural development: the lack of local institutional capacity (McAreavey, 2009). In Alamendah, the youth are the institution.

### *Social Cohesion and the Role of Education*

The third critical aspect is Social Cohesion, underpinned by educational attainment. Local youth demonstrate a "broader vision" of social policy, prioritizing nation-building and redistribution (Anríquez & Stamoulis, 2007; Gallie & Jacobs, 2003). The ability of Alamendah's youth to pursue higher education has catalyzed this cohesion. Education acts as a primary driver for empowerment and critical thinking (Ahmad et al., 2023; Redding, 2023). Empowered individuals in Alamendah have become agents of change, leveraging their resilience to confront socio-economic shifts (Borase, 2023). In contrast to the "brain drain" phenomenon often seen in rural areas, Alamendah is experiencing "brain gain," where educated youth return to manage complex tourism systems.

Taken together, these three institutional dimensions do not operate merely as abstract social processes: as the following discussion demonstrates through spatial analysis, they materialize into observable, spatially measurable transformations of the village's physical landscape.

## Discussions

### *Reconstructing Collaborative Planning as an Institutional Catalyst*

In contemporary planning discourse, Healey (2006) argues that planning is not merely spatial allocation but a process of consensus-building through the reshaping of institutional culture. Healey emphasizes the importance of communication among stakeholders to bridge social hierarchies. Alamendah Village possesses distinct hierarchical social structures; however, the "collaborative space" has been actively created by the village's younger generation.

Complementing Healey's perspective, Judith Innes and David Booher in *Planning with Complexity* (Innes & Booher, 2018) introduce the concept of Collaborative Rationality. They assert that for collaboration to produce resilient decisions, "authentic dialogue" meeting the conditions of diversity and interdependence is required. Innes (1996) emphasizes that consensus is not merely compromise, but the result of joint learning. However, existing literature rarely elucidates *who* initiates this joint learning in rural communities transitioning from agriculture to tourism. Herein lies the limitation of Western planning theory when applied directly to the context of Indonesian tourism villages.


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This study in Alamendah offers theoretical novelty by positioning Youth Agency as the "missing link" in collaborative planning theory. Field findings indicate that collaborative rationality does not emerge from top-down bureaucratic mandates but is initiated organically by youth. Contrary to Healey's assumption of broad public participation, in Alamendah, collaboration begins with a specific segment—the youth—acting as intermediaries. They translate the language of modern tourism bureaucracy into terms acceptable to the customary norms and religious values held by village elders.

This research reveals that institutional success in Alamendah is the result of integrating Appadurai's (2004) "Capacity to Aspire" with Healey's framework. In this case, the Capacity to Aspire functions as the engine of Collaborative Planning. Without the youth's aspiration to transform "dormant assets"—such as forests and plantations—into new economic value, the collaborative institutions imagined by Healey would not form. The youth of Alamendah are not only planning *for* the future; they are using their cultural aspirations to *navigate* the current institutional map.

***The Youth-Driven Institutional Continuum Model***

Empirical evidence from Alamendah challenges traditional narratives of rural decline. The emergence of these youth figures aligns with Chen et al., (2022), who describe "rural tourism makers" as critical agents in bridging the rural-urban divide. Unlike passive aid recipients, Alamendah's youth demonstrate what Han (2020) identifies as the pivotal role of skilled labor in promoting revitalization. These youths exhibit inward-directed "lifestyle mobility," transforming the village into a fashionable destination (Yamagishi & Doering, 2025). Furthermore, the transformation of tea plantations into glamping sites represents profound "spatial restructuring" (Gao & Cheng, 2020). This validates the theory of Bi & Yang (2023) regarding the spatial production of rural settlements, where traditional spaces are reconfigured into commercial assets without losing their rural essence—a process requiring careful governance to avoid gentrification (Kan, 2021). This study concludes that the institutional success of Alamendah Tourism Village is not solely a product of government policy, but the result of Endogenous Institutional Construction driven by youth agency.

The Youth-Driven Institutional Continuum Model illustrates that sustainable rural tourism relies on three pillars (see Figure 3):

1. Spatial-Economic Optimization: Natural assets are creatively commodified through the "Capacity to Aspire."
2. Digital-Financial Inclusivity: Mediated by educated youth acting as digital brokers.
3. Cultural-Social Cohesion: Ensuring development benefits the broader community through redistribution.

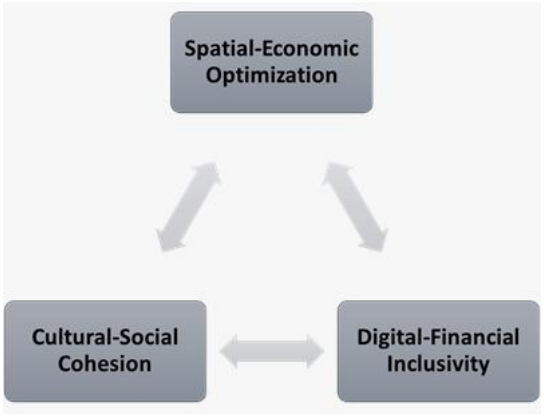



**Figure 3:** Youth-Driven Institutional Continuum Model
*Source: Authors (2026)*

***Spatial Analysis: Institutional Governance and Land-Use Transformation (2010–2025)***

To substantiate the Spatial-Economic Optimization pillar with observable physical evidence, this study extends the qualitative findings with a longitudinal spatial analysis of tourism accommodation units across the Ciwidey–Rancabali tourism-village cluster in which Alamendah is embedded. Point-location data for four benchmark years—2010, 2015, 2020, and 2025—were mapped in a Geographic Information System (GIS) and cross-verified against village monographic records and field observation, following the GIS-based facility-mapping approach recently applied to rural tourism governance by Fan and Subrina (2025). The resulting distribution maps (Figure 4) and growth trend (Figure 5) allow the institutional narrative developed above to be read directly onto the village landscape.


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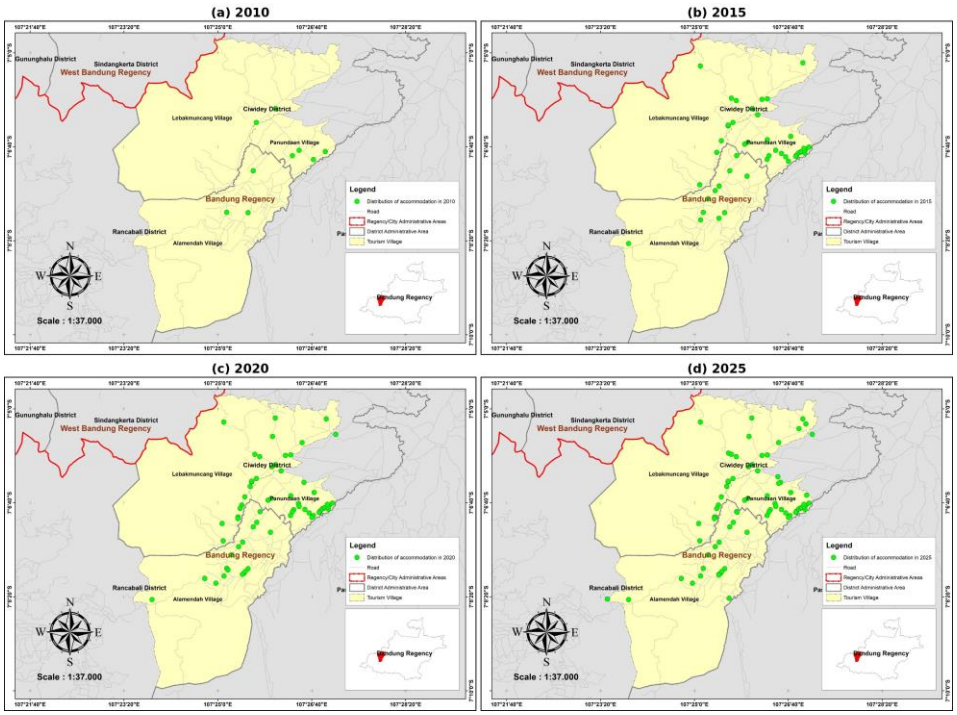



**Figure 4:** Spatial Distribution of Tourism Accommodation in the Ciwidey–Rancabali Tourism Village Cluster, 2010–2025
*Source: Authors (2026)*

As shown in Figure 4, the spatial pattern of accommodation shifted from a small, tightly clustered node of ten units concentrated around the Ciwidey District centre and its main arterial road in 2010 (Figure 4a) to a dispersed, linear pattern that progressively followed secondary access roads southward through Panundaan Village into Alamendah and the Rancabali periphery by 2025 (Figure 4d). This trajectory corroborates the "spatial production of rural settlements" documented by Bi and Yang (2023) and the tourism-driven spatial restructuring identified by Gao and Cheng (2020), while adding a distinctive governance signature: new nodes did not emerge randomly but along corridors actively curated by the youth-led collaborative institutions described above, as forest and tea-plantation plots were incrementally converted into glamping sites, homestays, and trekking bases. This governance-mediated diffusion pattern mirrors the mechanism recently identified by Zhang et al. (2026), who demonstrate that tourism-driven rural land-use change in metropolitan suburbs follows the institutional capacity of local actors rather than market forces alone.

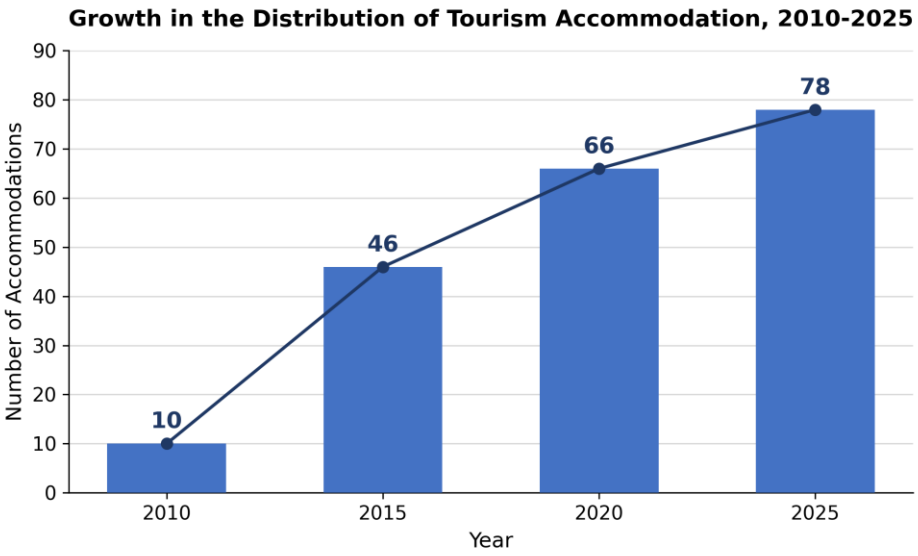



**Figure 5:** Growth Trend in the Number of Tourism Accommodation Units, 2010–2025
*Source: Authors (2026)*

This spatial diffusion is corroborated by the quantitative growth trend in Figure 5: the number of accommodation units rose from 10 in 2010 to 46 in 2015, 66 in 2020, and 78 in 2025—an increase of 680 per cent over fifteen years. The steepest increment (10 to 46 units, 2010–2015) coincides with the formative phase of youth-led organizational capability identified in the Results section, whereas the more moderate but sustained growth after 2020 corresponds to the consolidation of formal governance support following Bandung Regent Regulation No. 6 of 2020 concerning Halal Tourism. This pattern empirically echoes Wang et al. (2023), who demonstrate that the spatial distribution of rural governance demonstration villages in China is directly shaped by institutional and organizational factors rather than infrastructural endowment alone.

Taken together, these spatial findings respond directly to recent calls in the land-governance literature for closer coupling between regulatory institutions and observable land-use outcomes (Kourkouridis et al., 2026). In Alamendah, the youth-driven "Capacity to Aspire" functions as the missing institutional mechanism that translates policy instruments into measurable spatial-physical transformation—expanding accommodation supply and converting dormant agrarian assets into tourism infrastructure—while avoiding the land-market gentrification risk that Kan (2021) warns can accompany unmanaged rural tourism commodification. The spatial evidence thus reinforces, rather than merely illustrates, the institutional argument advanced in this study.


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## CONCLUSION

Based on the research objective to formulate a model of "youth agency" as a catalyst for sustainable Halal tourism, this study formulates three pillars: (1) Spatial-Economic Optimization, (2) Digital-Financial Inclusivity, and (3) Cultural-Social Cohesion. This research substantiates the form of "Capacity to Aspire" embodied by the village's younger generation, demonstrating that institutional governance produces not only social outcomes but also measurable physical transformation: longitudinal GIS analysis confirms a 680 per cent increase in tourism accommodation units between 2010 and 2025, diffusing along corridors actively curated by youth-led institutions rather than emerging from market forces or infrastructure investment alone. The findings provide a recommendation that rural human resources, particularly youth, serve as social capital and the driving engine of collaborative planning in village institutional development, while the accompanying spatial evidence underscores the need for continuous governance oversight so that this land-use transformation remains inclusive and does not tip into unmanaged commodification or gentrification.

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# PROJECT MANAGEMENT OFFICES AS ADAPTIVE PLANNING GOVERNANCE SYSTEMS: A RISK-DRIVEN CAPABILITY TRANSFORMATION MODEL

**Alin Veronika[1], Yusuf Latief[2], Leni Sagita Riantini[3]**

[1,2,3] *Civil Engineering Department, Faculty of Engineering,*
UNIVERSITY OF INDONESIA, INDONESIA

## Abstract

Project Management Offices (PMOs) are widely adopted to support coordination and governance in project-based organisations, yet their performance impact remains inconsistent, particularly within urban infrastructure and construction planning organisations, where multi-project coordination and regulatory complexity are most pronounced. Existing studies typically examine PMO capability, risk, or transformation in isolation and often assume linear relationships with performance. This study reframes PMOs as adaptive governance systems and examines how Capability (C), Risk Activation (R), Adjustment (A), and Performance (P) interact to shape organisational outcomes. Using survey data from 243 practitioners and structural equation modelling, the study shows that PMO capability conditions governance stability but does not directly suppress risk or guarantee performance. Risk does not directly impair performance; instead, it functions as an activation signal that triggers organisational adjustment. PMO transformation emerges as the primary stabilisation mechanism, mediating the effects of both capability and risk on performance. By conceptualising performance as an emergent system outcome, this study advances PMO research beyond maturity and role-based explanations and offers a mechanism-based account of governance behaviour under disturbance. The findings are particularly relevant to the governance of large-scale urban development projects, where capability transformation determines whether coordinated delivery is sustained under planning and regulatory disturbance.

***Keywords***: project management office; adaptive governance; risk activation; organisational capability; PMO transformation

[1] Corresponding author. Email: alin.veronika@ui.ac.id

## INTRODUCTION

Project-based organisations increasingly operate under conditions of uncertainty, fragmentation, and interdependence, where coordination and governance coherence are difficult to sustain. Decisions are often distributed across multiple projects, information flows unevenly across organisational boundaries, and responsibilities shift as priorities evolve. In such environments, instability is not an exception but a recurrent condition that challenges the translation of intent into coordinated action. Empirical studies have shown that unclear decision authority, inconsistent governance routines, and weak coordination mechanisms frequently disrupt organisational performance and lead to rework, delay, and loss of coherence (Long et al., 2004; Mohammed A. Altaefi & Altaefi, 2022; Shah & Kengatharan, 2011).

Project Management Offices (PMOs) are widely adopted to address these challenges by providing structure, standardisation, and coordination across projects. Prior research has examined PMOs from multiple perspectives, including their roles, functions, maturity levels, and capability configurations. Studies have distinguished between strategic and operational PMO roles, highlighting differences in how PMOs support alignment, governance, delivery, and value management (Andersen et al., 2007; Low & Yeow, 2004). Despite this growing body of work, empirical findings remain mixed. Some studies report positive performance effects associated with PMO capabilities, while others find limited or inconsistent impact, particularly for strategic PMO roles. This inconsistency is especially consequential in urban infrastructure and construction planning organisations, where PMOs are directly responsible for coordinating multi-project portfolios, managing regulatory approval processes, and sustaining alignment across the fragmented actors involved in large-scale urban development.

A related stream of research has examined risk in project and organisational contexts. Risk is commonly treated as a negative condition that directly undermines performance, often operationalised through project-level hazards, uncertainty, or exposure to adverse events (Ershadi et al., 2021; Lines et al., 2015; Nisrina et al., 2025). Within PMO research, risk is typically examined as something to be mitigated through stronger controls, better processes, or improved capability. However, this treatment implicitly assumes a linear relationship between risk and performance and overlooks how organisations actually respond when risk becomes visible.

Taken together, these streams reveal a persistent gap in the literature. Capability, risk, and organisational response are frequently analysed as separate phenomena. What remains underexplored is how these elements interact as part of a broader governance system, particularly under conditions where routine coordination mechanisms are no longer sufficient. From a systems perspective,

performance outcomes depend not only on structural conditions or the presence of disturbance, but on how organisations absorb, interpret, and respond once stability is disrupted (Leveson, 2011; Sterman, 2000). Yet this perspective has rarely been applied to PMOs as organisational governance mechanisms.

This study addresses this gap by reframing PMOs as adaptive governance systems and by examining the interaction among Capability (C), Risk Activation (R), Adjustment (A), and Performance (P). Capability is conceptualised as a conditioning structure that shapes organisational sensitivity to disturbance; risk as an activation signal that reveals misalignment rather than directly impairing outcomes; and adjustment, operationalised as PMO transformation, as the mechanism through which stability is restored.

By explaining PMO effectiveness as a system-level adaptive process rather than a linear capability–performance relationship, the study contributes a coherent account of how governance structures behave under pressure. The findings help clarify why organisations with similar capability profiles and risk exposure can experience divergent performance outcomes and position PMOs as adaptive infrastructures that support coordination and coherence in complex, multi-project environments.

**Sector Specificity and Planning Governance Relevance**

Although the respondent sample spans multiple project-based sectors, more than half are drawn from construction and infrastructure planning organisations (53.09%), the segment of the built environment most directly engaged in urban development governance. Within this sector, PMOs are rarely confined to single-project execution; instead, they operate as coordinating structures across programmes of urban infrastructure delivery, where planning approvals, land-use constraints, multi-stakeholder authority, and phased regulatory compliance introduce distinct sources of governance instability. Capability Transformation, examined in this study as organisational Adjustment, is therefore interpreted specifically as the mechanism through which PMOs in these organisations reconfigure planning governance routines, authority structures, and coordination mandates when misalignment across urban development programmes becomes visible. Framing the C–R–A–P model in this way positions PMO transformation not merely as a generic organisational response, but as a planning governance capability that determines whether large-scale urban development projects sustain coordinated delivery under conditions of institutional and regulatory disturbance.


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# LITERATURE REVIEW

## PMOs as Governance Mechanisms in Project-Based Organisations

Project-based organisations rely on temporary structures to deliver permanent strategic outcomes, creating inherent coordination and governance challenges across multiple projects. Prior research positions governance in such contexts as a mechanism for aligning authority, decision-making, and control across organisational levels rather than merely enforcing compliance (Müller & Söderlund, 2015; Turner, 2014).

Within this context, Project Management Offices (PMOs) have been widely conceptualised as organisational governance mechanisms that connect strategy, portfolios, and projects. Early studies emphasise the role of PMOs in establishing standards, monitoring performance, and supporting coordination across projects (Hobbs & Aubry, 2010; PMI, 2025). Subsequent research highlights that PMOs evolve in response to organisational needs rather than remaining static structural units (Aubry, 2011; Joslin, 2022).

These studies suggest that PMOs operate within dynamic organisational environments where stability cannot be assumed. Governance effectiveness therefore depends not only on formal structures, but on how PMOs adapt their roles when alignment between strategy, governance, and delivery is disrupted (Pellegrinelli & Garagna, 2009).

## PMO Capability as Organisational Conditioning (C)

PMO capability has been examined extensively through role typologies, functional scope, and maturity models. A recurring distinction differentiates strategic PMO capabilities, such as strategic alignment and benefits oversight, from operational capabilities, including standardisation, delivery support, and control (Andersen et al., 2007; Aubry et al., 2007).

Empirical evidence regarding the performance impact of these capabilities remains mixed. While operational capabilities are often associated with improved delivery consistency, strategic PMO roles show less consistent direct effects on organisational performance (Aubry, 2011; Müller & Lecoeuvre, 2014). This inconsistency suggests that capability alone does not guarantee performance outcomes.

Several studies therefore argue that PMO capability should be understood as a structural conditioning factor that shapes governance coherence and coordination readiness rather than as a direct performance driver (Aubry & Hobbs, 2011; Pellegrinelli & Garagna, 2009). Capability establishes the organisational conditions under which disturbances are either absorbed or amplified.

**Risk in PMO and Project Governance Research (R)**

Risk has traditionally been treated in project research as exposure to uncertainty that negatively affects cost, schedule, and quality outcomes. Within PMO studies, risk is commonly framed as something to be mitigated through stronger governance, standardisation, and control mechanisms (Andersen et al., 2007; Aubry et al., 2007).

However, empirical findings indicate that organisations with comparable governance structures and risk exposure often experience divergent performance outcomes. This observation challenges the assumption of a linear risk–performance relationship and suggests that risk does not operate as a direct performance determinant (Hobbs et al., 2010).

Emerging perspectives in project governance research conceptualise risk as a signal of misalignment that becomes visible when existing coordination mechanisms are insufficient (Aubry et al., 2011; Ershadi, 2021). From this view, risk indicates pressure on governance arrangements rather than directly causing performance degradation.

**Adjustment and PMO Transformation (A)**

PMO transformation has been widely documented as a recurring phenomenon rather than an exceptional event. Studies show that PMOs frequently change their mandates, structures, and governance roles in response to organisational pressures, strategic shifts, or perceived misalignment (Aubry, 2011; Joslin, 2022). Rather than representing linear maturity progression, transformation is increasingly viewed as an adaptive response through which organisations attempt to restore governance coherence. Such adjustment may involve redefining authority, reallocating responsibilities, or reconfiguring coordination mechanisms across portfolios and projects (Aubry et al., 2007; Müller & Lecoeuvre, 2014).

This perspective positions PMO transformation as a dynamic governance capability that enables organisations to respond once existing structures no longer stabilise performance.

**Performance as an Emergent Governance Outcome (P)**

Performance in project-based organisations is commonly assessed through indicators of efficiency, consistency, and reliability across projects. While many studies implicitly assume that stronger PMO capability leads directly to improved performance, empirical evidence remains inconclusive (Andersen et al., 2007; Aubry & Hobbs, 2011).

Recent governance-oriented research suggests that performance should be understood as an emergent outcome resulting from interactions between organisational structures, risk conditions, and adaptive response (Müller et al.,


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2019; Pellegrinelli & Garagna, 2009). Performance stability therefore depends not only on baseline capability, but on how organisations adjust when misalignment becomes visible.

### Research Gap and Conceptual Positioning

Although PMO capability, risk, and transformation have each been extensively studied, they are rarely integrated into a single explanatory framework. Existing research tends to examine capability–performance or risk–performance relationships in isolation, often assuming linear effects (Andersen et al., 2007; Aubry et al., 2007).

This study addresses this gap by integrating these elements through a Capability–Risk–Adjustment–Performance (C–R–A–P) framework, positioning PMOs as adaptive governance systems. The framework examines how capability conditions governance stability, how risk activates organisational response, and how adjustment restores performance coherence. The empirical testing of this framework is presented in the following section.

## RESEARCH DESIGN AND METHODS

### Research Design

This study adopts a quantitative, explanatory research design to examine how Project Management Offices (PMOs) function as adaptive governance systems in project-based organisations. A cross-sectional survey approach was employed to capture practitioners' assessments of governance capability, perceived risk activation, transformation responses, and performance outcomes.

The unit of analysis is the organisational PMO operating within a project-based environment. This focus is appropriate given the study's emphasis on governance behaviour beyond individual project execution.

### Conceptual Model and Hypotheses

The conceptual model is derived from the literature reviewed in Section 2 and positions PMOs as adaptive governance systems. The model comprises four interrelated subsystems: Capability (C), Risk Activation (R), Adjustment (A), and Performance (P). Capability represents structural governance conditions, risk activation reflects the visibility of misalignment, adjustment captures PMO transformation as an adaptive response, and performance denotes the stability and consistency of organisational outcomes.

Based on this framework, the study formulates hypotheses that examine:

1) the internal structure of PMO capability,
2) the relationship between capability and risk activation,

3) the role of risk activation in triggering adjustment, and
4) the contribution of adjustment to performance outcomes.

The hypothesised relationships are illustrated in Figure 1 and empirically tested using structural equation modelling.

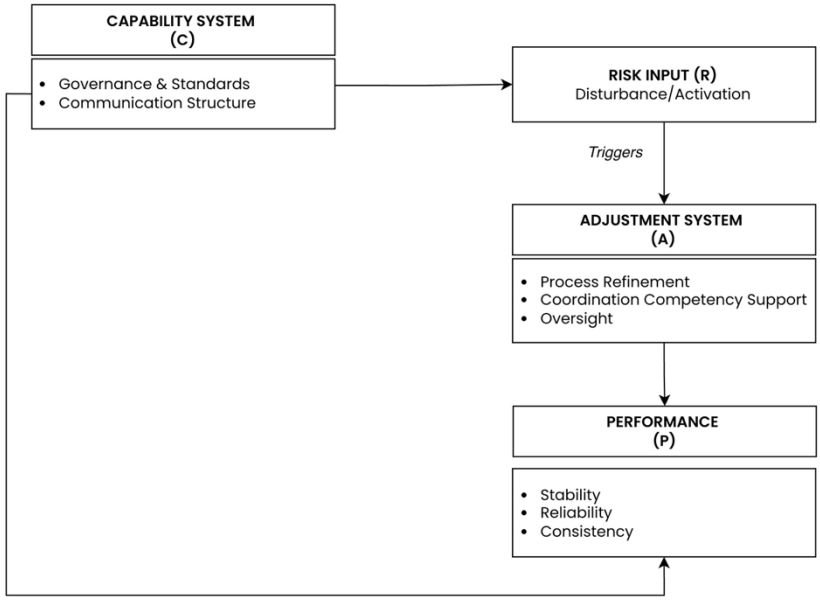



**Figure 1:** Conceptual Framework

## Measurement of Constructs

All constructs were measured using multi-item indicators adapted from established PMO and project governance literature. PMO capability was operationalised as a higher-order construct comprising strategic alignment, governance and standardisation, performance and value management, delivery support, and capability development. Risk activation captures observable deviations and governance instability arising from weak capability structures. Adjustment reflects PMO transformation activities undertaken in response to emerging misalignment, while performance represents perceived stability, reliability, and consistency of organisational outcomes.

All items were measured using a Likert-type scale. The validity and reliability of the measurement model are assessed and reported in the Results section.


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### Data Collection and Sample

Data were collected through a structured questionnaire distributed to practitioners working in project-based organisations. A total of 243 valid responses were obtained, representing a range of organisational roles, professional experience levels, and educational backgrounds. This diversity supports the examination of PMO governance behaviour across different organisational contexts. Respondents were drawn from a range of project-based sectors, including construction and infrastructure planning, information and communication technology, energy, finance, and oil and gas. Construction and infrastructure planning organisations constituted the largest share of the sample (53.09%), consistent with this study's emphasis on PMO governance within the built environment, while the remaining respondents (46.91%) were drawn from other project-based sectors, providing a comparative basis for interpreting sector-specific governance patterns.

Respondents were selected based on their involvement in PMO-related activities, ensuring that assessments reflected informed perspectives on governance capability, risk, and transformation.

### Data Analysis Technique

The proposed model was tested using Partial Least Squares Structural Equation Modelling (PLS-SEM), which is appropriate for analysing complex models with higher-order constructs and exploratory causal relationships. PLS-SEM enables simultaneous assessment of measurement properties and structural relationships while accommodating non-normal data distributions.

The analysis was conducted using SmartPLS software. Evaluation of the measurement model and structural model, including reliability, validity, and path relationships, is presented in the following Results section.

## RESULTS

### Respondent Profile

The analysis is based on 243 valid responses from practitioners involved in PMO-related activities within project-based organisations. Respondents represent a wide range of professional roles, experience levels, and educational backgrounds, ensuring that the data reflect diverse governance perspectives rather than a single functional viewpoint. A summary of respondent characteristics is presented in Table 1. Consistent with the study's emphasis on the built environment, 53.09% of respondents were affiliated with construction and infrastructure planning organisations, while the remaining 46.91% represented other project-based sectors such as ICT, energy, finance, and oil and gas.

**Table 1:** Respondent Characteristics (n = 243)

| Category | Distribution |
|---|---|
| Education | Bachelor's (48%), Master's (49%), Doctoral (3%) |
| Professional Experience | <5 years (7%), 6–10 (13%), 11–15 (19%), 16–20 (22%), 21–25 (18%), >25 (20%) |
| Position | Executive/Director (13%), Head of PMO/Department (19%), Program Manager (7%), PMO Expert (9%), Project Management Practitioner (32%), Project Manager (15%), PMO Staff (5%) |

## Capability System Results (C)

This section reports the internal structure of the PMO capability system. Capability was modelled as a higher-order construct comprising five domains: Strategic Alignment, Governance & Standardisation, Performance & Value Management, Delivery Support, and Capability Development.

The structural paths among these domains show a consistent and significant hierarchical pattern. Strategic Alignment exhibits significant relationships with Governance & Standardisation, Performance & Value Management, Delivery Support, and Capability Development, indicating its role as an upstream conditioning domain. Governance & Standardisation further demonstrates significant effects on Performance & Value Management, Delivery Support, and Capability Development. Downstream capability domains also show significant internal linkages, reflecting cumulative capability development rather than independent capability silos.

**Table 2:** Structural Paths within the Capability System

| Path | Result | p-value |
|---|---|---|
| Strategic Alignment → Governance & Standardization | Significant | < 0.001 |
| Strategic Alignment → Performance & Value Management | Significant | < 0.001 |
| Strategic Alignment → Delivery Support | Significant | 0.005 |
| Strategic Alignment → Capability Development | Significant | 0.005 |
| Governance & Standardization → Performance & Value Management | Significant | < 0.001 |
| Governance & Standardization → Delivery Support | Significant | < 0.001 |
| Governance & Standardization → Capability Development | Significant | 0.005 |
| Performance & Value Management → Delivery Support | Significant | 0.005 |
| Performance & Value Management → Capability Development | Significant | < 0.001 |
| Delivery Support → Capability Development | Significant | 0.005 |

These results confirm that PMO capability operates as an internally structured system rather than as a flat collection of functions.


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### Risk Activation Results (R)

Risk Activation was examined as an outcome of PMO capability conditions. The results show that capability significantly influences risk activation, indicating that observable governance instability emerges when structural capability arrangements are insufficient to absorb disturbance.

However, risk activation does not exhibit a significant direct relationship with organisational performance. This pattern indicates that risk does not function as a direct performance driver, but rather as an intermediate condition that reflects visible misalignment within governance arrangements.

**Table 3:** Structural Paths Involving Risk Activation

| Path | Result | p-value |
|---|---|---|
| Capability → Risk Activation | Significant | < 0.001 |
| Risk Activation → Performance | Not significant | > 0.05 |

### Adjustment and PMO Transformation Results (A)

Adjustment, operationalised as PMO Transformation, was examined as the organisational response to risk activation. The results show a strong and significant relationship between risk activation and adjustment, indicating that transformation is triggered when governance instability becomes visible.

Adjustment also exhibits a strong and significant direct effect on organisational performance. This relationship represents the most substantial effect observed in the structural model, indicating that performance stability is primarily achieved through organisational adjustment rather than through capability alone.

**Table 4:** Structural Paths Involving Adjustment

| Path | Result | p-value |
|---|---|---|
| Risk Activation → Adjustment (PMO Transformation) | Significant | < 0.001 |
| Adjustment → Performance | Significant | < 0.001 |

### Integrated System Behaviour

Taken together, the results describe a system in which capability establishes governance conditions, risk activation signals misalignment, and adjustment restores performance stability. Capability does not eliminate risk, and risk does not directly degrade performance. Instead, performance outcomes depend on whether risk activation is followed by effective organisational adjustment.

The absence of a direct risk–performance relationship, combined with the strong effect of adjustment on performance, indicates that PMO transformation functions as a stabilisation mechanism within the governance

system. Performance emerges from the interaction among capability, risk activation, and adjustment rather than from any single subsystem operating in isolation.

## DISCUSSION

This study advances PMO research by examining Project Management Offices as adaptive governance systems, rather than as static organisational units or maturity-driven support functions. By integrating Capability (C), Risk Activation (R), Adjustment (A), and Performance (P) into a single explanatory framework, the findings provide a system-level explanation of how PMOs contribute to organisational performance under conditions of disturbance.

### Reframing PMO Capability Beyond Linear Performance Effects

Consistent with prior studies, the results confirm that PMO capability is internally structured and hierarchically organised (Aubry et al., 2007; Aubry & Hobbs, 2011). Strategic alignment conditions governance standardisation and delivery support, which in turn shape downstream capability development. However, this study extends existing literature by demonstrating that strategic PMO capabilities do not exert direct performance effects.

Previous research has reported mixed and often contradictory findings regarding the value of strategic PMO roles (Aubry & Hobbs, 2011; Müller & Lecoeuvre, 2014). The present findings help resolve this inconsistency by showing that strategic capability functions as a conditioning structure rather than a performance lever. Its contribution lies in shaping governance coherence and response readiness, not in producing immediate performance gains.

This reframing moves PMO capability research away from accumulation and maturity logic toward an interaction-based interpretation of governance effectiveness.

### Risk as an Activation Signal, not a Performance Determinant

A central contribution of this study is the empirical demonstration that risk activation does not directly impair organisational performance. This finding contrasts with dominant assumptions in project and PMO risk literature, where risk is typically treated as a negative factor to be minimised in order to improve outcomes (Andersen et al., 2007).

Consistent with governance-oriented perspectives (Müller et al., 2019; Pellegrinelli & Garagna, 2009), the results support an alternative interpretation in which risk functions as an activation signal. Risk becomes consequential only when it exposes misalignment that exceeds the stabilising capacity of existing governance arrangements. This distinction clarifies why organisations facing similar risk exposure often experience divergent performance outcomes.


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By empirically separating risk visibility from performance impact, the study contributes a more precise conceptual role for risk within PMO governance research.

**Adjustment as the Core Stabilisation Mechanism**

The strongest relationship observed in the model is between adjustment—operationalised as PMO transformation—and performance. This finding reinforces prior observations that PMOs undergo recurrent reconfiguration in response to organisational pressures (Aubry, 2011; Joslin, 2022), but extends the literature by positioning transformation as the primary stabilisation mechanism.

Where earlier studies describe PMO transformation as structural change or maturity evolution (Aubry & Hobbs, 2010), this study demonstrates that transformation mediates the effects of both capability and risk. Adjustment enables organisations to restore governance coherence once instability becomes visible, explaining why performance recovery depends less on baseline capability and more on adaptive response.

This insight reframes PMO value as a function of adaptive governance behaviour, rather than of role classification or functional scope.

**Performance as an Emergent Governance Outcome**

Taken together, the findings support a system-level interpretation of PMO effectiveness. Performance does not result from capability strength or risk avoidance in isolation, but emerges from the interaction among conditioning structures, activation signals, and adaptive response. This aligns with organisational governance research that conceptualises performance as an emergent property of systems under pressure (Müller et al., 2019; Pellegrinelli & Garagna, 2009).

By empirically validating this interaction pattern, the study moves beyond maturity-based and best-practice explanations of PMO performance and provides a governance-centric account of how PMOs sustain organisational coherence in dynamic project environments.

**Implications for Urban Infrastructure and Construction Planning Governance**

The system-level pattern identified in this study carries particular significance for PMOs operating within urban infrastructure and construction planning organisations, which formed the majority of the study sample. In these organisations, capability alone rarely stabilises governance outcomes, because urban development programmes are subject to overlapping planning approvals, shifting land-use regulations, and multi-agency coordination requirements that routinely expose misalignment regardless of an organisation's baseline capability.

The finding that risk activation does not directly impair performance, but instead triggers adjustment, suggests that planning-related disturbances, such as delayed permits, revised zoning requirements, or contested stakeholder mandates, function as signals that prompt PMOs to reconfigure coordination routines rather than as forces that inevitably degrade project outcomes. Correspondingly, the strong effect of adjustment on performance indicates that PMOs governing large-scale urban development projects sustain delivery coherence primarily through their capacity to transform mandates, reallocate authority, and reconfigure coordination mechanisms in response to planning governance pressures, rather than through static capability or risk avoidance alone. This positions PMO transformation as a planning governance capability in its own right, relevant to how urban infrastructure organisations sustain coordinated delivery across fragmented, multi-stakeholder development programmes.

**Theoretical Implications**

The study contributes to PMO and project governance literature in three ways. First, it reframes PMO capability as a conditioning structure rather than a direct performance driver, helping explain inconsistent findings in prior empirical research. Second, it positions risk as an activation signal rather than a determinant of performance outcomes. Third, it empirically establishes PMO transformation as a dynamic governance capability that stabilises organisational performance. For planning governance research specifically, these contributions suggest that PMO transformation should be treated as a distinct planning governance capability warranting further attention in studies of urban infrastructure delivery and large-scale development programme management, rather than being treated as a generic organisational process.

Together, these contributions advance understanding of PMOs as adaptive governance systems and provide a coherent explanation of how governance structures function under conditions of uncertainty and disturbance.

## CONCLUSION

This study explains PMO effectiveness as an adaptive governance process rather than as a static organisational capability. Using the Capability–Risk–Adjustment–Performance (C–R–A–P) framework, the findings show that capability conditions governance stability, risk activates organisational response, and adjustment restores performance coherence. These findings are particularly relevant to PMOs operating within urban infrastructure and construction planning organisations, which constituted the majority of the study sample, underscoring the importance of adaptive planning governance capacity for sustaining coordinated delivery in large-scale urban development contexts.


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The results demonstrate that risk does not directly impair performance and that strategic PMO capabilities do not yield performance effects unless enacted through organisational adjustment. Performance emerges from system interaction rather than linear cause–effect relationships. By reframing PMOs as adaptive governance systems, the study provides a coherent explanation for why organisations operating under comparable conditions may experience divergent outcomes.

Several limitations should be noted. The cross-sectional design limits observation of dynamic adjustment processes over time. Future research could adopt longitudinal approaches to examine how PMO transformation unfolds across different stages of disturbance. In addition, while the findings are theoretically transferable, empirical validation across sectors and institutional contexts would strengthen generalisability.

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# ANALYSING CAUSES OF DELAY IN SARAWAK'S CONSTRUCTION INDUSTRY

**Chu Sheng Ding[1], Jiayi Poh[2], Shi Yee Wong[3], Saipol Bari Bin Abd Karim[4]**

[1,2,3]*School of Built Environment,*
UNIVERSITY OF TECHNOLOGY SARAWAK, MALAYSIA
[4]*Centre for Building, Construction & Tropical (BuCTA)*
*& Faculty of Built Environment,*
UNIVERSITY OF MALAYA, MALAYSIA

## Abstract

Construction delays are recurring issues in the construction industry. In Malaysia, numerous studies on construction delays have been conducted. However, studies specifically focused on Sarawak, the largest state in Malaysia, remain limited, despite the issue being common in the state. Therefore, the present study aimed to analyse the causes of delay from the perspectives of construction stakeholders in Sarawak. Two objectives were set to achieve the aim: (i) to prioritise the causes of delay and (ii) to examine if there are statistically significant differences in the rankings of causes of delay between clients, consultants, and contractors. A quantitative research method was adopted to collect research data by sending semi-structured questionnaires to the respondents. Eventually, 79 valid responses were collected. The data was analysed using the Descriptive Statistics method for ranking causes of delay and the Kruskal-Wallis test for examining the differences between groups. The results showed that the top three significant causes of delay are labour shortages, increases in material prices, and material shortages. The Kruskal-Wallis test revealed that there is consensus among the construction stakeholders for 65 causes, but differences also exist for 11 causes. The present study provides a comprehensive assessment of 76 causes of delay across different respondent groups. Therefore, the findings could provide valuable insights for the construction stakeholders. Mitigation strategies can be planned before project implementation to reduce the delay issues in Sarawak's construction industry.

***Keywords***: Delay, Construction Industry, Kruskal-Wallis Test, Sarawak, Malaysia

[1] Corresponding author. Email: ding.chu.sheng@uts.edu.my / dcs.sheng@gmail.com

# INTRODUCTION

Delay is a common issue in the construction industry; Malaysia is no exception (Adeleke et al., 2021; Bano et al., 2023; Faizal et al., 2025). According to Aziz and Prasetijo (2022), delay has become a major issue over the past few decades. Delay can bring many unfavourable consequences, including time and cost overruns, stakeholders' dissatisfaction, and negative reputation of the construction industry (Bano et al., 2023). The project's success is commonly tied to its timely completion; therefore, delays can affect the overall success of a project (Zagia et al., 2025). Additionally, these issues also affect the economic growth, long-term development of Malaysia, and the standard of living of the populace (Aziz et al., 2025; Zagia et al., 2025). In Malaysia, numerous studies have been conducted to examine the causes of delay and/or their prevention strategies (Adeleke et al., 2021; Aziz et al., 2022; Faizal et al., 2025; Sa'ad et al., 2022; Sharuddin et al., 2024). However, the delay issues persist. Additionally, a comprehensive literature review uncovers that previous studies mostly focused on West Malaysia. Similar studies on delay issues in Sarawak remain limited. Therefore, the present study aimed to analyse the causes of delay from the perspectives of construction stakeholders in Sarawak. To the best of the authors' knowledge, the present study is among the first to comprehensively examine 76 causes of delay across different respondent groups. Apart from bridging the gap of literature, it is also anticipated that the findings of the present study could provide valuable information to Sarawak's construction industry in reducing project delays.

# LITERATURE REVIEW

## Construction Delay and Its Impacts

According to Radmman et al. (2021), "delay" can be defined as "extra time required or incurred either beyond the stipulated completion date or beyond the project stakeholders' date to complete the project". Tariq and Gardezi (2023) noted that it refers to a project's deviation from its targeted schedule, which is a common problem in the construction industry. The common impacts of delay in includes cost & schedule overruns, scope creep, low quality, and customer dissatisfaction (Amoah et al., 2020). Furthermore, if not properly monitored, delay can also cause project abandonment and construction disputes (Aminorlah et al., 2023; Hoque et al., 2021). Additionally, if a project is delayed and necessitates work acceleration, this may increase weariness and the level of stress among the workers, thus increasing the risk of accidents (Sharuddin et al., 2024).

## Causes of Delay

Delay can arise from various factors involving clients, consultants, contractors, and external factors (Thorat et al., 2017; Ullah et al., 2018). The common causes involving clients include variation orders, delay in payment, and poor


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communication with other parties. Variation order may cause delay because it necessitates temporarily halting the project to allow the contractor to accurately document the changes. Variation order requires project rescheduling, impacts costs, and potentially results in lower quality works (Alshiri et al., 2022). Delay in payment is another common cause of delay. Contractors often rely on the payment from the client to fund the projects. In case of late payment, the contractors may be unable to afford the labour and material costs, which result in delay (Masrom et al., 2021; Shahron et al., 2023). For poor communication with other parties, this issue often stems from unclear information provided to the consultants and contractors by the client (Hasib & Al-Kilidar, 2021). This can lead to slow in decision making and poor design documents (Assaf et al., 2018).

The causes involving the consultants commonly include poor communication, delay in consultant's performance, mistakes and discrepancies in design and contract documents. Poor communication may result in design discrepancies and reworks, thus leading to delays (Aminorlah et al., 2023). Timely provision of drawings is a key responsibility of consultants; delayed in this aspect can cascade into project delays (Thorat et al., 2017). Delay in consultant's performance such as slow in providing feedback or crucial decision can also affect project timelines (Aldammark et al., 2025). Besides, design mistakes can lead to inaccurate project estimates, necessitating redesign, re-estimation and rework, thereby extending project timelines (Tahmasebinia & Song, 2022).

Delay can also be caused by contractors. The common causes include skill deficiency & low productivity of labour, poor management, and difficulties in financing projects. The Malaysian construction industry relies on foreign workers excessively (Bariono & Kamaruding, 2025; Hoo et al., 2024). However, most of the foreign workers do not possess sufficient skills to meet the local demands. Low level of skills often lead to substandard works and low productivity (Bariono & Kamaruding, 2025; Hoo et al., 2024). Effective site management is essential to ensure projects are completed on schedule by determining, planning, organizing, and controlling the use of resources (Aforla, 2016; Hasib & Al-kilidar, 2021; Tahmasebinia & Song, 2022). Poor management often caused low quality works which subsequently result in reworks (Aforla, 2016). Difficulties in financing projects can be due to poor cash flow management of the contractor, which include managing too many tasks at a time, underbidding a project, and inconsistent cash flow forecasting (Shahron et al., 2023).

Another type of delay is caused by external factors, which include severe weather conditions, national labour shortage, and changes in government requirements and regulations. Severe weather conditions, such as rain can lead to flooding, cause infrastructure failure, and impact site equipment and material transportation (Adeleke et al., 2021). Additionally, rainy, hot or dry conditions

can also cause physical discomfort among labours, thus affecting labour productivity (Gashahun, 2020). According to Hailu et al. (2023), labour related factors such as labour shortage are the most significant contributors to project delays. This issue is often stemmed from workplace hazards and low wages, prompting local workers to seek better-paying opportunities elsewhere (Theng & Techapeeraparnich, 2020). Changes in government regulations include restrictions on building material importation, inflation and interest rates (Opeyemi et al., 2022). The projects become more complicated where there is a change in regulations (Alshihri et al., 2022), and the project stakeholders will need to modify their initial plan to suit with the new regulations (Arantes & Ferreira, 2020).

## Research Gap

Numerous studies have been conducted in Malaysia to study the causes of delay, including those by Aminorlah et al. (2023), Hisham & Yah (2016), Memon et al. (2014), Mydin et al. (2014), Othman & Ismail, (2014), Shehu et al. (2014), and Yap et al. (2021). However, these studies primarily focused on Peninsular Malaysia. Studies specifically focused on Sarawak, the largest state in Malaysia, remain limited, despite the issue being common in the state. Some delayed projects include the construction of new classrooms and hostel at SK Metalun, which recorded a 785 days delay (Free Malaysia Today, 2025a), construction of multi-purpose hall at the Institute for Rural Advancement, which recorded an approximately 23 % behind the schedule (Borneo Post Online, 2025a), Dalat road project, which experienced 70 days delay (Borneo Post Online, 2025b), and Sejingkat Bridge project (Sarawak Tribute, 2025). Additionally, sick housing projects (DayakDaily, 2025a; Sarawak Tribute, 2025) and rural development projects (DayakDaily, 2025b) were also reported. Therefore, more studies focusing on Sarawak are necessary.

# RESEARCH METHOD

The present study adopted a quantitative research method as the authors intended to collect information from geographically dispersed respondents in Sarawak. Targeted respondents include clients (both public and private sectors), consultants (architects, engineers, and quantity surveyors), and G7 contractors, because they are the key stakeholders in the construction industry. Structured questionnaires were physically delivered to the targeted respondents and also sent to them via email. Each set of questionnaire consists of two sections. Section A was used to collect general information of the respondents including gender, group, and working experience. Under Section B, the respondents were requested to rank the 76 causes of delay based on a 5-point Likert scale, where 1 = Not significant, 2 = Slightly significant, 3 = Moderately significant, 4 = Significant, 5 = Very Significant. All the causes of delay were identified and compiled based


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on a comprehensive literature review. Next, the similar or overlapped causes were reviewed and consolidated to prevent duplication. Subsequently, a content validation process was carried out with 5 experts, comprising 2 academicians, 1 client, 1 consultant, and 1 contractor, to assess the appropriateness and relevancy of the refined list of delay causes. Based on the experts' comments, further modifications were made. Eventually, the total number of delay causes was fixed at 76.

Convenience sampling method was adopted in the present study. This is because the respondents were geographically dispersed and it was difficult to access a comprehensive sampling frame (Memon et al., 2025). It is also a cost effective and less time-consuming method (Golzar et al., 2022). Questionnaires were distributed to conveniently available respondents (Ahmed, 2024), including through personal delivery to facilitate participation. In addition, snowball sampling method was also adopted to recruit respondents through referrals from initial respondents to improve response rate (Ting et al., 2025). The collected data were analysed using Descriptive Statistics in SPSS to calculate the mean values and standard deviations of each cause of delay. Thereafter, a nonparametric Kruskal Wallis test was run to examine whether the distributions among different groups differ significantly. The significance level was set at 0.05, while the confidence interval was set as 95%. The effect sizes were calculated using epsilon squared formula (Tomczak & Tomczak, 2014), where H = Kruskal Walis H statistics, and n = total sample size. The formula is as follows:

$$E^2_R = \frac{H}{(n^2 - 1)/(n + 1)}$$

Additionally, K independent samples test under the legacy dialogs was also run to examine the mean ranks of different groups for each cause of delay.

## DATA ANALYSES AND DISCUSSIONS

### General Information of the Respondents

Out of 350 questionnaires sent, 79 valid questionnaires returned, representing a response rate of 22.6%. Table 1 shows the general information of the respondents. Most of the respondents were male (73.4%), whereas female respondents accounted for 26.6%. As for the respondent's group, most of them were contractors (54.4%), followed by client (25.3%) and consultant (20.3%). There was an unequal distribution of respondents due to differences in willingness to participate in the survey and respondent accessibility. To address this issue, the responses were also analysed according to the three respondent groups, as shown in Table 3, 4, and A1. Regarding the working experience, the majority of respondents possessed more than 10 years of working experience. 20.3% of respondents had more than 20 years of experience.

**Table 1:** General Information of the Respondents

| Category | | Frequency | Percentage |
|---|---|---|---|
| Gender | Male | 58 | 73.4% |
| | Female | 21 | 26.6% |
| Group | Client | 20 | 25.3% |
| | Consultant | 16 | 20.3% |
| | Contractor | 43 | 54.4% |
| Working experience | Less than 5 years | 7 | 8.9% |
| | 5 to 10 years | 22 | 27.8% |
| | 11 to 15 years | 26 | 32.9% |
| | 16 to 20 years | 8 | 10.1% |
| | More than 20 years | 16 | 20.3% |

## Reliability Analysis

The reliability of the questionnaire was analysed using Cronbach Alpha. As shown in Table 2, the Cronbach Alpha values for all categories exceeded the recommended threshold of 0.70, indicating good internal consistency (Hair et al., 2016, Taber, 2018).

**Table 2:** Cronbach Alpha Values of the Delay Categories

| Category | Cronbach Alpha |
|---|---|
| Causes of delay related to clients | 0.907 |
| Causes of delay related to consultants | 0.944 |
| Causes of delay related to contractors | 0.957 |
| Causes of delay related to external factors | 0.933 |

## Descriptive Statistics and Ranking of Causes of Delay

The overall rankings of the 76 causes of delay are presented in Appendix A (Table A1). The rankings were based on responses from (i) all parties (N = 79), (ii) clients (N = 20), consultants (N = 16), and contractors (N = 43). Based on Table A1, the top five rankings of the causes are summarized in Table 3.

As shown in Table 3, the most critical cause of delay is "labour shortage". From the consultant's perspective, this cause ranked first, whereas from the client's and contractor's perspectives, this cause ranked fourth. This finding is consistent with the current issue faced by Sarawak. According to the Sarawak Deputy Premier, contractors in Sarawak are facing a severe shortage of skilled workers due to the implementation of numerous infrastructure projects and strict immigration rules, which render the employment of foreign workers difficult (Department of the Premier of Sarawak, 2025a; Free Malaysia Today, 2025b). Sarawak's construction industry remains relying heavily on foreign labours, especially from Indonesia. A comprehensive analysis conducted by the Dayak Chamber of Commerce and Industry (DCCI) revealed that many construction-related jobs are unattractive to the locals due to limited benefits, low


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wages, and physically demanding conditions (Borneo Post Online, 2025c). Furthermore, Indonesia has tightened the immigration policy so that local projects, particularly Nusantara's new capital development, can be prioritized (Borneo Post Online, 2025c).

**Table 3:** Top Five Rankings Based on Overall 76 Causes of Delay

| | **All parties (N = 79)** | | **Client (N = 20)** | | **Consultant (N = 16)** | | **Contractor (N = 45)** | |
|---|---|---|---|---|---|---|---|---|
| **Rank** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** |
| 1 | Labour shortage (C15) | 3.91 | Poor management and supervision (C4) | 3.95 | Labour shortage (C15) | 4.13 | Increase in material prices (D1) | 4.00 |
| 2 | Increase in material prices (D1) | 3.79 | Unforeseen ground conditions (D4) | 3.95 | Inaccurate estimate of the project (C19) | 3.94 | Material shortage (D2) | 3.95 |
| 3 | Material shortage (D2) | 3.79 | Material shortage (D2) | 3.90 | Skill deficiency and low productivity among workers (C6) | 3.88 | Variation order (A3) | 3.91 |
| 4 | Subcontractors' or suppliers' issues (C12) | 3.72 | Labour shortage (C15) | 3.90 | Subcontractors' or suppliers' issues (C12) | 3.87 | Labour shortage (C15) | 3.84 |
| 5 | Variation order (A3) | 3.72 | Severe weather conditions (D5) | 3.80 | Late delivery of materials to the site (C2) | 3.81 | Delay in the consultant's performance (B2) | 3.79 |

Note: N= number of respondents; M = mean value

The cause ranked second is "increased prices of materials". From the contractor's perspective, this is the most critical cause, ranking first. According to the data released by the Department of Statistics Malaysia (DOSM, 2025), on a year-on-year basis, the steel prices showed a declining trend in 2025, while cement and sand showed an increasing trend. This suggests that construction costs remain under pressure. According to Sarawak Housing and Real Estate Developers' Association (SHEDA) (Borneo Post Online, 2025d), the construction industry has been experiencing rise of materials cost as well as construction service due to the expanded SST and e-invoicing system.

"Material shortage" ranked third within the all parties category, whereas from the clients' and the contractors' perspectives, it is ranked third and second, respectively. In recent years, some reasons of materials shortage include shortage of cement due to rapid infrastructure development (Office of the Premier of Sarawak, 2023), delays in importing materials (MalayMail, 2023), and constructing projects in remote areas, where building materials are limited (DayakDaily 2025c; Department of the Premier of Sarawak, 2025b).

"Subcontractors' or suppliers' issues" ranked fourth (3.722) in the present study. Similarly, in a study conducted by Yap et al., (2021) in Malaysia,

"incompetent subcontractors" ranked second. Previous studies also reported that incompetent subcontractors and suppliers often cause poor performance and lead to project delays (Aldammark et al., 2025; Romzi and Doh, 2022; Sarpin and Ramesh, 2024; Yap et al., 2021). According to Yap et al. (2021), the successful project completion in Malaysia depends on the competency of the project team and the performance of the subcontractors and suppliers. Therefore, to ensure the project success, main contractors should build a reliable subcontractors and suppliers pool and have good communication with them (Sarpin and Ramesh, 2024). According to Faizal et al. (2025), ensuring clear communication with the suppliers and collecting data from them regularly can help mitigate the issue of material shortage (ranked third in the present studies).

"Variation order" ranked fifth within the all parties category, and ranked third from the contractors' perspective. Variation orders are not only a common cause of delay globally (Ismaeil & Sobaih, 2024; Romzi and Doh, 2022), but also frequently occur in the Malaysian industry, commonly leading to cost and time overruns (Mohammad et al., 2022). This finding is consistent with the study conducted in Malaysia by Yap et al. (2021), who reported that "too many change orders by clients" ranked second of the leading causes of delay. In a study conducted by Sharuddin et al. (2024), "design changes during construction" ranked fourth among the factors causing delay. According to Amzafi et al. (2024), some of the most common causes of variation orders include errors and omission in designs, change in design by consultants, lack of coordination between the consultant and the contractor, and unforeseen site conditions.

Apart from the overall ranking based on the 76 causes delay, the top three barriers within each category of delay are presented in Table 4.

**Table 4:** Top Three Rankings of the Causes of Delay (Based on Category)

| | **All parties (N = 79)** | | **Client (N = 20)** | | **Consultant (N = 16)** | | **Contractor (N = 45)** | |
|---|---|---|---|---|---|---|---|---|
| **Rank** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** |
| **Causes of delay related to clients** | | | | | | | | |
| 1 | Variation order (A3) | 3.72 | Type of project bidding and award (A14) | 3.60 | Type of project bidding and award (A14) | 3.50 | Variation order (A3) | 3.91 |
| 2 | Slow in decision-making (A6) | 3.56 | Large project size and complex project (A19) | 3.60 | Variation order (A3) | 3.38 | Slow in decision-making (A6) | 3.67 |
| 3 | Delays in obtaining approval from the municipality (A18) | 3.49 | Variation order (A3) | 3.60 | Unrealistic contract duration and requirements (A11) | 3.31 | Delay in payment (A2) | 3.61 |
| **Causes of delay related to consultants** | | | | | | | | |
| 1 | Change in design and | 3.56 | Delay in the consultant's | 3.60 | Change in design and specification | 3.38 | Delay in the consultant's | 3.79 |


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| | All parties (N = 79) | | Client (N = 20) | | Consultant (N = 16) | | Contractor (N = 45) | |
|---|---|---|---|---|---|---|---|---|
| **Rank** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** | **Causes** | **M** |
| | specification (B7) | | performance (B2) | | (B7) | | performance (B2) | |
| 2 | Delay in the consultant's performance (B2) | 3.52 | Poor contract management (B1) | 3.55 | Mistakes or discrepancies in the design and contract document (B5) | 2.88 | Poor design leads to redesigning (B8) | 3.70 |
| 3 | Poor design leads to redesigning (B8) | 3.44 | Change in design and specification (B7) | 3.50 | Insufficient or improper data collection or survey (B6) | 2.88 | Mistakes or discrepancies in the design and contract document (B5) | 3.65 |
| **Causes of delay related to contractors** | | | | | | | | |
| 1 | Labour shortage (C15) | 3.91 | Poor management and supervision (C4) | 3.95 | Labour shortage (C15) | 4.13 | Labour shortage (C15) | 3.84 |
| 2 | Subcontractors ' or suppliers' issues (C12) | 3.72 | Labour shortage (C15) | 3.90 | Inaccurate estimate of the project (C19) | 3.94 | Subcontractors ' or suppliers' issues (C12) | 3.74 |
| 3 | Poor management and supervision (C4) | 3.71 | Unrealistic or improper planning and scheduling (C1) | 3.65 | Insufficient skill and low productivity among workers (C6) | 3.88 | Insufficient skill and low productivity among workers (C6) | 3.63 |
| **Causes of delay related to external factors** | | | | | | | | |
| 1 | Increase in material prices (D1) | 3.79 | Unforeseen ground conditions (D4) | 3.95 | Increase in material prices (D1)<br>Labour shortage (external factors) (D6) | 3.50<br>3.50 | Increase in material prices (D1) | 4.00 |
| 2 | Material shortage (D2) | 3.79 | Material shortage (D2) | 3.90 | - | - | Material shortage (D2) | 3.95 |
| 3 | Unforeseen ground conditions (D4) | 3.68 | Severe weather conditions (D5) | 3.80 | Unforeseen ground conditions (D4) | 3.38 | Severe weather conditions (D5) | 3.70 |

Note: N= number of respondents; M = mean value

Within the "causes of delay related to clients" category, the most critical cause is "variation order". It is ranked first, second, and third from the perspectives of contractors, consultants, and clients, respectively. In a study conducted by Goh et al. (2023), it was discovered that variation order is one of the key causes of disputes in Sarawak construction industry. Client-initiated variation orders can be reduced by establishing client requirement early, involving the client in the design stage, informing the client of the design before bidding, and improving communication between all parties (Albtoosh & Alkhamis, 2021). In addition, a formal change control mechanism can be designed to evaluate, approve, and implement changes (Ismaeil & Sobaih, 2024). From the perspectives of clients and consultants, "type of project bidding and

award" was another critical cause of delay. Tenders are commonly award to the lowest tenders (Bohari et al., 2021). However, selecting the contractor who submitted an unrealistic low price may lead to project delay, quality compromise, and disputes (Azlan et al., 2024). Therefore, apart from cost consideration, the client should also consider other contractor selection criteria such as technical capabilities, past experience, and project management expertise (Abedin et al., 2021).

The rankings within the "causes of delay related to consultants" category reveal that design issues remain a critical cause contributing to delay, with "change in design and specification" ranked first and "poor design leads to redesigning" ranked third. In addition, "mistakes or discrepancies in the design and contract document" ranked second and third from the perspectives of consultants and contractors, respectively. Therefore, the designers should place greater emphasis on design completeness before construction. Collaborative review can be conducted by an assembly of stakeholders at the preliminary stage for early detection of errors (Zhang et al., 2025). There is also a need for professional growth and the implementation of best practice in design management (Lim et al., 2025). Moreover, BIM can be adopted to improve designs and reduce inconsistencies by enabling clash detection and better coordination (Rahim et al., 2025). However, BIM adoption in Sarawak remains low (Razali et al., 2025). Furthermore, the findings also indicate that there is a need to improve consultants' response time and the administration of contracts.

Within the "causes of delay related to contractors" category, the most critical cause is "labour shortage", ranking either first or second from the perspectives of clients, consultants, and contractors. "Insufficient skill and low productivity among workers" ranked third from the perspectives of consultants and contractors. According to Dayak Chamber of Commerce and Industry (DCCI) Sarawak (Borneo Post Online, 2025c), labour shortage can be mitigated by diversifying labour sources (such as hiring workers from India, Nepal and East Timor), enhancing labour supply planning, investing in mechanism and technologies to reduce reliance on labour, and improving workers' wages and benefits to attract local workers. Another measure is to offer job opportunities to villagers in rural areas who are skilled (Rubin et al., 2024). In addition, workers development programme and training opportunities can also be provided to workers to improve their skills and productivity (Rubin et al., 2024). The findings also reveal that the clients opined that contractors' poor project management and improper planning were critical causes of project delays. Therefore, the contractors should give greater emphasis to project planning and construction progress monitoring. Performance indicators should be developed to ensure timely project delivery.

Within the "causes of delay related to external factors" category, the critical causes are related to materials, with "increasing prices of materials" and


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"material shortage" ranked high by of all parties. In Sarawak, many essential materials, such as aluminium frames, tiles, roofing, fire-rated doors, are sourced from peninsular Malaysia due to limited local suppliers, which may lead to higher cost and slower project delivery (Borneo Post Online, 2026). To mitigate this issue, it is recommended that the contractor should adopt a more proactive approach by incorporating risk management into supply chain management. Implementing time and inventory buffers would be an efficient preventive measure to address material disruptions (Kouvelis et al., 2023). The contractor should also adopt supplier diversification approach by establishing relationships with multiple suppliers, especially local suppliers, to maintain stability of material supply (Chen et al., 2024). Moreover, applying flexible contractual terms such as alternative sourcing terms and price fluctuation clauses can help mitigate the impacts of cost escalations (Joharudin et al., 2026). Furthermore, digital technologies such as BIM and Artificial Intelligence can also be adopted for real-time monitoring and demand prediction (Joharudin et al., 2026). From the perspective of the clients, "unforeseen ground conditions" is also critical. Therefore, thorough site investigations should be carried out during the tender stage to identify potential ground conditions (Albtoosh & Alkhamis, 2021).

**Kruskal-Wallis Test**

Table 5 shows the Kruskal-Wallis test statistics and effect sizes. The sig. values or p-values that are less than 0.05 (bold text) denote significance differences. For the effect sizes, values of ≥ 0.01, ≥ 0.06, ≥ 0.14 represent small, medium, and large effects, respectively (Tomczak & Tomczak, 2014). Out of a total of 76 causes, 11 show statistically significant differences in the rankings. For further comparison, the mean ranks and pairwise comparisons of the 11 causes are presented in Table 6.

**Table 5:** Kruskal-Wallis Test Statistics & Effect Sizes

| Causes | H | df | p-value | Effect size | |
|---|---|---|---|---|---|
| | | | | $\varepsilon^2_R$ | Effect |
| A1 | 5.817 | 2 | 0.055 | 0.075 | Medium |
| A2 | 9.185 | 2 | **0.010** | 0.118 | Medium |
| A3 | 3.542 | 2 | 0.170 | 0.045 | Small |
| A4 | 2.326 | 2 | 0.313 | 0.030 | Small |
| A5 | 1.140 | 2 | 0.565 | 0.015 | Small |
| A6 | 2.143 | 2 | 0.342 | 0.027 | Small |
| A7 | 0.590 | 2 | 0.745 | 0.008 | Small |
| A8 | 0.047 | 2 | 0.977 | 0.006 | Small |
| A9 | 0.564 | 2 | 0.754 | 0.007 | Small |
| A10 | 1.210 | 2 | 0.546 | 0.016 | Small |
| A11 | 1.776 | 2 | 0.411 | 0.023 | Small |
| A12 | 1.116 | 2 | 0.572 | 0.014 | Small |
| A13 | 2.217 | 2 | 0.330 | 0.028 | Small |

| Causes | H | df | p-value | Effect size | |
|---|---|---|---|---|---|
| | | | | $\varepsilon^2_R$ | Effect |
| A14 | 0.118 | 2 | 0.943 | 0.002 | Small |
| A15 | 3.155 | 2 | 0.207 | 0.040 | Small |
| A16 | 0.696 | 2 | 0.706 | 0.009 | Small |
| A17 | 1.414 | 2 | 0.493 | 0.018 | Small |
| A18 | 0.854 | 2 | 0.652 | 0.011 | Small |
| A19 | 2.973 | 2 | 0.226 | 0.038 | Small |
| B1 | 14.597 | 2 | **0.001** | 0.187 | Large |
| B2 | 11.480 | 2 | **0.003** | 0.147 | Large |
| B3 | 8.853 | 2 | **0.012** | 0.114 | Medium |
| B4 | 5.836 | 2 | 0.054 | 0.075 | Medium |
| B5 | 8.172 | 2 | **0.017** | 0.105 | Medium |
| B6 | 0.893 | 2 | 0.640 | 0.011 | Small |
| B7 | 1.374 | 2 | 0.503 | 0.018 | Small |
| B8 | 7.810 | 2 | **0.020** | 0.100 | Medium |
| B9 | 4.341 | 2 | 0.114 | 0.056 | Small |
| B10 | 4.779 | 2 | 0.092 | 0.061 | Medium |
| B11 | 6.357 | 2 | **0.042** | 0.082 | Medium |
| B12 | 3.779 | 2 | 0.151 | 0.048 | Small |
| B13 | 2.494 | 2 | 0.287 | 0.032 | Small |
| B14 | 1.872 | 2 | 0.392 | 0.024 | Small |
| B15 | 6.599 | 2 | **0.037** | 0.085 | Medium |
| C1 | 0.742 | 2 | 0.690 | 0.010 | Small |
| C2 | 1.755 | 2 | 0.416 | 0.023 | Small |
| C3 | 1.159 | 2 | 0.560 | 0.015 | Small |
| C4 | 1.964 | 2 | 0.375 | 0.025 | Small |
| C5 | 0.423 | 2 | 0.810 | 0.005 | Small |
| C6 | 1.752 | 2 | 0.416 | 0.022 | Small |
| C7 | 0.498 | 2 | 0.780 | 0.006 | Small |
| C8 | 1.420 | 2 | 0.492 | 0.018 | Small |
| C9 | 0.375 | 2 | 0.829 | 0.005 | Small |
| C10 | 1.339 | 2 | 0.512 | 0.017 | Small |
| C11 | 4.323 | 2 | 0.115 | 0.055 | Small |
| C12 | 1.010 | 2 | 0.604 | 0.013 | Small |
| C13 | 3.091 | 2 | 0.213 | 0.040 | Small |
| C14 | 1.850 | 2 | 0.397 | 0.024 | Small |
| C15 | 0.949 | 2 | 0.622 | 0.012 | Small |
| C16 | 0.589 | 2 | 0.745 | 0.008 | Small |
| C17 | 1.873 | 2 | 0.392 | 0.024 | Small |
| C18 | 0.216 | 2 | 0.897 | 0.003 | Small |
| C19 | 2.857 | 2 | 0.240 | 0.037 | Small |
| C20 | 2.623 | 2 | 0.269 | 0.034 | Small |
| C21 | 0.361 | 2 | 0.835 | 0.005 | Small |
| C22 | 0.055 | 2 | 0.973 | 0.001 | Small |
| C23 | 1.651 | 2 | 0.438 | 0.021 | Small |
| C24 | 0.637 | 2 | 0.727 | 0.008 | Small |
| C25 | 1.830 | 2 | 0.401 | 0.023 | Small |


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| Causes | H | df | p-value | Effect size | |
|---|---|---|---|---|---|
| | | | | $\varepsilon^2_R$ | Effect |
| C26 | 0.499 | 2 | 0.779 | 0.006 | Small |
| D1 | 6.287 | 2 | **0.043** | 0.081 | Medium |
| D2 | 6.262 | 2 | **0.044** | 0.080 | Medium |
| D3 | 9.689 | 2 | **0.008** | 0.124 | Medium |
| D4 | 3.345 | 2 | 0.188 | 0.043 | Small |
| D5 | 1.696 | 2 | 0.428 | 0.022 | Small |
| D6 | 0.543 | 2 | 0.762 | 0.007 | Small |
| D7 | 2.814 | 2 | 0.245 | 0.036 | Small |
| D8 | 3.361 | 2 | 0.186 | 0.043 | Small |
| D9 | 3.411 | 2 | 0.182 | 0.044 | Small |
| D10 | 4.761 | 2 | 0.092 | 0.061 | Medium |
| D11 | 1.648 | 2 | 0.439 | 0.021 | Small |
| D12 | 0.987 | 2 | 0.611 | 0.013 | Small |
| D13 | 0.796 | 2 | 0.672 | 0.010 | Small |
| D14 | 1.087 | 2 | 0.581 | 0.014 | Small |
| D15 | 1.189 | 2 | 0.552 | 0.015 | Small |
| D16 | 0.144 | 2 | 0.931 | 0.002 | Small |

Note: H = Kruskal-Wallis test statistics; df = degrees of freedom; $\varepsilon^2_R$ = epsilon squared

**Table 6:** Mean Ranks by Groups and Pairwise Comparisons

| Causes of delay | | Group | N | Mean Rank | Pairwise Comparison (Adj. Sig.) |
|---|---|---|---|---|---|
| **Causes of delay related to clients** | | | | | |
| A2 | Delay in payment | Client | 20 | 29.33 | Client-Consultant: 1.000 |
| | | Consultant | 16 | 35.19 | Client-Contractor: **.012** |
| | | Contractor | 43 | 46.76 | Consultant-Contractor: .234 |
| **Causes of delay related to consultants** | | | | | |
| B1 | Poor contract management | Client | 20 | 49.83 | Client-Consultant: **.001** |
| | | Consultant | 16 | 22.66 | Client-Contractor: .531 |
| | | Contractor | 43 | 41.88 | Consultant-Contractor: **.008** |
| B2 | Delay in the consultant's performance | Client | 20 | 40.85 | Client-Consultant: .063 |
| | | Consultant | 16 | 23.97 | Client-Contractor: 1.000 |
| | | Contractor | 43 | 45.57 | Consultant-Contractor: **.002** |
| B3 | Poor communication and coordination | Client | 20 | 41.18 | Client-Consultant: .107 |
| | | Consultant | 16 | 25.75 | Client-Contractor: 1.000 |
| | | Contractor | 43 | 44.76 | Consultant-Contractor: **.009** |
| B5 | Mistakes or discrepancies in the design and contract document | Client | 20 | 36.58 | Client-Consultant: .788 |
| | | Consultant | 16 | 28.34 | Client-Contractor: .344 |
| | | Contractor | 43 | 45.93 | Consultant-Contractor: **.018** |
| B8 | Poor design leads to redesigning | Client | 20 | 38.33 | Client-Consultant: .434 |
| | | Consultant | 16 | 27.50 | Client-Contractor: .706 |
| | | Contractor | 43 | 45.43 | Consultant-Contractor: **.017** |
| B11 | Delay in certifying interim certificates | Client | 20 | 30.90 | Client-Consultant: 1.000 |
| | | Consultant | 16 | 36.69 | Client-Contractor: **.045** |
| | | Contractor | 43 | 45.47 | Consultant-Contractor: .527 |
| B15 | Absence of the consultant's site staff | Client | 20 | 46.38 | Client-Consultant: **.038** |
| | | Consultant | 16 | 28.22 | Client-Contractor: 1.000 |
| | | Contractor | 43 | 41.42 | Consultant-Contractor: .115 |

| Causes of delay | | Group | N | Mean Rank | Pairwise Comparison (Adj. Sig.) |
|---|---|---|---|---|---|
| **Causes of delay related to external factors** | | | | | |
| D1 | Increasing prices of materials | Client | 20 | 33.53 | Client-Consultant: 1.000 |
| | | Consultant | 16 | 32.97 | Client-Contractor: .121 |
| | | Contractor | 43 | 45.63 | Consultant-Contractor: .143 |
| D2 | Material shortage | Client | 20 | 40.95 | Client-Consultant: .235 |
| | | Consultant | 16 | 28.16 | Client-Contractor: .1.000 |
| | | Contractor | 43 | 43.97 | Consultant-Contractor: **.038** |
| D3 | Changes in government requirements and regulations | Client | 20 | 48.63 | Client-Consultant: **.007** |
| | | Consultant | 16 | 25.88 | Client-Contractor: .654 |
| | | Contractor | 43 | 41.24 | Consultant-Contractor: .053 |

Note: N= number of respondents; Adj. Sig. = adjusted significance. The significant level is 0.05.

Based on Table 6, there is a significant difference between the opinions of clients and contractors in terms of "delay in payment" (A2). The contractors thought that this issue occurred frequently, whereas the client did not think so. This is also supported by pairwise comparison between the clients and contractors (adj. sig. = 0.012).

Within the "causes related to consultants" category, the participants have significantly different responses on seven causes of delay. Out of the seven causes, the clients and contractors have close or similar responses in four causes, namely, "poor contract management" (B1), "delay in consultant's performance" (B2), "poor communication and coordination" (B3), "mistakes or discrepancies in the design and contract document" (B5), "poor design leads to redesigning" (B8), and "absence of consultant's site staff" (B15). These causes received high mean ranks (occurred frequently or very frequently), indicating that both the clients and contractors expect the consultants to play a more important role in construction projects to minimize delays. However, the consultants thought differently, opining that these causes happened rarely or occasionally (all mean ranks are below 30). Interestingly, regarding "delay in certifying interim certificates" (B11), the mean rank by the consultants is higher (36.69), indicating this cause occurred occasionally or frequently. The mean rank of the contractors is the highest (45.47) among the three groups. The pairwise comparison shows that there are statistically significant differences between consultants and contractor for most of the causes, including B1, B2, B3, B5 & B8. Although there are differences in mean ranks between the clients and consultants, the differences are not statistically strong after accounting for the difference in mean rank, sample size, and comparison adjustment (Dunn, 1964).

As for the "causes related to external factors" category, the contractor opined that "increase in material prices" (D1) occurred frequently. In contrast, neither the clients nor the consultants thought that this is a critical cause of delay. However, this difference is not statistically significant after adjustment for comparisons. About "material shortage" (D2) and "changes in government requirements and regulations" (D3), both clients and contractors have different


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responses from the consultants, who thought that these two causes do not frequently occur. The pairwise comparison reveals that there is a larger difference between consultants and contractors (adj. sig. = 0.038) for D2, and between clients and consultants (adj. sig. = 0.007) for D3.

## CONCLUSION

A quantitative research method was adopted to collect research data by sending semi-structured questionnaires to the respondents. The data was analysed using the Descriptive Statistics method and Kruskal-Wallis test. All the 76 causes of delay within 4 main delay categories were ranked. The top three significant causes of delay based on overall rankings are labour shortages, increases in material prices, and material shortage. Additionally, the rankings based on four different categories showed that variation orders, change in design and specification, labour shortage, poor management, and increase in material prices are among the critical causes of delay. The findings provide several practical implications for construction stakeholders. Clients should minimize the variation orders by establishing design requirement early where applicable. Consultants should improve their performance by ensuring design completeness and proper preparation of contracts. Contractors, meanwhile, should improve project management and ensure an adequate labour supply. Impacts caused by material shortage and increase in material prices could be mitigated by implementing inventory buffers and supplier diversification approaches.

Furthermore, the Kruskal-Wallis test revealed that there is consensus among clients, consultants, and contractors for 65 causes, but differences also exist for 11 causes. Given the differing responses from the construction stakeholders, a uniform approach to address the causes may not be appropriate. It is suggested that tailored mitigation strategies should be considered for different groups of construction stakeholders. Future studies can include more responses from clients and consultants.

## LIMITATION AND FUTURE DIRECTION

Non-probability sampling carries a risk of selection bias, which may reduce the representativeness of the present study. Future studies could adopt probability sampling, provided that sufficient resources are available. In addition, the present study has an unequal distribution of respondents. The responses from the client (25.3%) and consultant (20.3%) are lower than contractor (54.4%). Although responses were also analysed according to the three respondent groups, caution should be exercised when interpreting the different opinions among the construction stakeholders reported in the present study. It is recommended that future studies can include more balanced samples to improve the result generalisability.

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# Appendix A

**Table A1:** Overall Ranking of the 76 Causes of Delay

| Code & causes of delay | | All parties (N = 79) | | | Client (N = 20) | | | CA (N = 16) | | | Contractor (N = 43) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | R | M | SD | R | M | SD | R | M | SD | R |
| **Causes of delay related to clients** | | | | | | | | | | | | | |
| A1 | Financial difficulties | 2.90 | 1.28 | 61 | 2.55 | 1.23 | 69 | 2.50 | 1.16 | 70 | 3.21 | 1.28 | 46 |
| A2 | Delay in payment | 3.22 | 1.31 | 41 | 2.60 | 1.14 | 67 | 2.94 | 1.34 | 39 | 3.61 | 1.26 | 15 |
| A3 | Variation order | 3.72 | 1.07 | 5 | 3.60 | 1.10 | 13 | 3.38 | 1.15 | 24 | 3.91 | 1.02 | 3 |
| A4 | Difficulty in defining project requirements | 3.17 | 1.06 | 42 | 3.40 | 1.00 | 30 | 2.88 | 1.15 | 44 | 3.16 | 1.05 | 49 |
| A5 | Delay in providing site possession | 2.98 | 1.14 | 57 | 2.90 | 1.25 | 56 | 2.75 | 1.13 | 51 | 3.09 | 1.11 | 52 |
| A6 | Slow in decision-making | 3.56 | 1.17 | 13 | 3.55 | 1.10 | 19 | 3.25 | 1.07 | 29 | 3.67 | 1.25 | 10 |
| A7 | Poor communication and coordination | 3.25 | 1.09 | 36 | 3.35 | 1.04 | 33 | 3.13 | 1.20 | 35 | 3.26 | 1.09 | 37 |
| A8 | Conflicts between the joint ownership of the project | 2.60 | 1.17 | 71 | 2.50 | 0.95 | 70 | 2.63 | 1.36 | 65 | 2.63 | 1.22 | 71 |
| A9 | Lack of incentives for contractors to finish earlier | 2.84 | 1.29 | 63 | 2.65 | 1.14 | 65 | 2.88 | 1.41 | 48 | 2.91 | 1.32 | 63 |
| A10 | Suspension of work | 2.53 | 1.29 | 73 | 2.75 | 1.21 | 61 | 2.56 | 1.36 | 67 | 2.42 | 1.31 | 75 |
| A11 | Unrealistic contract duration and requirements | 3.01 | 1.20 | 53 | 3.05 | 1.15 | 51 | 3.31 | 1.30 | 28 | 2.88 | 1.20 | 66 |
| A12 | Lack of knowledge or experience | 2.92 | 1.07 | 60 | 2.70 | 0.92 | 63 | 2.88 | 1.09 | 43 | 3.05 | 1.13 | 55 |
| A13 | Inadequate project feasibility study | 2.96 | 1.06 | 58 | 2.80 | 0.89 | 58 | 2.69 | 1.14 | 59 | 3.14 | 1.08 | 50 |
| A14 | Type of project bidding and award (the lowest bidder may bring a lower quality contractor) | 3.47 | 1.15 | 19 | 3.60 | 0.88 | 8 | 3.50 | 0.97 | 15 | 3.40 | 1.33 | 27 |
| A15 | Shortage and late delivery of material (procurement by the client) | 3.14 | 1.15 | 45 | 2.90 | 1.17 | 55 | 2.88 | 1.15 | 44 | 3.35 | 1.13 | 31 |
| A16 | Ineffective delay penalties | 2.60 | 1.09 | 69 | 2.70 | 1.13 | 64 | 2.75 | 1.18 | 53 | 2.51 | 1.06 | 73 |
| A17 | Excessive bureaucracy in the administration | 3.00 | 1.13 | 54 | 3.10 | 0.91 | 48 | 2.69 | 1.30 | 62 | 3.07 | 1.16 | 53 |
| A18 | Delays in obtaining approval from the municipality | 3.49 | 1.07 | 17 | 3.50 | 0.89 | 21 | 3.25 | 1.44 | 30 | 3.58 | 1.01 | 18 |
| A19 | Large project size and complex project | 3.39 | 1.18 | 22 | 3.60 | 1.00 | 11 | 2.94 | 1.18 | 38 | 3.47 | 1.24 | 22 |
| **Causes of delay related to consultants** | | | | | | | | | | | | | |
| B1 | Poor contract management | 3.11 | 0.93 | 48 | 3.55 | 0.83 | 15 | 2.38 | 0.81 | 73 | 3.19 | 0.88 | 47 |


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| Code & causes of delay | | All parties (N = 79) | | | Client (N = 20) | | | CA (N = 16) | | | Contractor (N = 43) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | R | M | SD | R | M | SD | R | M | SD | R |
| B2 | Delay in the consultant's performance | 3.52 | 1.07 | 16 | 3.60 | 0.94 | 9 | 2.69 | 1.14 | 59 | 3.79 | 0.97 | 5 |
| B3 | Poor communication and coordination | 3.37 | 1.02 | 27 | 3.45 | 0.89 | 25 | 2.69 | 1.20 | 61 | 3.58 | 0.91 | 16 |
| B4 | Insufficient experience of the consultant | 2.95 | 1.02 | 59 | 3.20 | 1.06 | 46 | 2.38 | 1.26 | 74 | 3.05 | 0.84 | 54 |
| B5 | Mistakes or discrepancies in the design and contract document | 3.38 | 1.00 | 23 | 3.20 | 1.01 | 44 | 2.88 | 0.81 | 40 | 3.65 | 1.00 | 11 |
| B6 | Insufficient or improper data collection or survey | 3.14 | 0.94 | 43 | 3.15 | 0.67 | 47 | 2.88 | 0.96 | 41 | 3.23 | 1.04 | 38 |
| B7 | Change in design and specification | 3.56 | 0.98 | 12 | 3.50 | 0.95 | 22 | 3.38 | 0.89 | 19 | 3.65 | 1.04 | 12 |
| B8 | Poor design leads to redesigning | 3.44 | 1.08 | 20 | 3.40 | 0.88 | 27 | 2.81 | 0.98 | 50 | 3.70 | 1.12 | 8 |
| B9 | Complexity of design | 3.13 | 0.93 | 46 | 3.20 | 0.83 | 39 | 2.69 | 0.70 | 56 | 3.26 | 1.00 | 36 |
| B10 | Rigidity or lack of flexibility | 3.280 | 0.97 | 32 | 3.30 | 0.80 | 34 | 2.81 | 0.75 | 49 | 3.44 | 1.08 | 25 |
| B11 | Delay in certifying interim certificates | 3.05 | 1.14 | 52 | 2.55 | 0.94 | 68 | 2.88 | 1.20 | 46 | 3.35 | 1.13 | 31 |
| B12 | Poor quality control | 2.750 | 0.93 | 67 | 2.80 | 0.77 | 57 | 2.31 | 0.87 | 75 | 2.88 | 0.98 | 65 |
| B13 | Conflict between consultants | 2.82 | 0.93 | 64 | 2.70 | 0.87 | 62 | 2.56 | 0.89 | 66 | 2.98 | 0.96 | 58 |
| B14 | Misunderstanding of the client's requirement | 2.99 | 0.98 | 56 | 3.20 | 0.89 | 42 | 2.75 | 1.13 | 51 | 2.98 | 0.96 | 58 |
| B15 | Absence of the consultant's site staff | 2.77 | 1.05 | 66 | 3.05 | 0.95 | 50 | 2.19 | 0.83 | 76 | 2.86 | 1.10 | 67 |
| **Causes of delay related to contractors** | | | | | | | | | | | | | |
| C1 | Unrealistic or improper planning and scheduling | 3.61 | 0.97 | 10 | 3.65 | 0.81 | 7 | 3.81 | 0.98 | 5 | 3.51 | 1.03 | 19 |
| C2 | Late delivery of materials to the site | 3.54 | 0.96 | 14 | 3.55 | 0.83 | 15 | 3.81 | 0.98 | 5 | 3.44 | 1.01 | 23 |
| C3 | Late delivery of equipment to the site | 3.33 | 1.03 | 28 | 3.40 | 0.88 | 27 | 3.56 | 1.09 | 13 | 3.21 | 1.08 | 42 |
| C4 | Poor management and supervision | 3.71 | 0.95 | 6 | 3.95 | 0.83 | 1 | 3.75 | 1.07 | 7 | 3.58 | 0.96 | 17 |
| C5 | Insufficient contractor experience | 3.25 | 1.02 | 33 | 3.35 | 0.99 | 32 | 3.38 | 1.15 | 24 | 3.16 | 1.00 | 48 |
| C6 | Insufficient skill and low productivity among workers | 3.65 | 0.99 | 9 | 3.50 | 0.76 | 20 | 3.88 | 1.03 | 3 | 3.63 | 1.07 | 13 |
| C7 | Difficulties in financing the project | 3.47 | 1.12 | 18 | 3.60 | 0.94 | 9 | 3.31 | 1.20 | 27 | 3.47 | 1.18 | 21 |
| C8 | Conflicts and disputes | 2.99 | 0.97 | 55 | 2.80 | 0.89 | 58 | 3.13 | 1.09 | 34 | 3.02 | 0.96 | 57 |
| C9 | Rework due to mistakes or defective work | 3.25 | 1.03 | 34 | 3.20 | 0.89 | 42 | 3.38 | 0.96 | 20 | 3.23 | 1.13 | 39 |

| Code & causes of delay | | All parties (N = 79) | | | Client (N = 20) | | | CA (N = 16) | | | Contractor (N = 43) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | R | M | SD | R | M | SD | R | M | SD | R |
| C10 | Poor communication and coordination | 3.38 | 0.98 | 24 | 3.35 | 0.88 | 31 | 3.69 | 1.14 | 10 | 3.28 | 0.96 | 35 |
| C11 | Improper construction methods | 3.11 | 1.07 | 49 | 3.10 | 0.91 | 48 | 3.63 | 1.20 | 12 | 2.93 | 1.06 | 61 |
| C12 | Subcontractors' or suppliers' issues | 3.72 | 0.97 | 4 | 3.55 | 0.95 | 17 | 3.87 | 1.03 | 4 | 3.74 | 0.98 | 6 |
| C13 | Ineffective teamwork | 3.32 | 0.99 | 29 | 3.20 | 1.01 | 44 | 3.75 | 1.07 | 7 | 3.21 | 0.94 | 40 |
| C14 | Frequent change of subcontractors or suppliers | 3.38 | 1.15 | 26 | 3.55 | 1.05 | 18 | 3.63 | 1.09 | 11 | 3.21 | 1.21 | 45 |
| C15 | Labour shortage | 3.91 | 1.09 | 1 | 3.90 | 1.02 | 4 | 4.13 | 1.09 | 1 | 3.84 | 1.13 | 4 |
| C16 | Poor material handling at the site | 3.30 | 1.13 | 31 | 3.40 | 0.88 | 27 | 3.44 | 1.32 | 18 | 3.21 | 1.17 | 44 |
| C17 | Equipment shortage or breakdown | 3.38 | 1.00 | 25 | 3.20 | 0.83 | 39 | 3.69 | 1.08 | 9 | 3.35 | 1.04 | 30 |
| C18 | Labour absenteeism or low morale | 3.22 | 1.07 | 38 | 3.25 | 1.02 | 38 | 3.19 | 1.22 | 33 | 3.21 | 1.06 | 41 |
| C19 | Inaccurate estimate of the project | 3.54 | 1.00 | 15 | 3.45 | 0.83 | 23 | 3.94 | 1.00 | 2 | 3.44 | 1.05 | 24 |
| C20 | Using improper or low-efficiency equipment | 3.06 | 1.03 | 50 | 3.20 | 0.83 | 39 | 3.38 | 1.36 | 26 | 2.88 | 0.96 | 64 |
| C21 | Delay in submission of drawings, documents, reports, or material samples | 3.41 | 0.93 | 21 | 3.40 | 0.68 | 26 | 3.56 | 1.09 | 13 | 3.35 | 0.97 | 29 |
| C22 | Delay due to safety and health issues | 2.63 | 1.00 | 68 | 2.60 | 0.88 | 66 | 2.69 | 1.01 | 57 | 2.63 | 1.07 | 70 |
| C23 | Delay in payment to the supplier, subcontractor or staff | 3.25 | 1.06 | 35 | 3.45 | 0.83 | 23 | 3.38 | 1.02 | 22 | 3.12 | 1.16 | 51 |
| C24 | Improper investigation during the bidding process | 3.13 | 1.03 | 47 | 3.25 | 0.85 | 36 | 3.19 | 0.98 | 31 | 3.05 | 1.13 | 55 |
| C25 | Shortage of materials at the site | 3.24 | 1.07 | 37 | 3.30 | 0.80 | 34 | 2.94 | 1.12 | 37 | 3.33 | 1.15 | 33 |
| C26 | Accident during construction | 2.44 | 1.10 | 75 | 2.25 | 0.97 | 75 | 2.50 | 1.21 | 71 | 2.51 | 1.12 | 74 |
| **Causes of delay related to external factors** | | | | | | | | | | | | | |
| D1 | Increase in material prices | 3.79 | 0.92 | 2 | 3.55 | 0.76 | 14 | 3.50 | 0.97 | 15 | 4.00 | 0.93 | 1 |
| D2 | Material shortage | 3.79 | 1.03 | 3 | 3.90 | 0.79 | 3 | 3.19 | 1.17 | 32 | 3.95 | 1.02 | 2 |
| D3 | Changes in government requirements and regulations | 3.22 | 1.09 | 39 | 3.60 | 1.00 | 11 | 2.50 | 1.10 | 69 | 3.30 | 1.04 | 34 |
| D4 | Unforeseen ground conditions | 3.68 | 0.97 | 7 | 3.95 | 0.95 | 2 | 3.38 | 0.96 | 20 | 3.67 | 0.97 | 9 |
| D5 | Severe weather conditions | 3.66 | 0.99 | 8 | 3.80 | 0.95 | 5 | 3.38 | 1.09 | 23 | 3.70 | 0.96 | 7 |
| D6 | Labour shortage (external factors) | 3.61 | 1.07 | 11 | 3.70 | 1.13 | 6 | 3.50 | 0.97 | 15 | 3.61 | 1.09 | 14 |


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| Code & causes of delay | | All parties (N = 79) | | | Client (N = 20) | | | CA (N = 16) | | | Contractor (N = 43) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SD | R | M | SD | R | M | SD | R | M | SD | R |
| D7 | Delay in land acquisition | 3.22 | 1.15 | 40 | 2.95 | 1.05 | 54 | 3.00 | 1.21 | 36 | 3.42 | 1.16 | 26 |
| D8 | Delay in releasing permits from the municipality | 3.30 | 1.10 | 30 | 3.25 | 0.91 | 37 | 2.88 | 1.20 | 46 | 3.49 | 1.12 | 20 |
| D9 | Traffic control and restrictions at the job site | 2.79 | 0.94 | 65 | 2.45 | 0.51 | 71 | 2.88 | 1.03 | 42 | 2.91 | 1.04 | 62 |
| D10 | Government authorities and bureaucracy | 3.14 | 1.12 | 44 | 3.00 | 0.92 | 52 | 2.69 | 1.08 | 58 | 3.37 | 1.18 | 28 |
| D11 | Delay in performing the final inspection and certification by a third party | 3.06 | 1.10 | 51 | 3.00 | 0.92 | 52 | 2.75 | 1.24 | 54 | 3.21 | 1.13 | 43 |
| D12 | Political situation or instability | 2.58 | 1.12 | 72 | 2.40 | 0.88 | 72 | 2.44 | 1.21 | 72 | 2.72 | 1.18 | 68 |
| D13 | Economic problems | 2.87 | 1.10 | 62 | 2.80 | 0.95 | 60 | 2.69 | 1.30 | 62 | 2.98 | 1.10 | 60 |
| D14 | Problem with neighbours | 2.60 | 1.04 | 70 | 2.35 | 0.88 | 74 | 2.75 | 1.24 | 54 | 2.65 | 1.04 | 69 |
| D15 | Force majeure | 2.51 | 1.28 | 74 | 2.25 | 1.25 | 76 | 2.69 | 1.45 | 64 | 2.56 | 1.24 | 72 |
| D16 | Corruption | 2.41 | 1.15 | 76 | 2.40 | 1.05 | 73 | 2.56 | 1.46 | 68 | 2.35 | 1.09 | 76 |

Note: N= number of respondents; M = mean value; SD = standard deviation; R = ranking

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# THE ROLE OF SOCIAL CAPITAL IN SUSTAINING TACTICAL URBANISM IN INDONESIAN KAMPUNGS

**Ismu Rini Dwi Ari[1*], Wulan Dwi Purnamasari[1], Azwa Safrina Chumaira Nugroho[2], Kiyoshi Kobayashi[3], Masamitsu Onishi [4]**

[1]*Urban and Regional Planning Dept., Engineering Faculty,*
UNIVERSITAS BRAWIJAYA
[2]*Injourney Tourism Development Corporation,*
INDONESIA
[3]*Graduate School of Management,*
KYOTO UNIVERSITY
[4]*Urban Management Dept., Graduate School of Engineering,*
KYOTO UNIVERSITY

## Abstract

In the Global South, Tactical Urbanism (TU) interventions are often confined to superficial changes within a specific area, failing to tackle the underlying structural and policy-related issues. This paper discusses TU as a survival mechanism and compares two cases, Kampung Warna-Warni Jodipan (KWJ, the Colourful Kampung) and Kampung Tridi. The study moves away from Western-centric models using a blend of Silva's theory, Quality of Life (QoL) indicators and Social Network Analysis (SNA). The study found that the main focus for successful urban development is to improve the social relations between residents, instead of physical transformation. What stands out is the gender-inclusive and decentralised decision-making processes and participatory 'Organic Resilience' of KWJ with 81% citizen participation and 0.436 network density. By contrast, Kampung Tridi has suffered ecological problems because of its rigid, top-down hierarchical management style. To be effective in addressing local issues, TU initiatives need a paradigm shift toward a more institutionally integrated approach to co-production with planning regulations that are adaptive to local creativity.

***Keywords***: Tactical Urbanism; Social Capital; Co-production; Sustainable Regeneration; Informal Settlements; Quality of Life

[1] Corresponding author. Email: dwiari@ub.ac.id

## INTRODUCTION

Tactical Urbanism (TU) provides a flexible alternative to rigid urban planning policies. However, when considering thematic kampungs in Indonesia, this phenomenon can be in the form of what Steinbrink (2012) conceptualizes as 'Global Slumming' where urban poverty is aesthetically commodified. Superficial physical interventions that aestheticize urban poverty tend to deflect attention away from more profound socio-economic structures and do little to redress the basic issues of spatial and political inequality (Dovey & King, 2012; Roy, 2011). These interventions are inherently temporary and often do not translate into long-term structural change (Stevens & Dovey, 2023), especially in the absence of formal institutional mechanisms to sustain early grassroots enthusiasm and motivation (Fitri & Sari, 2025). In addition to economic inefficiencies, the inevitable decay of these temporary interventions can lead to physical environmental disorder, which is known to undermine local social cohesion and have a negative impact on the subjective well-being of residents (Mouratidis, 2021).

Sustaining TU requires an institutionalized co-production model (Watson, 2014; Cariello et al., 2021), where formal administrative structures partner effectively with grassroots initiatives. In this context, building community resilience requires effective participation driven by local ability and capacity building (Kadir & Ni, 2024), as well as the transition from isolated bonding capital to more inclusive bridging capital (Putnam, 2000; Woolcock & Narayan, 2000). While existing literature highlights the role of trust and social capital in fostering collective action within Malang's rural tourism villages (Prayitno et al., 2022; Permana et al., 2025), empirical evidence remains limited regarding how the micro-structures of local social networks influence the long-term trajectory of TU development in dense, urban thematic kampungs.

This research is a comparative case study of two riverbank settlements in Malang, namely Kampung Warna-Warni Jodipan (KWJ, the Colorful Kampung) and Kampung Tridi. Both communities share the same ecological and socioeconomic baseline as they evolved into vulnerable settlements along the Brantas River that are threatened by flooding and displacement. Controlling for variables like geographic context, the timing of initiation (both transformed in 2016) and the type of external stimulus (CSR paint sponsorships) helps to identify the reasons for their developmental gap. Controlling for these variables, the structure of local governance and social networks remains the main mechanism accounting for their divergence. We posit that inclusive, decentralized social network with high bridging capital increase community resilience. Conversely, hierarchies restrict openness and collective action and tend to stagnate when external support is withdrawn. This research frames TU as an adaptive mechanism for the Global South using Silva's (2016) evolutionary perspective

and the three dimensions of Social Network Analysis (SNA) rather than a temporary design intervention.

This study highlights the essential role of decentralized social integration, particularly the involvement of women through the Family Welfare Movement (PKK), which exemplifies Simone's (2004) concept of 'People as Infrastructure.' By examining these network dynamics, this research underscores the urgency of shifting urban policy frameworks toward more agile and adaptive planning, utilizing short-term interventions to reduce the risks of failure (Stevens et al., 2021) while ensuring sustained community resilience.

## LITERATURE REVIEW

### *Tactical Urbanism*

While policy experimentation is common in the Global North, Tactical Urbanism (TU) in the Global South is often a survival response to the lack of government action (Miraftab & Hall, 2009; Lydon & Garcia, 2015). In Indonesia, this "Organic Tactical Urbanism" uses dynamic spatial changes to improve neglected kampungs and build community identity (Fitri & Sari, 2025; Putra et al., 2019; Scannell & Gifford, 2010; Boano & Talocci, 2014). However, if this local solidarity does not turn into long-term partnerships with the government, these efforts can become just surface-level fixes for poverty (Woolcock & Narayan, 2000; Watson, 2014; Rahil et al., 2020), reflecting Simone's (2004) concept of 'People as Infrastructure'. This analysis captures how these temporary interventions evolve into more permanent institutional forms by applying Silva's (2016) seven-phase schema (Specialising, Following-up, Adding, Settling, Claiming, Monitoring, and Merging). This evolution shows that grassroots initiatives must be included in standard city governance (Stevens et al., 2021; Cariello et al., 2021).

### *Social Capital*

The foundation of social capital includes social networks, trust, and community norms, which are crucial for organizing collective action, advocating for participatory democracy, and for community responsiveness to adaptive challenges (Putnam et al., 1993; Putnam, 2000; Jungsberg et al., 2020; Prayitno et al., 2022; Liu et al., 2022; Chen et al., 2024). In the context of Kampung Warna Warni Jodipan (KWJ) and Kampung Tridi, the social structure is primarily centred on social design, sustainable tourism, and poverty alleviation (Prayitno et al., 2019, 2023). Strengthened social capital, community cohesion, and civic participation create synergy for participatory tourism governance that effectively integrates ecological preservation with local economic development (Ari, Prayitno, et al., 2024; Ari, Purnamasari, et al., 2024). Strong social networks, inclusive and equitable participatory practices, and especially informal networks


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of women, are associated with the social welfare of the community (Ari et al., 2022).

### *Quality of Life*

Quality of Life (QoL) is a combination of personal assessment of the living environment (Abdullah et al., 2024) and social perception of the city (Serag El Din et al., 2013). This study evaluates QoL across five interrelated dimensions, environmental well-being (Henderson & Loreau, 2023; Musa et al., 2015), social well-being (Burke et al., 2010; Keyes & Shapiro, 2004), physical well-being (Serag El Din et al., 2013; Randall et al., 2021), economic well-being (Wang et al., 2025; Osman et al., 2019) and subjective well-being (Martin Ginis, 2025; Mouratidis, 2021), to rigorously assess urban liveability. This multi-dimensional framework allows a complex comprehension of how tactical urbanism interventions contribute to the holistic improvement of residents' everyday experiences.

## RESEARCH METHODOLOGY

This study aims to develop an exploratory, mixed-method, comparative case study of two thematic kampung settlements in Malang. It intends to analyse the unique development processes and outcomes of each kampung from the viewpoint of the local community. Data collection consisted of field observations to assess the quality of the existing infrastructure as well as semi-structured, in-depth interviews. In total, 34 participants were interviewed: 16 from KWJ (Colourful Kampung) and 18 from Kampung Tridi. Participants were selected through purposive sampling based on their active participation in tactical urbanism. The participant group represents a cross-section of the community which includes members of the Tourism Awareness Group (Pokdarwis), neighbourhood leadership (RT/RW), the Family Welfare Movement (PKK), religious associations (tahlil group), and independent residents.

To systematically assess tactical urbanism and Quality of Life (QoL), qualitative interview narratives were transformed into a 5-point Likert scale. This quantification acts as an analytical compass, providing an objective baseline to systematically compare the structural performance gaps between the kampungs via comparative radar plots. To avoid arbitrary judgements, respondents' statements were strictly matched against detailed, predefined parameters developed during a preliminary survey. The coding was conducted independently by two primary researchers familiar with the local context. To ensure inter-coder reliability, any subjective discrepancies in score assignments were resolved through rigorous consensus-building discussions involving a senior researcher. This rigorously quantified data was used to evaluate Silva's (2016) seven-variable tactical urbanism framework (specializing, following-up, adding,

settling, claiming, monitoring, merging) and five QoL dimensions (ranging from physical to subjective well-being). Finally, Social Network Analysis (SNA) was used to examine social capital by mapping the social structure of each village according to certain criteria to measure social participation, network density, and centrality (degree, closeness, and betweenness).

In an effort to operationalize the tactical urbanism framework of Silva (2016) in the thematic kampungs of Indonesia, the seven theoretical dimensions were translated into concrete and observable indicators. These indicators were also used to inform the evaluation rubrics for the 1 to 5 Likert scale scoring (see **Table 1**).

**Table 1:** Operationalization of Silva's (2016) Tactical Urbanism Dimensions

| Tactical Urbanism Dimensions | Operational Indicator | Likert-Scale Extremes (1 = Poor to 5 = Excellent) |
|---|---|---|
| 1. Specializing | Problem clearly identified and functional/symbolic purpose relevant to community needs. | **1:** Top-down, irrelevant to real problems.<br>**5:** Bottom-up, highly visionary and participatory. |
| 2. Following-up | Presence of collective maintenance mechanisms, community stewardship, and life-cycle management. | **1:** Abandoned without maintenance mechanisms.<br>**5:** Adaptive, structured, and sustainable maintenance. |
| 3. Adding | Introduction of different physical elements (paths, landmarks, nodes) and their role as active social infrastructure. | **1:** Sporadic and unintegrated additions.<br>**5:** Holistic, synergistic, and functionally integrated. |
| 4. Settling (Effect) | Lived Space and the integration of new infrastructures in daily routines and their psychological appropriation | **1:** Rejected or completely ignored by residents.<br>**5:** Fully integrated, meaningful, and iconic to the community. |
| 5. Claiming | The degree to which citizens participate in planning, decision-making and resource contribution. | **1:** Non-participation (manipulative/top-down).<br>**5:** Full citizen control and proactive ownership. |
| 6. Monitoring | We have proactive feedback systems, responsiveness to issues and adaptive learning. | **1:** No monitoring or feedback mechanism exists.<br>**5:** Systematic monitoring utilized for future adaptation. |
| 7. Merging | Quality of collaboration, role sharing and synergy among multiple stakeholders (citizens, government, private sector). | **1:** Isolated processes with high conflict/mistrust.<br>**5:** Synergistic and integrated governance network. |

*Source: Author's construct based on Silva (2016)*


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To explicitly map the social capital of the community, Social Network Analysis (SNA) was performed using the UCINET 6.742 software to generate network metrics and sociograms. The network boundary was defined socio-geographically, restricted to active residents and key community stakeholders within the administrative borders of KWJ and Kampung Tridi who are involved in tactical urbanism. Within this network, a 'tie' (edge) was defined as an active communicative and collaborative relationship, operationalized1 through shared participation (co-affiliation) in local civic organizations such as Pokdarwis, the Family Welfare Movement (PKK), and youth groups. Data for these ties were collected during the semi-structured interviews via affiliation surveys, where the 34 selected participants identified their active organizational memberships and coordination channels, which were subsequently converted into binary adjacency matrices.

Three specific SNA metrics were selected to evaluate the governance structures. Network Density was measured to justify the level of overall community cohesion and mutual trust, indicating strong bridging capital. Betweenness Centrality was applied to identify ‘gatekeepers’ or bottlenecks in communication. This identified actors that dominate the flow of information on a disproportionate scale. Lastly, the Network Centralization Index (NCI) was chosen to quantitatively validate the level of structural dependency, indicating whether a kampung is functioning in a vulnerable, centralized and top-down framework or resilient, decentralized structure.

## ANALYSIS AND DISCUSSION

KWJ (Colourful Kampung) and Kampung Tridi have had a similar trajectory in their evolution to tourist villages from informal slum settlements. But there were significant differences, despite these common origins. The characteristics of the development of KWJ (Colourful Kampung) are more stable than Kampung Tridi, especially in the management phase. Meanwhile, the development characteristics of Kampung Tridi have several problems, such as uncertainty regarding external support that affects the sustainability of the tourist village. Details regarding the developmental timelines of both kampungs are presented in **Table 2.**

**Table 2:** Comparison of KWJ (Colourful Kampung) timeline and Kampung Tridi timeline

| Timeline | Comparison of Two Kampungs |
|---|---|
| Phase 1 (Pre-Tourist Before 2016) | The KWJ (Colorful Kampung) at this stage was recognized as a slum area along the riverbanks. Major issues include the absence of a waste management system, the community’s habit of disposing waste into the river and the long-standing eviction threats that have persisted since the 1990s . Meanwhile, the Kampung Tridi was also recognized as a slum settlement and carried a negative social image. It was often referred to as the “Dayak Kampung” due |

| Timeline | Comparison of Two Kampungs |
|---|---|
| Phase 2 (Initiation & Development 2016-2017) | to low levels of public safety, the prevalence of alcohol consumption, and the community's limited concern for environmental cleanliness.<br>The initiation of tourism development in KWJ (Colourful Kampung) began with an idea proposed by students from the University of Muhammadiyah Malang through the GuysPro community. This idea subsequently received full support from the CSR program of PT Indana Paint through the "Decofresh Warnai Jodipan" initiative, along with the provision of new infrastructure, including a glass bridge connecting the area to the Kampung Tridi. Meanwhile, the initiation of tourism in the Kampung Tridi began with the painting of its main gate, facilitated by donated paint from Nippon Paint and supported by the former Mayor of Malang. The remaining paint was then used by a local artist, Mr. Eddy Gimbal, to create 3D murals along the main entrance of the settlement. These murals later became the new identity of Kampung Tridi and attracted the attention of the Mayor of Malang at the time, prompting a large-scale painting program from August to December 2016, sponsored by PT Indana Paint. |
| Phase 3 (Management 2017-now) | The local Tourism Awareness Group (Pokdarwis) of KWJ (Colourful Kampung) which comprises of local residents is responsible for the management of tourism such as ticket management, activities of repainting, cleanliness, and the development of local MSMEs. Revenue from entrance fees is still used to support routine maintenance, for example, regular repainting, so the tourism appeal is being maintained and visitor numbers remain steady, largely international tourists, which is proof of this. Meanwhile, management of the tourist village such as ticket sales, parking, and monitoring in Kampung Tridi is handled by the Tourism Awareness Group (Pokdarwis) formed in 2017. However, there are also several problems in its implementation, such as the lack of financial transparency by tourism managers, uneven development and uneven economic benefits. The problem can occur due to a rigid leadership structure, especially because the neighborhood head (RW) is also the Chair of the Tourism Awareness Group (Pokdarwis). Besides, PT Indana Paint also stopped supporting the repainting in the early 2025 due to the expired contract. |

*Source: Survey Results, 2025*

The infrastructure at KWJ (Colourful Kampung) and Kampung Tridi facilitates activities in the village both related to everyday life and also the functions as tourist villages. The various infrastructure includes blue, grey, green, and social. The primary blue infrastructure for both settlements is the Brantas River; once heavily polluted, it has seen gradual improvements due to regular community cleansing efforts. While these infrastructural categories are present in both kampungs, their specific characteristics differ according to the particular tourism demands and spatial constraints present at each site. Overall, the infrastructure at KWJ is more systematically and comprehensively maintained than at Kampung Tridi. The infrastructure of both villages is illustrated in **Figure 1.**


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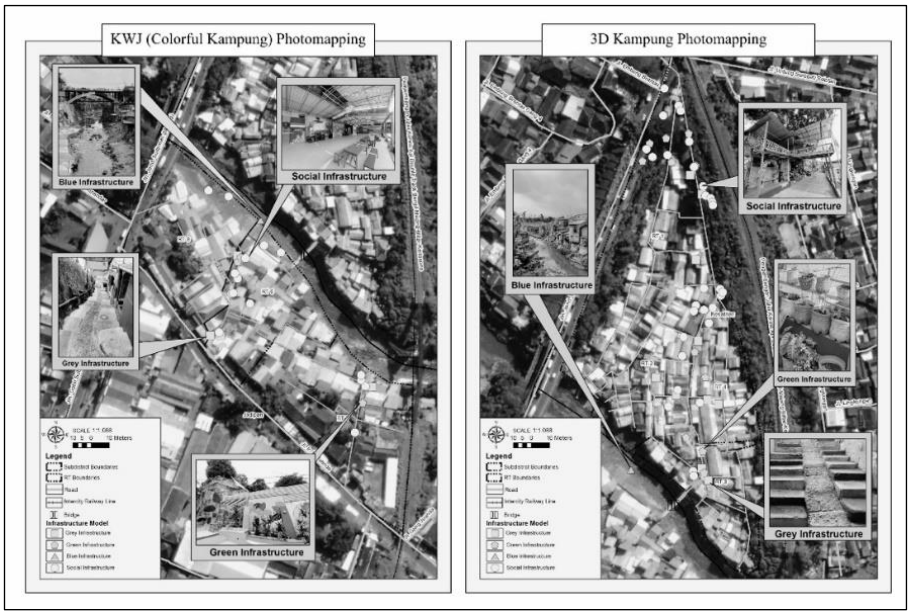



**Figure 1:** Comparison of KWJ (Colourful Kampung) infrastructure and Kampung Tridi infrastructure
*Source: Survey Results*, 2025

Precarious riverbank settlements are often characterized with entrenched infrastructural deficits and extreme flood vulnerabilities (Dangol, 2024). To address these very issues, Kampung Warna Warni Jodipan (KWJ) and Kampung Tridi employed tactical urbanism to transform their slum areas into themed tourist destinations. Although the starting conditions are similar, our results reveal a quite different evolution in the seven tactical urbanism dimensions (Silva, 2016; see Table 3). At the start of the Specialising phase, both settlements demonstrated good adaptability (KWJ: 4.44; Tridi: 4.28). However, differences increased during the maintenance period. KWJ was able to Add (4.00) and Follow-up (4.25) by successfully improving its environment. The downfall of the area's tourism inclusivity is due to the poor maintenance in Kampung Tridi. Meanwhile, KWJ moved forward into a more vibrant and creative tourist hub.

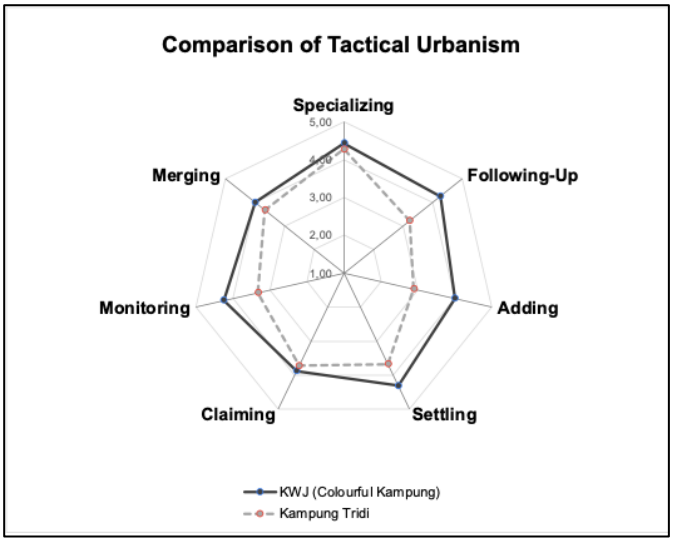



**Figure 2:** Comparison of Tactical Urbanism
*Source: Author's Analysis, 2025*

**Table 3**: Comparison of Tactical Urbanism

| Kampung | Specializing | Following-Up | Adding | Settling | Claiming | Monitoring | Merging |
|---|---|---|---|---|---|---|---|
| KWJ (Colourful Kampung) | 4.44 | 4.25 | 4.00 | 4.31 | 3.88 | 4.25 | 4.00 |
| Kampung Tridi | 4.28 | 3.22 | 2.89 | 3.67 | 3.72 | 3.33 | 3.67 |

*Source: Author's Analysis, 2025*

In addition to infrastructure differences, the two kampungs are also differentiated by governance metrics. KWJ scores higher on Settling (4.31 vs. 3.67), Merging (4.00 vs. 3.67) and Monitoring (4.25 vs. 3.33) which means KWJ has become a resilient community that merges successfully with municipal governance systems. Its decentralised trust networks promote high levels of civic engagement and collective governance of the commons (Cariello et al., 2021; Permana et al., 2025). However, Kampung Tridi's hierarchical structure lacks culture of continuous progress and mutual responsibility (Silva, 2016). This centralised approach might, at first, enhance internal cohesion (bonding capital), but it does not generate the 'bridging' social capital necessary for integration into broader institutional networks (Woolcock & Narayan, 2000; Fitri & Sari, 2025). The inherent brittleness of this system was exposed in early 2025 with the withdrawal of corporate sponsorship, leading to infrastructural decay in the face


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of bad communal self-management and adaptive feedback loops. Such poor governance mechanisms in the end reduce overall habitability, with unchecked aesthetic clutter increasing psychosocial distress (Mouratidis, 2021) and negatively affecting Quality of Life measures across relevant domains (see Table 4). It is important to point out that these QoL scores are not subjective interpretations by the researcher but coded outputs from the interviews that represent the perceptions of the residents in relation to their living environment. The qualitative narratives of the respondents were converted to the 1 to 5 scale systematically on the basis of predefined rubrics to make the structural comparison objective.

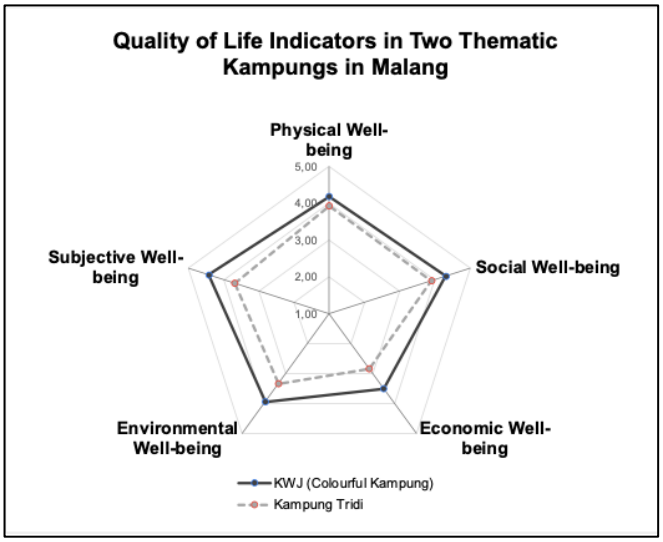



**Figure 3:** Quality of Life Indicators in Two Thematic Kampungs in Malang
*Source: Author's Analysis, 2025*

**Table 4**: Quality of Life Indicators in Two Thematic Kampungs in Malang

| Kampung | Physical Well-being | Social Well-being | *Economic Well-being* | Environmental Well-being | Subjective Well-being |
|---|---|---|---|---|---|
| KWJ (Colourful Kampung) | 4.18 | 4.31 | 3.50 | 3.94 | 4.42 |
| Kampung Tridi | 3.93 | 3.90 | 2.83 | 3.34 | 3.69 |

*Source: Author's Analysis, 2025*

Another aspect underlining the differences between the settlements is the quantitative indicators of Quality of Life (QoL). The economic (3.50 vs. 2.83) and social well-being (4.31 vs. 3.90) of KWJ are substantially higher than Kampung Tridi's. Tridi's centralised leadership provides sufficient internal

'bonding' capital, but severely lacks the 'bridging' capital needed for external economic growth and collective social integration (Woolcock & Narayan, 2000; Keyes & Shapiro, 2004). In contrast, KWJ has a decentralised approach that transforms spatial improvements into active economic assets, thus strengthening Sen's (1999) theory of agency. KWJ also uses social networks to develop strong collective action (Permana et al., 2025; Kadir & Ni, 2024). Moreover, Tridi's lower Physical (3.93 vs. 4.18) and Environmental Well-being (3.34 vs. 3.94) scores vis-à-vis KWJ (Musa et al., 2015) reflect Tridi's infrastructural deficiencies. Therefore, Tridi (3.69) has a lower level of Subjective Well-being than KWJ (4.42) due to the poorer living conditions (Randall et al., 2021; Mouratidis, 2021). Tridi's stagnation is a case of the 'aestheticisation of poverty' (Roy, 2011) and echoes Croce and Guastavino's (2025) argument that top-down strategic urbanism often leads to cosmetic interventions that lack basic liveability. Social Network Analysis (Zhou, 2023; see Figure 4) was used to empirically analyse participation, density, and centrality for these different social systems.

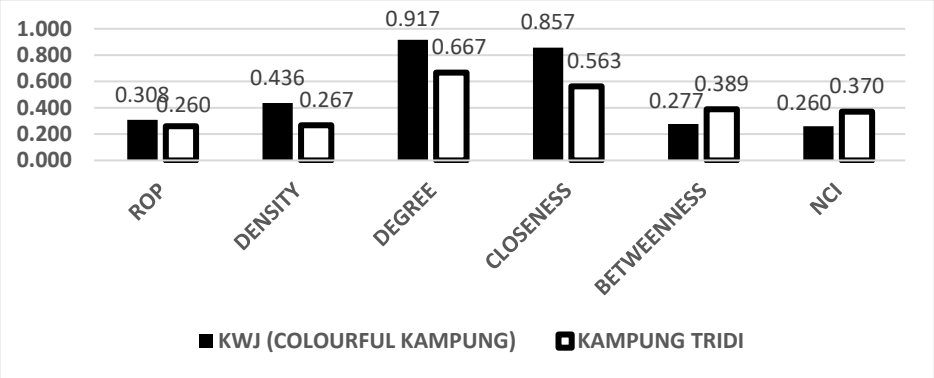



**Figure 4:** Social Capital Condition
*Source: Author's Analysis, 2025*

Social Network Analysis reveals that KWJ has a more evenly distributed and naturally inclusive social capital than Kampung Tridi with a centralised and fragile network structure. The data analysis reveals that KWJ enjoys a much higher level of community engagement (81%) than Tridi (56%). So, the KWJ community takes part in civic life actively. KWJ has a Rate of Participation of 0.308, while Tridi has 0.260. In addition, the network density of KWJ is 0.436. This implies that members in KWJ are closely connected. This helps in communication and sharing of information. As pointed out by Permana et al. (2025), dense networks build trust and that trust pushes collective action. In contrast, Tridi has a lower network density of 0.267. Tridi is limited by poor communication channels and by a reliance on a few key personnel. This structural fragility is consistent with Woolcock and Narayan (2000) who state that


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communication is centralised and limits the widespread of information. This means that the Tridi community is highly dependent on a few key individuals, and this makes the overall structure fragile. Figure 5 displays the sociograms of the two kampungs, highlighting the central nodes and the main communication channels. It is then possible to investigate what these network structures mean at the actor level.

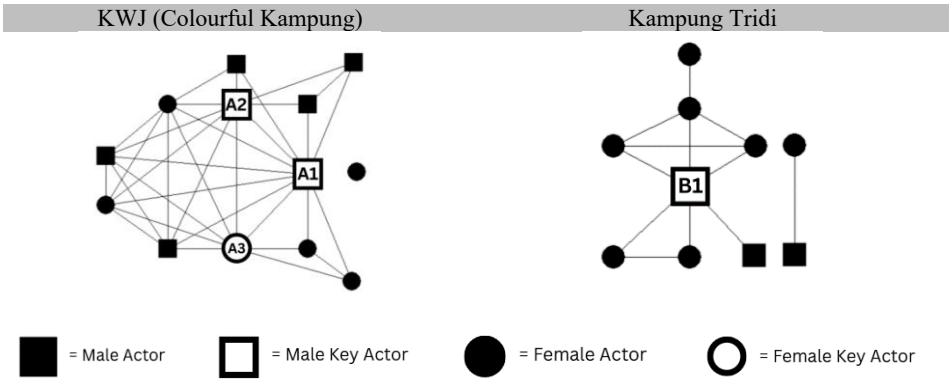



**Figure 5:** Visualized Social Networks
*Source: Author's Analysis, 2025*

The network of KWJ is more dynamic and responsive than Tridi's, as the degree centrality of KWJ is 0.917 while Tridi is 0.667. The closeness centrality of KWJ is 0.857 and that of Tridi is 0.563. Tridi, however, has a higher betweenness centrality (0.389 compared to 0.277) and is overly dependent on a single control point. Moreover, Tridi has a Network Centralization Index (NCI) of 0.370, which is much higher than KWJ's 0.260, showing that power is highly centralised (Fitri & Sari, 2025). The Tridi hierarchy is centralised and is led by the Neighbourhood Leader (RW) and head of Pokdarwis. Therefore, the hierarchical structure results in poor communication, complex financial arrangements, and dissatisfaction among the community (Fauzi, 2024; Rami et al., 2023). This centralised framework limits community participation (Alyani & Herlily, 2019; Huang et al., 2025) and negatively impacts tactical urbanism, as shown by Tridi's low scores in Adding (2.89) and Monitoring (3.33). This negatively affects the Economic (2.83), Environmental (3.34), and Social (3.90) dimensions of Quality of Life. This suggests the negative impact of traditional and rigid urban planning approaches on human well-being (Serag El Din et al., 2013).

KWJ works very differently. KWJ implements a decentralised governance system by involving neighbourhood leaders (RT/RW), youth groups (Karang Taruna), and the Family Welfare Movement (PKK). This supports the

development of 'Organic Tactical Urbanism' (Fitri & Sari, 2025). KWJ is an example of Simone's (2004) idea of 'People as Infrastructure,' in which social capital is dispersed and work is distributed across these groups. This implies that "Organic Resilience" is self-directed and not constrained by strict orders. KWJ's case ultimately shows that tactical urbanism in the Global South must be more than cosmetic. It has to be based on inclusive networks, not the control of a single person.

## CONCLUSION

The main factor causing organizational problems in Kampung Tridi is its hierarchical leadership structure, where a single authority directs the organization in a top-down manner. While exclusive top-down decisions can ease short-term execution, this approach is characterised by a severe lack of transparency and open communication, which inevitably fosters resistance and dissatisfaction within the community. Such governance also substantially increases the centralisation of the network by eroding mutual trust. Often, a lack of civic interest is cited as the cause of stagnation in community operations, but it is more accurately a systemic obstruction to collective capacity. This is especially evident when residents are assigned roles but are structurally unable to perform well in them, a finding that is consistent with Kadir and Ni (2024).

Moreover, the sustainability issues of Kampung Tridi is in accordance with the findings of Rahil et al. (2020) which stated that the communal social value is essentially diminished when residents are not fully engaged. This lack of engagement is reflected in Tridi's low Tactical Urbanism scores for Adding (2.89) and Monitoring (3.33), which at the same time degrade the overall Quality of Life. This supports the argument by Mouratidis (2021) that top-down urban interventions often overlook community well-being leading to the deterioration of physical environments and increased psychosocial stress among residents.

On the other side is Kampung Warna-Warni Jodipan (KWJ) with 'Organic Resilience'. The resilience comes from the absence of any centralised authority. The system has various communities such as neighbourhood leaders (RT/RW) and the Youth Organization (Karang Taruna). This type of inclusive leadership model largely eliminates the systemic vulnerabilities of centralised models. This situation is consistent with Simone's (2004) notion of the people and the social networks in which they are interconnected as the basic infrastructure of a community. Furthermore, as Putra et al. (2019) point out, when residents actively participate in grassroots place-making, it fosters a more robust and sustainable neighbourhood identity. To summarize, the KWJ project demonstrates that successful urban regeneration is based on the building of mutual trust and social capital and not on rigid top-down instructions.


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Some steps need to be taken to maintain this kind of community resilience and to link short-term changes with long-term city plans. First, local governments should support tactical urbanism not only by providing funding for cosmetic changes but also by supporting local capacity building and ensuring that these small-scale interventions are integrated into larger city plans. For example, they can ensure that local waste management efforts are included in formal municipal public works. Second, there is a need to make planning rules more flexible. This would allow communities to make contextual changes without going through too much red tape. Finally, collaborative initiatives in the kampungs of the Global South should be based on an institutionally integrated, decentralised model of co-production. In this context, local groups, such as neighbourhood associations and youth organisations, are given decision-making power and control over the way they operate. The government acts as a facilitator, providing equitable regulatory structures. Ultimately, this approach ensures that the transformation of cities is supported by the state while remaining firmly rooted in the strengths of the people themselves.

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# INTERPRETATION OF THE ARCHITECTURE OF MODERN KAZAKHSTAN MOSQUES THROUGH THE EXAMPLE OF T. ABILDA AND SH. YUSSUPOV PROJECTS

**Elvira Danibekova[1], Gulnara Abdrassilova[2], Raushan Daurenbekova[3], Aktorgyn Mannapova[4]**

[1,2,3,4]*School of Architecture,*
INTERNATIONAL EDUCATIONAL CORPORATION, KAZAKH LEADING ACADEMY OF ARCHITECTURE AND CIVIL ENGINEERING (KAZGASA), ALMATY, KAZAKHSTAN

## Abstract

The formation of Kazakhstani architecture is marked by both gradual changes and creative breakthroughs: starting from the search for innovation in the Soviet Era to national and regional features in the post-Soviet period. Many generations of talented masters have affected the formation of unique appearances of major Kazakh cities. Traditional forms and silhouettes, combined with the creativity and innovativeness of architects of the Independence Period in a regional context make up the basis for the figurative interpretation of regional meanings in the modern architecture of Kazakhstan. The diversity of individual architects' professional approaches shapes a complex, original image of Kazakhstani objects. A study of compositional and shape-generating techniques will allow determining the role of Kazakhstani architects' creative activity in providing uniqueness in Kazakhstan's architecture. This research's issue is associated with the insufficient state of knowledge of modern Kazakhstani architects' creative and authorial strategies. Religious structures are among the most significant architectural facilities reflecting the dynamics of historical-cultural, socio-economic and technological transformations of the country's transition period. This is due to the population's return to their roots and traditional faith, which has affected the intensive construction of new mosques and religious schools. The purpose of this study is to identify the compositional principles of the modern sacred architecture in Kazakhstan, using the creative activity of architects Tolegen Abilda and Shukhrat Yussupov as an example: the way the Islamic traditions are interpreted in the post-Soviet context in terms of regional identity. The research methodology is based on an integrated approach, comprising an analysis of the spatial and compositional specific features of modern mosque buildings and the urban planning role of the facilities under consideration. The interviews held with the above-mentioned architects are aimed at identifying the specific features of their creative activity, the tools for interpreting traditions and innovative solutions.

***Keywords***: mosque architecture, author's interpretation, volumetric and spatial composition, regional identity, traditions, innovation

[4] Corresponding author. Email: ak.mannapova@kazgasa.kz

## INTRODUCTION

The professional activity of Kazakhstan's architects started in challenging environment, when architecture was formed under the impact of a series of political conflicts and economic upheavals, sometimes followed by periods of stable development. In the context of global architectural trends and attainment of Independence, the Kazakhstani architects faced the challenges of developing new design strategies in form shaping, imaginative and compositional conceptions (Abdrassilova & Danibekova, 2021). The architecture of religious buildings especially felt the impact of both global and regional challenges.

Historically it is known that hundreds of mosques were operating in the territory of modern Kazakhstan before 1917, but in the 1930s, they were closed and destroyed in large numbers. The Soviet era of Kazakhstan's development was marked by almost a full elimination of the institutional Islamic infrastructure, and only a handful of mosques remained operational by 1990. At the cusp of the 20-21 centuries the post-Soviet society of Kazakhstan had been experiencing the self-identification and return of national traditions process (Lyukhurov, 2025).
The Law "On Free Exercise of Religion and Religious Organizations", adopted in 1992 and guaranteed every citizen's right to freedom of religion after the Soviet regime's restrictions activated the countrywide construction of the mosques, the imaginative solution thereof was inclined to the interrelation with a local cultural context (Kikimbayev, 2023; the Law of the Republic of Kazakhstan No. 1128-XII, 1992). The mosques of this period were the result of a common task among local architects to search for a national and regional imagery for the religious architecture of the new Kazakhstan.

The change in the government's political orientation from atheism to support for religious denominations has led to the widespread construction of mosques, churches, synagogues and other institutions in Kazakhstan. In 1991, there were 68 mosques in Kazakhstan, and by 2026, their number increased to 2,857, that is a 42-fold increase (Zhandossova et al., 2025). The architecture of Kazakhstan's mosques, including some of the largest ones (for example, the Khazret Sultan Mosque in Astana (architect Sagyndyk Zhanbolatov, 2012) and the Central Mosque of Almaty (architects Sultan Baimagambetov, Zhanabai Sharapiev, Kazbek Zharylgapov, 1999), mainly adheres to traditional visualization.

An important aspect of imparting uniqueness to a facility via its regional identity is the architect's creative vision through an individual style. The author's personal vision and authentic craftsmanship, nurtured within local specific features, shape a regionally sensitive architectural and spatial environment (Abdrassilova & Murzagaliyeva, 2020, Danibekova et al., 2025). It is often the case, that an architect's idiom evolves and transforms under the influence of


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collaborative design practice, where the design process takes the form of a field for negotiations (Ferreira, 2025).

The research range of issues lies in the insufficient study of compositional and form-shaping techniques, as well as in the interpretation of traditions and innovative solutions in the creative activity of modern Kazakhstani architects. The creative activity of the most modern Kazakhstani architects represents a rich resource to determine the mechanisms for forming regional identity in the country's architecture and requires a comprehensive study. Currently, one can observe a gradual shaping of a research foundation focused on the professional activities of Kazakhstani architectural masters. For instance, domestic scholars have conducted an analysis of the works by innovators of the Kazakhstani architecture (Abdrassilova & Aukhadiyeva, 2021, Danibekova, et al., 2026).

At the background of thousands of typologically recognizable structures, one can clearly distinguish those whose morphology utilizes new symbolic attributes: these include the mosque designs done by architects Tolegen Abilda and Shukhrat Yussupov. The creative activity of these two architects is of scientific and practical interest as the examples of new approaches to form shaping that expand the boundaries of the traditional understanding of the sacral facilities. The article considers three mosques: the “Imangali” in Atyrau city, the “Mashkhur Zhusup” in Pavlodar city and the “Vainakh" in Almaty city.

The article materials are based on a scientific generalization of the outcomes of compositional-spatial, comparative and urban planning analysis. Since architects T. Abilda and Sh. Yussupov are active designers, the authors have found it important to conduct an expert interview with them, the process of which is described in the article. This research work focuses on their significant examples of shaping modern sacral architecture in Kazakhstan during the formation of the young republic. Their works are based on a synthesis of the Islamic architectural canons, Kazakh cultural images and innovative compositional techniques from regional traditions and until recently, designer approaches had not been studied in detail.

Architects Tolegen Syzdykuly Abilda and Shukhrat Zainitdinovich Yussupov are among the modern masters of Kazakhstani architecture, whose creative activity covers an important period in the history of Kazakhstan and reflects significant epochal changes in the political and socio-cultural spheres of the country at the cusp of the 20th and 21st centuries, as well as the main trends in the development of domestic architecture. Their creative activity started in the late 1970s and evolved over decades at the AlmatyGiproGor-1 Design Institute LLP (AlmatyGiproGor-1 Design Institute LLC), from project architects to heads of the architectural and construction department. This generation of domestic architects has made a multifaceted contribution to the modern architecture of

Kazakhstan. In particular, this has been manifested itself in their attention to the continuance of traditions combined with new architectural trends and advanced technologies.

The most famous works of these architects include mosque buildings with distinctive architecture, which have become notable urban planning and architectural objects, combining the traditions of Islamic architecture with modern compositional solutions. A study of T. Abilda's and Sh. Yusupov's creative activity's specific features, based on the example of mosque designs, will allow determining their contribution to the development of modern architecture in Kazakhstan, in particular mosques, and identify general trends in forming concepts of regional identity.

## LITERATURE REVIEW

Current research of religious, in particular Islamic buildings, are associated with the study of modern trends in the development of mosque architecture in the 21st century and the issues of rethinking their images (Shukurov, 2014; Shanbayeva et al., 2024; Putra et al., 2025; Mertyürek & Demırbas, 2023; Al-Tamimi & Pankina, 2024).

The publications devoted to the unique creative activity of individual architects, pay special attention to the role their approaches and principles of architectural thinking have played in the design, as well as in the form-shaping concepts of the 20th and 21st centuries. They include: a study of digital and parametric aspects in Zaha Hadid creative activity (Coskun, 2024); identification of energy efficiency, environmental friendliness and innovation as the conceptual basis of Norman Foster's projects (Abdrassilova & Onichshenko, 2024); review of the works of architect Saken Narynov, an innovator of Kazakhstani architecture (Abdrassilova & Aukhadiyeva, 2021); a study of methods for rethinking forms in the creative activity of Tolegen Abilda (Kisamedin, 2012); definition of design principles in the works of Toyo Ito (Onichshenko, 2016). Single studies address the issues of co-authorship in architecture, which role is assigned to each participant in the design process, and the relationship with innovations (Marcos et al., 2024; Combrinck & Porter, 2021).

Current studies of the mosque architecture in Kazakhstan reflect immediate issues:

- analysis of planning, volumetric-spatial solutions and decorative design, identifying factors that shape regional identity and uncovering modern trends regarding Islamic culture buildings (Galimzhanova et al., 2020; Sadykova, 2014);
- exploring conventional specific features regarding shaping regional mosque architecture of Eastern and Western Kazakhstan, the impact of etnocultural


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foundations and motiffs, discovery of historical continuity (Baitenov, 2024; Tanzharykova & Maulenova, 2024);
- an interdisciplinary approach towards the study of mosque interiors, the role of ornament in symbolization, tradion and innovation, in the concept of fractals, etc. (Shklyaeva, 2016; Moralı & Topsakal, 2025; Galimzhanova, 2017).

A conducted review of the current status of mosque knowledge in Kazakhstan has shown that various researchers considered individual structures, conducted retrospective analyses of mosque buildings, identified the layout, volumetric and spatial specific features of a number of modern structures, revealed historical continuity and made attempts to define regional identity and the factors that shaped it, as well as published publications.

Meanwhile, there is insufficient revelation of the principles which are used to realize regional identity directly at the compositional level: the arrangement of spatial structure, silhouette construction, relationship between the entrance area and the main volume and interpretation of traditional architectural archetypes. It is also worth noting a trace amount of the research works focused on the author's approaches of Kazakhstani architects who affected the development of post-Soviet mosque architecture.

## RESEARCH METHODOLOGY

The methodology of this study is based on a comprehensive exploring of the creative specific features of architects T. Abilda and Sh.Yussupov, using the example of a contemporary Kazakhstani mosque: compositional-spatial analysis, comparative analysis and interviews. Identifying visual and figurative features and characteristics of forming has applied a method of scientific generalization.

Architects T. Abilda and Sh.Yussupov took part in two semi-structured face-to-face interviews as part of the qualitative portion of the researh work. Each interview lasted approximately forty minutes and was conducted on March 19, 2026 at the "90th Anniversary of the Union of Architects of the Republic of Kazakhstan" "Architecture of Three Generations" Anniversary Event at the National Central Museum in Almaty. Before holding the interviews, the participants were explained the goal of the study, and they provided their consent to audio recording. The main topics of the 10 questions asked during the interviews included mosque design methods used by architects, their interpretation of conventional architectural forms and symbols, regional identity, as well as the evolution of a modern sacral architecture. The audio recordings were fully deciphered after the interviews. The architects' statements were grouped into key topics and correlated with the outcomes of the compositional-

spatial and comparative analysis of the selected mosques within a thematic analysis of the data obtained during the interview.

The mosque buildings we have reviewed are the outcomes of projects completed under the leadership of T. Abilda or Sh. Yussupov as part of a creative team, where the authorship of the projects in public space is represented by a variable recognition of the leadership. These include: The Imangali Mosque in Atyrau city (1999-2001, architects Sh. Yussupov, T. Abilda, N. Popova); the Mosque named after Mashkhur Zhusup in Pavlodar city (2000-2001, architects T. Abilda, Sh. Yussupov, S. Dautov, S. Nurbai); the Vainakh Community Mosque in Almaty city (2004, architects T. Abilda, S. Nurbai, Sh. Yussupov).

The issue of individual and collective creative activity in architecture is related to the review of authorial strategies in piece of architecture (Ferreira, 2025). The facilities we have selected for the study are the examples of preserving the integrity of the author's idea, based on the coordinated distribution of each participant's contributions.

The chief architect of the Imangali Mosque project in Atyrau city is Shukhrat Yussupov, and Tolegen Abilda is a member of the creative team. The monumental and imposing appearance of the mosque, with its twenty-three-metre blue dome and two twenty-metre minarets, is based on the classical principles of the Islamic art of building.

The designer of the Pavlodar Central Mosque with its blue tower dome is Tolegen Abilda, and Shukhrat Yussupov is a member of the design team. The large-scale composition with a domed and tented roof solution for the main volume (the dome is fifty-four metres high) is emphasized by a central staircase structured in successive tiers and a main portal-gabled niche with sixty-three-metre-high minarets. The structure is named after Mashkhur Zhusup (1858-1931), a Kazakh poet, thinker, historian and ethnographer, who researched the culture and everyday life of the clans and tribes of Northern and Central Kazakhstan, and is located in the city centre.

Tolegen Abilda served as the chief architect for the Vainakh Mosque of regional significance, but a majestic building for the Chechen and Ingush diasporas of Almaty city, and the creative team included Shukhrat Yussupov and Sakabai Nurbai.

The examples of mosques we have reviewed, where T. Abilda and Sh. Yussupov alternated as chief architects, are of particular interest in determining the role of the architects' creative strategies in shaping the author's interpretation of the image. The research methodology we have used will allow identifying the specific features of the objects, and what compositional methods and means prevail the form shaping process.


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## ANALYSIS AND DISCUSSION

The review of these examples will enable determining the architectural specific features of the facilities, the author's strategies and their impact on the form shaping process in the architecture of a modern Kazakhstani mosque.

### *Town-Planning Analysis of the Facilities*

The Mashkhur Zhusup Mosque is located in the central part of Pavlodar city, limited by major city motor-roads. Pavlodar is a regional centre, a city in north-eastern Kazakhstan with a population of 335,000 people. One of the city's iconic landmarks is a long riverwalk along the Irtysh River. The mosque is located within the urban planning axis, in the direction of the riverwalk and the city beach. This visual planning axis embraces important city landmarks such as the Ice Palace, the Schoolchildren's Palace, the Regional Court and the City Hall, as well as extensively landscaped area, dominated by a high dome and minarets of the mosque - a key landmark in the structure of a large city block (Figure 1).

The Imangali Mosque is located on a city main near the central square of Atyrau and, alongside with it shapes an open public and cultural space, simultaneously serving as its dominant feature. Atyrau is a city in Western Kazakhstan on the Ural River with a population of 320,000 people. The mosque building is integrated into the citywide public facilities system, but its interaction with the river is fragmented, primarily on the level of the urban landscape (Figure 2).

The Vainakh Mosque's placement in the urban planning context in Almaty differs radically from the placement of mosques in Atyrau and Pavlodar cities. Almaty, the former capital of Kazakhstan (until 1997), is a major metropolitan city of the republican significance, with a population of over 2,200,000 people. The mosque is located in the area of low-rise buildings in the Zhetusy District – one of the city’s administrative-territorial units. A compact volume of the building aligns with its position nature: there is an emphasis of a local urban planning status of the facility as a district compositional focal point within a large metropolitan city (Figure 3). In the meantime, there is a reading-out of a narrow sphere of cultural and ethnic function of the sacral space, oriented primarily towards local residents of the region and representatives of specific diasporas.

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**Figure 1:** Mashkhur Zhusup Mosque in Pavlodar city (2000–2001; architects T. Abilda, Sh. Yussupov, S. Dautov, & S. Nurbai)
(a) Photographic documentation of the Mashkhur Zhusup Mosque.
(b) The mosque's peshtak (main entrance portal).
(c) Location of the Mashkhur Zhusup Mosque and other local mosques in the city.
(d) Urban planning organization of the mosque within the urban structure.
*Source: (a) Authors' photograph; (b) Kisamedin (2012); (c–d) Prepared by the authors.*

The magnificent silhouettes of the Imangali Mosque in Atyrau city and the Mosque named after Mashkhur Zhusup in Pavlodar city serve as compositional accents and can be seen from various locations. Each building, located in an open city square, creates a distinct sacred space with a special atmosphere of tranquility and harmony. This is the outcome of compositional integrity and, as a consequence, the urban-planning significance of each facility.

Architect Peter Zumthor associates the method of arranging a verified architectural space with the “image of place” and building attributes such as “balance”, “integrity” and “strength” and in general, with “regional rationality” (Bystrova, 2018). One can trace the indications that architects are turning to this method to achieve the organic integration of mosques into the modern urban-


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planning context. A commonality of compositional principles can be noted: the laconic yet stepped volumetric-spatial arrangement of the mosques is consistently revealed to a viewer through an interesting interplay of forms and shadows. In the meantime, there is a difference: the Imangali Mosque is simultaneously a massive and visually lightweight building, integrated into the space of the city square in Atyrau, forming a single compositional integrity with it. The solemn and representative silhouette of the Mashkhur Zhusup Mosque, in contrast, prevails and subjugates its surroundings as a major religious centre of regional significance in Pavlodar.




**Figure 2:** Imangali Mosque in Atyrau city (1999–2001; architects Sh. Yusupov, T. Abilda, and N. Popova)
(a) Photographic documentation of the Imangali Mosque. Source: Authors' photographs.
(b) Location of the Imangali Mosque and other local mosques in the city.
(c) Urban planning organization of the mosque within the urban structure.
*Source: (a) Authors' photograph; (b–c) Prepared by the authors.*




**Figure 3:** Vainakh Mosque in Almaty city (2004; architects T. Abilda, S. Nurbai, & Sh. Yussupov)
(a) Architectural model of the Vainakh Mosque in Almaty (created by T. Abilda and S. Nurbai).
(b) Photographic documentation of the Vainakh Mosque.
(c) Location of the Vainakh Mosque and other local mosques in the city.
(d) Urban planning organization of the mosque within the urban structure.
*Source: (a) Photograph from the personal archive of T. Abilda; (b) Authors' photograph; (c–d) Prepared by the authors.*

### *Compositional-Spatial Analysis*

The conventional architecture of sacral structures in Kazakhstan and Central Asia is marked by monumentality and symmetry (Abdrassilova, Murzagaliyeva & Kuc, 2021). All three modern facilities under consideration share the principle of strict centric hierarchy, where the dome serves as both the primary geometric centre and the spatial focal point it creates. The expressive silhouettes and plasticity of the elevations of the mosque buildings we are studying have been achieved through the contrast and rhythmicity of the rows of cascading volumes, by alternation of openings, and arranging the main entrances. Thus, one can note the commonality in the axial symmetry of the mosques in Atyrau and Pavlodar, as well as the variability of compositional methods in the distribution of masses and proportionality relations in the forms.

The compositions of buildings in Pavlodar and Atyrau are characteristic of a radial arrangement of forms, and the mosque in Almaty - of a more complex


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fractal hierarchy. The metrical repetition of five smaller domes around the main large volume builds a multi-level plastic pattern.

The planning structure of the Imangali Mosque is based on the interconnection of the main compositional axes along which the rooms and architectural elements are arranged. The volumetric and spatial solution is built on a cascading system of architectural forms of the main and auxiliary rooms and is arranged in a static, symmetrical composition. Each element, varying in size, is rhythmically repeated while maintaining proportions. There is a dome on a tall twenty-three-metre-high drum above the intersection of the main axes. The main transverse axis of the building is emphasized by more than twenty metres high minarets on both sides, while the corners of the square second-story volume formed in the centre under the dome are fixed by low, slender turrets. The outline of the main volume with the entrance portal is close to a square and is also marked on both sides by graceful turrets. In general, the building is remarkable by its grace and lightness thanks to the sequential opening of the volumes to a viewer in the form of a stepped pyramid, contrasting the main, massive minarets with the slender turrets. The light colour scale of the façades with their subtle decorative mask and the blue colour of the domes enhance the lightness of perception. This is also contributed by a metro-rhythmic co,position of openings and architectural elements.

The Mashkhur Zhusup Mosque building plan configuration is built on-corner of the square modules 45 degrees around the centre. The radial geometry of the layout is represented byn eight-ray symmetry around a single compositional centre - a circle of the building's main volume.

The mosque's volumetric and spatial composition is based on a three-part structure of successively diminishing in plan, according to the principle of a pyramid: the lower level has an octagonal configuration; the second level, with a smaller built-up area, is circular in plan and is simultaneously visually read as a drum for the fifty-four-metre conical ribbed dome. Sixty-metre-high minarets dominate equidistantly on all four sides, and access to natural light in the lower level is provided by conical skylights. The composition is characterized by a predominant vertically developed volumetric dynamics. The verticality of the composition and monumentality of the architectural silhouette are provided by a contrasting collation of the massive tented dome and the prominent main entrance with graceful, slender minarets, the cones of the skylights and the vertical lines of window openings. The metro-rhythmic sequence of the levels and the static nature of the central dome are contrasted with the dynamic rhythm of the composition, beginning from the ceremonial staircase of the mosque and gradually flowing into the massive volume of the inclined pylons of the main entrance, as well as the sharp angles of the vertices on the facades.

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The Vainakh Mosque's floor plan composition in Almaty is expressed by a modular grid of identically repeating squares – the bases of small domes and a large square of the main dome, formed by the superposition of two identical, smaller, similar shapes as per the modularity principle. Meanwhile, the composition is asymmetrical due to the corner location of the main entrance. The architecture of the building has a dynamic silhouette due to the consistent openability of the domes and their bases. The broken lines and geometric consistency of the minaret lend a lively and modern feel to the image.

We have proposed graphical-analytic models that clearly illustrate the correspondence of building layouts to stable radial, triangular and square systems.

***Interpretation of Traditions and Innovative Solutions***

In general, the nature of the structures reflects the cultural context in the symbolization of traditional forms, the continuity of geometric construction principles referring to religious symbolism and visual correspondence to local traditions. At the same time, the appearances of the mosques are up-to-date and reflect continuity (Kisamedin, 2012). The architects were faced with the challenge of selectively citing traditional forms and elements to create a unique contemporary facility: "... there is no need to follow stereotypes in the issues regarding the design of religious buildings and adhere to established classical images...", "... in the third millennium, the religious architecture, like faith itself, may be subject to transformation...", "... the new century requires completely new approaches in the design..." (from an interview with T. Abilda and Sh. Yussupov).

For example, the tower-like silhouette of the Mosque named after Mashkhur Zhusup recreates the images of a khan's tent, a warrior batyr, the traditional mobile dwelling of the Kazakhs – the yurt, etc. At the same time, the central volume of the dome with its vertically corrugated plasticity alludes to the architectural traditions of mausoleums of the Karakhanid era of the 11th–12th centuries. The layout of the plan forms the Rub al-Hizb symbol, sacred to Muslims, and the height of the minarets refers to the age of the Prophet Muhammad. It is known that the traditional peshtak in the architecture of Central Asia is a high arched niche, a portal-entrance to a mosque or caravan-serai (Galimzhanova & Glaudinova, 2011). In this mosque, the established niche form has been transformed into a geometrically expressive, dynamic silhouette of the entrance group, consisting of sloping lines and sharp breaks.

The up-to-date interpretation of traditional forms characteristic of Muslim architecture makes up the basis of the complex structure of sequentially unfolding volumes, broken lines and value contrasts in the Imangali and Vainakh mosques. In the architecture of the Vainakh mosque, a metro-rhythmic series of elegant window openings and an interesting pencil-shaped minaret solution have


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been performed in a contemporary style. For example, a delicate combination of innovation and respect for the traditional culture of the peoples of the North Caucasus has created an authentic, prominent image.

To achieve the compositional integrity in the architectural structure in Pavlodar, the access to natural light in the mosques' interior spaces has been achieved through the use of a cone/pyramid shape made of a transparent material. T. Abilda and Sh. Yussupov often use these forms in their other creative projects as well. The modernized interpretation of simple cube and pyramid shapes reflects a dialogue between traditions and innovations based on culture, natural and climatic peculiarities, and a review of local symbols and artistic appearances.

The cone/pyramid is an archetype created on the basis of the original spatial archetype of the "platform". A compact centric volume (square, rectangle, circle, polygon) as a culturally fixed archetype in Kazakh religious architecture reflects the spiritual, ethnic and historical basis associated with the traditional image of a dwelling – a yurt (Baitenov et al., 2019) (Figure 4).

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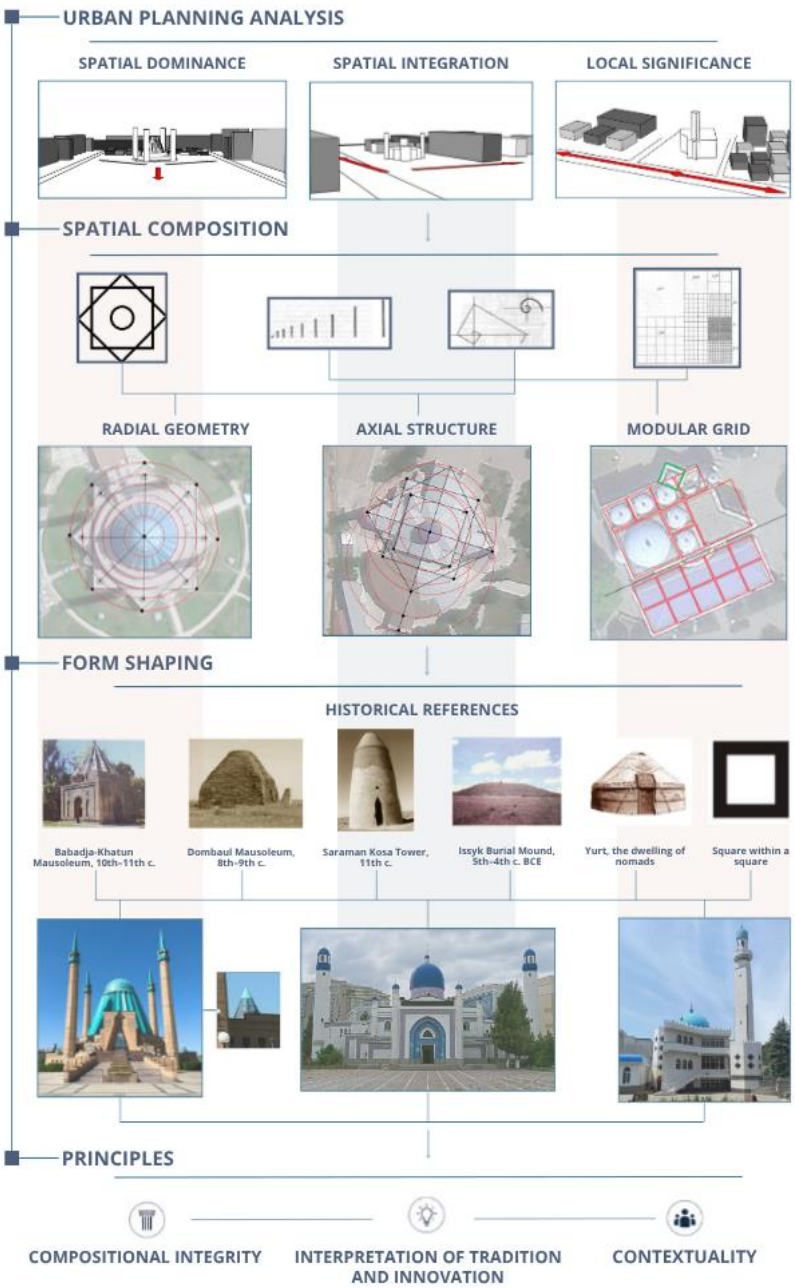



**Figure 4:** The Identified Architectural Principles
Note: Developed by the authors based on the analytical and methodological approaches proposed by Ikonnikov and Stepanov (1975), Baitenov (2009), and Lynch (1960).


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The colour modelling of the project plays a significant role in the perception of the entire image: the domes of mosques are designed in a sky-blue colour, and the walls are sandy ochre-coloured or white. For the steppe space regions of Central Asia, Kazakhstan and Mongolia, where the colour palette of the natural setting is limited due to local climatic conditions, and conventionally the following optimal colour combinations have been formed: white with black, with blue, with green, blue with yellow, light blue with green, etc. In traditional nomadic culture, the Space and the Universe are inseparable from the human soul. Blue is associated with open space, tranquility, peace, clarity (Askarov, 1988; Ibrayeva, 1994) and even the end of life (Ardalan & Bakhtiar, 1973). Some sources associate blue with "...the endless water cycle in nature...", making its use logical in the cladding and epigraphic decoration of the khanaka of Khoja Ahmed Yasawi (Turkestan, 1385-1405), when the light blue (blue, turquoise) dome, floating in the air, symbolizes a source of life, an oasis in the hot steppe and desert (Tuyakbayeva, 1989; Abdrassilova et al., 2021). For example, the use of warm tones characteristic of the region's traditional architecture in modern religious buildings, and blue-light blue shades in the dome's erection, enhances the association with the ingrained steppe landscape. This forms the figurative content of the space for the recipient and affects their emotional state.

A study of the spatial and compositional peculiarities of modern mosques in Kazakhstan conducted, as well as an urban planning analysis, have revealed the way the creative strategies of architects Tolegen Abilda and Shukhrat Yussupov affected the development of the author's interpretation of sacred architecture projects. The analysis has revealed that Kazakhstani architects Tolegen Abilda and Shukhrat Yussupov undertook their own creative strategies for shaping a modern religious architecture in Kazakhstan. Their creativity is based on innovative ideas according to the following principles: the interpretation of traditions and innovation, contextuality, and compositional integrity.

The principle of interpreting traditions and innovation lies in a noticeable deviation from traditional architectural canons of religious architecture - the authors' interpretation of regional motifs. The acknowledging examples include a deviation from classical figurative solutions of the Islamic architecture and a reference in form to the architectural traditions of mausoleum construction during the Karakhanid era of the 11th-12th centuries; rethinking regional images, forms and archetypes, experimental design approaches, etc.

The contextuality principle is expressed in the integration of mosque buildings into the urban realm context. The mosques with indigenous silhouettes shape sacred spaces around themselves as projects of pronounced urban-planning significance.

The compositional integrity principle has been built on the use of rectangular, hemispherical, and conical modules. The logical volumetric-spatial

composition represents a clear hierarchy of both volumes and fractal elements: the prevalence of the dome and minaret as the semantic and compositional core of the sacred space; the metro-rhythmic alternation of identical modules; and the mathematical precision of proportions.

The compositional-spatial techniques, form-shaping ways and interpretations of traditions applied by the architects in the design process are supported by innovative approaches. This has stipulated the development of new images of religious spaces and may serve as a prerequisite for the practice of Islamic traditions in mosque architecture in contemporary Kazakhstan in the post-Soviet context.

## CONCLUSION

Modern sacral architecture in Kazakhstan has developed in the context of post-Soviet socio-cultural transformations, a revival of religious consciousness, and a search for national identity. The construction of mosques under the conditions of a new independent state has become an important are for development in national architecture at the turn of the 20th and 21st centuries.

Mosques designed by architects Tolegen Abilda and Shukhrat Yussupov stand out among the numerous existing Islamic infrastructure facilities in the country. The analysis of their creativity conducted by the article authors enables identifying the fundamental compositional principles of modern mosque architecture in Kazakhstan. These include: preserving the canonical structure of the Islamic religious building; shaping an expressive volumetric and spatial composition based on the combination of a central dome and minarets; the use of symmetry, axial tracings and architectural dominants; the interrelationship between the building's exterior and the functional arrangement of its interior space; consideration of the urban planning and environmental context.

As can be seen from the research work, these architects' appeal to the Islamic architectural traditions goes beyond a direct reproduction of historical prototypes. Conventional forms, silhouettes, ornamental motifs and symbolic elements undergo author’s interpretation and are adapted to up-to-date functional, structural and technological requirements. Through this the architecture of the mosques under consideration combines the recognizability of the Islamic religious structure with images associated with the culture and artistic traditions of modern Kazakhstan.

The creative approaches of T. Abilda and Sh. Yussupov reveal the unity of common professional principles and individual methods of form shaping. The joint design practice promoted the development of a coherent architectural language based on a synthesis of traditions and innovation. Meanwhile, the originality of each facility is conditioned by the specific features of the site, urban


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planning situation, the scale of a structure, and nature of the author's interpretation of conventional architectural forms.

The mosques examined serve not only religious but social, symbolic and important urban planning functions as well. Owing to their expressive silhouette and compositional integrity, they shape visual landmarks of the urban environment, contribute to the creation of the site image and anchor regional cultural meanings in modern architecture. Herewith regional identity is manifested not through the literal citation of historical forms, but via their creative rethinking, inclusive of the local cultural context.

Thuswise, the creative activity of T. Abilda and Sh. Yussupov represents a significant contribution to the development of up-to-date sacral architecture in Kazakhstan. Their works are indicative of the possibility for harmonious combining Islamic architectural canons, Kazakh cultural images and contemporary compositional and technological solutions.

Research of the architects' author strategies expands our understanding of the mechanisms for the formation of national and regional identity and allows determining their contribution to the development of architecture in independent Kazakhstan. These scientific findings are of great importance for design practice, contributing to the enrichment of architects' activities with new creative techniques and methods.

Further research prospects are associated with expanding the range of facilities under consideration, comparing the individual methods of Kazakhstani architects, and studying the impact of regional cultural-symbolic, climatic, structural and urban planning factors on formation of modern architecture in Kazakhstan.

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# SPATIAL DYNAMICS OF URBAN SPRAWL AND THE CHALLENGES OF TRANSBOUNDARY GOVERNANCE IN BOGOR'S PERI-URBAN

**Janthy Trilusianthy Hidayat[1], Lilis Sri Mulyawati[2], Batara Surya[3], Marlyana Azyyati Marzukhi[4], Zaharah Mohd Yusoff[5]**

[1,2]*Urban and Regional Planning Department,*
PAKUAN UNIVERSITY
[3]*Urban and Regional Planning Department,*
BOSOWA UNIVERSITY
[4]*Studies of Town and Regional Planning,*
UNIVERSITI TEKNOLOGI MARA
[5]*Studies of Surveying Science & Geomatics,*
UNIVERSITI TEKNOLOGI MARA

## Abstract

Bogor City, as a satellite of the Jakarta Metropolitan Area, is experiencing demographic pressure and rapid urbanization. This growth has triggered massive spillover effects, manifesting as urban sprawl beyond administrative boundaries into the outskirts of Bogor Regency. This study aims to analyze the spatial dynamics of urban sprawl and analyze the challenges that arise for transboundary governance. Through a mixed-methods approach, this study uses Remote Sensing analysis with assessment by Normalized Difference Built up index (NDBI) and the sprawl index to measure built-up area expansion. Local Indicators of Spatial Association (LISA) analysis to detect significant spatial clusters of development from 2001 to 2023. Interpretative Structural Modelling (ISM) analysis is used to structure the constraints and challenges that occur. The analysis results identify that High-High clusters are located along the northern and western administrative boundaries, indicating that functional urban expansion has been detached from formal spatial planning. It also reveals a significant regulatory gap between city and district governments in the study area. The study concludes that the current rigid administrative-based planning is inadequate to manage peri-urban dynamics. Transformative transboundary governance, which emphasizes cross-jurisdictional synchronization and functional spatial management, is urgently needed to mitigate the negative externalities of uncontrolled urban sprawl and ensure regional sustainability.

***Keywords***: Index Sprawl, ISM, LISA, NDBI, *Peri-urban area, Transboundary Governance, Urban Sprawl.*

[1] Corresponding author. Email: janthyhidayat@unpak.ac.id

## INTRODUCTION

Rapid urban growth has become an inevitable global phenomenon, with the United Nations (UN) projecting a global increase in the urban population of 2.5 billion by 2050, 90% of which will occur in Asia and Africa (UNDESA, 2019). This rapid growth in urban populations across these two continents often exceeds the capacity of governments to plan and provide housing in city centers (Sudhira et al., 2007). In Southeast Asia, contemporary urbanization is no longer limited to rural-to-urban migration, as noted by McGee (2017); this process has evolved into area-based urbanization, where development spills beyond the boundaries of the core city to form functionally integrated metropolitan areas. This situation has given rise to peri-urban areas, a transitional zone between rural and urban centers characterized by mixed land use, blurred boundaries, and the integration of urban economic activities with rural-style activities (Rakodi, 1998; Webster, 2002; Sahana et al., 2023), where these peri-urban areas serve as preferred residential zones and encourage inefficient land use (Rustiadi et al., 2014) resulting in uncontrolled and haphazard development known as the phenomenon of urban sprawl. Population growth and increasing demands lead to a rise in urban activities, a situation that is accompanied by a significant increase in the need for urban space (Pacione, 2009). As a manifestation of geographical space that accommodates human activity, a city will always experience growth. According Firman (2004), urban growth in Indonesia is physically characterized by rapid expansion in peri-urban. This physical expansion occurs through the phenomenon of urban sprawl, which is a spatial manifestation resulting from the spillover effect that crosses city boundaries; this causes peri-urban areas to act as a receptacle for pressures that can no longer be accommodated (Hudalah et al., 2020).

The urbanization rate in Indonesia reached 56.7% in 2020 and is predicted to reach 66.6% by 2045 (BAPPENAS, 2023). This burden has a direct impact on land conversion in suburban areas. This situation indicates that urban sprawl is not merely a demographic shift, but a tangible pressure on space and ecosystems in peri-urban areas as buffer zones. The City of Bogor and Bogor Regency form part of the Jabodetabek metropolitan area, which has experienced the conditions described above; the physical growth of Bogor City has surpassed its administrative boundaries, encroaching into the peri-urban areas situated within the jurisdiction of Bogor Regency. Within the regional constellation of the Jabodetabek Metropolitan Area, the City of Bogor no longer functions merely as a self-sufficient city but has transformed into a strategic buffer hinterland for DKI Jakarta. The spatial significance of this region over the past decade reflects the pressures of global urbanization, which have triggered massive shifts in land use. Based on primary demographic data, the population of the City of Bogor is


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recorded to have grown from 1,013,017 people in 2013 to 1,137,018 people in 2023. This increase in demographic pressure has fueled aggressive dynamics in the peri-urban area, where the need for residential space has overridden environmental carrying capacity considerations.

This consistently high rate of population growth is the main driver of radical physical changes in land cover. The ever-increasing demand for space in these urban areas is fueling the phenomenon of urban sprawl in peri-urban areas. Urban sprawl presents a major challenge for spatial planning, potentially leading to more complex problems such as a decline in environmental quality due to the negative impacts of uncontrolled land conversion. The current trajectory of peri-urban development in Bogor poses significant management challenges, as evidenced by symptoms such as environmental degradation, congestion, disaster risk, and the unpreparedness of government officials to manage these impacts. Therefore, understanding the growth processes at play is essential for creating integrated regional development that does not burden the environment, but rather constitutes a sustainable functional expansion. Although the phenomenon of urban sprawl in the Jakarta Metropolitan area has been extensively studied, the integration of peri-urban spatial dynamics with the institutional capacity of local governments in spatial planning has received insufficient attention. This study aims to address this gap by analyzing the dynamics of peri-urban growth arising from the phenomenon of urban sprawl and formulating management guidelines based on the local government's capacity to plan and control spatial planning.

## LITERATURE REVIEW

### Urbanization and Urban Development

Traditionally, urbanization has been understood as a demographic process involving the movement of people from rural areas to cities (rural-to-urban migration). However, in the contemporary context, particularly in Asia, this phenomenon has evolved into area-based urbanization. McGee (2017) introduced the concept of Desakota, where in the intensity of interaction between urban and rural activities creates new functional spaces no longer constrained by administrative boundaries. Urbanization today occurs not only through natural growth or migration, but also through the physical expansion of cities that encroach upon surrounding areas (UNDESA, 2019). A city is not a static entity; it is the geographical manifestation of human activity that continues to evolve in line with increasing demand for space (Pacione, 2009). Urban growth is driven by two main forces: centripetal factors (the pull of the city center) and centrifugal factors (outward pressure from the city).

**Characteristics of urban sprawl in Peri-urban Areas**

Jaeger et al. (2010) explain that urban sprawl is the expansion of built-up areas marked by dispersed and fragmented development and a disproportionately high consumption of land relative to the population indicating inefficient land use Dadashpoor and Shahhassein (2024) defines urban sprawl as the unplanned, random, and diffuse expansion of the city's physical form into peri-urban areas. Thus, growth in peri-urban areas is not merely a geographical phenomenon of territorial expansion, but also a manifestation of people's need for affordable living space. When this phenomenon is not managed properly, the result is uncontrolled and sporadic development. Visual identification is undertaken as an initial step because urban sprawl is an ex- pression of deviation from compact urban development. Spatially, urban sprawl occurs when physical urban development exceeds the boundaries of city planning or administration (Ewing, 2008). While this step is relatively straightforward, it can identify the physical overflow of urban areas in general. Peri-urban areas are defined as transitional zones between urban centers and rural areas that possess unique characteristics (Iaquinta and Drescher, 2000). Urban sprawl impacts spatial dynamics by fragmenting urban areas and diminishing the efficiency of land use, integration of peri-urban spatial dynamics with the institutional capacity of local governments in spatial planning has received insufficient attention. As suggested by Labuz (2025)**,** the effectiveness of spatial planning strategies is heavily dependent on the integration of monitoring tools and institutional control mechanisms to curb land dispersion. These areas are not merely administrative boundaries, but functional zones where urban economic activities and rural lifestyles interact intensively (Rakodi, 1998). According Webster (2002) and Asli et.al. (2022) emphasizes that peri-urban areas are characterized by mixed land use and increasingly blurred spatial boundaries. In the context of major cities in Indonesia, peri-urban areas function as a receptacle for development pressures that can no longer be accommodated by the city center (Firman, 2004). This dynamic is often driven by the need for housing on more affordable land, which ultimately triggers the massive conversion of productive agricultural land. If left unmanaged, this growth will be sporadic and create inefficiencies in the provision of public infrastructure (Yunus, 2008; Roosni et al. 2016).

**Institutional Governance Capacity in Spatial Planning**

The challenges in managing peri-urban areas are institutional fragmentation. Physical growth that extends beyond administrative boundaries is often not accompanied by strong inter-regional coordination (Hudalah, 2020; Gallent, 2006). Weak institutional capacity in terms of supervision and control means that spatial planning instruments (such as the RTRW and RDTR) remain merely administrative documents lacking strong enforcement power on the ground.


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Consequently, the phenomenon of urban sprawl continues unchecked, disregarding environmental carrying capacity and threatening the sustainability of the region (OECD, 2022). Spatial planning measures often fail to keep pace with spatial changes on the ground due to inconsistencies in the application of regulations (Hidayat et al., 2014; Andari et al., 2022). Currently, the spatial planning control system in Indonesia is based on zoning regulation in accordance with the Spatial Planning Act and its developments under the Job Creation Act. The implementation of policies following the Job Creation Law has introduced a new paradigm in spatial planning, namely the transition to the Spatial Utilization Activity Compliance (KKPR) system. The capacity of local governments is now being tested as they adapt to the integrated digital licensing system (OSS), which demands accurate digital spatial data and a faster bureaucratic response to mitigate the impacts of urban growth.

**Interpretative Structural Modelling (ISM)**

The limitations of the government's capacity mean that spatial planning and control directives cannot be implemented as intended; peri-urban areas are transition zones governed by complex and overlapping institutional frameworks, each with differing levels of autonomy, vision, governance style and capacity (Hudalah, 2020; Gallent 2006). This situation poses a challenge to the management of peri-urban areas; through the ISM method, the resulting structural model will capture the complexities of a condition through patterns carefully designed using graphics and text (Eriyatno, 2003). Based on Eriyatno and Sofyar (2006), the first step involves analyzing the structural hierarchy within peri-urban area management programs, which are divided into elements and further broken down into sub-elements. In this study, two elements were used: the constraints faced and the changes expected. The selection of these elements was based on a review of relevant policies and research, as well as expert interviews. Subsequently, based on the results of the expert interviews, a Structural Self-Interaction Matrix (SSIM) was compiled, followed by the creation of a Reachability Matrix (RM) through calculations based on transitivity rules, whereby the SSIM matrix was adjusted until a closed matrix was achieved. This involved levelling the sub-elements within each element according to both vertical and horizontal hierarchies, and the compilation of a Driver Power Dependence (DPD) matrix for each sub-element which are divided into four: Quadrant 1 (Autonomous), Quadrant 2 (Dependent), Quadrant 3 (Linkage) and Quadrant 4 (Independent). A hierarchical structure was then established.

## RESEARCH METHODOLOGY

The study area is the peri-urban area of Bogor, comprising nine sub-districts surrounding the city of Bogor. Administratively, these fall within the administrative boundaries of Bogor Regency, namely the sub-districts of Bojonggede, Caringin, Ciawi, Cijeruk, Ciomas, Dramaga, Kemang, Sukaraja and \Tamansari, covering a total area of 9,713.56 ha.

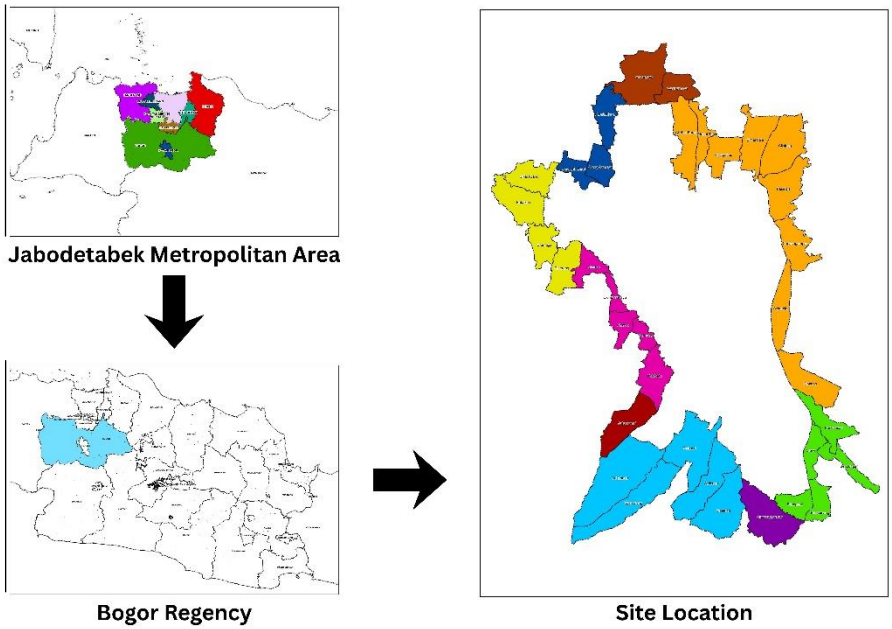



**Figure 1:** Study area

The analysis comprises the following two stages: 1) spatial analysis of urban sprawl dynamics, development using Landsat satellite imagery covering the years 2001, 2013 and 2023. represent Bogor's transition phase from the urbanization explosion resulting from decentralization to the synchronization of spatial planning through Law No. 6 of 2023 as the basis for development 2025–2045. A multi-temporal spatial analysis was conducted using satellite imagery: Landsat 7 ETM+ (2001), Landsat 8 OLI (2013), and Landsat 9 OLI-2 (2023), all with a spatial resolution of 30 meters. Each selected image underwent a standard pre-processing workflow prior to analysis, including geometric, radiometric, and atmospheric corrections. The calculation of built-up area for each year was performed using the Normalized Difference Built-Up Index (NDBI) method in


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Google Earth Engine (GEE), which yielded effective and efficient results, with an overall accuracy values ranging from 75% to 90%.

The sprawl index is determined using the sub-district unit. The calculation of the urban sprawl index in study area covers 9 sub-districts are calculated using the following formula:

$$Urban\ Sprawl\ Index = \frac{Percentage\ of\ built-up\ areas}{Percentage\ of\ population\ growth}$$

This study employs a manual classification method (user defined methods) to categorize Urban Sprawl Index values into three classes: Non-Sprawl, Low Sprawl, and Strong Sprawl. This approach is justified by the mathematical nature of the ratio formula itself, wherein a value of 1 represents the equilibrium point between physical urban expansion and demographic growth. The manual setting of class (thresholds values ≤ 1 for the non-sprawl category, values 1.01–1.49 for the low sprawl category and values ≥ 1.50 for the strong sprawl category) was deliberately established to ensure a consistent, objective, and spatially comparable assessment standard across the City and Regency of Bogor, while also serving as a basis for rigorous spatial planning control instruments.

The analysis of local spatial patterns in this study employs the Local Indicators of Spatial Association (LISA) method to identify the presence of spatial clusters, as represented by the following calculation:

$$Ii = \frac{n\sum_{j=1}^{n} W_{ij}\,(x_i - x)(x_j - x)}{Z_x^2 \sum_{j=1}^{n} W_{ij}}$$

Ii = Local Indicators of Spatial Association (LISA);
x = percentage of built up area at the sub-district level, where i represents sub-districti and j represents neighboring sub-district;
Wij = spatial proximity matrix representing the degree of spatial adjacency between sub-district and its neighboringsub-district; and
$z^2/x$ = variance of the percentage of built up area at the sub-district level.

The calculation results classify the study area into four spatial indicator quadrants (Moran Quadrants): 1) High-High (Hotspot): a district with a high sprawl index value surrounded by other districts that also exhibit high values; 2) Low-Low (Coldspot): a district with a low sprawl index value surrounded by other districts that also exhibit low values; 3) High-Low (Outlier): a district with a high sprawl index value that is isolated, being surrounded by districts with low

values; and 4) Low-High (Outlier): a district with a low sprawl index value surrounded by districts with high values. To ensure that the observed patterns did not arise by chance, a significance test was conducted using the Conditional Random Permutation method.

2) The Interpretative Struktural Modelling (ISM) analysis was conducted by gathering data based on the subjective assessments of experts competent in the field; these experts were selected via purposive sampling based on the following criteria: (1) possessing academic or practical expertise relevant to the research topic, (2) having at least three years of work or policy-making experience, and (3) being willing to fully participate in completing the research instrument. The panel of experts comprised one academic, two government officials, and two practitioners; their perceptions were elicited through structured interviews using a questionnaire designed based on identified elements and sub-elements—specifically, the Existing constraints/challenges element consist of 11 sub-elements and the Expected changes element consist of 12 sub-elements. A Structural Self-Interaction Matrix (SSIM) was constructed to assess the direction of contextual relationships between sub-element i and sub-element j based on expert consensus, utilizing the four symbols V (if sub-element i influences or leads to sub-element j), A (if sub-element j influences or leads to sub-element i), X (if sub-elements i and j mutually influence each other), and O (if there is no relationship between sub-elements i and j) (Eriyatno & Sofyar, 2006). Subsequently, a Reachability Matrix was created by converting the SSIM symbols into binary values (1 or 0) based on ISM substitution logic and transitivity rules, iterating until a closed matrix was achieved. ISM modeling was then performed by calculating the Driving Power (horizontally) and Dependence Power (vertically) for each sub-element; based on these values, all sub-elements within each element were mapped onto a Cartesian graph divided into four quadrants and a hierarchical structure.

## ANALYSIS AND DISCUSSION

The rate of development of built-up areas in the study area from 2001 to 2013 was 19.18% and from 2013 to 2023 was 77.56 %, when compared with the average population growth rate of 1.72%, this indicates a spatial imbalance between physical land development and population growth, resulting in inefficient land use, and built-up areas are spread out horizontally with low density. The increase in the NDBI in the study area, indicates that Bogor Regency functions merely as a spill over for the development of Bogor City and from a governance perspective, this suggests that spatial control instruments have not been able to stem the flow of capital in land acquisition. This situation confirms that the phenomenon of urban sprawl has occurred in the study area.


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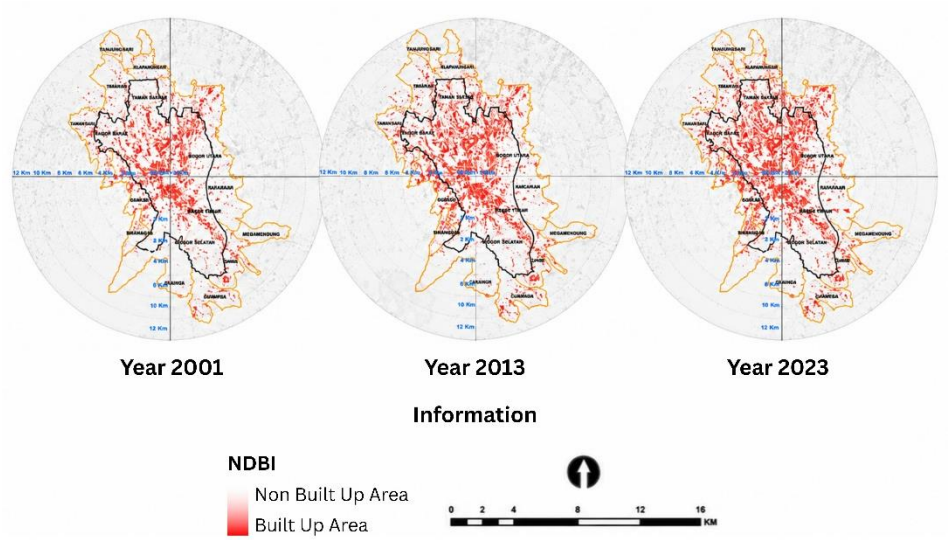



**Figure 2**: Land use changes in the Bogor City 2001 2013 and 2023
*Source: Landsat image processing result*

The spatial distribution of urban sprawl from 2001 to 2013 and from 2013 to 2023 in the study area, based on the sprawl index values, is presented in Table. 1 and Figure. 3 below.

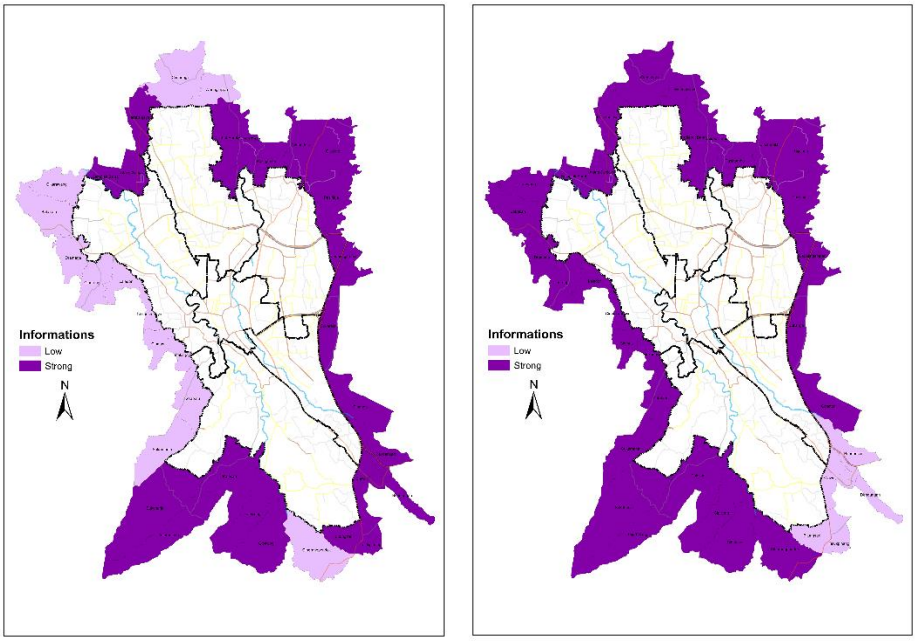
**Table 1:** Area and margin of urban sprawl

| Index urban sprawl | Year 2001-2013 (ha) | Year 2013-2023 (ha) | Margin (ha) |
|---|---|---|---|
| Non-Sprawl: < 1 | 0 | 0 | 0 |
| Low Sprawl: 1.01 – 4.99 | 559.38 | 152.77 | - 406.61 |
| Strong Sprawl: > 5 | 487.71 | 1,706.43 | 1,218.72 |
| Total | 1,047.09 | 1,859.20 | 812,11 |

*Source: Author's Calculation*

Based on Table. 1 and Figure. 3, there has been a decrease in the area of low sprawl accompanied by an increase in the area of strong sprawl. This indicates that during the 2001 - 2013 period the study area still exhibited controlled physical growth however during the 2013 - 2023 period, it became an area characterized by highly irregular and dispersed building density, as well as aggressive growth. During the 2013 - 2023 period, the strong sprawl category dominated the built-up area, thus the analysis indicates that the spatial structure in the study area is now dominated by inefficient development patterns characterized by elongated or scattered layouts that consume vast tracts of land.

The absence of non-sprawl areas indicates that in both periods there was no development in the study area following a planned growth pattern, and all physical development that emerged from 2001-2023 was of a scattered nature.




**2001-2013** **2013-2023**

**Figure 3 :** Distribution of the sprawl index values in 2001-2013 and 2013-2023
*Source: Author's Calculation*

The LISA analysis groups regions into four quadrants based on the values of variables within those regions when compared to the average of the surrounding regions, The result of LISA analysis are as follow of Table. 3 and Figure. 4 in the next page.


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**Table 3:** Results of the LISA analysis of the sprawl index in the study area

| LISA Year 2001 – 2013 | LISA Year 2013 – 2023 |
|---|---|
| **High-High Quadrant (Hotspots)**<br>Areas with a high urban sprawl index, surrounded by areas with a high tendency for urban sprawl, constitute centers of massive physical growth, including:<br>1. Kemang Sub-district, which exhibits highly uncontrolled and extensive land development.<br>2. Cijeruk Sub-district, which shows significant land conversion,<br>3. Sukaraja Sub-district, classified as a high-growth area, driven by accessibility to the city center, which has triggered widespread new housing development. | **High–High Quadrant (Hotspot)**<br>Areas with a high sprawl index surrounded by areas with a high tendency for massive urban expansion include:<br>1. Cijeruk Sub-district indicates a very strong center of sprawl growth.<br>2. Kemang Sub-district shows a high intensity of land conversion.<br>3. Bojong Gede Sub-district, which borders directly on the growth center, consistently falls into the high-growth category due to the concentration of physical growth |
| **Low-Low Quadrant (Cold spot)**<br>Areas with a low sprawl index, surrounded by areas with a low tendency and which are relatively more physically stable, include:<br>1. Darmaga Sub-district indicates a more controlled or compact land-use pattern.<br>2. Caringin Sub-district shows slow physical growth.<br>3. Tamansari Sub-district remains well below the average sprawl index. | **Low-Low Quadrant (Cold spot)**<br>An area with a low sprawl index surrounded by areas with a low tendency. This area is relatively more physically stable, comprising:<br>1. Ciawi and Ciomas sub-districts show more controlled physical growth compared to the northern sub-districts,<br>2. Caringin sub-district indicates a land-use pattern that is not yet overly fragmented. Spatially, this area tends to be more stable or has better development control compared to the northern areas |
| **Low-High & High-Low Quadrants (Outliers)**<br>Areas exhibiting characteristics that contrast with those of their neighboring groups include:<br>1. Ciawi Sub-district is at increased risk due to its proximity to high-growth zones such as Sukaraja Sub-district.<br>2. Although Bojong Gede and Ciomas Sub-districts are densely populated, their growth is more concentrated | **High-Low & Low-High Quadrants (Outliers)**<br>Areas with characteristics opposite to those of their neighbors include:<br>1. Dramaga and Tamansari sub-districts are below average but close to the High-High area, which is at risk of future sprawl pressure due to its strategic location.<br>2. Sukaraja sub-district is below average but has strong spatial links to growth centers such as Cibinong and the city of Bogor. |

*Source: Author's Analysis*

The dynamics of spatial sprawl during the study period in the study area indicate increasingly haphazard urban expansion, with the center of gravity of sprawl shifting from the Kemang sub-district (north-west) towards the Cijeruk and Bojong Gede sub-districts (central-south). This suggests that infrastructure development in the city of Bogor significantly influences the physical distribution of buildings in the study area. Sub-districts with a high surge

in sprawl—namely Dramaga, Bojong Gede and Caringin—show a worsening of sprawl conditions, whilst relatively stable areas include Sukaraja, Ciawi, Ciomas and Tamansari, as their irregularity has decreased and they have successfull curbed the rate of land expansion, likely due to the limited remaining land.

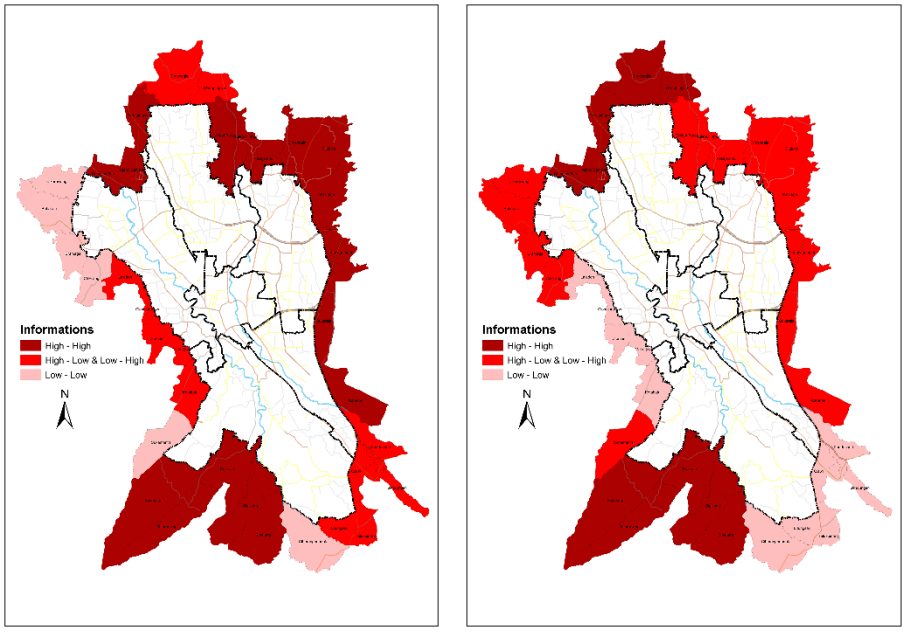



**Figure 4:** Distribution of Lisa scores for 2001–2013 and 2013–2023
*Source: Author's Calculation*

The study area is a region characterized by dynamic, rapid and haphazard growth during the period 2001–2023, indicating that it has not yet been able to maintain a regular pattern of growth. This limitation has resulted in spatial planning and control directives not being implemented as they should be. To identify issues relating to governance in the study area, an analysis was conducted of the existing constraints and the changes required for effective management, The element and sub element can be seen Tabel. 4 in the next page.

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**Table 4:** Governance elements and sub-elements

| **Element: Existing constraints/challenges** | **Element: Expected changes** |
|---|---|
| **Sub-elements:**<br>1. Coordination and cooperation between relevant agencies remain weak<br>2. Consistency in the implementation of spatial planning remains weak<br>3. Enforcement against violations is weak<br>4. Detailed plans are not yet in place<br>5. Existing spatial plans do not meet requirements<br>6. Unplanned development of built-up areas<br>7. Enforcement of the law regarding spatial planning violations remains weak<br>8. Low public awareness regarding land use in accordance with regulations<br>9. High interest in development within the study area<br>10. Zoning regulations as a tool for controlling land use and spatial management are not yet in place<br>11. Limitations in the development and management of infrastructure | **Sub-elements:**<br>1. Participatory spatial planning<br>2. Translation of the Regional Spatial Plan (RTRW) into detailed plans and the preparation of micro-zoning maps<br>3. improved coordination between agencies responsible for spatial planning<br>4. Harmonization of spatial plans across administrative regions<br>5. Consistent application of regulations relating to spatial control<br>6. Public awareness of area management programmed through dialogue among stakeholders<br>7. Cooperation in the provision of infrastructure and environmental conservation across administrative regions<br>8. Urban growth limits through the establishment of buffer zones<br>9. Increasing carrying capacity through improvements to Floor Area Ratio (FAR), Building Coverage Ratio (BCR), and Public Open Space (POS)<br>10. Incentives and disincentives to strengthen the Regional Regulation on Sustainable Food Agricultural Land (LP2B) to safeguard local food security<br>11. Digital monitoring using periodic satellite imagery to monitor land cover changes in real-time in hotspot areas<br>12. Implementation of green infrastructure |

*Source: Author's Analysis*

Based on the results of the ISM analysis of existing constraints reveals a simple hierarchical structure (comprising only two levels) that highlights two primary issues: weak coordination (sub-element 1) and the absence of zoning regulations (sub-element 10). This identifies the factor with the highest driving power that is difficult to influence via other sub-elements yet is crucial to the system's overall success and triggers a domino effect on other sub-elements. The structure indicates a bureaucratic and regulatory impasse wherein development occurs in the study area not merely due to non-compliance or rules go unheeded, but because the government has failed to provide detailed zoning regulations and

inter-agency coordination is lacking; this confirms that the root of the governance deadlock lies in the regulatory aspect. Consequently, there is a need for an institutional arrangement in the form of an Integrated Cross-Sectoral Working Group tasked with synchronizing spatial policies across administrative boundaries and accelerating the formulation of legally binding Detailed Spatial Plans (RDTR). Institutional strengthening is imperative, as detailed zoning regulations serve as the primary prerequisite (trigger) to halt the domino effect of spatial planning violations at the operational level. Public non-compliance and ignorance regarding building construction in the study area are classified as consequences of the absence of regulatory guidance. Therefore, institutional arrangements at the site level should focus on dissemination and participatory oversight. Local governments must establish a publicly accessible zoning information system, supported by strengthening the roles of sub-district and urban village officials as the frontline of supervision, thereby ensuring governance accountability from the upstream (regulation) to the downstream (public compliance).

**Table 5:** Level of ISM, Institutional Transformation and Output of Existing Contrains Element

| **Level of ISM** | **Focus of sub-elements** | **Institutional Transformation** | **Output** |
|---|---|---|---|
| Level 1 (driver/root cause) | • Weak inter-administrative coordination.<br>• Absence of detailed zoning regulations. | Collaborative and Legislative Functions<br>• Establishing a Joint Committee spanning administrative boundaries and planning authorities. | • Official Detailed Spatial Plan (RDTR) and zoning regulation.<br>• Inter-regional spatial planning Memorandum of Understanding (MoU). |
| Level 2 (outcome) | • Lack of public awareness regarding regulations.<br>• Uncontrolled development in the study area. | Dissemination and Surveillance Functions<br>• Involving licensing agencies, the communications and informatics department, and sub-district or village-level government bodies. | • Interactive digital zoning map platform.<br>• Local-level spatial planning patrol team. |

*Source: Author's Analysis*


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Based on the ISM analysis of the expected changes element, a three-tiered hierarchical structure emerges. For effective management, Level 3 (the foundation) focuses on managerial (coordination) and legal (zoning regulations) sub-elements; Level 2 (the process) focuses on technical implementation, public awareness, and administrative coordination sub-elements; and Level 1 (the final outcome) focuses on realizing an ideal physical environment. This underscores that the primary issue in the study area lies not in technical-physical aspects, but rather in weak governance (coordination) and the absence of control instruments (zoning regulations). The most effective strategy is to prioritize institutional and legal reforms before proceeding to physical interventions. Practical institutional implementation must follow a structured hierarchy, beginning with the strengthening of Level 3 (Foundation) through the issuance of a Cross-Sector Spatial Planning Committee Decree and the ratification of a Detailed Spatial Plan (RDTR) Regional Regulation to produce valid legal spatial planning documents and synchronized territorial boundaries. This legal framework is then operationalized at Level 2 (Process) by activating Cross-Agency Field Working Groups and providing Spatial Planning Clinic services at the sub-district level, thereby tightening permit oversight and ensuring public education prior to building construction. Through consistency across these two stages, governance culminates at Level 1 (Final Outcome) in the institutionalization of a Spatial Planning Audit System and the use of a Citizen Participation Complaint Application; these measures can concretely curb the growth of unauthorized structures while creating a well-organized and ideal physical environment.

**Table 6:** Level of ISM, Actional Institutional and Output of the expected changes element

| **Level of ISM** | **Focus of Sub-elements** | **Actionable Institutional** | **Outputs** |
|---|---|---|---|
| Level 1 (Fondation) | Policies and Zoning Regulation | Decree of the Cross-Sector Spatial Planning Committee<br>Regional Regulation on Detailed Spatial Plans (RDTR) | Valid spatial planning documents and synchronized territorial boundaries. |
| Level 2 (Process) | Technical Aspect and Public Awareness | Cross-Agency Field Working Group<br>Spatial Planning Clinic Services at the District Level | Public education prior to construction; stricter oversight of permits. |

| Level of ISM | Focus of Sub-elements | Actionable Institutional | Outputs |
|---|---|---|---|
| Level 3 (Final) | Ideal Physical Environment | Spatial Planning Audit System (Zoning incentive & disincentive System)<br>Citizen Participation Complaint Application | Reduction in illegal structures; creation of well-organized physical spaces |

*Source: Author's Analysis*

The planning instruments for the City of Bogor and Bogor Regency are legally linked through their respective Regional Spatial Plans (RTRW) and are hierarchically coordinated by the West Java Provincial RTRW and the Jabodetabekpunjur National Strategic Area Spatial Plan. There is an ecological interdependence in which Bogor Regency serves as the upstream area and a buffer zone for the City of Bogor; consequently, planning decisions at the regency level significantly affect the city's ecological stability. Similarly, the regional connectivity and infrastructure systems outlined in the City of Bogor's RTRW must be synchronized with Bogor Regency's RTRW to ensure smooth accessibility throughout the region. At the operational level, land use along administrative boundaries is regulated by the Detailed Spatial Plan (RDTR) and the zoning regulations of each respective area; inconsistencies among these instruments trigger land-use conflicts. Peri-urban areas—the transition zones between these two regions—are experiencing uncontrolled development and sporadic urban sprawl, leading to inconsistencies in land-use designations. This situation undermines the effectiveness of land-use controls.

## CONCLUSION

This study examines the development of the study area through an analysis of built-up area growth and the calculation of an urban sprawl index to highlight uncontrolled growth resulting from the spillover effects of the city of Bogor, as well as the phenomenon of urban sprawl during the period 2001–2023. The current growth and governance conditions in the study area present constraints and challenges that require a structured approach.

The analysis results identify that High-High clusters are located along the northern and western administrative boundaries, indicating that functional urban expansion has been detached from formal spatial planning. It also reveals a significant regulatory gap between city and district governments in the study area

The results of the ISM analysis indicate that the main challenges and issues in the study area do not lie in physical technical aspects, but rather in weak


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governance (coordination) and the absence of control instruments (zoning regulations); therefore, the most effective approach to achieving appropriate environmental conditions and quality is to priorities institutional and legal reforms before proceeding to physical interventions.

As physical development in the study area continues to increase, it is hoped that stricter law enforcement will be implemented, ensuring compliance by all relevant parties as stipulated in Presidential Regulation No. 60 of 2020 on the Spatial Plan for the Jabodetabekpunjur National Strategic Area. Further studies are required, focusing on collective action, regulations, and community engagement regarding management in the study area, as well as to ensure that these measures can be applied to peri-urban locations in other regions.

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# INTEGRATING COMMITTEE MEMBERS' PERSPECTIVES INTO PERFORMANCE-BASED MAINTENANCE PLANNING: EVALUATING SERVICE QUALITY AND SAFETY AND HEALTH FOR MASJID KARIAH IN KELANTAN, MALAYSIA

**Azhar Yusof[1], Mohamad Ridzuan Yahya[2], Faridah Ismail[3], Siti Fatimah Hashim[4]**

[1,2,3,4]*College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA

## Abstract

This study investigates the integration of committee members' perspectives into performance-based maintenance planning, focusing on service quality and safety and health aspects in Masjid Kariah across 10 districts in Kelantan, Malaysia. Through a structured questionnaire survey involving 354 committee members from 59 mosques, the research examines reported practices and assessments of three maintenance strategies. Planned Corrective Maintenance (PCM) accounted for 66.1% of recorded strategy categories. Planned Preventive Maintenance (PPM) received the highest mean ratings across all nine indicators. Exploratory Friedman comparisons of mosque-level mean ratings identified overall differences among strategy ratings for every indicator (Holm-adjusted permutation $p < 0.001$; Kendall's W = 0.903–1.000). An additional mosque-level chi-square test found no statistically significant association between maintenance frequency and recorded strategy category ($p = 0.765$). The findings highlight committee members' priorities for service delivery, equipment inspections and cleanliness. These assessments represent management perceptions and do not establish the operational effectiveness of individual maintenance strategies.

***Keywords***: Performance-Based Maintenance, Service Quality, Safety and Health, Committee Perspectives, Masjid Kariah

[1] Corresponding author. Email: azharbinyusof@gmail.com

## INTRODUCTION

The maintenance of religious facilities, particularly mosques, plays a vital role in preserving their functionality, safety and service quality (Zaini & Mizal Azzmi, 2023). In Malaysia, Masjid Kariah serves as community hubs, providing not only a place for worship but also a space for various social and educational activities (Au-Yong et al., 2017). As these facilities age and face increasing demands, ensuring their upkeep through effective maintenance planning becomes imperative. The performance-based approach has emerged as a key framework, prioritizing measurable outcomes such as reliability, safety, and user satisfaction (Swanson, 2001; Tsang, 2002). Maintenance concept development provides a framework for relating strategy choices to facility requirements (Waeyenbergh & Pintelon, 2002). Examining mosque committee members' perspectives adds an organisational view of the priorities guiding these choices.

Kelantan offers a context for examining maintenance practices in Masjid Kariah. Research on mosque design failures demonstrates the importance of considering facility-specific requirements in maintenance management (Khalid et al., 2024). This study incorporates the insights of committee members, who possess firsthand knowledge of the operational and maintenance challenges faced by their respective mosques. Their administrative responsibilities provide access to maintenance decisions and arrangements, although their views do not necessarily represent the experiences of all mosque users.

The objective of this study is to evaluate committee members' perceptions of performance-based maintenance strategies for Masjid Kariah in Kelantan, emphasizing service quality, safety, and health. By integrating committee members' perspectives, this study aims to provide actionable recommendations for enhancing maintenance practices. The study employs a quantitative methodology, analyzing data from 354 committee members across 59 mosques. Its contribution lies in examining service quality and safety and health assessments together within a religious-facility maintenance context. The analysis distinguishes recorded maintenance categories from respondents' evaluations of Planned Preventive Maintenance (PPM), Planned Corrective Maintenance (PCM) and Unplanned Maintenance (UM).

## LITERATURE REVIEW

Performance-based maintenance planning is a structured approach that focuses on achieving specific outcomes, such as reliability, safety, and operational efficiency. Tsang (2002) examines the strategic alignment of maintenance with organisational goals, while Swanson (2001) considers the relationship between maintenance strategies and performance. In the context of religious institutions, PPM's emphasis on regular inspections and systematic interventions aligns well

with the operational requirements of mosques. However, strategy selection also involves responding to defects and operational constraints. Waeyenbergh & Pintelon (2002) provide a framework for developing maintenance concepts that connects these decisions to organisational and technical requirements. This supports examining preventive, corrective and unplanned maintenance within a common assessment framework.

The integration of stakeholder perspectives is increasingly recognized as a critical factor in maintenance planning. Au-Yong et al. (2017) highlight that engaging key stakeholders enhances service quality and fosters a sense of ownership. This participatory approach is particularly relevant for community facilities like Masjid Kariah, where the involvement of committee members can bridge the gap between centralized policies and localized needs. Zaini and Mizal Azzmi (2023) further note that committee members provide an organisational perspective because their responsibilities involve administration, resource allocation and maintenance decisions. Their assessments can identify management priorities, while mosque users and maintenance personnel can provide complementary evidence on service experiences and technical performance.

Maintenance planning involves coordinating preventive activities, corrective work and responses to unexpected defects. A maintenance concept therefore requires consideration of organisational objectives and technical requirements rather than reliance on a single strategy in all circumstances (Waeyenbergh & Pintelon, 2002). For mosque facilities, research on design failures illustrates the relevance of building-specific conditions to maintenance management (Khalid et al., 2024). These considerations support examining committee members' assessments of different strategies, while distinguishing perceived service performance from independently measured costs, defects and safety outcomes.

This study builds on these insights by examining the application of performance-based maintenance planning in the specific context of Masjid Kariah in Kelantan. By incorporating the perspectives of committee members, it seeks to identify maintenance priorities reflected in service quality and safety and health assessments. The research considers preventive, corrective and unplanned maintenance through a common set of indicators. These assessments provide evidence on management perceptions without directly establishing the operational effectiveness of the strategies.

Service quality provides a complementary perspective by examining how maintenance services are perceived. Parasuraman et al. (1988) developed SERVQUAL around five dimensions: reliability, assurance, tangibles, empathy and responsiveness. Reliability concerns dependable and accurate service delivery; assurance relates to the knowledge and courtesy of personnel and their


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ability to inspire confidence; tangibles concern physical facilities, equipment, and personnel; empathy involves individualised attention; and responsiveness concerns willingness to help and provide prompt service. These dimensions provide the conceptual basis for the service quality indicators adapted in this study. Within the mosque maintenance context, the indicators address scheduled service delivery, perceived efficiency, maintenance service provision, attention to complaints and assistance from maintenance personnel.

Safety and health extend maintenance evaluation beyond service delivery to the conditions supporting safe and suitable facility use. Research on design failures in mosque facilities illustrates the relevance of building-specific issues to maintenance management (Khalid et al., 2024). In the present study, safety indicators concern perceived protection from falls and trips and the regular inspection of equipment systems. Health indicators address perceptions of building-related health conditions and cleanliness. Considering these dimensions alongside service quality enables maintenance priorities to encompass both service provision and the mosque environment. Nevertheless, these indicators capture respondents' assessments rather than independently verified safety or health outcomes. Their interpretation therefore requires a distinction between perceived maintenance performance and evidence obtained through physical inspections, environmental measurements, or incident records.

## RESEARCH METHODOLOGY

This study employed a quantitative questionnaire survey to examine committee members' perceptions of maintenance strategies in relation to service quality and safety and health in Masjid Kariah, Kelantan, Malaysia. The survey formed part of a wider study on mosque maintenance planning. This study focused on reported maintenance practices, the association between maintenance frequency and recorded strategy category, and respondents' evaluations of Planned Preventive Maintenance (PPM), Planned Corrective Maintenance (PCM) and Unplanned Maintenance (UM). The study covered 59 Masjid Kariah across 10 districts: Kota Bharu, Pasir Puteh, Jeli, Machang, Gua Musang, Tanah Merah, Pasir Mas, Tumpat, Kuala Krai and Bachok. Figure 1 shows the geographical distribution of the 59 selected Masjid Kariah across the ten districts of Kelantan. The sample comprised 13 mosques in Kota Bharu, nine in Pasir Mas, seven in Pasir Puteh, six in Bachok, five each in Tumpat and Kuala Krai, four each in Machang, Tanah Merah and Gua Musang, and two in Jeli.

A multistage sampling approach was adopted. The sampling frame comprised 584 Masjid Kariah, from which approximately 10% were selected within each district, resulting in 59 participating mosques. Six committee members represented each mosque: the chairman or nazir, deputy chairman or deputy nazir, development committee representative, secretary, deputy secretary

and treasurer. These positions were selected for their involvement in mosque administration and maintenance-related decisions. The final dataset comprised 354 respondents. Individual committee members constituted the unit of analysis for descriptive perception ratings, while mosques constituted the units for the additional inferential analyses.

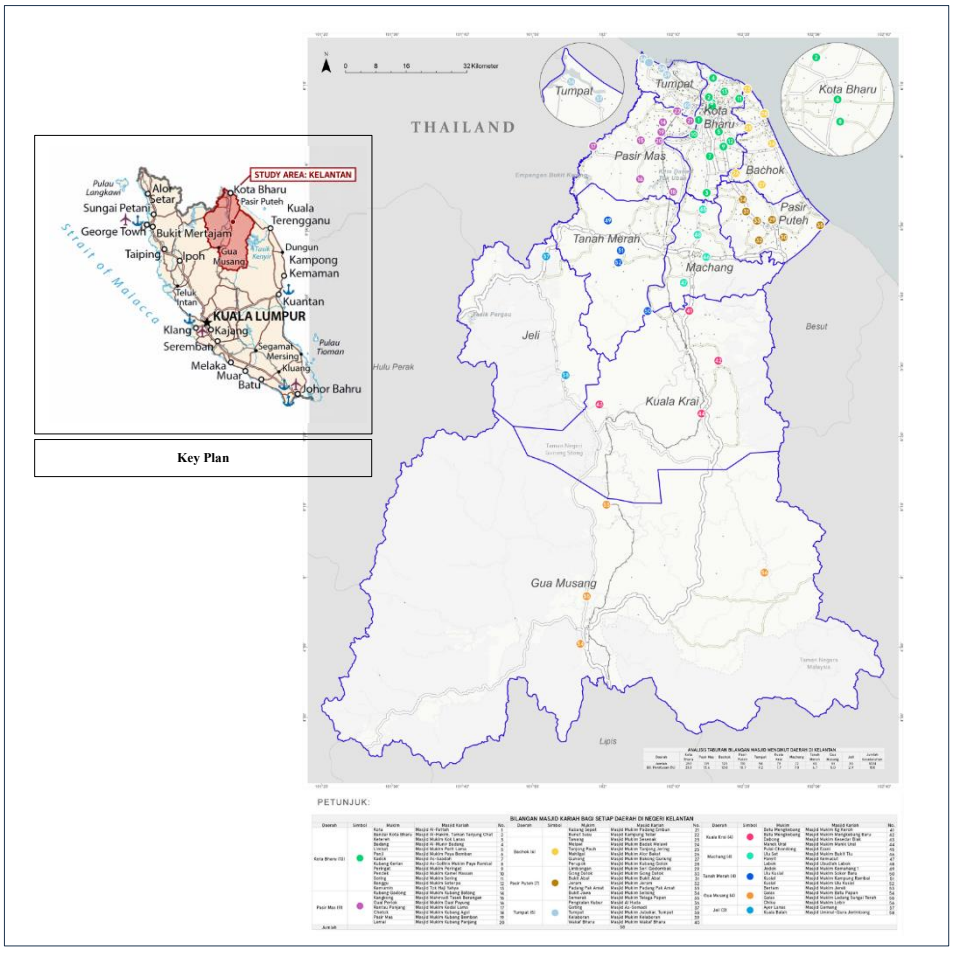



**Figure 1:** Distribution of the 59 Selected Masjid Kariah in Kelantan
*Source: Researcher (2026)*

The structured questionnaire collected information on mosque characteristics, respondents' positions, maintenance practices, and assessments of the three maintenance strategies. Service quality was assessed through five indicators adapted from the dimensions of reliability, assurance, tangibles,


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empathy, and responsiveness proposed by Parasuraman et al. (1988). Safety and health were assessed through four indicators covering protection from falls and trips, equipment inspections, building-related health conditions, and cleanliness. Respondents evaluated each strategy irrespective of the maintenance category recorded for their mosque. Following the thesis questionnaire, service quality items used a five-point satisfaction scale, safety items used a five-point perceived-safety scale, and health items used a five-point agreement scale. Higher scores indicated more favourable assessments.

Descriptive analysis comprised frequencies, percentages, cross-tabulations, and mean scores. Frequencies and percentages summarised respondent characteristics and reported maintenance practices, while cross-tabulations described strategy categories by district and maintenance frequency. Mean scores summarised respondents' evaluations of the three strategies across the service quality and safety and health indicators. All 354 respondents had complete responses for these indicators. Counts in respondent-based tables were distinguished from counts of separate mosques.

Pearson's chi-square test of independence was used to examine the association between reported maintenance frequency and recorded maintenance strategy category. Before analysis, the six respondents within each mosque were checked for agreement on both variables. As their responses were consistent, one record per mosque was retained, yielding 59 mosque-level observations and avoiding repeated counting of the same facility. The resulting contingency table comprised three frequency categories; monthly, every three months, and every six months and two strategy categories, PCM and UM. Categories with no observations were excluded. Statistical significance was assessed at the 0.05 level, and Cramér's V was calculated to describe the strength of association.

Additional exploratory Friedman tests compared respondents' evaluations of PPM, PCM and UM for each of the nine indicators. The six committee responses within each mosque were averaged separately for each indicator and strategy, yielding three paired ratings for each of 59 mosques. This approach retained the paired structure of the evaluations while avoiding treating committee members within the same mosque as independent observations. Friedman statistics were corrected for ties, and permutation p-values were calculated using 99,999 within-mosque permutations of strategy labels. Holm adjustment controlled for multiple testing across the nine indicators at the .05 level. Kendall's W was calculated to describe consistency in strategy rankings. No pairwise significance tests were conducted.

Ethical approval was obtained from the Universiti Teknologi MARA Research Ethics Committee under reference REC/12/2021 (MR/936), dated 14 December 2021. Participants were informed of the research purpose, and the questionnaire included an agreement to participate. Participation was voluntary,

respondents could withdraw without providing a reason, and their information was treated confidentially.

The findings are subject to several methodological limitations that define the scope of their interpretation. Restricting participation to committee members privileged management perspectives, leaving the service experiences of mosque users and the technical assessments of maintenance contractors and officers unrepresented. Consequently, favourable strategy ratings reflect committee judgements and cannot independently substantiate improvements in service delivery, safety or health outcomes. Self-reported assessments were also susceptible to social desirability and variation in respondents' interpretations of maintenance performance, potentially affecting the comparability of ratings. The cross-sectional design precluded establishing temporal order or attributing observed differences to the effects of particular maintenance strategies. Aggregating responses into mosque-level means avoided treating members of the same committee as independent observations in the exploratory comparisons, but obscured variation within each mosque; these averages therefore do not establish consensus among committee members.

## RESEARCH FINDINGS

Table 1 highlights that all 354 respondents in the 59 Masjid Kariah reported employment on a contractual basis. Each of the six committee positions accounted for 59 respondents (16.7%). These data describe reported service status and role distribution; contractual status alone does not establish commitment, accountability or maintenance performance. The positions comprised the chairman or nazir, deputy chairman or deputy nazir, development committee representative, secretary, deputy secretary, and treasurer. Equal representation across these positions reflected the sampling design, which included six designated committee members from each mosque. Their involvement in administration and maintenance-related decisions provided a basis for examining management perspectives on maintenance planning. Au-Yong et al. (2017) identified a positive association between stakeholder involvement and maintenance management effectiveness, highlighting the relevance of participation by managers, maintenance personnel, users and service providers. Within the present study, committee responses therefore provide one organisational perspective within this broader stakeholder context. The absence of permanent or voluntary appointments among the sampled respondents does not establish the absence of volunteers or other personnel in wider mosque operations.


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**Table 1:** Positions Held at the Masjid Kariah

| No. | Positions held at the Kariah Mosque | Serving as | | | |
|---|---|---|---|---|---|
| | | **Permanent** | **Voluntary** | **Contract** | **Others** |
| 1. | Chairman/ Nazir | 0 | 0 | 59 | 0 |
| 2. | Deputy Chairman/ Deputy Nazir | 0 | 0 | 59 | 0 |
| 3. | Exco for Development | 0 | 0 | 59 | 0 |
| 4. | Secretary | 0 | 0 | 59 | 0 |
| 5. | Deputy Secretary | 0 | 0 | 59 | 0 |
| 6. | Treasurer | 0 | 0 | 59 | 0 |
| | Total | **0** | **0** | **354** | **0** |

*Source: Researcher (2026)*

Table 2 shows that all 354 respondents from the 59 Masjid Kariah classified their respective mosques as government-owned, with no private, waqf or other ownership categories recorded. Kota Bharu contributed the largest number of respondents (78), while Jeli contributed the fewest (12). These frequencies represent respondent reports rather than counts of separate mosques, and the differences between districts reflect their representation in the sample. The uniform ownership classification provides an institutional context for interpreting the reported maintenance arrangements. However, it does not establish equivalent funding, consistent management procedures or comparable maintenance outcomes across the participating mosques. In a study of public facilities managed by Malaysian local authorities, Mong et al. (2019) identified maintenance management barriers and cost-related challenges, highlighting the relevance of operational conditions to maintenance delivery. This provides a broader context for distinguishing institutional ownership from the resources and practices through which facilities are maintained. For the present sample, assessing these relationships would require additional evidence on budget allocation, maintenance responsibilities and implementation at each mosque.

**Table 2:** Districts by Ownership Type

| No. | District | Ownership Type | | | |
|---|---|---|---|---|---|
| | | **Government** | **Private** | **Waqaf** | **Others** |
| 1. | Kota Bharu | 78 | 0 | 0 | 0 |
| 2. | Pasir Puteh | 42 | 0 | 0 | 0 |
| 3. | Jeli | 12 | 0 | 0 | 0 |
| 4. | Machang | 24 | 0 | 0 | 0 |
| 5. | Gua Musang | 24 | 0 | 0 | 0 |
| 6. | Tanah Merah | 24 | 0 | 0 | 0 |
| 7. | Pasir Mas | 54 | 0 | 0 | 0 |
| 8. | Tumpat | 30 | 0 | 0 | 0 |
| 9. | Kuala Krai | 30 | 0 | 0 | 0 |
| 10. | Bachok | 36 | 0 | 0 | 0 |
| | Total | **354** | **0** | **0** | **0** |

*Source: Researcher (2026)*

Table 3 shows that mosques reported as more than 15 years old accounted for 330 respondents (93.2%). 18 respondents (5.1%) reported mosque ages of 6–10 years, while six (1.7%) reported ages of 11–15 years. No respondents reported mosques aged 1–5 years. These frequencies represent respondent reports rather than counts of separate mosques. The predominance of older buildings provides a context for examining maintenance requirements, although building age alone does not establish deterioration, structural deficiencies or inadequate maintenance. Khalid et al. (2024) examined mosque facilities in Perak Tengah and identified design and construction-related defects with implications for maintenance management. These findings highlight the relevance of building-specific conditions when interpreting the maintenance needs of mosque facilities. Accordingly, the age profile in the present study provides background information for maintenance planning, while priorities for inspection and repair require evidence on actual building conditions and maintenance history. The small proportion of newer mosques describes the composition of the sample and does not establish a shortage of facilities or demand for additional construction.

**Table 3:** Districts by Age of Masjid Kariah

| No. | District | Age of Masjid Kariah (Years) | | | | |
|---|---|---|---|---|---|---|
| | | **1-5** | **6-10** | **11-15** | **>15** | **Total** |
| 1. | Kota Bharu | 0 | 6 | 0 | 72 | 78 |
| 2. | Pasir Puteh | 0 | 0 | 0 | 42 | 42 |
| 3. | Jeli | 0 | 0 | 0 | 12 | 12 |
| 4. | Machang | 0 | 6 | 0 | 18 | 24 |
| 5. | Gua Musang | 0 | 0 | 0 | 24 | 24 |
| 6. | Tanah Merah | 0 | 0 | 6 | 18 | 24 |
| 7. | Pasir Mas | 0 | 6 | 0 | 48 | 54 |
| 8. | Tumpat | 0 | 0 | 0 | 30 | 30 |
| 9. | Kuala Krai | 0 | 0 | 0 | 30 | 30 |
| 10. | Bachok | 0 | 0 | 0 | 36 | 36 |
| | Total | **0** | **18** | **6** | **330** | **354** |

*Source: Researcher (2026)*

Table 4 presents the distribution of recorded maintenance strategy categories by district, based on reports from 354 committee members representing 59 Masjid Kariah. PCM accounted for 234 responses (66.1%), while UM accounted for 120 (33.9%). No responses were classified as PPM or other strategies in the selected categorical variable. PCM was more frequently reported than UM in nine districts, while Machang recorded equal frequencies for both categories. These district-level patterns were described using frequencies without inferential testing. The predominance of PCM reflects the recorded strategy


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classification and does not establish the absence of preventive activities or the effectiveness of the maintenance arrangements.

**Table 4:** Recorded maintenance strategy categories by district

| No. | District | Planned Preventive Maintenance (PPM), n | Planned Corrective Maintenance (PCM), n | Unplanned Maintenance (UM), n | Others, n | Total, n |
|---|---|---|---|---|---|---|
| 1 | Kota Bharu | 0 | 54 | 24 | 0 | 78 |
| 2 | Pasir Puteh | 0 | 24 | 18 | 0 | 42 |
| 3 | Jeli | 0 | 12 | 0 | 0 | 12 |
| 4 | Machang | 0 | 12 | 12 | 0 | 24 |
| 5 | Gua Musang | 0 | 18 | 6 | 0 | 24 |
| 6 | Tanah Merah | 0 | 18 | 6 | 0 | 24 |
| 7 | Pasir Mas | 0 | 36 | 18 | 0 | 54 |
| 8 | Tumpat | 0 | 18 | 12 | 0 | 30 |
| 9 | Kuala Krai | 0 | 18 | 12 | 0 | 30 |
| 10 | Bachok | 0 | 24 | 12 | 0 | 36 |
| | Total | **0** | **234** | **120** | **0** | **354** |

**Note: Counts represent respondent reports, with six committee members per mosque. Zero counts for PPM indicate that no responses were assigned to this category in the selected categorical variable; they do not establish the absence of preventive maintenance activities.**

*Source: Researcher (2026)*

For Table 5, each mosque was counted once after confirming within-mosque consistency for frequency and strategy category. Monthly maintenance was reported for 25 mosques (42.4%), followed by every six months (23; 39.0%) and every three months (11; 18.6%). Frequency described maintenance activity generally and did not establish that individual unplanned interventions followed fixed schedules. PCM accounted for 39 mosques (66.1%), while UM accounted for 20 (33.9%). No mosque was classified as PPM in the categorical variable used for this analysis; this does not establish the absence of preventive maintenance activities. Pearson's chi-square test did not identify a statistically significant association between maintenance frequency and recorded strategy category, $\chi^2$ (2, N = 59) = 0.537, p = 0.765. Cramér's V (.095) indicated a small observed association. These results describe the distribution of recorded strategy categories across maintenance frequencies and do not establish the effectiveness of individual strategies.

**Table 5:** Association between maintenance frequency and recorded maintenance strategy category

| No. | Maintenance Frequency | Types of Maintenance Strategy used | | | |
|---|---|---|---|---|---|
| | | **Planned Preventive Maintenance (PPM), n** | **Planned Corrective Maintenance (PCM), n** | **Unplanned Maintenance (UM), n** | **Total, n (%)** |
| 1. | Monthly | 0 | 17 | 8 | 25 (42.4) |
| 2. | Every Three Months | 0 | 8 | 3 | 11 (18.6) |
| 3. | Every Six months | 0 | 14 | 9 | 23 (39.0) |
| | Total | **0** | **39** | **20** | **59 (100.0)** |

Notes: n = 59 mosques. Percentages in the total column are based on all 59 mosques. PPM = planned preventive maintenance; PCM = planned corrective maintenance; UM = unplanned maintenance. PPM is displayed for completeness but excluded from the chi-square calculation because its recorded frequency is zero. Pearson's $\chi^2(2) = 0.537$, $p = 0.765$; Cramér's V = 0.095. One of six expected cell counts was below five; the minimum was 3.73.

*Source: Researcher (2026)*

Table 6 presents committee members' ratings of various maintenance strategies on Service Quality at Masjid Kariah, using a 5-point satisfaction scale. Planned preventive maintenance received the highest mean scores across all dimensions of service quality, with mean scores ranging from 4.46 to 4.52. This reflects strong satisfaction among committee members regarding its reliability, assurance, tangibility, empathy, and responsiveness. PCM mean scores ranged from 2.64 to 2.96. In contrast, unplanned maintenance received lower mean scores, with means ranging from 1.91 to 2.17. All 354 respondents evaluated each strategy, irrespective of the maintenance category recorded for their mosque. Swanson (2001) supports these findings, noting that reactive maintenance often results in higher costs and lower performance due to unplanned downtime. Similarly, Waeyenbergh & Pintelon (2002) emphasize the role of a well-developed maintenance framework in enhancing overall service quality and operational efficiency. The emphasis on planned preventive maintenance aligns with best practices in facility management, advocating for proactive strategies that enhance service quality and operational performance (Pintelon & Parodi-Herz, 2008).


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**Table 6:** Service Quality Indicators

| No. | Dimension of Service Quality | Mean Score |
|---|---|---|
| ***1.*** | *Reliability:*<br>*You are satisfied that the strategy below is able to perform the service according to the schedule* | |
| 1a. | Planned Preventive Maintenance | 4.46 |
| 1b. | Planned Corrective Maintenance | 2.73 |
| 1c. | Unplanned Maintenance | 2.17 |
| ***2.*** | *Assurance:*<br>*You are satisfied that the strategy below can guarantee the maintenance service is done efficiently* | |
| 2a. | Planned Preventive Maintenance | 4.52 |
| 2b. | Planned Corrective Maintenance | 2.96 |
| 2c. | Unplanned Maintenance | 2.02 |
| ***3.*** | *Tangible:*<br>*You are satisfied that the strategy below allows the maintenance staff to provide a good maintenance service* | |
| 3a. | Planned Preventive Maintenance | 4.50 |
| 3b. | Planned Corrective Maintenance | 2.78 |
| 3c. | Unplanned Maintenance | 1.91 |
| *4.* | *Empathy:*<br>*You are satisfied that the strategy below allows the maintenance staff to pay special attention to the complaints received* | |
| 4a. | Planned Preventive Maintenance | 4.48 |
| 4b. | Planned Corrective Maintenance | 2.64 |
| 4c. | Unplanned Maintenance | 1.92 |
| *5.* | *Responsiveness:*<br>*You are satisfied that the strategy below allows the maintenance staff to be able to help provide maintenance services to this mosque* | |
| 5a. | Planned Preventive Maintenance | 4.49 |
| 5b. | Planned Corrective Maintenance | 2.70 |
| 5c. | Unplanned Maintenance | 2.15 |
| Notes: Mean scores were based on a five-point Likert scale (1 = Very Dissatisfied, 2 = Dissatisfied, 3 = Neutral, 4 = Satisfied, and 5 = Very Satisfied). | | |

*Source: Researcher (2026)*

Table 7 presents committee members' ratings of maintenance strategies across safety and health indicators at Masjid Kariah. For safety, PPM received the highest mean ratings for perceived protection from falls and trips (4.50) and regular equipment inspections (4.49), followed by PCM (2.65 and 2.75, respectively) and UM (2.10 and 1.94). For health, PPM also received the highest ratings for perceived protection from sick building syndrome (4.46) and cleanliness (4.53). The corresponding ratings were 2.77 and 2.79 for PCM, and 2.02 and 1.35 for UM. Cleanliness displayed the largest descriptive difference between PPM and UM, indicating a particularly pronounced contrast in

committee assessments. Al-Turki et al. (2014) discussed the relationship between maintenance and safe and healthy working environments in manufacturing facilities, providing a broader conceptual context for considering safety and health within maintenance planning. In the present study, the consistently higher PPM ratings reflect favourable committee perceptions. The ratings do not measure accident occurrence, environmental conditions or diagnosed building-related illness. These findings identify safety and health priorities for maintenance planning, while assessment of operational effectiveness requires complementary evidence from inspections, incident records and environmental measurements.

**Table 7:** Safety and Health Indicators

| No. | Dimension of Safety and Health | Mean Score |
|---|---|---|
| *1.* | *Safety:* | |
| *a.* | *The strategy below ensures that this maintenance provides safety from accidents due to falling, and tripping* | |
| 1a.1 | Planned Preventive Maintenance | 4.50 |
| 1a.2 | Planned Corrective Maintenance | 2.65 |
| 1a.3 | Unplanned Maintenance | 2.10 |
| *b.* | *The strategy below regularly inspects the equipment system of the Masjid Kariah to ensure the safety of users* | |
| 1b.1 | Planned Preventive Maintenance | 4.49 |
| 1b.2 | Planned Corrective Maintenance | 2.75 |
| 1b.3 | Unplanned Maintenance | 1.94 |
| ***2.*** | *Health:* | |
| *a.* | *You agree that the strategy below ensures that this mosque is free from sick building syndrome* | |
| 2a.1 | Planned Preventive Maintenance | 4.46 |
| 2a.2 | Planned Corrective Maintenance | 2.77 |
| 2a.3 | Unplanned Maintenance | 2.02 |
| *b.* | *You agree that the strategy below ensures the cleanliness of the maintained area* | |
| 2b.1 | Planned Preventive Maintenance | 4.53 |
| 2b.2 | Planned Corrective Maintenance | 2.79 |
| 2b.3 | Unplanned Maintenance | 1.35 |
| Note. Mean scores are based on responses from 354 committee members. Safety items used a five-point perceived-safety scale, while health items used a five-point agreement scale. Higher scores indicated more favourable assessments. | | |

*Source: Researcher (2026)*

Table 8 presents exploratory Friedman comparisons of PPM, PCM and UM ratings across nine service quality and safety and health indicators. Statistically significant overall differences among the three strategy ratings were identified for every indicator following Holm adjustment of permutation p-values (all adjusted $p < 0.001$). Kendall's W ranged from 0.903 to 1.000, indicating strong consistency in strategy rankings across the 59 mosques. Together with the


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descriptive means in Tables 6 and 7, these findings indicate that committee members consistently rated PPM more favourably. For cleanliness, W = 1.000 reflected identical strategy ordering across mosques, with PPM ranked above PCM and UM. The omnibus tests establish overall differences in ratings but do not identify statistically significant individual pairwise comparisons or demonstrate the operational effectiveness of particular strategies.

**Table 8:** Exploratory Friedman comparisons of maintenance strategy ratings at mosque level

| Indicator | Friedman Q | Adjusted p-value | Kendall's W |
|---|---|---|---|
| Service quality | | | |
| Reliability | 106.496 | < 0.001 | 0.903 |
| Assurance | 115.111 | < 0.001 | 0.976 |
| Tangibility | 116.034 | < 0.001 | 0.983 |
| Empathy | 115.566 | < 0.001 | 0.979 |
| Responsiveness | 113.265 | < 0.001 | 0.960 |
| Safety and health | | | |
| Protection from falls and trips | 113.426 | < 0.001 | 0.961 |
| Regular equipment inspections | 116.558 | < 0.001 | 0.988 |
| Perceived protection from sick building syndrome | 112.592 | < 0.001 | 0.954 |
| Cleanliness | 118.000 | < 0.001 | 1.000 |

Notes: n = 59 mosques; df = 2 for each test. Each mosque contributed three paired strategy ratings, calculated by averaging its six committee members' responses for each indicator and strategy. Friedman statistics were corrected for ties. Permutation p-values were calculated using 99,999 within-mosque permutations and adjusted across nine tests using Holm's procedure. Kendall's W represents consistency in strategy rankings. W = 1.000 indicates identical strategy ordering across mosques, not identical scores or perfect maintenance performance.

*Source: Researcher (2026)*

## DISCUSSION

The findings indicate that committee members evaluated PPM more favourably than PCM and UM across service quality and safety and health indicators. This pattern is consistent with the emphasis on proactive maintenance and organisational performance discussed by Swanson (2001) and Tsang (2002). The exploratory Friedman analyses extend the descriptive findings by identifying overall differences in mosque-level strategy ratings across all nine indicators. Strong Kendall's W values indicate consistent ranking patterns, but do not quantify improvements in maintenance outcomes.

The service quality findings show that committee members' evaluations extended beyond task completion to how services were delivered. PPM received favourable assessments for scheduled services, perceived efficiency, attention to complaints, and assistance from maintenance personnel. These concerns correspond to the dimensions developed by Parasuraman et al. (1988). The

comparatively low empathy rating for PCM identifies complaint handling as a potential planning priority. However, the ratings do not establish whether concerns arose from staffing constraints, funding, communication difficulties or delays, as these explanations were not tested.

The recorded strategy distribution was dominated by PCM, despite the favourable perception ratings for PPM. This contrast separates recorded practice categories from assessments of perceived performance and provides a basis for examining the incorporation of preventive activities into existing arrangements, without assuming their complete absence. Waeyenbergh and Pintelon (2002) emphasise systematic maintenance concept development, supporting coordination of inspections, corrective work and responses to unexpected defects. The reasons for the recorded distribution remain questions for further investigation.

Safety and health ratings also favoured PPM, with cleanliness displaying the widest descriptive separation between PPM and UM. All 59 mosque-level averages ranked cleanliness in the same order, PPM above PCM above UM. Equipment inspections and protection from falls and trips connect maintenance planning with everyday facility use. Research by Khalid et al. (2024) on mosque design failures demonstrates the relevance of building-specific issues to maintenance management. These ratings indicate committee members' perceived safety, health and cleanliness priorities but do not represent independently measured facility conditions.

At mosque level, the association between maintenance frequency and recorded strategy category was not statistically significant ($p = 0.765$), with a weak observed association (Cramér's $V = 0.095$). This addresses a different question from the significant strategy-rating comparisons. It does not establish equivalence between PCM and UM or demonstrate that frequency is unimportant. Broad frequency categories do not describe task scope, asset condition or response timeliness. Maintenance planning benefits from considering frequency alongside inspection records and service outcomes.

The study contributes a committee-level perspective by integrating service quality and safety and health assessments within religious-facility maintenance planning. Complaint handling, equipment inspections and cleanliness emerged as practical priorities. However, the findings represent management perceptions rather than independently verified maintenance outcomes, and the exploratory omnibus tests do not establish pairwise differences or causal effectiveness. Future studies should incorporate mosque users, maintenance personnel, physical inspections and operational records to evaluate whether these perceptions correspond with actual facility performance.


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## CONCLUSION AND RECOMMENDATION

This study examined assessments from 354 committee members representing 59 Masjid Kariah across ten districts in Kelantan. PPM received the highest descriptive ratings across all nine service quality and safety and health indicators, while PCM predominated in the recorded strategy distribution. Exploratory Friedman tests demonstrated consistent differences in committee members' ratings of the three strategies after adjustment for multiple testing. The chi-square analysis found no significant association between maintenance frequency and recorded strategy category. The findings identify complaint handling, equipment inspections and cleanliness as priority areas for maintenance review. Committees can use these priorities to strengthen inspection schedules, maintenance records and responses to reported defects. Differences between districts were not examined inferentially and should therefore be investigated in future research.

To address these challenges, the following recommendations are proposed:

a) **Develop a Coordinated Maintenance Plan**: Committees can incorporate preventive tasks into routine maintenance plans, document defects and repair completion, and establish clear responsibilities for inspections and complaint handling. Staff training can focus on inspection procedures, maintenance records and responses to reported defects. The effects of these arrangements on service continuity and repair performance require evaluation during implementation.
b) **Strengthen Maintenance Records**: Committees can maintain records of inspections, reported defects, repair completion and recurring complaints to support maintenance scheduling and follow-up. The suitability of digital tools can be assessed against staffing capacity, available resources and record-keeping needs before adoption.
c) **Promote Inclusive and Participatory Planning:** Establishing regular feedback mechanisms, such as community surveys and stakeholder meetings, can provide valuable insights into user satisfaction and emerging challenges. Feedback from mosque users and maintenance personnel can complement committee assessments and help identify priorities that are not fully represented by management perspectives.
d) **Strengthen Technical Collaboration:** Committees can seek technical input from relevant agencies and maintenance practitioners when reviewing inspection priorities, recurring defects and repair requirements. The scope of collaboration can be matched to identified facility needs and available resources. Any effects on maintenance performance require subsequent evaluation.

e) **Examine Variation Across Districts**: Future research can investigate whether maintenance arrangements and stakeholder assessments vary across districts using a sampling and analytical design suited to such comparisons. Combining questionnaire responses with inspections and operational records can help explain any observed variation.

The study contributes to maintenance planning literature by integrating committee assessments of service quality and safety and health in Malaysian religious facilities. Future work can combine management and user perspectives with inspections and operational records to examine correspondence between perceived and measured performance. Independently collected data and longitudinal evaluation can assess whether changes in maintenance arrangements are accompanied by improvements in service delivery, safety and cleanliness.

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# COMMUNITY PERCEPTION ON LAND-USE CHANGE IN VICINITY OF FLOOD DETENTION PONDS IN KUALA LUMPUR

**Illyani Ibrahim[1], Aina Afiqah Wahyudi Iskandardinata[2], M Zainora Asmawi[3], Norzailawati Mohd Noor[4], Alias Abdullah[5]**

[1,2,3,4,5]*Kulliyyah of Architecture and Environmental Design,*
UNIVERSITI ISLAM ANTARABANGSA MALAYSIA

## Abstract

Escalating urban flash floods have become a critical socio-environmental crisis. The continuous conversion of natural, permeable landscapes into impervious urban surfaces such as asphalt and high-density concrete has drastically accelerated surface water runoff. This study aims to understand the community's knowledge, flood experiences, and the authority's response and planning around the flood detention pond area. The research methodology uses a structured survey format, ensuring the collection of standardised data that can be objectively compared across the various detention pond catchment areas. Analysis shows that over 83.5% (mean = 3.28) of respondents observe intensive construction around detention basins, mirrored by an 82.7% (mean = 3.26) agreement rate that natural green buffers have diminished over the past five years. Residents expressed confidence in the physical safety (mean = 3.22) and routine upkeep (mean = 3.15) of local detention ponds, their trust declined (mean = 2.99) in the ponds' ability to prevent overflow during prolonged, multi-day rainfall. In addition, the community is not inherently opposed to development but instead requests sustainable planning that balances economic growth with rigorous environmental safeguards.

***Keywords***: community knowledge, detention ponds, flash flood, Kuala Lumpur, perception

[1] Corresponding author. Email: illyani_i@iium.edu.my

## INTRODUCTION

Escalating urban flash floods have become a critical socio-environmental crisis in tropical metropolises. Driven by climate change-induced erratic rainfall and rapid urban expansion, cities like Kuala Lumpur face severe hydrological imbalances (D'Ayala et al., 2020). The continuous conversion of natural, permeable landscapes into impervious urban surfaces, such as asphalt and high-density concrete, has drastically accelerated surface water runoff, fundamentally altering catchment hydrology, and overwhelming the existing municipal drainage infrastructure (Stewart, 2023).

To manage these peak discharge rates, Kuala Lumpur relies on a network of decentralised structural mitigation assets, specifically flood detention ponds managed by the Department of Irrigation and Drainage (JPS) and Kuala Lumpur City Hall (DBKL). These facilities are engineered to capture and temporarily store excess stormwater, thereby protecting downstream zones from sudden inundation (Takaijudin et al., 2012). However, aggressive micro-level land-use changes and spatial encroachment increasingly compromise these assets' operational integrity.

Recent governance assessments in Kuala Lumpur have highlighted critical institutional failures. According to a 2026 investigation by the Malaysian Anti-Corruption Commission (MACC), the failure to gazette Kuala Lumpur's flood detention ponds for 18 years created a loophole that allowed 32 hectares of protected land to be alienated for mixed development projects, despite the areas being approved for reservation as early as 1998 (The Star, 2026). Furthermore, Federal Territories Minister Hannah Yeoh (2026) revealed that the alienation of 17 land lots within the Jinjang and Batu detention pond zones to private developers since 2015 has reduced their active water storage capacity by an estimated 70%. Technical assessments by the Department of Irrigation and Drainage (JPS) confirmed that this rapid encroachment has hindered crucial maintenance and desilting works, directly exacerbating local flood risks (Yeoh, 2026).

Despite these technical findings, a notable research gap remains in the socio-technical reality of these sites. While hydrological data show infrastructure decline, empirical evidence on how communities living adjacent to these compromised ponds experience and perceive these changes remains limited. This study addresses this gap by utilising a community survey to evaluate the operational reality of flood infrastructure under the strain of continuous urban development. The primary objectives are to establish the demographic profile of affected residents, evaluate community perception of infrastructure effectiveness, assess governance and authority response, and identify grassroots recommendations for long-term urban flood resilience (Abid et al., 2024; Shariff & Hamidi, 2019).

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To address the gap of existing studies, the study seeks to fulfil the following objectives: i) to identify the community's knowledge and perception of detention ponds around their residences; ii) to understand their perception of flood impact and land-use changes around detention ponds; and iii) to understand the authority's response and planning for flood management around the area. The findings will provide insights into community perspectives on land-use change and flood mitigation strategies while assessing the effectiveness of current planning and management approaches in enhancing urban flood resilience.

## LITERATURE REVIEW

This section synthesises existing research on the intersection of rapid urbanisation, structural flood mitigation, and participatory disaster governance in the Malaysian context, specifically focusing on the Kuala Lumpur and Klang Valley regions.

### Urbanisation, Land-use Change, and Hydrological Impacts

Rapid urbanisation and the proliferation of impervious surfaces are the primary drivers of increased flood vulnerability in tropical metropolitan areas such as Kuala Lumpur (Mohameda, 2024). The shift from natural, permeable landscapes to built-up urban environments characterised by concrete and asphalt drastically limits soil infiltration, accelerating surface runoff and increasing peak discharge during monsoon seasons (Mazlana, 2026; Mohameda, 2024). Research indicates that uncontrolled development in catchment areas directly correlates with increased flood frequency and severity, as existing drainage networks, often designed based on outdated historical rainfall data, have failed to accommodate current extreme weather patterns exacerbated by climate change (Liew et al., 2021; Mohameda, 2024). Consequently, hydrological modelling in the Klang Valley has consistently demonstrated that traditional urban expansion strategies without adequate green infrastructure contribute significantly to the catastrophic flooding events observed in recent years (Mazlana, 2026).

### Governance and Community Participation in Disaster Management

Flood risk management in Malaysia has traditionally operated on a "top-down," government-centric model, where federal and state agencies are the primary actors in infrastructure development and crisis response (Shariff & Hamidi, 2019). However, scholars argue that this approach often results in a disconnect between policy and the lived realities of vulnerable communities (Abid et al., 2024). Evidence suggests that integrating local knowledge into flood management is essential, as residents frequently act as the "first responders" and possess granular, historical insights into local flood patterns and infrastructure vulnerabilities that external engineering models may overlook (Abid et al., 2024;


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Shariff & Hamidi, 2019). Community-based disaster risk management (CBDRM) frameworks, which emphasise public education, neighbourhood-level action plans, and collaborative engagement, have been shown to strengthen community resilience and provide contextually relevant solutions that rigid structural measures often miss (Abid et al., 2024; Rameli et al., 2024).

### The Psychology of Flood Risk and Lived Community Experience

A critical component of community analysis involves understanding how residents perceive structural mitigation. Reliance on large-scale engineering projects often triggers the "levee effect", a psychological phenomenon in which communities develop a false sense of absolute security, increasing their vulnerability when these infrastructures ultimately fail or are breached during extreme events (Kuhlicke et al., 2020). Furthermore, marginalised or highly exposed communities often have unique observational data on incremental environmental degradation, such as the gradual shallowing of retention ponds, which is vital for accurate risk reduction (Few et al., 2017). Evaluating the community's roles in mitigating and adapting to localised floods shows that public perception is directly shaped by proximity to the hazard and the transparency of local authorities (Karki et al., 2016). Li et al. (2022) found that over half of respondents reported some worry about stormwater-related damage and, overall, perceived floodable areas as less safe than retention ponds under storm conditions. The same study (Li et al. 2022) also reported that respondents who had more frequently experienced localised flooding near their homes were more worried about potential property damage from flooding. Kumaresen et al. (2025) conducted a survey in Kuala Lumpur and found that residents generally reported high levels of risk perception and preparedness. However, adaptive capacity exhibited greater variability, with a mean score of 3.97 (SD = 0.64), and a positive association was found among risk perception, flood preparedness, and adaptive capacity. Benardi et al. (2026) explained that uncontrolled land-use changes driven by rapid population growth and expanding residential development have significantly heightened flood risk in the Kendal Watershed, Kendal District. Community perceptions reveal that these land-use changes have contributed to increased flood frequency, greater flood intensity, and longer inundation duration.

## RESEARCH METHODOLOGY

### Study Area and Scope

This study focused on a cross-section of flood-prone catchments in Kuala Lumpur, which encompass 24 designated flood detention ponds. These sites were selected for their strategic importance to the city's stormwater management network and because they fall under the jurisdiction of the DBKL and JPS, the

city's primary stormwater-management authorities. For a clear overview of the spatial scope of this study, Table 1 provides a complete inventory of the 24 authorised flood detention ponds categorised by their managing authority and catchment.

**Table 1**: Flood Detention Ponds around Kuala Lumpur

| Name of Flood Retention Pond | Primary Catchment Area | Managing Authority |
|---|---|---|
| KTB Kg. Batu Flood | Kg. Batu, Kuala Lumpur | JPS |
| KTB Taman Wahyu | Jinjang / Taman Wahyu | JPS |
| KTB Nanyang, Delima, Jinjang | Jinjang Utara | JPS |
| KTB Sungai Midah | Taman Midah, Cheras | JPS |
| KTB Sri Johor | Sri Johor, Cheras Baru | JPS |
| KTB Cheras Baru | Cheras Baru | DBKL |
| KTB Taman Desa | Taman Desa Siputeh | JPS |
| KTB Air Leleh | Setapak / Air Leleh | DBKL |
| KTB Kg. Berembang | Kg. Berembang | JPS |
| KTB Danau Kota | Danau Kota, Setapak | DBKL |
| KTB Kg. Bohol | Pekan Sungai Besi | DBKL |
| KTB Lorong Maarof | Bangsar Baru | DBKL |
| KTB Sri Permaisuri 1 | Bandar Sri Permaisuri | DBKL |
| KTB Sri Permaisuri 2 | Bandar Sri Permaisuri | DBKL |
| KTB Intan Baiduri | Taman Intan Baiduri, Kepong | DBKL |
| KTB Pasar Borong Selayang | Selayang / Kepong Border | DBKL |
| KTB Kg. Melayu Kepong | Kepong | DBKL |
| KTB Sunway Montana | Wangsa Melati | DBKL |
| KTB Taman Sri Rampai | Wangsa Maju / Sri Rampai | DBKL |
| KTB Segambut | Segambut Luar / Dalam | JPS |
| KTB Sri Johor | Cheras | JPS |
| KTB Cheras Baru | Cheras | DBKL |
| KTB Tasik Ampang Hilir | Ampang Hilir Corridor | DBKL |
| KTB Batu 4 ½ | Jalan Genting Klang | JPS |


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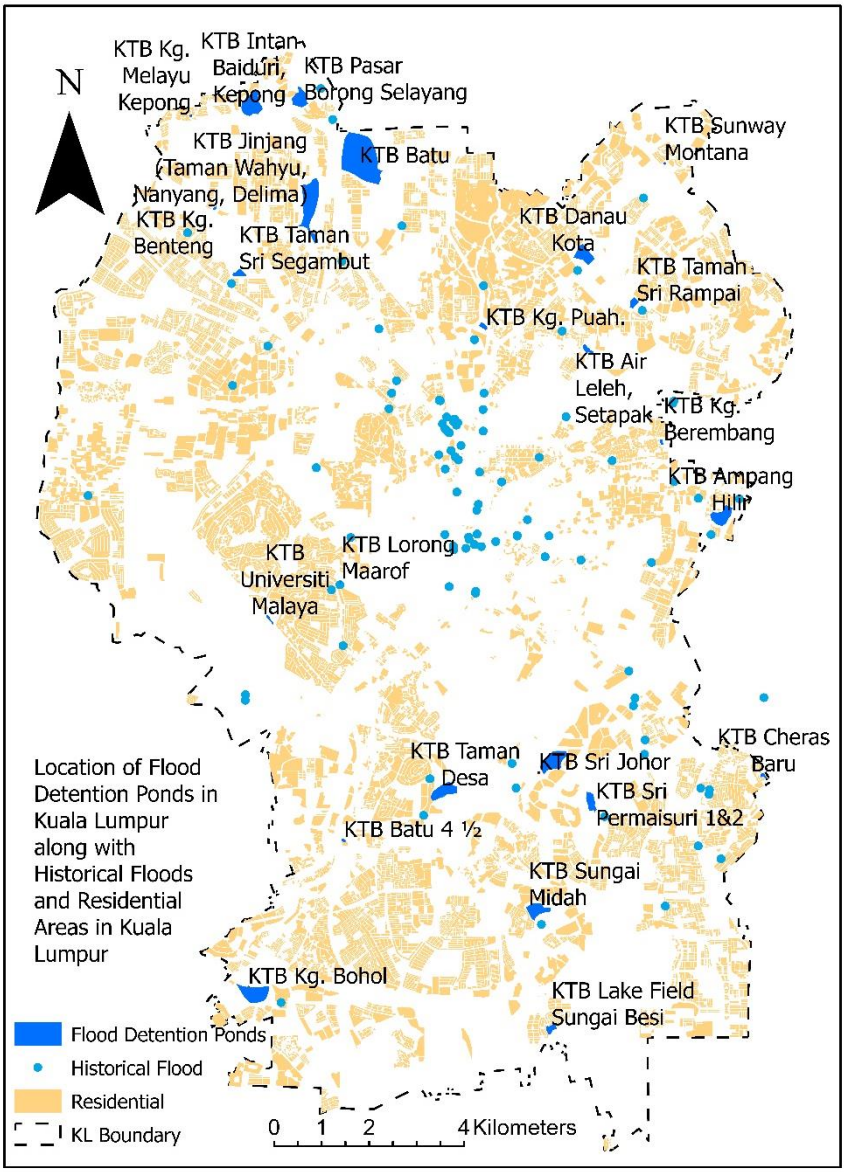



**Figure 1**: Spatial Distribution of detention ponds, historical floods, and residential areas

Figure 1 presents the locations of the 24 flood-detention ponds, historical floods, and residential areas in Kuala Lumpur. These ponds were overlaid with historical flood data collected from reports issued by the National Flood Forecasting and Warning Centre (available data from 2016 to 2021) and

newspaper clippings, while residential areas were extracted from land-use data. The map highlights communities that may be more exposed to flooding, enabling planners to prioritise land use monitoring and community-based flood risk management.

The inclusion of locations ranging from established neighbourhoods to rapidly developing commercial zones enabled a comparative analysis of how different land-use pressures and administrative oversight affect the perceived effectiveness of detention ponds in mitigating flash floods. This geographic spread ensured that the community perception data reflected Kuala Lumpur's broader urban landscape and flood vulnerability profile.

Most ponds are surrounded by extensive built-up development. This pattern is particularly evident around ponds in the northern and eastern parts of Kuala Lumpur, including KTB Batu, KTB Danau Kota, KTB Taman Sri Rampai, and KTB Ampang Hilir. A similar concentration is evident around several southern ponds, including KTB Taman Desa, KTB Sri Johor, and KTB Sri Permaisuri 1 and 2. The blue points show that the flood-exposed locations are distributed widely across Kuala Lumpur, with notable concentrations along the central drainage network and in the southern part of the city. Several detention ponds are located near these points, including KTB Taman Desa, KTB Sri Johor, KTB Sungai Midah and KTB Cheras Baru. This spatial proximity suggests that some detention ponds serve the communities located within or near historically affected or potentially flood-exposed areas.

**Research Design**

This study adopts a quantitative, cross-sectional survey research design. This approach is well suited for capturing a snapshot of community perceptions, flood experiences, and awareness levels at a specific point in time. The structured survey format ensures the collection of standardised data that can be objectively compared across the various detention pond catchment areas. The design was tailored to measure the correlation between the physical land-use changes observed by residents and their subsequent evaluation of the effectiveness of the local flood detention infrastructure.

Respondents were recruited directly from communities living near the selected flood-retention ponds, targeting at least 10 respondents per pond to ensure coverage across all study locations. Eligible residents were approached by data collectors and invited to complete the questionnaire using an online form. Although responses were submitted digitally, data collectors were present during the survey to explain the study, guide respondents through the form, and clarify any questions that they did not understand. This face-to-face, interviewer-assisted digital survey method allowed respondents to enter answers online while data collectors assisted without influencing their responses. As the questionnaire was


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administered through this combined approach, balancing independent online and face-to-face samples was not applicable. This method also reduced misunderstandings of the questionnaire items and ensured that respondents from each retention pond location were adequately represented.

The instrument was structured into four components to ensure comprehensive data gathering. The first section is Respondent Profiling (Section A), which gathers respondents' demographic data, including residency duration and proximity to the detention pond, to contextualise the responses. The second section (Section B) is Perception Assessment utilises a 4-point Likert scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) to quantify community opinion regarding the operational effectiveness of local ponds. The third section is Governance Evaluation (Section C), which probes the socio-political aspects of flood management, specifically evaluating the clarity of authority communication and the responsiveness of agencies. The final section, Qualitative Feedback (Section D) consists of an open-ended section designed to capture grassroots recommendations and concerns that are not adequately addressed by the structured Likert-scale questions. The questionnaire was distributed to communities living near the selected flood-retention ponds in Kuala Lumpur. The questionnaire was distributed through a survey link to residents living within or near the ponds and were familiar with local development and flood conditions. This sampling approach enabled the study to collect community perceptions of land-use change, retention pond effectiveness, and flood risk across different pond locations.

A total of 328 valid responses were included in the analysis. The raw survey data were processed using descriptive statistics. For the Likert-scale items in Sections B and C, mean scores and standard deviations were calculated to determine the central tendency of community opinion toward pond effectiveness and governance performance. Frequency distributions and cross-tabulating demographic profiles with perception scores were used to identify specific governance gaps and infrastructure vulnerabilities. Spearman's rank correlation was used to examine the relationship between perceived land use change and perceived flood risk around flood detention ponds because the questionnaire responses were measured using a four-point Likert scale. We calculated the composite scores by averaging the relevant items for each variable and assessed item reliability using Cronbach's alpha. Statistical significance was determined at $p < 0.05$. The correlation coefficient was used to identify the direction and strength of relationships.

The final analysis synthesised the findings towards suggesting recommendations for improving urban flood resilience and community-authority collaboration in Kuala Lumpur. To contextualise these recommendations, the study area was categorised according to administrative management. The selected

locations range from established neighbourhoods to rapidly developing commercial zones, allowing a comparative analysis of how different land-use pressures and administrative oversight affect the perceived effectiveness of detention ponds in mitigating flash floods. This geographic spread ensured that the community perception data collected in this study were representative of Kuala Lumpur's broader urban landscape and flood vulnerability profile.

## Results and Discussion

### *Section A: Respondent Information and Demography Profiling*

This section outlines the demographic profiles of the survey participants to provide essential context for the subsequent analysis. A total of 328 respondents participated in this study, representing residential communities located within the vicinity of all the detention ponds described in Table 1.

### *Age and Employment Distribution*

Table 2 presents the demographic distribution of the 317 respondents across six age brackets and five employment statuses. Overall, the sample skews toward younger adults, with the 20–29 age group forming the largest cohort at 34.7%, followed by those aged 30–39 years (19.9%) and 40–49 years (18.3%). The rest of the respondents (11) did not answer this question.

**Table 2**: Distribution of Respondents by Age and Employment Category

| Age Category | Student | Private | Government | Self-Employed | Unemployed | Total (n) |
|---|---|---|---|---|---|---|
| 15 - 20 | 10 | 1 | 0 | 0 | 0 | 11 |
| 20 – 29 | 45 | 42 | 10 | 7 | 6 | 110 |
| 30 – 39 | 6 | 25 | 22 | 8 | 2 | 63 |
| 40 – 49 | 2 | 12 | 18 | 19 | 7 | 58 |
| 50 – 59 | 0 | 7 | 10 | 12 | 14 | 43 |
| 60 + | 0 | 3 | 2 | 6 | 21 | 32 |
| Total ($n$) | 63 | 90 | 62 | 52 | 50 | 317 |
| Percentage (%) | 19.9 | 28.4 | 19.6 | 16.4 | 15.8 | 100 |

Across the sample, the private sector constituted the largest occupational group, accounting for, accounting for 28.4% of respondents, followed closely by Students (19.9%) and Government employees (19.6%). Self-employed and unemployed respondents comprised 16.4% and 15.8% of the sample, respectively.

In terms of age distribution, the survey captured a wide, multigenerational demographic, although it leans heavily toward youth and young adults. The largest segment of respondents fell within the 20–29 age bracket, accounting for more than a third of the total sample (34.9%). Combined


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with the 30–39 (19.9%) and 40–49 (18.3%) age groups, most respondents (73.1%) were of working age. This high participation rate among young adults and the working-class population suggests strong civic awareness and concern about urban planning, environmental risks, and local infrastructure among those who live in and actively navigate the city itself. Representation of older adults (50–59 years at 13.5%) and seniors (60+ years at 10.1%) ensured that the survey incorporated the perspective of long-term residents who were likely to have observed historical environmental and developmental changes in Kuala Lumpur over several decades.

***Duration of the Residency Profile***

Understanding how long respondents have lived in their respective neighbourhoods is an important variable because long-term residents may possess historical knowledge of the area. This knowledge enables them to provide informed observations on land-use changes, the reduction of green spaces, and changes in the effectiveness of local flood detention ponds over time. Of the 328 respondents, 327 reported their residency duration. The following table (Table 3) summarises the frequency and percentage distribution of respondents based on the length of time they have resided in the area.

**Table 3**: Duration of Residency Profile

| Category | Frequency (n) | Percentage (%) |
|---|---|---|
| < 1 Year | 17 | 5.2% |
| 1 – 5 Years | 76 | 23.2% |
| 6 – 10 Years | 78 | 23.9% |
| > 10 Years | 89 | 27.2% |
| Unspecific | 67 | 20.5% |
| Total | 327 | 100.0 |

As Table 3 indicates, the largest single specified proportion of respondents have lived in the area for more than 10 years, followed closely by those residing there for 6 to 10 years (23.9%). Collectively, over half of the sampled population (51.1%) were long-term residents with at least six years of experience in these catchments. Meanwhile, respondents with 1–5 years of residency accounted for 23.2%, and recent arrivals with less than 1 year accounted for 5.2%. The remaining 20.5% were categorised as unspecified. The high proportion of long-term inhabitants provides strong contextual reliability as these respondents have long-term historical awareness of neighbourhood development patterns, environmental changes and flood mitigation performance

in their localities. Data were also analysed by location and residency duration. Older settlements around detention ponds (KTB), including KTB Sg Midah (100%), KTB Sri Johor (80%), KTB Taman Sri Permaisuri (75%), and KTB Kg. Melayu Kepong (57.5%), are dominated by long-term residents who have lived in the area for more than 10 years. Areas such as KTB Lorong Maarof (58.33% residing 1–5 years) and KTB Sunway Montana (100% residing 1–5 years) reflect a concentration of newer residents, aligning with recent commercial and residential developments in their surroundings.

***Proximity to Flood-Prone Areas***

Respondents were asked to identify whether their current residence is located within an area known to be flood-prone (Table 4). This determines whether their perceptions of detention pond effectiveness are shaped by direct, localised experiences with flooding or by general community awareness.

**Table 4**: Flood-Prone Respondents Linked Directly to Detention Ponds

| Category | Frequency (n) | Percentage (%) |
|---|---|---|
| Yes | 74 | 22.6% |
| No | 217 | 66.4% |
| Not Sure | 36 | 11% |
| Total | 327 | 100.0 |

Most of the survey participants (66.4%) reported that they did not live in designated flood-prone zones, while nearly a quarter (22.6%) explicitly stated that they did. An additional 11.0% were unsure of their area's official flood-risk status. This distribution was highly beneficial for the study. This indicates that the concerns raised about land use and pond effectiveness throughout the survey are not solely grievances from direct flood victims. Instead, they reflect the broader community awareness and public concern regarding Kuala Lumpur's flood management infrastructure. The 22.6% of respondents who live in flood-prone areas provided a sufficiently large subset of direct insights into the localised, immediate impacts of heavy rainfall and detention pond overflows, grounding the survey in lived experiences. Over 60% of respondents with direct flood risk are concentrated in two major corridors: Bukit Jalil / Kinrara (32.4%) and Kepong / Jinjang / Batu (28.4%), residents living near the Kg. Bohol Flood Detention Pond frequently report flood pressure as intense upstream development meets the basin boundaries. In Kepong and Jinjang, communities surrounding the Kg. Batu, Taman Wahyu, and Intan Baiduri Pond chains experiencing fllooding challenges driven by rapid urbanisation altering natural stormwater pathways. The feedback from Lake Fields (Sungai Besi) and Ampang/Setapak reflects


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localised drainage strains where high-density housing developments sit immediately adjacent to linear detention facilities like the Lake Field Sungai Besi Pond and Kg. Berembang Pond. While 66.4% of participants do not live in designated flood-prone zones, the 22.6% do provide a robust subset of direct insights into the localised impacts of heavy rainfall.

### *Section B: Community Perception on Land-use Changes and The Effectiveness of Flood Detention Ponds*

This section evaluates the community's perceptions of physical transformations in urban land use and their direct consequences for the functionality, capacity, and management of flood detention ponds in Kuala Lumpur.

### *Impact of Land Use Changes Around Detention Ponds*

The survey assessed how the respondents perceived recent spatial transformations around detention basins. Table 5 summarises the descriptive statistics and percentage distribution for each item under the land-use impacts.

**Table 5**: Impact of Land-use Changes Around Detention Ponds

| Indicator | Mean (n) | Agreement (%) | Std. Dev (SD) |
|---|---|---|---|
| There is a lot of new development around the detention pond | 3.28 | 83.5 | 0.86 |
| Green areas around reservoirs have been decreasing over the past five years | 3.26 | 82.6 | 0.84 |
| Land use changes affect the effectiveness of flood detention ponds | 3.28 | 86.6 | 0.82 |
| New housing areas are built near flood catchment ponds | 3.22 | 82 | 0.87 |
| There is a change in land use from agriculture to commercial development | 2.69 | 59.8 | 1.01 |
| Development near reservoirs provides economic benefits to the economy | 3.04 | 72.9 | 0.93 |

The data reflects a statistical convergence around physical urban transformation. Over 83.5% (mean = 3.28) of respondents report intensive construction around retention basins, mirrored by an 82.6% (mean = 3.26) agreement rate on the depletion of natural green buffers over the past five years. When cross-referenced with the inventory, this spatial pressure is most felt in high-growth corridors such as the KTB Kg. Bohol near Bukit Jalil and the KTB Lake Field Sungai Besi, where active real estate projects directly abut basin perimeters. Furthermore, the community explicitly identifies high-density residential expansion as the primary engine of this change (mean = 3.22; 82.0% agreement),

while agricultural-to-commercial shifts scored significantly lower (mean = 2.69), indicating that these catchments were already urbanised spaces whose remaining open margins and drainage reserves are now being built up. Crucially, residents make a direct cognitive link between these land-use shifts and compromised pond functionality (mean = 3.28; 86.5% agreement). Despite these profound environmental concerns, the table reveals a pragmatic public stance: 72.9% of respondents agree (mean = 3.04) that proximate developments deliver economic value. This indicates that the community is not inherently opposed to development but instead demands a sustainable planning framework that balances economic growth with rigorous environmental safeguards.

***Physical and Functional Effectiveness of Flood Detention Ponds***

Respondents evaluated the physical dimensions, structural integrity, maintenance standards, and safety features of the detention ponds located within their catchments, as presented in Table 6.

**Table 6**: Physical and Functional Effectiveness of Flood Detention Ponds

| Indicator | Mean (n) | Agreement (%) | Std. Dev (SD) |
|---|---|---|---|
| I feel this reservoir is safe for the surrounding residents | 3.22 | 80.8 | 0.88 |
| This reservoir is well maintained in terms of structure and cleanliness | 3.15 | 78.4 | 0.90 |
| This reservoir design looks ideal for reducing flooding | 3.09 | 77.4 | 0.91 |
| This reservoir has a green area or good landscaping | 3.08 | 73.5 | 0.92 |
| I think this reservoir is big enough to hold heavy rain water | 3.08 | 73.5 | 0.95 |
| The depth of this reservoir is sufficient to accommodate water during continuous rain | 3.02 | 72.6 | 0.96 |
| I am sure this reservoir can hold water if heavy rain continues for several days | 2.99 | 71.0 | 0.95 |

Residents generally give high marks to the physical safety (mean = 3.22) and routine cleanliness (mean = 3.15) of local flood ponds. These positive scores are driven by well-maintained, mature sites managed by authorities, such as the Sri Permaisuri 1 and 2, Sungai Midah, and Sri Johor ponds in Cheras, as well as Taman Sri Rampai and Danau Kota in Setapak. In these areas, regular upkeep keeps the grounds clean and secure. However, approval drops when evaluating the ponds' actual flood-holding capacity. While basic surface size (Mean = 3.08) and overall design (mean = 3.09) receive moderate support, there


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are still agreement regarding pond depth during continuous rain (mean = 3.02). The lowest rating is for multi-day rain storage (mean = 2.99), where nearly 29% of respondents expressed disagreement. This concern is highest in heavily strained basins like the Kg. Bohol and Lorong Maarof (Bangsar) detention ponds. Overall, the findings suggest that while these ponds handle short, intense rainstorms well, residents fear they cannot handle prolonged monsoonal rainfall without overflowing.

### *Cumulative Impacts of Land Use on Drainage, Sedimentation, and Long-Term Mitigation*

Table 7 reports the respondents' views on how surrounding developments physically altered hydrological dynamics within specific pond catchments, leading to drainage disruptions, siltation, and accelerated overflow risks.

**Table 7**: Cumulative Impacts of Land Use

| Indicator | Mean (n) | Agreement (%) | Std. Dev (SD) |
|---|---|---|---|
| Land use changes increase the risk of water overflowing from reservoirs | 3.27 | 82.6 | 0.82 |
| The function of reservoirs as long-term flood mitigation is being affected by uncontrolled land use changes | 3.15 | 81.4 | 0.83 |
| Development around reservoirs disrupts water drainage | 3.13 | 77.4 | 0.97 |
| Land use changes cause reservoirs to fill quickly during heavy rains | 3.12 | 78.7 | 0.86 |
| Land use changes cause the catchment pond to become shallow due to sedimentation | 3.16 | 78.7 | 0.84 |
| Development near reservoirs increases the risk of water overflowing into residential areas | 2.98 | 73.8 | 0.99 |
| The effectiveness of reservoirs in reducing floods is decreasing due to surrounding development | 2.73 | 58.8 | 0.98 |

Consensus was noted that urban expansion actively accelerates overflow hazards. With an 82.7% agreement rate (mean = 3.27), the respondents confirmed that replacing natural permeable ground with concrete and buildings forces basins to fill at alarming speeds during heavy downpours (mean = 3.13; 78.6% agreement), and development around reservoirs disrupts water drainage (mean = 3.12). They also strongly recognised that this silt accumulation actively reduces basins of vertical depth (mean = 3.16; 78.7% agreement). Collectively, these pressures were perceived to severely compromise the role of detention ponds as long-term macro-mitigation assets, with over 81.4% of participants agreeing (mean

= 3.15). However, respondents expressed lower agreement that surrounding development has reduced reservoirs' effectiveness in flood reduction (mean = 2.73).

***Local Authority (PBT) Governance, Monitoring, and Community Engagement***

The respondents appraised the regulatory oversight, planning transparency, buffer-zone enforcement, and public participation frameworks managed by Local Authorities across these specific pond catchments (Table 8).

**Table 8**: Local Authority (PBT) Action

| Indicator | Mean (n) | Agreement (%) | Std. Dev (SD) |
|---|---|---|---|
| Local authorities monitor land use changes around flood ponds effectively | 2.88 | 73.8 | 0.80 |
| A study of the impact of development on the function of the reservoir is carried out before new projects are approved | 2.88 | 71.3 | 0.91 |
| Development around catchment ponds complies with river and pond buffer zone guidelines | 2.88 | 71.6 | 0.86 |
| Local authority provides enough information about flood-prone areas | 2.82 | 69.8 | 0.86 |
| Local authorities control land use changes in areas around reservoirs | 2.79 | 66.8 | 0.86 |
| Community has been involved in any awareness or consultation programs about flood risk or land use planning | 2.75 | 64.9 | 0.90 |

Every indicator was below the neutral 3.0 threshold. The respondents expressed concern on three aspects of land-use governance: (i) the consistency of municipal land-use monitoring, (ii) whether development-impact assessments are conducted before new projects are approved, and (iii) compliance with river and retention-pond buffer-zone guidelines. The mean score of 2.88 indicates a moderate perception of these practices, suggesting some uncertainty regarding their consistent implementation. These findings highlight opportunities to strengthen monitoring, improve transparency in development approval processes, and communicate buffer-zone compliance more clearly to local communities.

Local zoning regulations governing detention basins received a modest mean strictness score (2.79). Residents frequently witnessed construction encroaching on official river and pond surrounding areas (mean = 2.88). Community participation received the lowest mean score (mean = 2.75), with 35.1% of respondents disagreeing or having a negative opinion. This suggests opportunities to strengthen existing public consultation mechanisms and


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encourage more meaningful community involvement. Communities around the key detention nodes reported limited involvement in early-stage risk awareness initiatives, zoning decisions, and municipal planning dialogues. This suggest that while the municipal agencies demonstrated strength in mechanical maintenance, there are opportunities to improve inter-agency coordination, strengthen the integration of flood-retention engineering with transparent spatial planning, and enhance community participation.

### *Section C and D: Community Perspectives, Governance Preferences, and Future Outlook*

This section explores the community's perspectives on the primary physical causes of flooding, the most noticeable land-use transformations, desired governance reforms, and long-term aspirations for Kuala Lumpur's 24 flood retention ponds and their surrounding catchments.

### *Physical Causes of Flooding in the Local Area*

Respondents identified the primary physical factors contributing to flooding in their respective neighbourhoods. As multiple responses were permitted, the findings capture both natural weather phenomena and anthropogenic (human-induced) pressures linked to urban drainage.

**Table 9**: Physical Causes of Flooding in the Local Area

| **Perceived Physical Cause of Flooding** | Frequency (n) | Share of Response (%) |
|---|---|---|
| Drainage or river blocked | 122 | 37.2 % |
| Heavy rainfall | 101 | 30.8% |
| Construction activities | 48 | 14.6% |
| Overflow from flood retention ponds | 31 | 9.5% |
| Reduction of green and open spaces | 13 | 4.0% |
| Other / Unspecified / No floods | 13 | 3.9% |
| Total | 328 | 100.0% |

Blocked drains and rivers emerged as the leading perceived physical cause of flooding (37.2%). This points to localised maintenance failures, such as siltation, debris accumulation, and unmaintained secondary municipal drains managed by the authority, which prevent stormwater from reaching the 24 primary retention basins. Heavy rainfall was the second major cause (30.8%), confirming that extreme precipitation events driven by climate anomalies continue to overwhelm the baseline urban drainage capacity. Significantly, 14.6% of the respondents attributed flooding directly to ongoing construction activities.

***Most Changes of Land Use around Detention Pond***

To identify the nature of spatial transformation, the respondents were asked to identify the most prominent land-use shifts occurring within their detention pond catchments. They were allowed to select multiple responses, with the results shown in Table 10.

**Table 10**: Most Significant Types of Land Use Changes

| **Types of Land Use Change** | Frequency (n) | Percentage (%) |
|---|---|---|
| New housing development | 186 | 39.5% |
| Clearing and removal of green areas | 121 | 35.7% |
| Commercial development | 95 | 20.2% |
| Industrial development | 66 | 14.0% |
| Other / Minor Notes | 3 | 0.6% |
| Total Cumulative Mentions | 471 | 100.0% |

New housing development was identified as the most prevalent land-use change (39.5% of the total mentions). This rapid residential expansion is acutely visible around major catchments such as the KTB Kg. Bohol in Bukit Jalil and the KTB Danau Kota and KTB Taman Sri Rampai Ponds in Setapak, where high-rise apartments and terrace housing have replaced open tracts. The aggressive removal of green buffers (25.7%) highlights the systematic replacement of natural sponges with impermeable concrete. This corroborates community concerns that natural absorption zones around basins. Commercial (20.2%) and industrial (14.0%) expansions further compound hydrological stress, sealing catchment surfaces and accelerating peak stormwater discharge into municipal drainage networks.

***Relationship between perceived land-use change and perceived flood risk***

Another analysis (Table 11) used two composite variables in the Spearman's correlation analysis. Perceived land-use change was measured using three items: new development, reduction of green areas, and new housing development around flood-retention ponds. Perceived flood risk was measured using eight items related to drainage disruption, sedimentation, rapid pond filling during heavy rainfall, pond overflow, flooding, risk to nearby residential areas, and the reduced long-term flood mitigation function of the ponds. We calculated the mean scores for the relevant items for each variable, with higher scores indicating stronger perceptions of land-use change and flood risk. The two variables demonstrated acceptable internal consistency, with Cronbach's alpha values of 0.698 for perceived land-use change and 0.781 for perceived flood risk.


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**Table 11**: Correlation analysis between perceived land-use change and perceived flood risk

| Variables | Mean | SD | Cronbach's α | $r_s$ | $p$ |
|---|---|---|---|---|---|
| Perceived land-use change | 3.252 | 0.679 | 0.698 | 0.418 | <0.001 |
| Perceived flood risk | 3.100 | 0.562 | 0.781 | — | — |

The Spearman's rank correlation showed a statistically significant positive relationship between perceived land-use change and perceived flood risk around the flood-retention ponds ($r_s = 0.418,\ p < 0.001,\ n = 328$). The strength of the relationship was moderate, indicating that respondents who perceived greater development pressure, housing expansion, and reductions in green areas also tended to perceive higher flood risk. The perceived risks included disrupted drainage, increased sedimentation, rapid pond filling, and possible overflow into nearby residential areas. However, the results reflect an association between community perceptions and do not confirm that land-use change directly caused flooding.

***Better Governance and Policy Improvements***

Respondents highlighted specific regulatory and administrative reforms they wanted local authorities to implement to improve urban flood management. Multiple responses were allowed for this question, and the results are presented in Table 12.

**Table 12**: Better Governance Improvements

| Request for Governance Improvement | Frequency (n) | Share of Response (%) |
|---|---|---|
| Transparent land use planning | 113 | 32.8% |
| Regular maintenance of flood ponds | 80 | 23.2% |
| Community inclusion in decision-making | 53 | 15.4% |
| Enforcement of no-development zones | 53 | 15.4% |
| Public access to flood zone maps | 27 | 7.8 |
| Other / Unspecified | 19 | 5.4% |
| Total Selections | 345 | 100.0% |

Transparent land-use planning ranked first as a governance priority (32.8%). The communities demanded the open disclosure of zoning approvals, Environmental Impact Assessments (EIAs), and hydrological studies before greenlighting high-density projects near basins, such as Intan Baiduri or Lorong Maarof. Regular, scheduled maintenance of retention basins (23.2%) and the

strict enforcement of statutory no-development buffer zones (15.4%) were viewed as critical deterrents against illegal encroachment. The call for community inclusion in decision-making (15.4%) and public access to hazard maps (7.8%) directly addresses the governance deficit identified in Section B. Residents expect municipal authorities to transition from top-down administration to collaborative, transparent risk governance.

***Community Hopes for the Future of Retention Ponds and Land Use***

The 299 valid responses to the open-ended questions revealed the public expectations and long-term aspirations for Kuala Lumpur's flood retention infrastructure. The responses were thematically analysed to systematically categorise the community's grassroots aspirations into three core domains: governance integrity, ecological harmony, and proactive resilience.

Collectively, the responses suggest that community members see urban flooding as more than an engineering or weather-related issue. They also place considerable importance on how flood risks are managed and communicated. A recurring pattern across the responses is a plea for moral integrity and diligence among municipal planners and private contractors. One respondent perfectly captured this sentiment, stating: *"Semoga tulus dalam membuat pekerjaan dan semoga masalah banjir diatasi dengan cermat"* (Hoping for sincerity in execution and careful mitigation of flood problems). Residents consistently underscored that even the most advanced engineering solutions will ultimately fail without conscientious oversight and a zero-tolerance policy for corrupt zoning practices and unauthorised land alienation. Another respondent commented: "*Harapan saya ialah untuk mengawal pembangunan dan tambahkan lagi kolam takungan*" (Hoping to hope to see controlled development and add more flood retention ponds).

The qualitative feedback strongly advocates for a harmonious balance between urban economic growth and environmental preservation. The community members strongly resisted viewing detention ponds as merely concrete bowls intended solely for emergency stormwater storage. Instead, the communities surrounding heavily pressured basins, such as KTB Bohol and KTB Lake Fields, expressed hope that future zoning laws protect the remaining water bodies from being "choked by concrete". The overarching aspiration is for authorities to rehabilitate and transform these retention ponds into clean, functional "green lungs" and biodiverse recreational spaces that naturally absorb rainwater rather than allowing them to degrade into neglected, silt-filled stormwater sumps bordered by high-density real estate.


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**Table 12:** Better Governance Improvements

| Category | Key Insights | Frequency | Percent(%) |
|---|---|---|---|
| Keep Maintenance Routine | Demands for regular desilting, trash cleanup, drain clearing, and prompt structural repairs to prevent blockages. | 38 | 31.10% |
| Development Control and Buffer Zones | Requests for strict "no-development zones," controlled land use, and preventing commercial encroachment that compromises the pond. | 31 | 25.40% |
| Flood Mitigation and Impact | Direct concerns about protecting homes/flats from overflowing, flash floods, and property damage during heavy rain. | 24 | 19.70% |
| Capacity Upgrades and Infrastructure | Calls to deepen/enlarge retention ponds, widen drainage channels, and modernise water retention systems. | 15 | 12.30% |
| Recreational and Green Space | Hopes to repurpose surrounding land into sustainable urban parks, community recreational zones, or eco-educational spaces. | 8 | 6.60% |
| Governance, Enforcement and Public Awareness | Demands for transparent management, anti-corruption, public awareness campaigns on anti-littering, and community dialogues. | 6 | 4.90% |
| Total Responses | | 122 | 100% |

Finally, the qualitative data revealed widespread frustration with reactive, crisis-driven disaster management. The overarching hope for the future is a systemic shift toward proactive and long-term climate resilience. The public recognises the mechanical limitations of the current infrastructure under climate change; therefore, they wish for a city where authorities do not just wait for the monsoon season but actively prepare for it. The community demands that retention basins be continuously dredged to maintain vertical depth, secondary drainage networks be rigorously maintained year-round, and future urban density be strictly calibrated to the existing ecological carrying capacity of local catchments.

The qualitative feedback clearly showed that the community was well informed about the root causes of urban flooding. They understood that sustainable flood mitigation cannot be achieved by pouring more concrete; it requires sincere administration, legal protection of natural buffers, and relentless scheduled maintenance.

Nevertheless, the community perceptions may be affected by response bias because their assessments of retention pond effectiveness did not directly measure the actual hydrological performance. Their responses may be influenced by personal flood experiences, length of residence, proximity to the pond, familiarity with local development, recent heavy rainfall events, and the visible

condition of the pond. Respondents who previously experienced flooding may perceive the pond as less effective, whereas those without such experience may provide more favourable assessments. The presence of data collectors may also encourage socially desirable responses or general agreement with the questionnaire statements.

To reduce this limitation, future studies may compare perception findings with spatial and environmental data, including historical flood records, rainfall, elevation, slope, impervious surface percentage, land-cover change, and the MCDA flood susceptibility index. Combining community perceptions with these measurements provides a more comprehensive assessment and helps identify areas where perceived risk corresponds with observed environmental conditions. Public education can enhance community resilience (Abid et al., 2024).

An integrated strategy that incorporates development control, routine maintenance, catchment monitoring, nature-based solutions, and community involvement should be used to manage flood-retention ponds. By limiting development encroachment and mandating drainage and flood-impact evaluations for planned developments within pond catchments, related agencies can safeguard pond capacity and designated buffer zones. To prevent post-development runoff from exceeding pre-development levels, planning decisions should also account for the cumulative consequences of land-use change. To track changes in impervious surfaces, vegetation, pond area, drainage networks, and adjacent development, establish a shared GIS-based system. Retention ponds should also be integrated with rain gardens, bioswales, permeable surfaces, urban wetlands, and other blue-green infrastructure to reduce runoff at its source. Stronger coordination among DBKL, JPS, planning authorities, developers, and utility agencies is necessary to clarify responsibilities and share relevant data. Nearby communities should be involved through consultation, flood reporting, and environmental stewardship programmes, supported by clear information on maintenance, development proposals, and emergency procedures. Finally, the authorities should introduce measurable performance indicators and periodic policy reviews to ensure that pond-management strategies remain responsive to continuing urbanisation, changing rainfall patterns, and future flood risks.

## CONCLUSION

This study investigated community perceptions of urban land-use changes and the operational effectiveness of Kuala Lumpur's 24 authorised flood retention ponds. The survey successfully captured a representative cross-section of Kuala Lumpur's population, anchored by a mature core of long-term residents (>51% residing in their areas for over six years) and a robust representation of working professionals and students. Over 22.6% of respondents reported experiencing


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direct flood events. These events were concentrated in high-stress catchments, including KTB Kg. Bohol, KTB Taman Wahyu, and KTB Kg. Batu. Therefore, their evaluations are rooted in authentic, long-term observational knowledge rather than abstract speculation.

While the community acknowledges that municipal agencies maintain acceptable baseline structural safety and routine cleanliness (~78–80% agreement), external spatial pressures rapidly undermine this operational competence. A majority (>83%) observed intensive high-density housing construction and aggressive depletion of natural green buffers around the retention basins. This concrete expansion accelerates surface runoff velocity and generates heavy construction sediment, actively reducing retention depth, choking drainage networks, and heightening overflow risks during extreme weather.

Governance indicators received the lowest ratings, consistently falling below the neutral threshold. Community members expressed doubt regarding municipal land-use monitoring, pre-development Environmental Impact Assessments (EIAs), and the strict enforcement of statutory buffer zones. Most notably, public participation received the lowest overall rating, exposing a systemic gap in which the residents felt largely excluded from early-stage risk planning, transparent hazard mapping, and municipal zoning decisions.

To safeguard Kuala Lumpur's flood mitigation infrastructure against ongoing urban sprawl and climate uncertainty, intervention strategies must be targeted by the relevant jurisdictions. Accordingly, the recommendations are organised according to the responsibilities of local planning authorities and federal hydrological agencies. Authorities must enforce strict, statutory prohibition on development within buffer zones surrounding all 24 flood detention ponds. Commercial and residential encroachment adjacent to vulnerable basins must be halted to preserve natural hydrological absorption margins. DBKL must address the public governance deficit by publishing transparent pre-development Environmental Impact Assessments (EIAs) and open-access flood hazard maps. Multi-stakeholder public consultation frameworks must be institutionalised to ensure that local communities are actively engaged before zoning approvals are granted near detention catchments. Authorities must also implement proactive routine dredging schedules for detention basins affected by severe siltation to restore the lost vertical storage volume. In addition, the authorities must combat construction runoff upstream by enforcing mandatory silt trap compliance and requiring temporary sediment retention basins for all active development sites that drain into the primary municipal network.

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# YOUTH HOMEOWNERSHIP READINESS AND ACCESS TO GOVERNMENT HOUSING PROGRAMMES IN MALAYSIA

**Nur Arnie Aziera[2], Ezdihar Hamzah[1&2] and Nurul Ain Najwa[2]**

*[1]Centre for Real Estate Studies (UTM CRES),*
*Institute for Smart Infrastructure and Innovative Construction (ISIIC),*
*[2]Department of Real Estate,*
*Faculty of Built Environment and Surveying (FABU),*
UNIVERSITI TEKNOLOGI MALAYSIA,
81310, Skudai, Johor, MALAYSIA

## Abstract

This study examines factors associated with homeownership readiness among young adults in selected urban areas of Malaysia, focusing on perceived homeownership barriers, financial capacity and access to government housing programmes. A quantitative cross-sectional research design was adopted using a structured questionnaire, with 551 valid responses collected. Descriptive statistics, reliability and factorability analysis, and multinomial logistic regression were employed. Among the 235 non-homeowners, only 21.7% intended to purchase a house within the next five years, while 57.4% had no intention and 20.9% were uncertain. Deposit requirements, location and house price emerged as the most prominent perceived barriers. The six barrier items demonstrated strong internal consistency and were consolidated into a Perceived Homeownership Barriers (PHB) construct. However, PHB was not statistically significant in explaining homeownership intention after controlling for age, monthly income and residential location. Monthly income showed significant associations, particularly between respondents with no purchase intention and those who were uncertain. Although awareness of government housing programmes was high at 86.2%, financial requirements, house prices, financing limitations and insufficient programme information remained prominent challenges. The findings highlight the importance of improving affordability, financing accessibility, information clarity and housing suitability to strengthen youth homeownership readiness.

***Keywords***: Youth Homeownership, Homeownership Readiness, Perceived Homeownership Barriers, Financial Capacity, and Government Housing Programmes.

[1] Corresponding author. Email: ezdihar@utm.my

## INTRODUCTION

Homeownership is important for socio-economic stability and long-term financial security. However, youth homeownership in Malaysia, particularly in the Klang Valley, is increasingly challenged by rising house prices, slow income growth, and financing difficulties. Although the government has introduced programmes such as Skim Rumah Pertamaku and other affordable housing initiatives, homeownership among youths remains relatively low. Therefore, this study examines the challenges affecting youth homeownership and evaluates their perceptions of government housing programmes in the Klang Valley.of government housing programmes from the perspective of urban youth.

Housing affordability is a major socio-economic issue in Malaysia, particularly in the Klang Valley, where house prices have increased faster than income, reducing young adults' purchasing power (Muhammad Nazhan Kamaruzuki & Mohd Amirul Rafiq Abu Rahim, 2024). High living costs, including rent, transportation, and daily expenses, further limit youths' ability to save for homeownership (Norazmawati Md. Sani & Nurul Shafiqah Mohd Nori, 2021). In addition, mortgage requirements such as Debt Service Ratio (DSR) and credit assessments may restrict access to housing finance. According to Institute for Youth Research Malaysia (IYRES, 2022), the growing gap between house prices and wage growth has created significant affordability challenges among young working adults. Although government initiatives such as *Skim Rumah Pertamaku* aim to reduce these barriers, challenges remain. Therefore, youth homeownership should be examined through factors such as house prices, income, cost of living, financing requirements, and government housing programmes.

Despite continuous government intervention through affordable housing Youth homeownership in the Klang Valley remains challenging despite government affordable housing initiatives. The main issue is the growing gap between house prices and income, which reduces the purchasing power of young adults and delays homeownership (Mohd Sahrul Syukri, 2024). In addition, rising living costs such as rent, transportation, food, and utilities reduce youths' ability to save for down payments and other housing costs (Lim H. & Abdul Malek M., 2021). Furthermore, strict housing loan requirements, including Debt Service Ratio (DSR), credit scoring, and repayment assessments, may limit access to financing, particularly for young borrowers with existing financial commitments or limited credit history (Ismail N. et al., 2021). The divergence between income growth and house prices also contributes to delayed ownership and reduced opportunities for long-term wealth accumulation (Yaacob R. & Mohd Noor N., 2023).

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Although government housing programmes such as *Skim Rumah Pertamaku* are intended to assist first-time homebuyers, the availability of such programmes does not necessarily eliminate the financial and affordability barriers faced by young households. Potential buyers may still experience difficulties related to income affordability, loan eligibility, down-payment requirements, financial commitments, and limited awareness of programme requirements. Therefore, examining the relationship between housing affordability factors and youth awareness of government housing programmes is important to determine whether existing assistance adequately addresses the needs of potential young homeowners in the Klang Valley.

## LITERATURE REVIEW

Youth homeownership must be examined through an integrated framework that combines housing affordability theory, urban spatial economics, and institutional financing behaviour. Previous studies suggest that youth homeownership outcomes are shaped by the interaction between structural market forces (referring to supply) and individual financial capability (referring to demand) rather than income level alone (Shahril Omar, 2023). Therefore, a multidimensional theoretical lens is necessary to understand the complexity of affordability challenges within metropolitan housing markets.

### Housing Affordability Theory

Housing affordability theory explains the relationship between housing costs and household income, commonly measured through the price-to-income ratio. However, affordability also depends on factors such as down payment, transaction costs, loan requirements, and mortgage commitments. These combined factors can create significant barriers for young buyers in the Klang Valley (Shahril Omar, 2023). Rising house prices and limited income growth further widen the affordability gap, while delayed homeownership may reduce youths' opportunities for long-term wealth accumulation. Therefore, this theory provides an important basis for understanding the factors affecting youth homeownership.

### Urban Spatial Economics and Location Efficiency

Urban spatial economics explains that housing affordability depends not only on house price but also on location and transportation costs. Affordable housing in suburban areas may involve higher commuting expenses and longer travel times, especially when employment centres are concentrated in urban areas. For young professionals, proximity to workplaces, public transportation, and amenities is important when choosing a home. Therefore, housing that is cheaper but located far from employment and facilities may not be economically efficient (Shahril


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Omar, 2023). Hence, location efficiency should be considered when assessing housing affordability and youth homeownership.

**Institutional Financing and Credit Constraints**

Institutional financing plays an important role in youth homeownership. Loan requirements such as Debt Service Ratio (DSR) and credit scoring may limit young borrowers, particularly those with existing financial commitments or limited credit history (Shahril Omar, 2023). Even when house prices are affordable, strict financing requirements can prevent loan approval and delay homeownership. Therefore, housing affordability and financing accessibility should be considered together when examining the barriers to youth homeownership.

**Financial Behaviour and Readiness**

Financial behaviour influences youth homeownership through budgeting, saving habits, debt management, and financial literacy. Strong financial knowledge helps youths evaluate mortgage options, plan for down payments, and manage long-term repayments, while limited financial literacy may delay homeownership decisions (Lim H. & Abdul Malek M., 2021). However, financial behaviour alone cannot overcome high house prices and living costs. Therefore, financial readiness should be considered together with structural affordability and financing constraints when examining youth homeownership.

**Theoretical Framework**

The theoretical framework integrates economic affordability, financing accessibility, spatial efficiency, and financial readiness to explain the factors influencing youth homeownership. House price and income represent key economic factors, while cost of living affects youths' ability to save for homeownership (Shahril Omar, 2023). Loan requirements, such as DSR and credit scoring, may further influence access to housing finance. Meanwhile, financial literacy supports better financial planning, mortgage evaluation, and repayment decisions (Lim H. & Abdul Malek M., 2021). Overall, the framework suggests that youth homeownership is influenced by the combined effects of house price, income, cost of living, loan requirements, location, and financial literacy.

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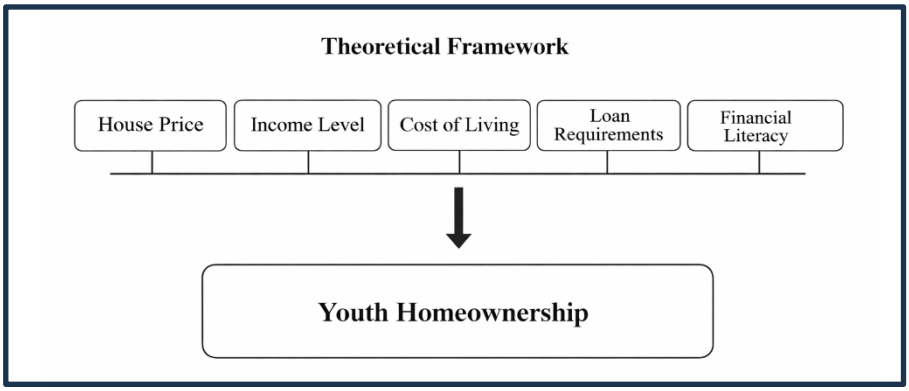



**Figure 1.** Theoretical Framework of Youth Homeownership

Figure 1 illustrates the theoretical framework of youth homeownership by identifying five independent variables that influence homeownership outcomes among youths in the Klang Valley. These five independent variables were subsequently examined through statistical analysis to determine their relationships with youth homeownership.

**House Price** refers to residential property costs that influence housing affordability. Rising house prices relative to income reduce purchasing power and lower youth homeownership potential (Arham et al., 2025; Sukereman et al., 2021).

**Income Level** represents an individual's financial capacity to afford housing. Higher income improves savings capability, mortgage eligibility, and repayment ability (Sukereman et al., 2021).

**Cost of Living** includes daily expenses such as rent, transport, food, and utilities. Higher living costs reduce disposable income and limit savings for homeownership (Arham et al., 2025).

**Loan Requirements** refer to financing conditions such as DSR, credit scoring, and loan eligibility. Strict lending criteria may restrict youths' access to housing finance (Ismail et al., 2023; Ahmad et al., 2012).

**Financial Literacy** refers to knowledge of budgeting, savings, and mortgage planning. Stronger financial literacy supports informed housing decisions and ownership readiness (Ismail et al., 2023).


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Therefore, youth homeownership is influenced by the interaction of affordability, financing accessibility, and financial capability (Badrudin et al., 2022; Leh et al., 2016).

## RESEARCH METHODOLOGY

### Research Design

This study adopted a quantitative**,** cross-sectional research design to examine factors associated with homeownership readiness among young adults in selected urban areas of Malaysia. A quantitative approach was considered appropriate as the study sought to identify patterns in respondents' socio-demographic characteristics, homeownership status and intention, perceived barriers to homeownership, and awareness of government housing programmes. Data were collected at a single point in time using a structured questionnaire, enabling the study to describe the characteristics of the respondents and examine the relationship between perceived barriers and homeownership intention.

The research framework focused primarily on two dimensions. The first was perceived homeownership barriers, which captured respondents' perceptions of the financial and practical constraints associated with purchasing a house. The second was homeownership intention, particularly among respondents who did not currently own a house. Government housing programmes were examined as an additional policy-related dimension to assess respondents' awareness, perceived challenges and reasons for not purchasing through available programmes. This design enabled the study to consider both individual-level constraints and the accessibility of government housing support within the context of youth homeownership.

### Population, Sampling and Data Collection

The target population comprised young adults residing in selected urban areas of Malaysia. Primary data were collected through a structured questionnaire distributed to eligible respondents. A total of 551 valid responses were obtained and used for the descriptive analysis. The respondents provided information on their socio-demographic characteristics, current homeownership status, intention to purchase a house, perceived barriers to homeownership, and experiences or perceptions concerning government housing programmes.

For the analysis of homeownership intention, the study specifically focused on respondents who did not currently own a house. This approach was adopted because the intention question concerned respondents' plans to purchase a house within the following five years and was therefore more directly applicable to non-homeowners. Of the 551 respondents, 235 (42.6%) were non-homeowners and were subsequently used to examine purchase intention. Among these respondents, 51 (21.7%) indicated that they intended to purchase a house within

five years, 135 (57.4%) indicated that they did not intend to do so, while 49 (20.9%) were uncertain. The questionnaire was administered using an online survey format to facilitate access to respondents across the selected urban areas. Participation was voluntary, and the collected responses were screened before statistical analysis. The resulting dataset was subsequently analysed using descriptive and inferential statistical techniques appropriate to the research objectives.

**Research Instrument and Measurement**

The questionnaire consisted of several sections covering respondents' demographic characteristics, homeownership status and intention, perceived barriers to homeownership, and government housing programmes. Respondents' perceptions of homeownership barriers were measured using six items covering house price, income and loan affordability, existing debt commitments, deposit requirements, location constraints, and home-buying knowledge.

The barrier items were originally measured using a five-point response scale ranging from *Strongly Agree* to *Strongly Disagree*, with an additional *Don't Know* category. For statistical analysis, the agreement responses were recoded so that higher scores represented a stronger perceived barrier. The *Don't Know* responses were treated as missing values when calculating the composite barrier score rather than being interpreted as a higher level of constraint. This treatment was necessary because uncertainty about an item does not represent the same underlying construct as agreement with a perceived barrier.

The six barrier items were subsequently examined for internal consistency and factorability before being combined into a broader Perceived Homeownership Barriers (PHB) construct. The analysis indicated strong internal consistency, with a Cronbach's alpha of 0.917. The suitability of the items for factor analysis was further supported by a Kaiser-Meyer-Olkin (KMO) value of 0.879 and a significant Bartlett's Test of Sphericity, $\chi^2(15) = 1{,}817.99$, $p < .001$. The results supported the use of a single composite measure representing respondents' overall perception of homeownership barriers.

Government housing programmes were assessed through questions concerning programme awareness, information sources, perceptions and challenges associated with programme participation. Several questions allowed respondents to select more than one response. These items were therefore treated as multiple-response variables, with the results reported using both response percentages and case percentages where appropriate. This approach allowed the study to identify the most frequently reported challenges and reasons for not purchasing through government housing programmes without imposing a single-response structure on respondents.


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### Data Analysis

The collected data were analysed using descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, percentages, means and standard deviations, were first used to summarise respondents' demographic characteristics, homeownership status, purchase intention, perceived barriers and government programme awareness. For the six perceived barrier items, the analysis excluded *Don't Know* responses from the calculation of means and the composite PHB score. The reliability and dimensionality of the perceived barrier construct were subsequently assessed using Cronbach's alpha, KMO and Bartlett's Test of Sphericity. The six items demonstrated strong internal consistency and sufficient factorability, supporting their aggregation into the PHB construct. The resulting PHB index was then used as a predictor in the subsequent inferential analysis.

To examine the factors associated with homeownership intention, multinomial logistic regression was conducted among the 235 non-homeowners. The dependent variable consisted of three categories: *Yes*, *No*, and *Not sure*, with *Not sure* specified as the reference category. The independent variables comprised the Perceived Homeownership Barriers (PHB) index, age, monthly income and residential location. The analysis was based on complete cases, resulting in an analytical sample of 230 respondents. Multicollinearity among the predictors was also assessed using tolerance and Variance Inflation Factor (VIF) values.

Finally, multiple-response analysis was used to examine respondents' reported challenges and reasons associated with government housing programmes. This analysis enabled the study to distinguish between general programme awareness and the practical constraints affecting programme participation. The combination of descriptive analysis, construct validation and multinomial regression provided an integrated basis for interpreting the factors associated with homeownership readiness among young adults in the study area.

## RESEARCH FINDINGS

### Respondents' Profile and Homeownership Status

A total of 551 valid responses were obtained and included in the analysis. The respondents represented diverse employment and income backgrounds. The largest employment group comprised private-sector employees (40.1%), followed by self-employed respondents (27.4%), government employees (17.8%) and students (14.5%). In terms of monthly income, 46.3% reported earning RM6,001 and above, while 22.9% earned RM4,001–RM6,000, 14.2% earned RM2,001–RM4,000 and 16.7% earned less than RM2,000. Residential location was almost equally distributed between urban (50.3%) and rural (49.7%) respondents. These characteristics indicate that the sample included respondents

with different employment and income circumstances, providing a useful basis for examining differences in homeownership readiness.

**Table 1.** Key Characteristics of Respondents (N = 551)

| Variable | Category | Frequency | Percentage |
|---|---|---|---|
| **Employment status** | Government sector | 98 | 17.8 |
| | Private sector | 221 | 40.1 |
| | Self-employed | 151 | 27.4 |
| | Unemployed/Retired | 1 | 0.2 |
| | Student | 80 | 14.5 |
| **Monthly income** | Less than RM2,000 | 92 | 16.7 |
| | RM2,001–RM4,000 | 78 | 14.2 |
| | RM4,001–RM6,000 | 126 | 22.9 |
| | RM6,001 and above | 255 | 46.3 |
| **Residential location** | Urban | 277 | 50.3 |
| | Rural | 274 | 49.7 |

*Source: SPSS analysis.*

In terms of current homeownership, **3**16 respondents (57.4%) reported that they owned a house, while 235 respondents (42.6%) did not own a house. Since the purchase-intention question specifically concerns future house purchase, the subsequent analysis of homeownership intention was restricted to the 235 non-homeowners. Among this group, only 51 respondents (21.7%) indicated an intention to purchase a house within five years, compared with 135 respondents (57.4%) who did not intend to purchase and 49 respondents (20.9%) who were uncertain.

**Table 2.** Homeownership Status and Purchase Intention

| Measure | Category | Frequency | Percentage |
|---|---|---|---|
| **Current homeownership status (N=551)** | Own a house | 316 | 57.4 |
| | Do not own a house | 235 | 42.6 |
| **Purchase intention among non-homeowners (n=235)** | Yes | 51 | 21.7 |
| | No | 135 | 57.4 |
| | Not sure | 49 | 20.9 |


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The relatively small proportion of non-homeowners expressing a definite intention to purchase within five years provides an important context for understanding the barriers examined in the subsequent analysis. Rather than assuming that all non-homeowners are immediate potential buyers, the findings indicate that a substantial proportion remain either unwilling or uncertain about purchasing a house. This distinction is important because homeownership readiness involves not only the existence of perceived barriers but also the financial and practical capacity to translate an intention into an actual purchase.

**Perceived Barriers to Homeownership**

Six factors were examined to assess respondents perceived barriers to homeownership: deposit requirements, location, house price, income and loan affordability, home-buying knowledge, and existing debt commitments. The original response scale ranged from *Strongly Agree* to *Strongly Disagree*, with an additional *Don't Know* option. For the analysis, the agreement responses were recoded such that higher scores represented stronger perceived barriers, while *Don't Know* responses were treated as missing.

**Table 3.** Perceived Barriers to Homeownership

| Rank | Perceived Barrier | N | Mean | SD |
|---|---|---|---|---|
| 1 | Deposit constraint | 449 | **2.644** | 1.226 |
| 2 | Location constraint | 450 | **2.544** | 1.038 |
| 3 | House price | 459 | **2.466** | 1.060 |
| 4 | Income / loan affordability | 505 | **2.289** | 1.080 |
| 5 | Home-buying knowledge | 506 | **2.208** | 1.214 |
| 6 | Existing debt commitment | 459 | **2.020** | 1.054 |

*Note: "Don't Know" responses were treated as missing in the calculation of means.*

The results indicate that deposit requirements represented the highest-rated perceived barrier (M=2.644, SD=1.226)**,** followed by location constraints (M=2.544, SD=1.038) and house price (M=2.466, SD=1.060). Income and loan affordability recorded a lower mean of 2.289, while home-buying knowledge and existing debt commitments recorded means of 2.208 and 2.020, respectively. Therefore, the findings suggest that respondents perceived the initial financial requirement associated with purchasing a home, particularly the ability to provide a deposit, as more prominent than existing debt commitments.

An important methodological consideration is the relatively substantial proportion of respondents selecting *Don't Know* for several barrier items. The proportion ranged from approximately 8.2% for home-buying knowledge to 18.5% for deposit requirements. These responses were not interpreted as evidence of either agreement or disagreement and were therefore excluded from the

calculation of the barrier means. This treatment provides a more meaningful representation of respondents who expressed an actual perception of the respective barrier.

To determine whether the six items could reasonably be represented as a broader construct, internal consistency and factorability tests were conducted.

**Table 4.** Reliability and Factorability of Perceived Homeownership Barriers

| Test | Result |
|---|---|
| Cronbach's Alpha | **0.917** |
| KMO | **0.879** |
| Bartlett's Test of Sphericity | $\chi^2(15) =$ **1,817.99** |
| Significance | **p < .001** |
| Eigenvalue – Factor 1 | **4.382** |
| Variance explained | **≈73.0%** |

The six items demonstrated high internal consistency, with a Cronbach's alpha of 0.917. The KMO value of 0.879 and significant Bartlett's Test of Sphericity further indicated that the correlation structure among the items was suitable for factor analysis. The first factor had an eigenvalue of 4.382 and accounted for approximately 73% of the total variance. Accordingly, the six items were aggregated into a single Perceived Homeownership Barriers (PHB) index for subsequent analysis.

These findings are important because they suggest that the barriers are not necessarily isolated concerns. Instead, respondents' perceptions of deposit requirements, location, house price, financing affordability, knowledge and debt can be considered collectively as a broader perception of the constraints associated with homeownership

.

**Factors Associated with Homeownership Intention**

To further examine whether perceived barriers and selected socio-demographic characteristics were associated with homeownership intention, a multinomial logistic regression analysis was conducted among the 235 respondents who did not currently own a house. The dependent variable consisted of three categories: *Yes*, *No*, and *Not sure*. The *Not sure* category was used as the reference category. The predictors included the PHB index, age, monthly income and residential location. After accounting for cases with missing values across the variables included in the model, the analysis was based on 230 complete cases.


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**Table 5.** Multinomial Logistic Regression Predicting Homeownership Intention

| Predictor | Comparison | B | p-value | OR |
|---|---|---|---|---|
| **PHB Index** | Yes vs. Not sure | -1.042 | .100 | 0.353 |
| | No vs. Not sure | -0.031 | .953 | 0.970 |
| **Income: RM3,001–RM4,500** | No vs. Not sure | -2.937 | <.001 | 0.053 |
| **Income: RM4,501–RM6,000** | No vs. Not sure | -2.899 | .002 | 0.055 |
| **Income: >RM6,000** | No vs. Not sure | -4.626 | <.001 | 0.010 |
| Age | Yes/No vs. Not sure | — | >.05 | — |
| Residential location | Yes/No vs. Not sure | — | >.05 | — |

*Note: OR = odds ratio. Income comparisons are relative to the lowest income category. Only statistically significant income estimates are presented in detail.*

The overall multinomial regression model was statistically significant, $\chi^2(18)=88.86$, $p<.001$, with a McFadden pseudo- of 0.200. This indicates that the set of predictors provided meaningful explanatory information regarding differences in homeownership intention categories.

However, the results provide an important finding concerning the role of perceived barriers. The PHB index was not statistically significant in either comparison. For respondents indicating *Yes* compared with those who were *Not sure*, the PHB coefficient was negative but did not reach statistical significance (B=-1.042, p=.100). Similarly, the PHB effect for respondents indicating *No* compared with those who were *Not sure* was negligible and statistically insignificant (B=-0.031, p=.953). Thus, although respondents reported several substantial perceived barriers descriptively, the overall intensity of these barriers did not independently explain homeownership intention once age, income and residential location were considered simultaneously.

In contrast, monthly income demonstrated statistically significant associations, particularly in distinguishing respondents who reported *No* intention from those who were *Not sure*. Respondents earning RM3,001–RM4,500 had substantially lower odds of reporting *No* rather than *Not sure* compared with the lowest income group (OR=0.053, p<.001). Similar patterns were observed among respondents earning RM4,501–RM6,000 (OR=0.055, p=.002) and those earning above RM6,000 (OR=0.010, p<.001). These results indicate that income provides stronger differentiation in homeownership intention than the overall perceived barrier index within the present sample.

**Table 6.** Summary of Regression Findings

| Variable | Relationship with Homeownership Intention |
|---|---|
| Perceived Homeownership Barriers | Not statistically significant |
| Age | Not statistically significant |
| Monthly income | Significant for No vs. Not sure |
| Residential location | Not statistically significant |
| Overall model | Significant, $p < .001$ |

The findings therefore suggest an important distinction between perceived barriers and behavioural intention. Respondents may recognise deposits, house prices, location and financing as barriers, but the presence or intensity of these perceived barriers alone does not necessarily determine whether a non-homeowner expresses a definite intention to purchase. Within this model, income appears to provide greater differentiation in respondents' certainty regarding future homeownership.

**Awareness and Challenges of Government Housing Programmes**

The final component of the analysis examined respondents' awareness and experiences relating to government housing programmes. The findings show a relatively high level of programme awareness. Out of 551 respondents, 475 (86.2%) indicated that they were aware of government housing programmes, while 76 respondents (13.8%) reported that they were not aware.

**Table 7.** Awareness of Government Housing Programmes

| Awareness | Frequency | Percentage |
|---|---|---|
| Yes | 475 | **86.2%** |
| No | 76 | **13.8%** |
| **Total** | **551** | **100.0%** |

The high awareness level, however, should not be interpreted as evidence that respondents fully understood programme requirements or were able to access the programmes. In the perception-related question examined in the dataset, 27.6% of respondents selected the "Don't Know" category, indicating that uncertainty remained present despite the generally high level of programme awareness. This distinction suggests that awareness and practical understanding of housing assistance should be treated as separate dimensions. The multiple-response analysis further identified the major challenges perceived by respondents in relation to government housing programmes.


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**Table 8.** Challenges Associated with Government Housing Programmes

| Rank | Challenge | Responses | % of Responses | % of Cases |
|---|---|---|---|---|
| 1 | House price increase | 416 | 18.8 | **75.5** |
| 2 | No housing loan guarantee | 361 | 16.3 | **65.5** |
| 3 | Low income | 302 | 13.6 | **54.8** |
| 4 | High down payment | 292 | 13.2 | **53.0** |
| 5 | Strict eligibility | 286 | 12.9 | **51.9** |
| 6 | Unstrategic location | 276 | 12.5 | **50.1** |
| 7 | Insufficient programme information | 275 | 12.4 | **49.9** |
| 8 | Other | 5 | 0.2 | **0.9** |
| **Total** | | **2,213** | **100.0** | |

*Note: Multiple responses were permitted; therefore, percentages of cases do not sum to 100%.*

House price increase was the most frequently reported challenge, selected by 75.5% of respondents, followed by the absence of housing loan guarantees (65.5%) and low income (54.8%). High down-payment requirements, strict eligibility conditions, location and insufficient programme information were also reported by approximately half of the respondents. These findings demonstrate that respondents' concerns extend beyond the nominal availability of government housing programmes towards the affordability, financing, eligibility and practical suitability of the available assistance. The original study similarly identified house price, financing and income-related issues as prominent concerns. The analysis also examined the reasons respondents gave for not purchasing a house through government programmes.

**Table 9.** Reasons for Not Purchasing Through Government Housing Programmes

| Rank | Reason | Responses | % of Responses | % of Cases |
|---|---|---|---|---|
| 1 | Financial requirements | 364 | 22.5 | **66.1** |
| 2 | Lack of programme information | 361 | 22.3 | **65.5** |
| 3 | Lack of suitable housing options | 304 | 18.8 | **55.2** |
| 4 | No house in desired area | 296 | 18.3 | **53.7** |
| 5 | Requirements too strict | 286 | 17.7 | **51.9** |
| 6 | Other | 6 | 0.4 | **1.1** |
| **Total** | | **1,617** | **100.0** | |

*Note: Multiple responses were permitted; therefore, percentages of cases do not sum to 100%.*

Financial requirements emerged as the most frequently selected reason for not purchasing through government programmes, reported by 66.1% of respondents, closely followed by lack of programme information (65.5%). More

than half of the respondents also reported a lack of suitable housing options (55.2%), absence of housing in their desired location (53.7%) and overly strict requirements (51.9%). The original dataset confirms these multiple-response results.

Taken together, the findings indicate that the main issue is not simply whether young people know that government housing programmes exist. Rather, the results point towards a gap between programme awareness and practical accessibility. Respondents may be aware of government assistance but still face financial requirements, financing limitations, information gaps, eligibility constraints and location mismatches that affect their ability or willingness to participate.

**Summary of Research Findings**

Overall, the findings demonstrate that homeownership readiness among the respondents is shaped by a combination of financial and practical considerations. Although 57.4% of the total respondents currently owned a house, only 21.7% of the non-homeowners indicated an intention to purchase within the next five years, while 57.4% reported no intention and 20.9% remained uncertain. Among the perceived barriers, deposit requirements, location and house price recorded the highest mean scores, indicating that upfront financial requirements and the suitability of housing locations were particularly prominent concerns. The six barrier items also demonstrated strong internal consistency and factorability, supporting their consolidation into the Perceived Homeownership Barriers (PHB) construct.

The inferential findings provide a further distinction between perceived constraints and actual homeownership intention. While respondents reported several significant practical and financial concerns, the PHB construct was not statistically significant in explaining differences in purchase intention after controlling for age, income and residential location. Instead, monthly income showed statistically significant associations, particularly in distinguishing respondents who had no intention to purchase from those who were uncertain. At the government programme level, awareness was relatively high at 86.2%; however, financial requirements, house prices, financing limitations and insufficient programme information remained prominent challenges. Taken together, the findings suggest that improving youth homeownership requires attention not only to programme awareness but also to the extent to which housing assistance is financially accessible, understandable and practically suitable for potential buyers.


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## CONCLUSIONS

This study examined the factors associated with homeownership readiness among young adults in selected urban areas of Malaysia, with particular attention to perceived homeownership barriers and the role of government housing programmes. The findings indicate that although 57.4% of the respondents currently owned a house, only 21.7% of non-homeowners reported an intention to purchase a house within the next five years, while 57.4% had no intention and 20.9% remained uncertain. Deposit requirements, location and house price emerged as the most prominent perceived barriers, highlighting the importance of upfront financial capacity and housing suitability in the homeownership decision. The six barrier items also demonstrated strong reliability and factorability, supporting their consolidation into a Perceived Homeownership Barriers (PHB) construct.

The inferential findings provide an important distinction between perceived barriers and actual homeownership intention. Although respondents identified several substantial financial and practical constraints, the PHB construct was not statistically significant in explaining differences in purchase intention after controlling for age, income and residential location. In contrast, monthly income demonstrated significant associations, particularly in distinguishing respondents with no intention to purchase from those who were uncertain. This suggests that homeownership readiness cannot be understood solely through the presence of perceived barriers; the financial capacity of potential buyers remains an important factor in shaping their position towards future home purchase. In relation to government housing programmes, the high level of awareness (86.2%) indicates that information about such programmes has reached a substantial proportion of respondents. However, house prices, financial requirements, financing limitations and insufficient programme information continued to be prominent challenges. Therefore, the findings suggest that the issue extends beyond programme awareness towards the ability of potential buyers to translate awareness into actual and financially feasible access to housing.

The study contributes to the existing literature by providing an integrated empirical perspective on youth homeownership readiness that distinguishes between perceived barriers, financial capacity, purchase intention and government programme accessibility. Methodologically, the study demonstrates the usefulness of consolidating related barrier items into a reliable PHB construct while subsequently examining its association with categorical homeownership intention. From a practical and policy perspective, the findings provide evidence that housing interventions should not focus solely on increasing awareness of government programmes, but should also consider the financial circumstances of potential buyers, particularly their ability to meet deposits,

housing prices and financing requirements, as well as their need for clear programme information and suitable locations. For developers and housing providers, the findings highlight the relevance of affordability and locational suitability in responding to the needs of younger potential buyers. Overall, the study reinforces that improving youth homeownership requires a broader approach that connects financial affordability, access to financing, information clarity and housing suitability, rather than treating awareness of government programmes as the only pathway towards homeownership readiness.

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# MEASURING EFFICIENCY IN MALAYSIAN REAL ESTATE INVESTMENT TRUSTS

**Nurin Iyazi Raman[1], Nor Nazihah Chuweni[2], Sara Wibaning Respati[3], Emil Azmanajaya[4]**

[1]*Institute of Postgraduate Studies, Faculty of Built Environment,*
[2]*Faculty of Built Environment,*
UNIVERSITI TEKNOLOGI MARA, PERAK BRANCH,
SERI ISKANDAR CAMPUS, MALAYSIA
[3,4]*Department of Civil Engineering,*
BALIKPAPAN STATE POLYTECHNIC, INDONESIA

## Abstract

This paper highlights the necessity of evaluating the efficiency of Malaysian Real Estate Investment Trusts (M-REITs) across the pre-pandemic, pandemic, and post-pandemic phases. While the sector holds significant strategic value, there is a lack of empirical research focusing on the technical, managerial, and scale efficiencies of M-REITs. To address this gap, the study analyses M-REITs efficiency between 2015 and 2024 by applying a non-parametric Data Envelopment Analysis (DEA) methodology. Specifically, the input-oriented Variable Return to Scale (VRS-DEA) model was employed to determine the efficiency scores for M-REITs. The findings indicate the average technical efficiency score is 0.633, indicating moderate overall performance. Pure technical efficiency is relatively high at 0.801, while scale efficiency averages 0.783. This suggests that M-REITs demonstrate strong relative resource-conversion capabilities under managerial control, but efficiency losses are partly due to operating at a non-optimal scale. Ultimately, this study highlights the importance of better resource utilisation and appropriate scale adjustments to improve performance.

***Keywords***: data envelopment analysis, efficiency, REITs

[2] Corresponding author. Email: norna692@uitm.edu.my

# INTRODUCTION

The real estate industry plays a vital role in driving economic expansion and enhancing the maturity of capital markets. In recent years, there has been a significant shift toward indirect property investment, as it provides investors with a pathway to gain market exposure without the complexities of managing physical properties. The REIT has emerged as a primary vehicle for this purpose, serving as a corporate entity that owns, manages, or invests in various types of income-producing real estate. REITs provide a mechanism for investors to access large-scale property investments and returns without having the responsibilities of directly owning, managing, or funding any properties themselves (Zhang *et* al., 2023). Operating in a manner comparable to mutual funds, REITs specialize in the ownership and management of various real estate assets, including commercial properties, office buildings, retail centres, hospitality venues, and industrial warehouses. Their primary objective is to generate consistent rental income and long-term capital gains for their investors (Haslam *et* al.,2015).

Despite the strategic importance of this sector, there is currently a lack of comprehensive research evaluating the efficiency of M-REITs. Therefore, this study seeks to fill that gap by providing an empirical assessment of their performance. Most previous studies on real estate performance have predominantly relied on conventional methods, with relatively few studies adopting modern methods like efficiency and productivity analysis (Chuweni & Eves, 2019). This reliance on conventional methods has left a significant gap in the understanding of technical, managerial, and scale efficiencies within the Malaysian context. Therefore, this study addresses the research gap by conducting a comprehensive ten-year assessment from 2015 to 2024 using a non-parametric frontier approach. By categorising the data into three distinct economic phases, namely pre-pandemic, pandemic COVID-19, and post-pandemic phases, this study offers a unique perspective on how shifting market conditions and external shocks influence the operational and scale efficiency of M-REITs.

# LITERATURE REVIEW

## Concept of Efficiency

Efficiency is broadly defined as the operational ratio of outputs to inputs, serving as a metric to evaluate how effectively a system utilizes its available resources to generate desired outcomes (Ayres *et* al., 2011). In an organizational context, a firm is deemed efficient when it successfully maximizes its output from a predetermined set of inputs or, conversely, achieves a targeted level of output by employing the minimum necessary volume of resources (Alfiero & Esposito, 2018). Within the specific framework of property investment, efficiency represents the capacity of a REIT to convert operational and financial inputs into meaningful returns for stakeholders. In this study, efficiency is analyzed through

an input-output framework where the primary objective is to maximize outputs, such as distribution per unit (DPU) (sen) and property revenue, from a given set of inputs. These inputs typically include the major costs of managing and financing assets, such as property operating expenses, interest expenses as well as administration and management fees.

To provide a comprehensive assessment, this study decomposes efficiency into three specific metrics. Technical Efficiency (TE) assesses a firm's overall capacity to maximize output from its resources, which, according to Mohan (2020), indicates that a firm is operating on the production frontier where increasing output requires additional input. To further refine this, the study distinguishes between management and structural factors by examining Pure Technical Efficiency (PTE) and Scale Efficiency (SE). Under the Variable Returns to Scale (VRS) framework, PTE isolates internal managerial effectiveness by removing the influence of firm size, thereby measuring how successfully a decision-making unit utilizes its assets (Wang, 2009; Jha et al., 2013). Meanwhile, Scale Efficiency (SE) evaluates whether a REIT is functioning at its most productive scale size, calculated as the ratio of TE to PTE to determine if inefficiency arises from the firm being too large or too small (Jha et al., 2013; Ray, 2015). By evaluating these three components, the study determines whether the success of Malaysian REITs stems from superior management or the structural benefits of their operating scale.

**Measurement of Efficiency**

There are two methods that are commonly used to evaluate efficiency namely parametric and non-parametric. Parametric methods involve specifying a functional form for the production or cost function and estimating the parameters of this function. The most widely used version is Stochastic Frontier Analysis (SFA), which assumes that any deviations from the efficiency frontier are caused by a combination of inefficiency and random error (Mateo, 2012). While these methods are beneficial because they allow for statistical testing and the estimation of confidence intervals, the process can be complex. This complexity arises from the requirement to make specific assumptions about how inefficiency and error terms are distributed (Bannour & Labidi, 2015). Conversely, non-parametric techniques avoid the need for a predetermined functional form, offering greater flexibility across diverse datasets (Murillo, 2004). Data Envelopment Analysis (DEA) stands as the primary non-parametric tool, utilizing observed data to develop a piecewise linear frontier (Mateo, 2012; Sharma et al., 2013). Unlike parametric models, DEA operates without a fixed production function, allowing the efficiency frontier to be dictated directly by the data. This characteristic makes the analysis more flexible and helps reduce potential bias (Amin & Boamah, 2025). Furthermore, DEA is particularly useful for complex scenarios like REIT performance because it can handle multiple inputs and outputs simultaneously


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(Amin & Boamah, 2025). By using this approach, the study can effectively capture how various factors influence the overall efficiency of the M-REITs. Despite these methodological strengths, DEA has certain limitations. Because it is a non-parametric technique, it does not include a statistical error term. This means that any reporting mistakes, data errors, or unexpected market shocks are treated entirely as inefficiency rather than random statistical noise. Additionally, DEA is sensitive to outliers. Since the efficiency frontier is built using the best-performing units in the sample, a single extreme data point can alter the shape of the frontier and affect the scores of other units. Even though parametric methods like Stochastic Frontier Analysis can handle random errors, DEA is still preferred here for its ability to handle multiple inputs and outputs at the same time without needing a fixed production formula.

## RESEARCH METHODOLOGY

### Data Collection

This study employs secondary data obtained from annual reports of M-REITs for the period 2015 to 2024. The selected time frame was used to capture three important economic phases defined by global health milestones and market shifts. The pre-pandemic period is categorized as the years 2015 to 2019, representing stable market conditions before the World Health Organization (WHO) declared COVID-19 a global pandemic in March 2020 (Coughtrey et al., 2025; Dhariwal et al., 2025). The pandemic phase spans from 2020 to 2022, aligning with the duration of the international public health emergency and significant market uncertainty (Coughtrey et al., 2025; Lundberg et al., 2024). Finally, the post-pandemic period covers 2023 and 2024, following the WHO's May 2023 declaration that the emergency had ended and the transition to long-term management of the virus had begun (Lundberg et al., 2024; Wu et al., 2024). Segmenting the timeline along these public health and economic milestones is essential because it isolates how structural shocks, sudden lockdowns, and subsequent monetary policy normalization uniquely impacted the operational and scale efficiency of M-REITs across different market cycles. In addition, a total of 174 annual reports were collected and analysed over the ten years. While 16 M-REITs were active and tracked continuously since the baseline year of 2015, additional trusts were included as they entered the market during the study period, resulting in an unbalanced panel dataset comprising 19 REIT entities overall. However, one observation for the year 2016 was excluded from the analysis due to the non-disclosure of interest expense, which serves as a required input variable in the efficiency model. Omitting this single missing observation does not compromise year-to-year comparability, as Data Envelopment Analysis (DEA) evaluates relative efficiency on an annual cross-sectional basis where the frontier is independently constructed for each specific year. This exclusion merely ensures consistency and reliability within that year's specific efficiency

estimation without distorting the longitudinal trends across the broader ten-year timeline. The omission of this outlier ensures consistency and reliability in the estimation process.

**Variables Selection**

In this study, a framework consisting of three inputs and two outputs was utilized to evaluate efficiency levels. The selected input variables include property operating expense ($x^1$), interest expense ($x^2$), fees related to administrative and management ($x^3$), following established methodologies (Anderson et al., 2002; Chuweni et al., 2017; Topuz et al., 2005; Topuz and Isik, 2009). Conversely, the efficiency outputs are measured through the distribution per unit (DPU) in sen ($y^1$) and total property revenue ($y^2$), as suggested by Chuweni et al., (2017). The selection of the input and output variables is theoretically grounded and justified as follows:

***Input 1: Property Operating Expenses ($x^1$)***

Representing the direct costs associated with maintaining, repairing, leasing, and operating physical properties (such as utilities, assessment rates, and maintenance contracts), these variable measures management's ability to control routine overheads. Efficient property maintenance directly impacts net operating income, making cost containment here critical for maximizing overall technical efficiency.

***Input 2: Interest Expenses ( $x^2$)***

As capital-intensive vehicles, REITs heavily rely on debt financing to fund property acquisitions and expansions. Interest expenses reflect the cost of servicing this debt. Including this variable captures how effectively management utilizes financial leverage to generate revenue without overburdening the trust with excessive financing costs, which is especially vital during periods of macroeconomic monetary tightening.

***Input 3: Administrative and Management Fees ($x^3$)***

Encompassing manager remuneration, trustee fees, valuation fees, and corporate overheads, these fees measure structural governance expenses. Lower relative administrative costs indicate superior managerial efficiency and alignment of interest between management companies and unitholders.

***Output 1: Distribution Per Unit (DPU) in sen ($y^1$)***

Serving as the ultimate financial return metric for unitholders, DPU captures the income-distributing mandate characteristic of REIT structures. Maximizing DPU from a given set of operational and financing inputs is the primary goal of retail and institutional investors alike, rendering it an indispensable output variable.


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***Output 2: Property Revenue ($y^2$)***
Representing the gross top-line income generated from rental streams, car park operations, and other asset-derived services, property revenue reflects the core commercial productivity and asset utilization capacity of the REIT portfolio before accounting for operating expenses and financing costs.

**DEA Application in Measuring REITs' Efficiency**
To evaluate efficiency, this study utilized the Variable Return to Scale (VRS) DEA model, which effectively accounts for the diverse operational sizes and scale fluctuations inherent in M-REIT portfolios. An input-oriented perspective was selected, given that REIT managers have greater control over input costs such as operating expenses, interest expenses, and management fees, rather than output levels. The efficiency scores were estimated in the form of technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE). TE reflects the overall ability of a REIT to convert inputs into outputs, PTE isolates internal management performance by adjusting for scale, and SE assesses whether the REIT functions at its most productive size. Efficiency is measured on a scale from 0 to 1, where a score of 1 signifies that the REIT is positioned on the efficient frontier, serving as a benchmark for the industry. Conversely, scores below 1 suggest inefficiency, meaning the REIT could reduce resources while maintaining the same level of output. Although an input-oriented model was selected because managers have direct control over operational costs, a robustness check was also performed using an output-oriented DEA specification and the resulting scores remained consistent with no significant differences, confirming the stability of the empirical findings.

## ANALYSIS AND DISCUSSION
A standard guiding principle in DEA analysis suggests that the number of observations should be at least three times the sum of the input and output variables (Chuweni & Eves, 2019; Avkiran, 2004; Coelli *et* al., 2005; Sufian *et* al., 2014). This ensures the model has sufficient discriminatory power to identify efficient and inefficient units. For this study, the dataset spans an unbalanced panel of 19 distinct M-REITs, featuring 16 M-REITs tracked continuously since 2015. Given that the model utilizes three inputs and two outputs, the total number of variables is five. Applying the rule of thumb (3 x 5 = 15), both the baseline cross-section of 16 firms and the total panel successfully exceed the minimum required threshold. Consequently, the dataset is considered valid and statistically sound for calculating the technical, pure technical, and scale efficiency scores of M-REITs from 2015 to 2024.

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**Efficiency Scores of M-REITs between 2015 and 2024**

Table 1 presents the mean efficiency scores for M-REITs for the years 2015 to 2024. The overall mean TE for the entire ten-year period was 0.633, which indicates that M-REITs generally operated at a moderate level of efficiency. This result shows that there is a 36.7% gap in efficiency, suggesting that many firms are using more inputs than necessary to reach their current level of output. When comparing the different types of efficiency, it is notable that the average PTE of 0.801 was consistently higher than the SE of 0.783. Rather than implying exhaustive corporate governance quality, this high PTE score specifically reflects effective relative control over operational cost conversion at the firm level, while overall productivity is constrained because many firms are not operating at optimal size or scale.

Furthermore, an analysis of the scale properties reveals that the majority of M-REITs operate under decreasing returns to scale (DRS) rather than increasing returns to scale (IRS). Across the ten-year study period from 2015 to 2024, DRS is consistently the dominant scale regime, accounting for more than half of the observations annually, including 62.50% in 2016 and 63.16% in 2023. This indicates that many M-REITs have expanded beyond their optimal scale size, leading to managerial congestion or structural inefficiencies where a proportional increase in inputs yields a smaller increase in outputs. Conversely, a smaller proportion of firms operate under increasing returns to scale (IRS) or constant returns to scale (CRS), suggesting that while a few smaller trusts could benefit from scaling up, the primary sectoral issue is over-expansion rather than sub-optimal size.

The efficiency trends of M-REITs between 2015 and 2024, as illustrated in Figure 1, reveal a decade of significant change and recovery. Throughout the study period, PTE remains constantly higher than TE and SE. This suggests that while M-REIT managers were generally effective at controlling internal costs and daily operations, the sector's overall productivity was often pulled down because the firms were not operating at their most efficient size. The trend started with a noticeable decline in 2016, when all efficiency metrics dropped to a significant low. Following this, the sector faced a steady but uneven recovery leading up to 2019. Surprisingly, during the time of global economic uncertainty, which was from 2020 to 2022, M-REITs showed a consistent improvement in efficiency, whereby SE increased steadily to meet PTE, indicating that the firms were successfully optimizing their size and resource use despite external pressures. However, the sector experienced another sharp downturn in 2023, in which TE fell back to a significant low of 0.500. This represents a time when the sector moved further away from its full potential. Fortunately, the data for 2024 shows a very strong and rapid recovery, with all three efficiency lines trending sharply upward. By the end of 2024, the M-REIT sector had regained its momentum. This suggests that the sector has become more


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resilient, ending the decade in a much stronger and more efficient position than in the previous year.

**Table 1:** Average M-REITs efficiency scores 2015 – 2024

| Year | Technical Efficiency | | Pure Technical Efficiency | | Scale Efficiency | |
|---|---|---|---|---|---|---|
| | **Mean** | **Min. - max** | **Mean** | **Min. - max** | **Mean** | **Min. - max** |
| **Panel A: Malaysian REIT** | | | | | | |
| 2015 | 0.709 | [0.362-1.000] | 0.889 | [0.512-1.000] | 0.791 | [0.460-1.000] |
| 2016 | 0.514 | [0.112-1.000] | 0.641 | [0.227-1.000] | 0.733 | [0.420-1.000] |
| 2017 | 0.655 | [0.400-1.000] | 0.883 | [0.520-1.000] | 0.742 | [0.405-1.000] |
| 2018 | 0.587 | [0.282-1.000] | 0.813 | [0.346-1.000] | 0.713 | [0.310-1.000] |
| 2019 | 0.567 | [0.255-1.000] | 0.789 | [0.348-1.000] | 0.718 | [0.322-1.000] |
| 2020 | 0.597 | [0.270-1.000] | 0.772 | [0.306-1.000] | 0.777 | [0.369-1.000] |
| 2021 | 0.670 | [0.416-1.000] | 0.818 | [0.486-1.000] | 0.824 | [0.436-1.000] |
| 2022 | 0.760 | [0.443-1.000] | 0.855 | [0.508-1.000] | 0.893 | [0.489-1.000] |
| 2023 | 0.503 | [0.144-1.000] | 0.701 | [0.233-1.000] | 0.727 | [0.212-1.000] |
| 2024 | 0.767 | [0.451-1.000] | 0.849 | [0.464-1.000] | 0.908 | [0.490-1.000] |
| **2015 - 2019** | **0.606** | **[0.112-1.000]** | **0.803** | **[0.227-1.000]** | **0.739** | **[0.310-1.000]** |
| **2020 - 2022** | **0.676** | **[0.270-1.000]** | **0.815** | **[0.306-1.000]** | **0.831** | **[0.369-1.000]** |
| **2023 - 2024** | **0.635** | **[0.144-1.000]** | **0.775** | **[0.233-1.000]** | **0.818** | **[0.212-1.000]** |
| **Overall (2015 - 2024)** | **0.633** | **[0.112-1.000]** | **0.801** | **[0.227-1.000]** | **0.783** | **[0.212-1.000]** |

*Source: Author's Own*

While the earlier discussion focused on longitudinal trends over time, Table 2 summarizes the average efficiency scores for each REIT between 2015 and 2024. The top-performing industry leaders are highlighted with grey shading in the table. The results show a wide range of efficiency levels across the 19 firms studied. There is only one firm, namely REIT 19, had achieved a perfect efficiency score of 1.000 across all three categories, which are TE, PTE, and SE. This highlights that while other firms had gaps in their performance, REIT 19 consistently hit 100% of its potential, proving it could use its resources and manage its scale more effectively than all other firms. The data also reveals that several other firms, specifically REIT 5, REIT 10, and REIT 15, achieved a

perfect 1.000 in PTE. This suggests that their management teams are highly skilled at controlling costs and managing day-to-day operations. However, because their SE scores were slightly below 1.000, these firms were still not operating at their most productive size. On the other hand, several firms struggled significantly during the study period. For instance, REEIT 6, REIT 8, and REIT 12 recorded TE scores below 0.400, suggesting they are operating at less than 40% of their optimal efficiency level and reflecting a significant gap from the efficiency frontier, with improvement potential exceeding 60%.

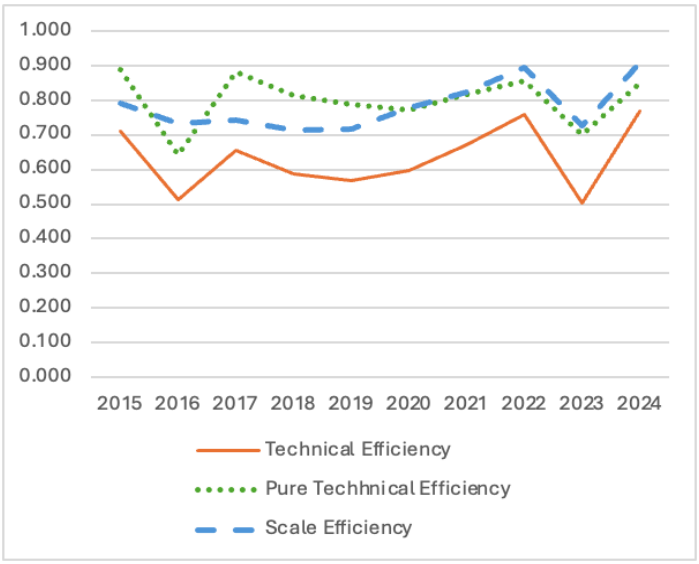



**Figure 1:** The trend of average M-REITs efficiency scores 2015 - 2024
*Source: Author's Own* (2026)

**Table 2:** The mean efficiency scores for 2015 to 2024 by REIT

| REIT ID/ Mean Score | Technical Efficiency | Pure Technical Efficiency | Scale Efficiency | Count Return to Scale |
|---|---|---|---|---|
| REIT 1 | 0.458 | 0.562 | 0.812 | 0% |
| REIT 2 | 0.970 | 0.993 | 0.976 | 50% |
| REIT 3 | 0.582 | 0.828 | 0.717 | 0% |
| REIT 4 | 0.800 | 0.971 | 0.821 | 40% |
| REIT 5 | 0.997 | **1.000** | 0.997 | 90% |
| REIT 6 | 0.393 | 0.595 | 0.706 | 0% |
| REIT 7 | 0.402 | 0.476 | 0.837 | 0% |


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| REIT ID/ Mean Score | Technical Efficiency | Pure Technical Efficiency | Scale Efficiency | Count Return to Scale |
|---|---|---|---|---|
| REIT 8 | 0.393 | 0.559 | 0.695 | 0% |
| REIT 9 | 0.462 | 0.505 | 0.903 | 10% |
| REIT 10 | 0.976 | **1.000** | 0.976 | 90% |
| REIT 11 | 0.414 | 0.918 | 0.452 | 0% |
| REIT 12 | 0.391 | 0.703 | 0.547 | 0% |
| REIT 13 | 0.499 | 0.925 | 0.539 | 0% |
| REIT 14 | 0.510 | 0.926 | 0.542 | 20% |
| REIT 15 | 0.974 | **1.000** | 0.974 | 80% |
| REIT 16 | 0.898 | 0.965 | 0.925 | 50% |
| REIT 17 | 0.657 | 0.728 | 0.893 | 0% |
| REIT 18 | 0.474 | 0.590 | 0.797 | 0% |
| REIT 19 | **1.000** | **1.000** | **1.000** | **100%** |

*Source: Author's Own*

**Notes**: grey shading indicates that the M-REITs were operating at a technical, pure technical, and scale-efficient frontier; bold font indicates the M-REIT was operating efficiently; count RTS denotes the frequency for REITs operating at the optimum scale between 2015 and 2024.

Additionally, the Count Return to Scale (CRS) column in Table 2 shows how often each REIT reached its best possible size over the ten years. REIT 19 led the group with a 100% CRS, followed closely by REIT 5, REIT 10, and REIT 15. In contrast, ten different REITs (REIT 1, 3, 6, 7, 8, 11, 12, 13, 17, and 18) recorded a 0% CRS frequency. This highlights a major challenge for over half of the M-REITs in the study, as they failed to reach optimal operating scale even once between 2015 and 2024. This reinforces findings that the main struggle for M-REITs is not just management skill but also finding the right size to compete effectively in the market.

**Efficiency Performance of M-REITs across Different Phases**

Figure 2 categorizes the efficiency performance of M-REITs into three distinct phases to better understand how economic shifts impacted the sector, spanning the period from 2015 to 2024. By examining these phases, the specific periods of strength and the external factors that caused fluctuations in efficiency can be identified.

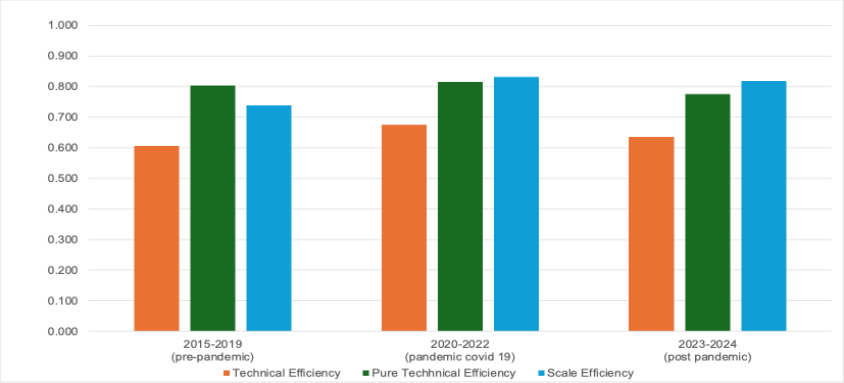



**Figure 2:** M-REITs efficiency scores across different phase
*Source: Author's Own* (2026)

Each of the distinct phases are briefly explained as follows:

***2015 - 2019: Pre-Pandemic Phase***
During the pre-pandemic phase, M-REITs exhibited a moderate TE of 0.606. While managers were generally capable of controlling internal costs, as evidenced by PTE of 0.803, the overall efficiency was still significantly constrained by SE of 0.739. This indicates that prior to global health crisis, the primary structural weakness in the Malaysian market was the failure of trusts to operate at an optimal scale, rather than a lack of managerial competence.

***2020 - 2022: Pandemic COVID-19 Phase***
Figure 2 depicts a compelling finding between 2020 and 2022. Despite the global economic crisis caused by COVID-19, the efficiency scores did not decline and deteriorate. Instead, the sector demonstrated remarkable resilience, with the mean TE rising to 0.676 and SE reaching its highest sectoral peak of 0.831. This upward trend demonstrates the resilience of the M-REIT sector. This trend suggests that under the pressure of lockdowns and market uncertainty, REIT managers were likely forced to implement rigorous resource optimization and cost-cutting strategies. The fact that SE was the primary driver of efficiency during this phase highlights that firms successfully adjusted their operational scale to withstand market volatility.

***2023 - 2024: Post-Pandemic Phase***
The post-pandemic recovery phase recorded a noticeable downturn, with TE and PTE declining to 0.635 and 0.775, respectively. This drop during an era of economic reopening can be attributed to the aggressive normalisation of the Overnight Policy Rate (OPR) by the central bank, which significantly increased interest expense as a primary input. Furthermore, the transition toward a new


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normal required significant capital reinvestment in property modifications, which may have temporarily lowered efficiency as these new inputs have yet to generate stabilized returns.

## CONCLUSION

This research provides a rigorous assessment of M-REITs from 2015 to 2024, revealing a moderate mean technical efficiency of 0.633. A critical finding is that pure technical efficiency at 0.801 consistently outperformed scale efficiency at 0.783, suggesting that while relative operational conversion is high, the primary driver of sectoral inefficiency remains the failure to achieve an optimal operating scale. Interestingly, the analysis proves that M-REITs exhibited remarkable resilience during the COVID-19 pandemic phase, where efficiency metrics improved as firms adopted stricter resource management to withstand market volatility. However, the subsequent post-pandemic downturn highlights a heightened vulnerability to external economic shifts, particularly rising interest expenses.

For regulators and policymakers, these results emphasize the necessity of monitoring how rapid interest rate adjustments impact debt capabilities and technical efficiency, ensuring governance guidelines do not inadvertently encourage inefficient bloating among larger trusts. Property trust managers are encouraged to prioritize finding an optimal operating scale by moving away from aggressive, size driven asset acquisition to eliminate managerial congestion and streamline administrative overhead. For investors, evaluation metrics must transcend traditional market capitalization because identifying benchmark performers provides an empirical standard for assessing management quality and directing capital toward trusts with disciplined scale management. Finally, regarding portfolio restructuring, underperforming M-REITs must initiate targeted strategies to right-size their portfolios by divesting redundant assets to return closer to their optimal scale size. Future research should pursue cross border comparative analyses and incorporate ESG variables as output metrics to provide a more holistic assessment of REIT performance. Additionally, while this study implements an input-oriented VRS DEA model and robustness checks using an output-oriented model were incorporated in the methodology, exploring other financial variables for inputs and outputs is recommended for future research to further enhance robustness results.

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# FACTORS INFLUENCING RUMAH SELANGORKU PURCHASE-RELATED DECISIONS AMONG YOUNG PROSPECTIVE BUYERS IN SELANGOR, MALAYSIA

**Nurul Ain Najwa[1], Ezdihar Hamzah[2] and Nur Arnie Aziera[1]**

[1]*Department of Real Estate,*
*Faculty of Built Environment and Surveying (FABU),*
[2]*Centre for Real Estate Studies (UTM CRES),*
*Institute for Smart Infrastructure and Innovative Construction (ISIIC),*
UNIVERSITI TEKNOLOGI MALAYSIA,
81310 SKUDAI, JOHOR, MALAYSIA

## Abstract

Home ownership among young adults in Malaysia, particularly in Selangor, has become increasingly challenging due to rising property prices, income imbalance, and financial commitments. Although the Rumah Selangorku Scheme was introduced by the Selangor State Government to provide affordable housing for the B40 and M40 groups, concerns remain regarding its ability to meet the needs and expectations of young prospective buyers. This study aims to identify the factors associated with Rumah Selangorku purchase-related decisions among young prospective buyers and to examine differences in perceptions according to their application status. A quantitative approach was adopted using questionnaire data collected from 325 respondents aged 18 to 35 who live or work in Selangor. Data were analysed using descriptive statistics, the Relative Importance Index (RII), reliability and item analysis, exploratory factor analysis, Welch's ANOVA, Games–Howell post-hoc analysis, and multinomial logistic regression. The findings indicate that respondents generally placed high importance on housing price, facilities, location, developer reputation, government incentives, and related housing information. A single underlying perception factor was identified across the 27 items. Overall perception differed significantly by application status, with respondents who had previously applied but were unsuccessful reporting the highest perception scores. The findings provide insights for improving the implementation and delivery of Rumah Selangorku.

***Keywords***: Rumah Selangorku, young buyers, affordable housing, purchasing decision, determinants

[1] Corresponding author. Email: ainnajwasabri@gmail.com

## INTRODUCTION

Home ownership is an important element in enhancing quality of life, social stability and individual economic well-being. It is not only a basic necessity but also a symbol of achievement and a long-term investment. In Malaysia, home ownership among the younger generation has become increasingly challenging due to high property prices, low income levels and existing financial commitments. Although initiatives such as Rumah Selangorku were introduced to assist the B40 and M40 income groups, questions remain as to whether the scheme truly meets the needs and expectations of young buyers. In Selangor, pressure on the affordable housing market has intensified due to population growth, urban migration and the rising cost of living. Rumah Selangorku offers residential units priced between RM42,000 and RM250,000 however, many young buyers remain uncertain about the pricing and quality offered. Key concerns include non-strategic locations, questionable construction quality, impractical designs and delays in project delivery.

Financial burdens such as student loans, vehicle financing, and relatively low salaries further hinder young adults from owning homes. A study by the Khazanah Research Institute (2015) classified Malaysia's housing market as "unaffordable," even though certain units are technically categorized as affordable. As a result, young buyers tend to be more cautious and rely heavily on their perception of value, including house size, surrounding facilities and building materials. Moreover, national housing policies often emphasize the quantity of units rather than the quality of buyer experience. Thus, there is a lack of in-depth research exploring young buyers' perceptions and expectations of schemes such as Rumah Selangorku. Therefore, this research aims to analyse young buyers' perceptions of the price and quality of Rumah Selangorku and to examine how these perceptions influence their purchasing decisions. The findings are expected to provide valuable input to the state government, developers and relevant stakeholders in improving affordable housing policies and implementation to better reflect the current realities faced by young people.

## RESEARCH BACKGROUND

Home ownership among young people in Malaysia, particularly in Selangor, has become increasingly challenging despite various affordable housing schemes introduced by the state government. Individuals aged between 18 and 35 often face financial constraints such as low starting salaries, rising living costs, existing debt commitments, and difficulties in obtaining housing loans from financial institutions (Ismail & Mohd Thalha, 2017). This situation raises concerns about whether affordable housing schemes such as Rumah Selangorku truly meet the needs and expectations of young buyers. Although Rumah Selangorku units are priced below market value, the level of acceptance among young buyers remains

inconsistent. This indicates that purchasing decisions are not influenced solely by price but also by perceptions of value and suitability. Previous studies highlight that factors such as house type and size, design, facilities, location and developer reputation significantly shape buyers' perceptions (Azmi et al., 2020). Negative perceptions may arise if houses are located far from employment centres, lack public amenities or have impractical layouts. Besides, external influences including government incentives, social media exposure and communication effectiveness, also affect buyer perceptions. Other than that, the perspective of liveable neighbourhood through community and social dimension is also another concern (Nabiha and Siti Hajar, 2025). From a consumer behaviour perspective, perceived value in terms of quality, comfort, and long-term potential plays a crucial role in purchase decisions (Adzhar et al., 2021). Previous study from Arham et. al., (2025) indicated that the barriers for affordable housing and sustainable housing for Malaysia youth are including financial constraints, limited housing supply in well-connected urban areas and a lack of awareness about government housing scheme. Thus, there is limited empirical research specifically examines young buyers' perceptions of Rumah Selangorku as an affordable housing in Selangor. Therefore, this study aims to address this gap and provide insights for policymakers and developers.

The scope of this study defines its boundaries in terms of location, time, subjects and thematic focus, ensuring that research is conducted systematically and aligns with its objectives. This study focuses on several dimensions of geographic, demographic, thematic and temporal. Selangor was selected as the study location due to its rapid economic and housing development, particularly in affordable housing projects under the Rumah Selangorku scheme, implemented through strategic collaboration between the state government, private developers and relevant agencies. According to the Lembaga Perumahan dan Hartanah Selangor (LPHS), over 60,000 Rumah Selangorku units have been planned or constructed, reflecting strong government commitment. Selangor also records the highest registration of young buyers in the Sistem Pendaftaran Rumah Mampu Milik (SPRMM), highlighting significant demand. The demographic focus is on young buyers aged 18–35, including early career individuals and first-time home seekers from the Millennial and Gen Z generations. The study examines factors influencing purchase decisions, such as awareness and knowledge of the scheme, financial capacity, perceptions of price and quality, social influences, and government incentives. Temporally, the study covers the past five years, reflecting post-COVID-19 shifts in financial ability and housing priorities. Limitations include the focus on Selangor only, time and resource constraints and potential response bias. Overall, the study aims to provide insights into young buyers' housing decisions and inform improvements in affordable housing policies.


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The significance of this study extends beyond guiding the overall research structure, as it also provides meaningful contributions to key stakeholders within the affordable housing ecosystem, particularly in the context of the Rumah Selangorku programme. By focusing on young buyers' perceptions of housing quality and price, the findings are expected to generate several important impacts to the State Government and the Lembaga Perumahan Hartanah Selangor (LPHS), property developers, young buyers and to the academicians and researchers**.** This study assists the Selangor State Government and the Lembaga Perumahan dan Hartanah Selangor (LPHS) in evaluating the effectiveness of current affordable housing policies. Empirical data collected from young buyers enable policymakers to identify weaknesses in planning, implementation and monitoring processes. The findings may serve as a foundation for improving existing schemes or formulating new, more inclusive and responsive policies that address mismatches between price, quality, and affordability.

Besides**,** the study offers in-depth insights into young buyers' behaviour, preferences, motivations and expectations. Developers can use this information to enhance housing design, construction quality, supporting facilities and marketing strategies. It also helps identify value-added elements such as smart features, sustainable design, security and accessibility, thereby strengthening competitiveness in a dynamic housing market. This research amplifies the voices of young first-time homebuyers by reflecting their real challenges and aspirations. The findings encourage stakeholders to provide housing solutions that truly meet their financial, locational and quality needs. Finally, this study contributes to the literature on affordable housing, consumer behaviour and urban planning, providing a foundation for future research in similar or different contexts.

## LITERATURE REVIEW

The following literature review discusses the factors that influencing the purchasing decisions of Rumah Selangorku among young buyers in Malaysia.

### Type, Size and Price

Among young and lower-income buyers, affordability is highly constrained by unstable income, student loan commitments and rising living costs. Previous studies indicate that when house prices grow faster than wages, young households are more likely to turn to affordable housing schemes (Ismail & Mohd Thalha, 2017). In Selangor, average house prices frequently exceed RM300,000, while young household incomes generally range between RM3,000 and RM5,000 per month, widening the affordability gap and increasing Debt Service Ratios (DSR) beyond acceptable lending thresholds. The Lembaga Perumahan dan Hartanah

Selangor (LPHS) administers the Rumah Selangorku scheme, which offers units priced between RM42,000 and RM250,000 depending on type, size and location. The programme is structured into several categories. Type A units (approximately 550–650 sqft) are priced up to RM42,000 for households earning below RM3,500. Type B (700–750 sqft) is capped at RM100,000 for incomes up to RM7,000. Type C and D provide larger units (800–900 sqft) priced between RM150,000 and RM250,000 for middle-income groups. More recent categories, such as Type E and E Special, integrate smart-home features and improved finishes while maintaining price ceilings below RM288,000.

Overall, competitive pricing combined with regulated eligibility criteria ensures that the scheme targets B40 and M40 groups effectively. Government-backed affordable housing plays a critical role in reducing inequality in homeownership access and supporting sustainable urban development (Salleh & Yusof, 2019). Furthermore, variations in unit size and specifications allow buyers to select housing options aligned with their financial capability, household size and long-term living needs, thereby enhancing satisfaction and perceived value.

**Design of Rumah Selangorku**

Housing design plays a crucial role in ensuring not only affordability but also residents' quality of life. Within the Rumah Selangorku programme introduced by the Selangor State Government, design elements are emphasized to enhance both physical comfort and psychological well-being, particularly among young buyers. As demand for affordable housing among youth increases, the design approach has evolved from basic structural layouts to more sustainable and user responsive concepts.

Typical Rumah Selangorku units generally consist of three bedrooms, two bathrooms, a living area, a kitchen, and in selected projects, a small balcony. These layouts are targeted at young couples and small families, who represent the majority of buyers. Ergonomic spatial planning ensures efficient space utilization without compromising comfort. Minimalist concepts, natural lighting and cross ventilation are key features incorporated to improve indoor comfort and reduce energy consumption. Studies indicate that proper cross ventilation can reduce reliance on air-conditioning by up to 30%, thereby lowering utility costs for low and middle-income households (Ismail et al., 2021). According to Lembaga Perumahan dan Hartanah Selangor (LPHS), recent projects also integrate community-oriented facilities such as playgrounds, green spaces, and multipurpose halls to promote social interaction and overall well-being. Furthermore, selected developments in areas such as Puchong and Shah Alam adopt Transit Oriented Development (TOD) principles, enhancing accessibility and supporting sustainable urban growth.


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Smart-ready features, including energy-efficient LED lighting, infrastructure for future solar systems, and high-speed internet connectivity, are increasingly incorporated to meet the digital lifestyle needs of millennials. Such design innovations reflect a shift toward people-centric and sustainable housing models. Overall, the design of Rumah Selangorku demonstrates how affordable housing can simultaneously address ownership accessibility, environmental sustainability and improved living standards (Zaid & Graham, 2020).

**Facilities Provided and Location Preferences**

The provision of physical and digital facilities within affordable housing developments has become a critical determinant of residents' quality of life, particularly among technology-oriented young buyers. In the Rumah Selangorku programme, basic amenities such as parking spaces, playgrounds, prayer rooms, and multipurpose halls are commonly provided to meet essential social and recreational needs. According to the Lembaga Perumahan dan Hartanah Selangor (LPHS), these facilities are part of the minimum planning requirements to ensure community well-being and liveability. However, market trends indicate growing demand for enhanced facilities and smart features that support modern lifestyles. Young buyers increasingly prioritize safety, convenience, and digital accessibility. Features such as digital door locks, CCTV systems linked to mobile applications, biometric access, and smart meters are no longer perceived as luxuries but as essential components of contemporary housing. Salimon et al. (2018) found that the integration of smart technologies significantly influences purchase intention among Malaysian urban buyers, particularly in the Klang Valley. Smart meters, for instance, provide real-time energy consumption data, encouraging efficient energy use and supporting sustainable living practices.

Beyond facilities, location remains a decisive factor in housing decisions. Young buyers prefer residences with strong connectivity to employment hubs, shopping centres, educational institutions and healthcare services. Developments near public transportation networks, including MRT and LRT stations, are especially attractive as they reduce reliance on private vehicles and improve daily commuting efficiency. Studies show that over 60% of young buyers prioritize accessibility and infrastructure when selecting a property (Fatimah Zulkifli & Hafiszah Ismail, 2023). In Selangor, areas such as Shah Alam, Puncak Alam and Cyberjaya are popular due to their strategic positioning and integrated urban planning. Overall, both comprehensive facilities and strategic location significantly shape young buyers' perceptions and purchasing decisions, reinforcing the importance of holistic, inclusive and future-ready affordable housing strategies in rapidly urbanising regions.

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**Developer Reputation and Government Incentives**

Developer reputation plays a vital role in shaping buyers' perceptions of housing projects, including affordable schemes such as Rumah Selangorku. For first-time buyers, particularly young households, purchasing a home represents a long-term financial commitment involving decades of mortgage repayment. Therefore, trust in the developer becomes a significant determinant in the decision-making process. Cheng and Cheok (2008) emphasize that brand awareness and corporate image strongly influence property purchase decisions, as reputable developers signal construction quality, timely delivery and professional governance.

Developer reputation is commonly evaluated based on past project performance, construction quality, adherence to legal standards, timely completion, and after-sales service. Nursal et al. (2019) found that trust in developers significantly affects buyer confidence, especially for projects under construction. In the context of Rumah Selangorku, this issue is particularly relevant as some projects are undertaken by small to medium-scale developers with limited high-rise experience. Concerns over delays, abandoned projects, or construction defects may weaken buyer confidence. Hence, regulatory monitoring by the Lembaga Perumahan dan Hartanah Selangor (LPHS) and the Kementerian Perumahan dan Kerajaan Tempatan (KPKT) is essential to ensure compliance and safeguard purchasers' interests.

Beyond reputation, government incentives substantially influence young buyers' purchasing decisions. At the federal level, schemes such as Skim Rumah Pertamaku (SRP) provide up to 110% financing for eligible first-time buyers, reducing the burden of upfront deposits. The Skim Jaminan Kredit Perumahan (SJKP) further supports self-employed and gig workers by offering government-backed loan guarantees. Additionally, stamp duty exemptions for first homes valued below RM500,000 remain effective until 31st December 2025. Collectively, strong regulatory oversight and financial incentives enhance buyer confidence and improve accessibility to homeownership. These measures demonstrate the government's commitment to strengthening affordable housing participation among young Malaysians while ensuring accountability and sustainability within the property development sector.

**Social Media Influence and Communication Channels**

In today's fast-paced digital era, social media has emerged as a primary channel for information dissemination and perception shaping, particularly in the residential property sector. Its role extends beyond promotion, serving as a platform for interaction, testimonials, share their services and developer reputation evaluation (Siti Munirah & Ezdihar, 2022). This is especially evident among younger buyers, such as Millennials and Generation Z, who rely heavily on social media for property-related decisions. Affordable housing projects like


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Rumah Selangorku are directly impacted by digital content in shaping public perception. Studies indicate that over 97% of homebuyers conduct initial research online, with 74% assessing property offerings through social media before making decisions (Ho, Zakaria & Foo, 2024).

Developers leveraging platforms such as Facebook, Instagram, TikTok, and YouTube can engage potential buyers through virtual tours, 3D design showcases and user testimonials. Electronic word-of-mouth (e-WOM) and interactive content influence both cognitive and emotional engagement, significantly affecting purchase intentions. Furthermore, social media enables two-way communication, allowing developers to respond to inquiries, provide construction updates and share information on government incentives. This transparency strengthens buyer confidence, particularly among tech-savvy young purchasers. High digital visibility also increases trust, as frequent exposure to project updates, tips, and achievements builds a positive narrative and strengthens brand recognition. Negative experiences shared online, such as construction delays or poor service, can quickly impact reputation, highlighting the necessity for careful social media management.

Effective communication channels are equally critical. The Selangor state government utilizes official social media, agency websites like Lembaga Perumahan dan Hartanah Selangor (LPHS), the Smart Selangor mobile app and property exhibitions to reach young buyers. Collaboration between government, developers, and financial institutions ensures information clarity and accessibility. Cross-sector partnerships enhance outreach efficiency, enabling buyers to understand eligibility, financing and procedural requirements (Yusof et al., 2020). In conclusion, social media and strategic communication channels are essential in influencing young buyers' perceptions and decisions. For Rumah Selangorku, integrating digital marketing, interactive content and multi-platform communication strengthens engagement, trust and overall program success, ensuring affordable housing reaches its intended demographic effectively.

## RESEARCH METHODOLOGY

This study employs a structured and systematic research methodology to examine factors influencing young buyers' decisions under the Rumah Selangorku scheme, providing a framework to ensure the validity, reliability and transparency of findings. The primary instrument used was a structured questionnaire, developed based on prior literature, empirical studies on housing purchase behavior and the local context of affordable housing in Selangor (Zainon et al., 2017). The questionnaire captured data on demographic characteristics, housing type, size and price, design preferences, facilities, location considerations, developer reputation, government incentives, social media influence, communication channels and eligibility and application processes. Respondents

rated items on a five-point Likert scale, allowing quantitative analysis of perceptions and priorities.

**Data Collection**

Data were collected using an online survey via Google Forms and distributed through social media and messaging platforms such as WhatsApp, Telegram and Instagram. The questionnaire was shared in targeted housing and property related groups to reach individuals aged 18–35 associated with Rumah Selangorku. A screening question was included at the beginning to ensure only eligible respondents could proceed. Out of 400 questionnaires distributed, 325 were valid, yielding an 81.25% response rate, indicating reliable and representative data. This study adopted a quantitative research approach to examine the factors associated with Rumah Selangorku purchase-related decisions among young prospective buyers in Selangor. The questionnaire consisted of demographic questions and 27 Likert-scale items covering nine areas, namely housing type, size and price; housing design; facilities; location; developer reputation; government incentives; social media; communication channels; and eligibility and application processes. A five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to measure respondents' perceptions of the identified factors. A total of **325 valid responses** were obtained and included in the analysis.

**Data Analysis**

The data analysis was conducted using SPSS, beginning with descriptive statistics to summaries the characteristics of the respondents and their responses to the questionnaire items. The Relative Importance Index (RII) was subsequently employed to rank the perceived importance of the 27 factors. RII was calculated using the formula $RII = \Sigma W / (A \times N)$, where $\Sigma W$ is the respondent score, A is the highest value on the Likert scale and N is the total number of respondents. RII, widely used in construction, social research and housing studies, captures both the frequency and importance of responses (Zainon et al., 2017). This approach allowed prioritization of factors such as house price, location, facilities, construction quality and government policies, providing actionable insights for policymakers and developers (Mohd Rahim et al., 2019). Reliability and item analysis were conducted using Cronbach's alpha and corrected item-total correlations to assess the internal consistency of the measurement items. Exploratory factor analysis was then performed to examine the underlying dimensionality of the 27 items, supported by the Kaiser Meyer Olkin (KMO) measure and Bartlett's test of sphericity. The factor analysis was used to determine whether the individual items represented distinct dimensions or a broader underlying perception construct.


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Following the measurement assessment, an Overall Perception Index (OPI) was constructed by averaging the 27 perception items to provide an overall measure of respondents' perceptions towards Rumah Selangorku. Differences in OPI across the three application status groups that are those who had never applied, those considering applying, and those who had applied but were unsuccessful. These groups were examined using Welch's ANOVA, followed by the Games–Howell post-hoc test due to unequal group variances. Finally, multinomial logistic regression was employed to examine the association between overall perception and respondents' application status. The regression model used respondents who had never applied as the reference category. The analytical procedures were designed to provide both descriptive and inferential evidence on the relationship between young prospective buyers' perceptions and their engagement with the Rumah Selangorku application process.

## RESEARCH FINDINGS

### Descriptive Analysis and Relative Importance of the Factors

The first objective of this study was to identify the factors associated with Rumah Selangorku purchase-related decisions among young prospective buyers. A total of 325 valid responses were analysed. Descriptive statistics and the Relative Importance Index (RII) were used to assess the perceived importance of 27 items across nine factor areas, namely housing type, size and price, design, facilities, location, developer reputation, government incentives, social media, communication channels, and eligibility and application processes.

The results indicate that house price was the highest-ranked individual factor (RII = 0.811; mean = 4.06), demonstrating the importance of affordability in respondents' housing-related considerations. This was followed by neighbourhood safety and environment (RII = 0.796; mean = 3.98) and basic project facilities (RII = 0.791; mean = 3.96). Other highly rated considerations included checking the developer's background (RII = 0.779; mean = 3.90), government assistance (RII = 0.780; mean = 3.90), confidence in information provided through official channels (RII = 0.780; mean = 3.90), and location accessibility (RII = 0.767; mean = 3.83). These findings suggest that young prospective buyers place considerable emphasis on affordability, safety, accessibility, facilities, developer credibility and reliable information when evaluating Rumah Selangorku.

At the lower end of the ranking, interaction with developers through WhatsApp or Telegram recorded the lowest RII (0.707), followed by online housing advertisements (0.719) and understanding of eligibility requirements (0.718). However, the relatively high RII values across all 27 items indicate that the factors were generally perceived as relevant rather than being unimportant. Therefore, the findings suggest that respondents consider Rumah Selangorku

through a combination of financial, physical, locational, institutional and informational considerations, rather than relying on a single factor. Importantly, these findings represent respondents' perceptions and purchase-related considerations, and should not be interpreted as evidence of actual purchasing behaviour.

**Table 1**. Findings of RII

| Rank | Factor/ Item | Mean | RII |
|---|---|---|---|
| 1 | House price | 4.06 | 0.811 |
| 2 | Neighbourhood safety and environment | 3.98 | 0.796 |
| 3 | Basic project facilities | 3.96 | 0.791 |
| 4 | Developer background | 3.90 | 0.779 |
| 5 | Government assistance | 3.90 | 0.780 |
| … | … | … | … |
| 25 | Online housing advertisements | 3.59 | 0.719 |
| 26 | Understanding eligibility requirements | 3.59 | 0.718 |
| 27 | Developer interaction via WhatsApp/Telegram | 3.54 | 0.707 |

Based on the RII analysis, the three highest-ranking factors were as follows:

1. **House Price (RII = 0.811):** Price emerged as the most significant factor affecting young buyers' decisions. The highest RII value confirms that financial capability is a primary concern for young adults entering the workforce. Buyers evaluate monthly installment affordability, overall house cost and price suitability relative to income as critical conditions before selecting a property. This factor reflects the real challenges faced by young buyers in a housing market with rising prices and living costs.
2. **Neighborhood Safety and Environment (RII = 0.796):** Safety was the second-highest priority. Young buyers pay significant attention to the security level, crime rates, and the harmony and conduciveness of the neighborhood. This indicates that buyers seek not only affordable homes but also stable and safe environments, particularly for those planning to start a family.
3. **Basic Project Amenities (RII = 0.791):** Essential facilities such as adequate parking, recreational parks and places of worship were the third most significant factor. The high RII value highlights that young buyers value the comfort and convenience provided by housing projects. These amenities not only enhance the practical value of the home but also improve daily life quality and resident experience.


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The three lowest RII values are recorded for interaction with developers via WhatsApp or Telegram, understanding of eligibility requirements and online property advertisements. These low values indicate that digital communication and promotions do not play a major role in purchase decisions. Instead, young buyers focus more on factors with direct, tangible impacts on daily life and homeownership experience, such as the physical condition of the house, neighborhood safety and price affordability relative to income. This suggests that practical needs drive purchase decisions more than marketing influence or online information.

**Reliability and Factor Structure of the Measurement Items**

Prior to further inferential analysis, the internal consistency and dimensionality of the 27 perception items were examined. The reliability analysis demonstrated very high internal consistency, with Cronbach's alpha values ranging from 0.863 to 0.903 across the nine factor areas, while the overall 27-item scale recorded an alpha of 0.985. Corrected item-total correlations ranged from approximately 0.65 to 0.84, indicating that all items contributed adequately to the overall measurement and were therefore retained for subsequent analysis.

Exploratory factor analysis further indicated that the 27 items were highly suitable for factor analysis. The Kaiser Meyer Olkin (KMO) value was 0.964, while Bartlett's test of sphericity was statistically significant, $\chi^2(351) = 11{,}621.40$, $p < 0.001$. The analysis identified one dominant underlying factor, with an eigenvalue of 19.561 and accounting for approximately 72.45% of the total variance. All 27 items demonstrated strong factor loadings, ranging from approximately 0.769 to 0.896. This result indicates that, despite being organised into nine thematic areas in the questionnaire, the items exhibit a strong common underlying perception towards Rumah Selangorku.

**Overall Perception and Differences by Application Status**

Based on the factor analysis, an Overall Perception Index (OPI) was constructed by calculating the mean score across all 27 items. The OPI was subsequently compared across three application-status groups: respondents who had never applied, respondents considering applying, and respondents who had applied but were unsuccessful. The results show a clear pattern in which respondents who had applied but were unsuccessful recorded the highest overall perception score ($M = 4.325$, $SD = 0.685$), followed by those who were **c**onsidering applying ($M = 3.769$, $SD = 1.005$) and those who had never applied ($M = 3.580$, $SD = 1.227$). Given the unequal variances across groups, Welch's ANOVA was employed. The analysis demonstrated a statistically significant difference in OPI across the three groups, $F(2, 168.713) = 17.619$, $p < 0.001$, with an omega-squared effect size of 0.052, indicating a moderate overall group effect.

**Table 2.** Overall Perception Index by Application Status

| Application status | n | Mean | SD |
|---|---|---|---|
| Never applied | 182 | 3.580 | 1.227 |
| Considering applying | 87 | 3.769 | 1.005 |
| Applied but unsuccessful | 56 | 4.325 | 0.685 |
| **Overall** | **325** | **3.759** | **1.124** |

Games–Howell post-hoc analysis showed that respondents who had applied unsuccessfully reported significantly higher perceptions than both respondents who had never applied ($p < 0.001$) and those considering applying ($p = 0.001$). In contrast, the difference between respondents who had never applied and those considering applying was not statistically significant ($p = 0.374$). The results therefore indicate a consistent pattern of Never Applied ≈ Considering Applying < Applied but Unsuccessful. This suggests that stronger overall perceptions of Rumah Selangorku are particularly evident among respondents who had already engaged with the application process, although the findings represent association rather than causation.

**Multinomial Logistic Regression**

To further examine the relationship between overall perception and application engagement, a multinomial logistic regression model was estimated using "never applied" as the reference category. The overall model was statistically significant, with a likelihood-ratio test of $p < 0.001$ and a McFadden pseudo-$R^2$ of 0.037. A one-standard-deviation increase in OPI was not significantly associated with being in the "considering applying" group relative to the "never applied" group (OR = 1.175, 95% CI = 0.911–1.515, $p = 0.215$). However, higher OPI was significantly associated with membership in the "applied but unsuccessful" group compared with the "never applied" group (OR = 2.785, 95% CI = 1.655–4.686, $p < 0.001$). Thus, respondents with higher overall perceptions were approximately 2.8 times more likely to belong to the group that had previously applied but was unsuccessful, relative to respondents who had never applied.

Overall, the findings demonstrate that price, safety and basic facilities are among the most highly perceived individual considerations, while the broader 27-item measurement reflects a strong common perception towards Rumah Selangorku. More importantly, overall perception differs according to respondents' level of application engagement, with the highest scores observed among those who had previously attempted to apply. These findings provide empirical evidence that young prospective buyers' perceptions are associated with their engagement with the Rumah Selangorku application process, while


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avoiding the assumption that perceived factors directly cause actual purchasing behaviour.

## CONCLUSION

This study concludes that young prospective buyers evaluate Rumah Selangorku through a combination of affordability, safety, facilities, location, developer credibility and access to reliable information. Among the individual considerations, house price, neighbourhood safety and basic project facilities emerged as the most prominent factors. The findings also demonstrate that the 27 perception items share a strong underlying perception, while respondents who had previously applied but were unsuccessful recorded significantly higher overall perception scores than those who had never applied or were merely considering applying. These findings suggest that improving affordable housing provision should extend beyond offering lower-priced units to ensuring that properties provide a safe, accessible and functional living environment. For potential buyers, the findings highlight the importance of evaluating Rumah Selangorku holistically, considering affordability alongside location, safety, facilities and developer reliability when assessing housing options.

For **p**olicymakers and housing agencies such as LPHS, the findings provide empirical evidence to support improvements in housing delivery, particularly in maintaining affordability while strengthening the quality, safety and liveability of housing projects. Application-related information and support should also remain clear and accessible to reduce barriers to participation. For developers, the findings suggest that greater emphasis should be placed on value-for-money housing, functional facilities, strategic locations, neighbourhood safety and transparent information rather than relying heavily on promotional or digital communication strategies. Overall, the study contributes to a better understanding of young prospective buyers' perceptions and application engagement towards Rumah Selangorku and provides practical direction for aligning affordable housing provision with the needs and expectations of its intended market. Future studies should expand geographic scope, incorporate mixed methods and examine broader socio-economic variables (Creswell & Creswell, 2018).

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# EXPLORING POTENTIAL HOMEBUYERS' PERCEPTIONS AND CONSIDERATION OF FLOOD RISK IN RESIDENTIAL PROPERTY PURCHASING IN SHAH ALAM, SELANGOR

**Muhammad Arif Syukran Zairudin[1], Thuraiya Mohd[2*]**

[1]*Department of Real Estate Management, Faculty of Built Environment,*
[2*]*Green Safe Cities, Faculty of Built Environment,*
UNIVERSITI TEKNOLOGI MARA CAWANGAN PERAK, MALAYSIA

## Abstract

Urban flooding has become a recurring issue in Malaysia's rapidly developing cities, posing increasing risks to residential properties and homebuyers. In cities such as Shah Alam, flooding has led to significant property damage and disruptions to community well-being. In response, this study serves as a perception-based exploratory investigation to assess potential homebuyers' awareness of flood risks and examine the extent to which these risks influence their residential property purchasing decisions in Shah Alam, Selangor. A quantitative cross-sectional approach was employed, gathering primary data via structured questionnaires from 102 respondents in Shah Alam. The sample demographic consists predominantly of university-level students and young adults evaluating prospective purchasing criteria. Data were analysed using descriptive statistics, Exploratory Factor Analysis (EFA), and Multiple Linear Regression to evaluate measurement structures and examine relationships between decision-making variables. The results indicate that potential homebuyers demonstrate a high level of awareness regarding flood risks, treating flood risk as a significant consideration alongside traditional housing factors. This study contributes valuable insights for government agencies in formulating effective policies aligned with *Rancangan Malaysia Ke-13 (RMK-13)* and the National Housing Policy, while promoting climate-resilient housing practices.

***Keywords***: Flood Risk Awareness, Homebuyer Decision Making, Residential Property, Shah Alam

[2] Corresponding author. Email: thura231@uitm.edu.my

# INTRODUCTION

Housing is a fundamental human necessity, providing stability and security for the global population (Ismail et al., 2021). In Malaysia, rapid urbanisation in centres like Kuala Lumpur and Shah Alam has intensified housing demand, leading to a highly competitive market where property price, location, and neighbourhood quality traditionally dominate homebuyer priorities (Majid et al., 2023). However, the increasing frequency of natural disasters has recently forced a shift in these traditional considerations (Geng et al., 2024). Several studies have argued and concluded that the reality of the strata law that has given broad powers to the Management Bodies, but has failed to instil good governance. The law introduced does not counsel enforceable standards of good governance (Wong, 2019). Gaps were also found between the responsibilities of the management bodies and the residents' role in ensuring smooth management and maintenance works.

Flooding currently represents the most critical environmental hazard impacting Malaysian residential areas (Abid et al., 2021). Driven by climate change and urban expansion, recent severe flood incidents in Shah Alam and the wider Selangor region have caused extensive property damage and communal disruption (Sarhan et al., 2024). Consequently, integrating environmental risk into the housing decision-making process has become as vital as assessing price or location for properties in vulnerable zones.

While existing literature extensively covers disaster management and urban planning, there is a significant research gap regarding individual homebuyer perceptions of flood risk during the acquisition process. This study addresses this gap by examining how flood risk influences residential property purchasing decisions in Shah Alam, Selangor. Specifically, it assesses homebuyer awareness and the significance of flood risk relative to other decision-making factors.

# LITERATURE REVIEW

## Urban Flooding and Property Market

Flooding remains the most pervasive natural hazard in Malaysia, categorized primarily into seasonal monsoon floods and localized urban flash floods (Muhamad & Shaidin, 2022). While climatic shifts have intensified rainfall patterns across Southeast Asia, the escalating vulnerability of economic hubs like Selangor is largely attributed to rapid urbanization and the proliferation of impervious surfaces, which overwhelm traditional drainage infrastructures (Ahmad et al., 2025). The capital city of Shah Alam exemplifies this issue, as recent spatial assessments show that rapid development in low-lying floodplain areas has significantly increased vulnerability in key locations such as Taman Sri Muda (Leeonis et al., 2024; Idris et al., 2026). The 2021 "Great Flood" serves as

a critical socioeconomic benchmark, resulting in over RM6 billion in national losses and highlighting a widening "income-resilience gap" where asset depreciation affects property owners disproportionately (DOSM, 2022). Despite structural mitigation efforts such as retention basins, the pace of urban development continues to outstrip infrastructure capacity, creating a high-risk environment for residential investments (Ahmed et al., 2024).

**Flood Risk Perception and Buyer Awareness**

While flood risk is technically defined by the intersection of hazard, exposure, and vulnerability, homebuyers often perceive it through the "availability heuristic," where personal experience with past disasters outweighs official data (Reckien et al., 2018; Feng, 2022). This creates a "knowledge-action gap," where high awareness does not necessarily result in risk-aversion. According to Protection Motivation Theory (PMT), a buyer only acts to avoid a flood zone if they possess the "coping appraisal", the belief that they can financially or physically mitigate the threat (Ahmed et al., 2018; Kumaresen et al., 2025).

Theory of Planned Behavior (TPB) suggests that purchase intentions are driven by a mix of personal attitude and subjective norms, such as the social stigma associated with flood-prone neighbourhoods (Vinnell et al., 2021). Therefore, understanding the cognitive process behind risk awareness provides the necessary foundation for analysing the specific physical and economic factors that dictate property selection in vulnerable regions.

**Homebuyer's Decision-Making Factors**

The decision to purchase a home is a multi-dimensional trade-off where buyers must balance financial constraints against lifestyle and safety needs (Saraf et al., 2025). Financial capability serves as the primary "gatekeeper," particularly for Malaysian M40 and B40 households where the "financing accessibility gap" often overrides personal preference (Seng & Tham, 2024). Beyond the initial price, buyers evaluate "Value for Money" by comparing perceived benefits like unit size and facilities against the cost of investment (Rachmawati et al., 2019). This economic logic also includes long-term asset protection; buyers increasingly seek properties with high potential for capital appreciation while avoiding areas where recurring environmental issues might cause property values to stagnate or depreciate (Ying et al., 2025).

While finance dictates the ability to purchase, location and neighborhood quality determine the specific choice of address. In the Klang Valley, location is measured by "time-utility," where proximity to workplaces and connectivity via major highways or LRT3 stations are prioritized to minimize commuting costs (Zakaria et al., 2022; Nordin & Rahim, 2023). Furthermore, because many homes are sold off-the-plan, a developer's track record for timely


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completion and structural integrity serves as a critical proxy for trust, helping buyers manage the risks associated with their life savings (Saad et al., 2024; Khoo et al., 2024).

However, while housing preferences and the physical impacts of flooding are well-documented, a significant empirical void remains regarding the psychological integration of flood risk into the actual pre-purchase stage. Limited research explores how this risk specifically competes with dominant factors like affordability in urban centers. To address this gap, Figure 2 illustrates the conceptual framework of this study, depicting how five conventional housing determinants (Financial, Location, Neighbourhood Quality, Developer Reputation, and Property Layout) and Flood Risk Factors serve as independent variables (IV) hypothesized to influence homebuyers' risk consideration (DV) in Shah Alam. Grounding these relationships empirically provides behavioral insights that traditional real estate models currently overlook.

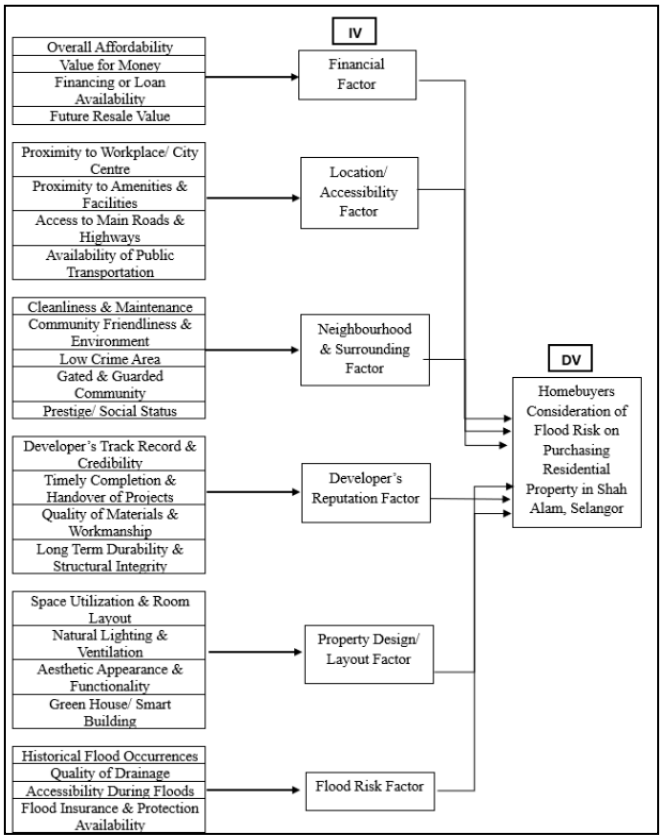



**Figure 1:** Conceptual Framework
*Source: Author (2026)*

**Spatial Exposure and GIS Context in Shah Alam**

The empirical focus on Shah Alam aligns with recent spatial-temporal assessments in the Klang River Basin, which highlight that rapid urban expansion in low-lying floodplains has severely compromised natural retention capacities. As illustrated in Figure 2, GIS-based hazard mapping reveals distinct spatial exposure tiers across the municipality, with critical residential zones in southern Shah Alam, most notably Taman Sri Muda (Seksyen 25), Seksyen 13, and Batu Tiga, which classified under High and Very High Risk zones due to their proximity to major river networks like Sungai Rasau and Sungai Klang. These areas frequently experience severe flash flooding when localized drainage networks are overwhelmed during high-intensity rainfall events. Integrating spatial exposure context into this study confirms that homebuyers' risk perceptions and pre-purchase checking behavior are strongly grounded in real-world spatial hazard patterns across these vulnerable urban sectors.

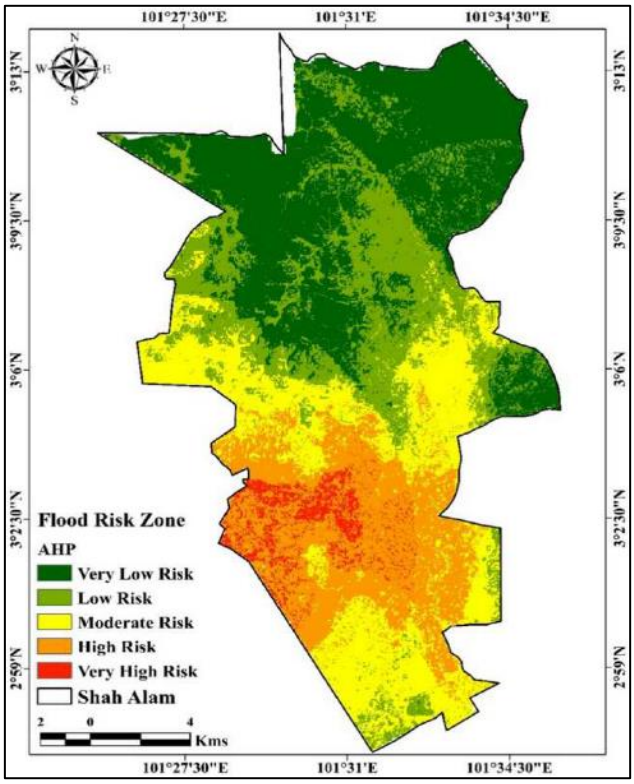



**Figure 2:** GIS-based Flood Risk Hazard Map of Shah Alam Municipality Using Analytical Hierarchy Process (AHP)
*(Source: Ahmed et al., 2024)*


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## RESEARCH METHODOLOGY

This study focuses on Shah Alam, Selangor, a key urban residential hub in Malaysia characterized by rapid development and a significant history of recurring flood incidents. Despite environmental vulnerabilities, Shah Alam remains a high-demand housing market, providing a critical context for examining risk-behavior trade-offs. The study utilizes a quantitative, cross-sectional research design to evaluate how flood risk awareness influences purchasing decisions.

Primary data was collected via a structured questionnaire. The target population consists of individuals aged 20–59 residing in Shah Alam, representing the primary home-buying demographic. Using Yamane's (1967) formula with a margin error of 0.1, a sample size of 100 respondents was targeted. A random sampling approach was employed to ensure demographic representativeness. The survey instrument was divided into three sections: (A) Demographics, (B) Flood risk awareness, and (C) Levels of consideration for purchasing factors. Responses in Sections B and C were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Secondary data were also gathered from academic journals, government reports, and online publications to support the literature review and contextual understanding of flood risk in Malaysia.

For measurement and data analysis, 25 sub-factors across six (6) key determinants were evaluated: financial factors, location, neighborhood quality, developer reputation, property design, and flood risk. Data analysis was conducted using SPSS. Descriptive statistics summarized demographic characteristics and buyer awareness. Exploratory Factor Analysis (EFA) using Principal Axis Factoring with Varimax rotation was conducted to validate factor structure and factorability. Subsequently, Multiple Linear Regression analysis was performed to measure the relative statistical impact of flood risk against conventional housing factors on purchasing decisions.

## ANALYSIS AND DISCUSSION

A total of 102 valid questionnaires were retained for analysis. **Table 1** summarises the respondents' demographic characteristics, including gender, age, educational attainment, and occupational status.

**Table 1** Section A: Demographic Table

| Item | Answers | Frequency | Percentage (%) |
|---|---|---|---|
| Age | 18-22 | 31 | 30.4 |
| | 23-27 | 54 | 52.9 |
| | 28-32 | 5 | 4.9 |
| | 33-37 | 5 | 4.9 |
| | 38-42 | 5 | 4.9 |

| Item | Answers | Frequency | Percentage (%) |
|---|---|---|---|
| | 43-47 | 0 | 0 |
| | 48-above | 2 | 2 |
| Gender | Male | 56 | 54.9 |
| | Female | 46 | 45.1 |
| Education | Secondary | 3 | 2.9 |
| | Diploma | 19 | 18.6 |
| | Bachelor's | 71 | 69.6 |
| | Master | 6 | 5.9 |
| | Phd | 1 | 1 |
| | Others | 2 | 2 |
| Occupatiom | Unemployed | 7 | 6.9 |
| | Governement | 9 | 8.8 |
| | Private | 12 | 11.8 |
| | Self-Employed | 3 | 2.9 |
| | Student | 71 | 69.6 |

*Source: Author 2026*

In terms of gender, 54.9% of the respondents were male, while 45.1% were female. The sample is then heavily weighted toward younger demographics, with 52.9% aged 23–27 and 30.4% aged 18–22. Furthermore, 69.6% of the respondents are current students holding or pursuing higher education degrees. While this profile represents an educated segment of prospective buyers preparing to enter the urban property market in the Klang Valley, the high proportion of non-active buyer/student respondents limits the direct generalizability of the findings to current, active homebuyers with immediate transaction capacity. Consequently, this study is framed as a preliminary, perception-based exploratory investigation into the risk perceptions and decision-making preferences of emerging homebuyer cohorts in flood-prone urban zones.

This study further examines the level of homebuyers' awareness of flood risk in potential residential areas in Shah Alam. Table 2 presents the mean scores and standard deviations for each awareness statement, highlighting the respondents' level of awareness towards flood-related issues when considering property purchases.

**Table 2** Mean Score for Homebuyer's Awareness

| Statement | N | Mean Value | Standard Deviation | Interpretation |
|---|---|---|---|---|
| I am familiar with the flood situations in my residential area. | 102 | 4.06 | 1.003 | High |
| Before purchasing a property, I will check whether the area is flood-prone. | 102 | 4.58 | 0.776 | Very High |


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| Statement | N | Mean Value | Standard Deviation | Interpretation |
|---|---|---|---|---|
| I am aware of which areas in Sha Alam are more prone to flooding. | 102 | 3.96 | 1.168 | High |
| I believe the risk of flooding in Shah Alam has increased in recent years. | 102 | 4.13 | 0.930 | High |

*Source: Author (2026)*

The study assessed homebuyers' awareness of flood risks in potential residential areas in Shah Alam using four (4) survey statements (N = 102). As shown in Table 2, respondents demonstrated a generally high level of awareness of flood-related issues. The interpretation of mean scores was based on class intervals as suggested by Alkharusi (2022), where 3.43–4.23 indicates a high level and 4.24–5.04 indicates a very high level. The item "Before purchasing a property, I will check whether the area is flood-prone" recorded the highest mean (M = 4.58, SD = 0.78), indicating that flood risk is actively considered during property selection. Respondents also showed awareness of local flood conditions (M = 4.06, SD = 1.00) and flood-prone areas in Shah Alam (M = 3.96, SD = 1.17). Additionally, the perception that flood risk has increased in recent years (M = 4.13, SD = 0.93) suggests growing concern among homebuyers regarding climate-related hazards.

This study further examines the suitability of the collected data for factor analysis by assessing the validity of the measurement items. Tables 3 and 4 present the results of the Kaiser-Meyer-Olkin (KMO) Measure, Bartlett's Test of Sphericity, and the Anti-Image Correlation analysis, which determine the adequacy of the data and the significance of each measurement variable.

**Table 3:** KMO and Bartlett's Test

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | 0.918 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 2720.203 |
| | Df | 300 |
| | Sig. | <0.001 |

*Source: Author (2026)*

**Table 4:** Anti Image Correlation

| Main Factors | Sub Factors | Measures of Sampling Adequacy (MSA) | Communalities Value (CV) | Remarks |
|---|---|---|---|---|
| **Financial** | Overall Affordability (F1) | 0.926 | 0.704 | Significant |

| Main Factors | Sub Factors | Measures of Sampling Adequacy (MSA) | Communalities Value (CV) | Remarks |
|---|---|---|---|---|
| | Value For Money (F2) | 0.941 | 0.816 | Significant |
| | Financing Or Loan Availability (F3) | 0.925 | 0.709 | Significant |
| | Future Resale Value (F4) | 0.919 | 0.699 | Significant |
| **Location & Accessibility** | Proximity To Workplace & City Centre (L1) | 0.892 | 0.793 | Significant |
| | Proximity To Amenities & Facilities (L2) | 0.930 | 0.687 | Significant |
| | Access To Main Roads & Highways (L3) | 0.913 | 0.686 | Significant |
| | Availability Of Public Transportation (L4) | 0.959 | 0.622 | Significant |
| **Neighbourhood & Surrounding** | Cleanliness & Maintenance (N1) | 0.910 | 0.809 | Significant |
| | Community Friendliness & Environment (N2) | 0.906 | 0.700 | Significant |
| | Low Crime Area (N3) | 0.918 | 0.693 | Significant |
| | Gated & Guarded Community (N4) | 0.914 | 0.668 | Significant |
| | Prestige & Social Status (N5) | 0.830 | 0.705 | Significant |
| **Developer' Reputation** | Track Record & Credibility (D1) | 0.938 | 0.708 | Significant |
| | Timely Completion & Handover of Projects (D2) | 0.939 | 0.646 | Significant |
| | Quality of Materials & Workmanship (D3) | 0.888 | 0.752 | Significant |
| | Long Term Durability & Structural Integrity (D4) | 0.873 | 0.799 | Significant |
| **Property Design & Layout** | Space Utilization & Room Layout (DE1) | 0.947 | 0.717 | Significant |
| | Natural Lighting & Ventilation (DE2) | 0.949 | 0.786 | Significant |
| | Aesthetic Appearance & Functionality (DE3) | 0.943 | 0.772 | Significant |


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| Main Factors | Sub Factors | Measures of Sampling Adequacy (MSA) | Communalities Value (CV) | Remarks |
|---|---|---|---|---|
| | Green House & Smart Building (DE4) | 0.920 | 0.743 | Significant |
| **Flood Risk** | Historical Flood Occurrences (F1) | 0.919 | 0.654 | Significant |
| | Quality of Drainage (F2) | 0.902 | 0.800 | Significant |
| | Accessibility During Floods (F3) | 0.930 | 0.778 | Significant |
| | Insurance & Protection Availability (F4) | 0.915 | 0.804 | Significant |

*Source: Author (2026)*

## Exploratory Factor Analysis and Measurement Validation

An Exploratory Factor Analysis (EFA) using Principal Axis Factoring with Varimax rotation was conducted on the 25 sub-factors to examine the underlying factor structure. Data factorability was confirmed through the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, yielding an excellent score of 0.918 (exceeding the 0.60 threshold; Hair et al., 2013). Bartlett's Test of Sphericity was highly significant ($\chi^2_{300} = 2720.203, p < 0.001$), confirming sufficient correlation among items for factor extraction (Hair et al., 2013). Measure of Sampling Adequacy (MSA) values from the anti-image matrix all exceeded 0.80, and item communalities were well above 0.50. The EFA extracted six distinct constructs which includes Financial, Location, Neighborhood, Developer Reputation, Property Layout, and Flood Risk. Thus demonstrating robust construct validity without significant cross-loadings.

## Multiple Linear Regression Analysis

**Table 6:** Multiple Linear Regression Results

| Predictor Variables | Unstandardized B | Std. Error | Standardized Beta (β) | t-value | Sig. (p) | VIF |
|---|---|---|---|---|---|---|
| *(Constant)* | 1.824 | 0.393 | — | 4.636 | < 0.001 | — |
| Financial Factors | 0.190 | 0.107 | 0.156 | 1.779 | 0.077 | 1.954 |
| Location & Accessibility | 0.330 | 0.110 | 0.274 | 3.000 | 0.003 | 2.109 |

| **Predictor Variables** | **Unstandardized B** | **Std. Error** | **Standardized Beta (β)** | **t-value** | **Sig. (p)** | **VIF** |
|---|---|---|---|---|---|---|
| Neighbourhood Quality | -0.195 | 0.128 | -0.164 | -1.527 | 0.128 | 2.911 |
| Developer Reputation | 0.007 | 0.116 | 0.006 | 0.064 | 0.949 | 2.381 |
| Property Layout & Design | 0.026 | 0.125 | 0.022 | 0.206 | 0.837 | 2.878 |
| Flood Risk Factors | 0.255 | 0.091 | 0.257 | 2.795 | 0.006 | 2.132 |

*Note: Dependent Variable: "Before purchasing a property, I will check whether the area is flood-prone". Model Fit:* $R^2 = 0.237$*, Adjusted* $R^2 = 0.213$*,* $F(6,193) = 9.982, p < 0.001$*.*

*Source: Author (2026)*

To evaluate how significantly flood risk influences purchasing considerations relative to conventional housing determinants (Financial, Location, Neighbourhood Quality, Developer Reputation, and Property Layout), a Multiple Linear Regression analysis was conducted.

The overall regression model demonstrated a statistically significant fit ($F(6,193) = 9.982, p < 0.001$), accounting for 23.7% of the total variance in prospective homebuyers' risk assessment during property consideration ($R^2 = 0.237$, Adjusted $R^2 = 0.213$), which is considered an acceptable explanatory power in exploratory behavioral research (Hair et al., 2013). Multicollinearity diagnostics confirmed that Variance Inflation Factor (VIF) values for all predictors remained low, ranging between 1.954 and 2.911 (well below the critical threshold of 10.0; Hair et al., 2013), indicating the absence of severe multicollinearity among the explanatory variables.

Evaluating the standardized regression coefficients ($\beta$) reveals that Location & Accessibility ($\beta = 0.274, t = 3.000, p = 0.003$) and Flood Risk Factors ($\beta = 0.257, t = 2.795, p = 0.006$) exert the strongest statistically significant positive influence on homebuyer evaluation. Financial factors also demonstrated a moderate positive inclination ($\beta = 0.156, t = 1.779, p = 0.077$). Crucially, the statistical significance of Flood Risk confirms that environmental hazards, historical inundation experience, and drainage quality actively compete alongside spatial accessibility when prospective buyers evaluate residential properties in Shah Alam.

## CONCLUSION & POLICY RECOMMENDATIONS

The empirical findings provide clear evidence of an evolving paradigm in residential property decision-making within Shah Alam, where flood risk awareness has emerged as a critical factor shaping potential homebuyers' preferences. Beyond traditional determinants such as price, location, and property


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design, prospective buyers increasingly integrate environmental vulnerabilities into their pre-purchase housing evaluations. Based on these statistical insights ($\beta_{\text{Flood}} = 0.257, p = 0.006$) and the documented spatial exposure across high-risk municipal sectors such as Taman Sri Muda, Seksyen 13, and Batu Tiga, targeted institutional interventions are essential.

First, local authorities and the Ministry of Housing and Local Government (KPKT) must enforce mandatory flood-risk disclosure frameworks, ensuring buyers receive verified spatial exposure maps prior to contract execution.

Second, local planning authorities such as Majlis Bandaraya Shah Alam (MBSA) should incorporate strict GIS-based flood zoning controls into local structural plans, enforcing mandatory retention basins, permeable surfaces, and elevated building standards within high-risk zones.

Furthermore, conventional drainage management protocols must transition toward predictive AI-monitored smart drainage systems to mitigate localized flash flooding effectively.

Finally, financial institutions and insurers should collaborate to develop accessible, standardized micro-insurance packages tailored to residential assets in vulnerable zones, thereby bridging the financial resilience gap for urban property owners.

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# FINANCIAL AND LIFESTYLE FACTORS ASSOCIATED WITH HOMEOWNERSHIP READINESS AMONG GIG WORKERS IN MALAYSIA

**Ezdihar Hamzah[1&2], Rohaya Abdul Jalil[2], Fatin Umaira Muhamad Azian[3], Nurul Ain Najwa Sabri[2], Nur Arnie Aziera Mohd Ibrahim[2] and Suraya Ghani[4]**

[1]*Centre for Real Estate Studies (UTM CRES),*
*Institute for Smart Infrastructure and Innovative Construction (ISIIC),*
[2]*Department of Real Estate,*
*Faculty of Built Environment and Surveying (FABU),*
UNIVERSITI TEKNOLOGI MALAYSIA, 81310, SKUDAI, JOHOR, MALAYSIA
[3]*Centre for Research in Development, Social & Environment,*
*Faculty of Social Sciences & Humanities,*
UNIVERSITI KEBANGSAAN MALAYSIA, BANGI, SELANGOR, MALAYSIA
[4]*Valuation and Property Services Department (JPPH), MALAYSIA*

## Abstract

The expansion of gig work has raised concerns regarding workers' financial stability and access to homeownership due to irregular income and non-standard employment arrangements. This study examines the financial and lifestyle factors associated with homeownership readiness among gig workers in selected urban areas of Malaysia. A quantitative dominant mixed methods survey design with an embedded qualitative component was adopted. Data were collected through an online questionnaire from 22 purposively selected gig workers in Johor Bahru, Kuala Lumpur and Selangor. Quantitative data were analysed using descriptive statistics, the Relative Importance Index (RII), Cronbach's alpha and Spearman's rank order correlation, while open ended responses were analysed thematically. The findings indicate that prioritising daily living expenses was the most prominent lifestyle related consideration (RII = 0.755), followed by property saving priority and financial literacy/spending control (RII = 0.736). Income instability demonstrated a significant negative association with homeownership readiness ($\rho = -0.589$, $p = 0.004$), whereas savings behaviour, lifestyle spending and financial literacy/spending control showed no significant associations. Qualitative findings further highlighted income instability, documentation requirements, financing accessibility and housing affordability as key challenges. The study highlights the need for more inclusive and flexible housing finance policies for gig workers.

***Keywords***: Real estate, Gig Workers, Home ownership, Social and economic perspectives and Malaysia

[1] Corresponding author. Email: ezdihar@utm.my

## INTRODUCTION

Home ownership has long been considered a cornerstone of socio economic stability and upward mobility. In Malaysia, owning a home is often associated with financial security, social status, and long term wealth accumulation (Hashim, 2010). However, access to housing has increasingly become a challenge due to rising property prices, stringent mortgage requirements, and widening income disparities (Bank Negara Malaysia, 2017). These issues are particularly acute for individuals employed in the gig economy, whose income irregularities and lack of formal employment records pose unique challenges for financing home ownership. As the gig workers continues to grow in Malaysia, it becomes imperative to investigate the barriers faced by this segment and to explore new frameworks that could facilitate equitable access to housing. The gig economy, characterised by short term, flexible, and freelance work arrangements, has expanded rapidly in Malaysia over the past decade. Platforms such as Grab, Foodpanda, and Upwork have enabled workers to generate income outside traditional employment structures. According to the World Bank (2021), nearly 26% of Malaysia's labour force is engaged in informal or gig type employment. This growth reflects broader global trends where technological innovation and shifting work preferences reshape labour markets (De Stefano, 2016). While the gig economy provides opportunities for flexible income generation, it is often associated with income volatility, lack of employment benefits, and limited access to social protection schemes (Kamaruddin & Hassan, 2022). These conditions create substantial challenges when gig workers attempt to secure housing loans that require proof of stable income and creditworthiness.

Home ownership remains a deeply ingrained aspiration among Malaysians, supported by national policies such as the National Housing Policy (2018–2025). However, the affordability gap has widened, particularly for lower and middle income households. For gig workers, these challenges are compounded by the absence of payslips, inconsistent cash flows, and limited access to Employees Provident Fund (EPF) savings, which are traditionally leveraged for home financing (Rahman & Ahmad, 2019). Consequently, while gig workers share the same aspirations for home ownership, structural barriers prevent them from participating fully in the housing market. The inability of gig workers to access home ownership has broader socio economic implications. Studies indicate that housing stability contributes to community integration, psychological wellbeing, and intergenerational wealth transfer (Stone, Burke, & Ralston, 2011). Conversely, prolonged rental dependency or insecure housing conditions can perpetuate financial vulnerability and social exclusion. In Malaysia, the rise of the gig economy coincides with urbanisation pressures, as gig workers often operate in metropolitan areas such as Kuala Lumpur, Johor Bahru, and Penang where housing prices are steepest (Chiu, 2017). Without

targeted policies, gig workers risk being excluded from housing markets in these urban centres, reinforcing socio economic inequality and potentially undermining urban sustainability goals.

Despite the growing relevance of the gig economy, limited research has been conducted on its intersection with housing policy and home ownership of gig workers in Malaysia. Existing studies largely focus on labour market issues, income insecurity, or digital platform governance (De Stefano, 2016; Kamaruddin & Hassan, 2022). Few have explicitly examined the pathways to home ownership for gig workers, particularly within the Malaysian context. This research seeks to fill this gap by providing empirical insights capturing the perspectives of gig workers themselves other than the financial institution and also the employer for the gig business. The findings are expected to inform both academic discourse and practical policymaking, contributing to more inclusive housing strategies for gig workers in Malaysia.

## LITERATURE REVIEW

Malaysia MADANI concept and Housing Inclusion is about building an inclusive, participatory, and just civil society, which means promoting the principles of democracy, human rights, and the rule of law and ensuring that all citizens have an equal opportunity to participate in the political and economic life of the country. The Madani Inclusive Housing Concept aims to act as a catalyst for developing affordable housing projects, ensuring accessibility for various target groups in Malaysia, particularly disadvantaged communities. This research is closely aligned with the values embedded in the Malaysia MADANI framework**,** which emphasizes Sustainability (keMampanan), Wellbeing (kesejAhteraan), Creativity (Daya cipta), Respect (hormAt), Confidence (keyakiNan), and Compassion (Ihsan). By focusing on the housing barriers faced by gig workers, the study highlights issues of inclusivity and equitable access to economic opportunities. Home ownership for gig workers is not simply a financial issue but one tied to social stability, dignity, and long-term community well-being elements that are consistent with MADANI's goal of fostering an inclusive, compassionate, and resilient society.

### Economic Benefits of Homeownership for Gig Workers in Malaysia

Homeownership provides gig workers with a pathway to long term asset accumulation, transforming irregular income into a stable form of wealth. Unlike renting, where payments contribute to a landlord's equity, mortgage repayments enable gig workers to build personal equity in an appreciating asset. In Malaysia, housing remains one of the most significant components of household wealth, with residential property accounting for nearly 60% of household assets (Bank Negara Malaysia, 2019). For gig workers who face limited retirement savings due


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to their exclusion from traditional provident fund schemes, property ownership serves as a critical alternative means of financial security. Owning a home also provides gig workers with financial stability through capital appreciation. Despite fluctuations in the Malaysian property market, residential property has historically shown consistent long-term value growth, particularly in urban centres like Johor Bahru, Kuala Lumpur and Penang (Rahman and Ahmad, 2019). This appreciation not only safeguards gig workers against inflation but also offers opportunities for refinancing or leveraging property equity to access credit in the future. Such financial flexibility is particularly valuable for workers with irregular incomes, as it enhances their ability to adopt and remain resilience through economic shocks or fund entrepreneurial ventures.

Previous research by Ying et. al. (2025) indicated that financial considerations is the most significant factors (81%) that influencing to homeownership in Malaysia. Other than that, locational attributes and building design and quality are other top significant factors with 77% and 58% agreement based on the research findings.

**Social Implications of Homeownership for Gig Workers in Malaysia**

Homeownership offers gig workers more than financial security it provides a sense of stability, belonging, and identity within their communities. Unlike renters, homeowners are more likely to develop long-term attachments to their neighborhoods, participate in local associations, and invest in the upkeep of their surroundings (Zhu et al., 2020). For gig workers, whose employment arrangements are often precarious and mobile, owning a home anchors them socially and reduces the insecurity associated with transient living. This stability strengthens community cohesion, which is particularly important in urban centers such as Johor Bahru and Kuala Lumpur where gig workers are concentrated. Housing security is closely tied to mental health and overall well-being**.** Recent studies in Asia show that homeownership is associated with reduced stress levels and greater psychological resilience, as it alleviates worries about displacement and rental instability (Ghazali et al., 2021). For gig workers in Malaysia, who already face uncertainties in income and social protection, access to homeownership could significantly reduce life stressors. It provides a stable environment for families and children, supporting better educational outcomes and healthier lifestyles, thereby contributing to social mobility in the long run.

Owning a home has strong implications for family stability and intergenerational security**.** Homeownership provides a safe and stable environment for raising children, which is a cornerstone of social development. It also ensures that gig workers, who are typically excluded from structured retirement and social insurance schemes, can leave behind an asset for their heirs (Musa et al., 2022). In this way, homeownership becomes a substitute for traditional social safety

nets, helping gig workers to secure their family's long-term social well-being and reducing dependency on government aid. Homeownership among gig workers also has broader implications for social inclusion. Gig workers often occupy a marginal position in the labour market, lacking recognition and formal protections. By enabling them to become homeowners, Malaysia can reduce the risk of creating a dual society divided between asset-owning salaried workers and asset-less gig workers.

Ying et. al. (2025) indicates that the social implications of homeownership reflect to human survival in terms of stability and safety. The social implications also reflect to privacy, social interactions with neighbourhood and individual's need for sense of belonging (Hassan, 2023). Housing comfort is another term reflect to the state of well-being in which a person's psychological and psychological needs are fulfilled and balance, which reflect to social benefits of homeownership (Azian et. al., 2025).

**Factors Contributing Toward Lifestyle Spending Priorities**

The primary factors influencing lifestyle spending priorities is income instability, particularly for workers in non-traditional employment such as the gig economy. Fluctuating monthly earnings make individuals prioritize immediate consumption (e.g., food, transport, and communication) over long-term financial commitments like savings or mortgage payments. Studies show that households with irregular income flows are more likely to adopt short-term financial behaviors, often prioritizing discretionary spending over asset accumulation (Mokhtar & Husin, 2021). This creates challenges in balancing lifestyle desires with financial security, especially in urban Malaysia where the cost of living is rising. Rapid urbanization has also shaped spending patterns, particularly among younger populations and gig workers concentrated in metropolitan areas. Rising housing rents, transportation costs, and food prices force individuals to allocate a significant portion of income to basic needs, limiting their capacity to prioritize savings or investments.

Spending priorities are also driven by cultural norms and social expectations, particularly among younger Malaysians who associate lifestyle consumption with social identity. Research suggests that social media and peer influence play a significant role in shaping consumption choices, with younger generations often prioritizing branded goods, travel, and digital devices over savings (Tan et al., 2022). For gig workers, who may lack the stability of traditional employment, lifestyle spending often becomes a means of compensating for financial insecurity by pursuing social recognition and immediate gratification. A lack of financial literacy significantly affects lifestyle spending priorities. Many Malaysians, particularly those in informal or gig employment, have limited exposure to structured financial education, making


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them more susceptible to overspending and debt accumulation (Hassan & Rahim, 2021). In contrast, higher financial literacy levels are strongly correlated with better budgeting, higher savings rates, and more disciplined spending behavior.

## RESEARCH METHODOLOGY

This study adopts a quantitative-dominant mixed-methods survey design with an embedded qualitative component to examine lifestyle spending behaviour and homeownership readiness among gig workers in selected urban areas of Malaysia. The quantitative component constitutes the main analytical component of the study, while qualitative insights are obtained through open-ended questions embedded within the same questionnaire. This approach enables the study to identify measurable patterns in respondents' financial and lifestyle-related behaviour while also capturing their experiences, challenges, and perceptions regarding homeownership and housing financing.

For the purpose of this study, gig workers are defined as individuals who earn income through non-standard work arrangements without a fixed monthly salary, including freelancers, platform-based workers, and other self-directed service providers. The respondents therefore include individuals such as e-hailing workers, freelancers, and workers undertaking project- or service-based employment arrangements. The study focuses on gig workers located in selected urban areas, namely Johor Bahru, Kuala Lumpur, and Selangor, where various forms of flexible and non-standard employment are prevalent.

### Sampling and Data Collection

Data were collected through a structured online questionnaire administered using Google Forms. The questionnaire link was distributed directly and through relevant personal and professional networks to individuals engaged in gig and freelance work, including e-hailing workers such as Grab drivers and other freelance workers, including individuals undertaking project-based work in sectors such as oil and gas. The sampling approach was therefore non-probability and purposive in nature, as respondents were selected based on their involvement in income-generating activities without a fixed monthly salary. A total of 23 responses were initially obtained. Following data screening, one response was identified as a pilot/test response and was excluded from the analysis. Consequently, 22 valid responses were retained for the final analysis. The relatively small sample reflects the exploratory nature of the study and the practical difficulty of obtaining responses from workers operating under diverse and informal employment arrangements.

**Questionnaire Structure and Measurement**

The questionnaire consisted of several sections covering (i) socio-demographic characteristics, (ii) income patterns and financial behaviour, (iii) lifestyle spending priorities, (iv) savings practices, (v) homeownership aspirations and readiness, and (vi) perceptions of housing financing and institutional support. Most closed-ended items were measured using a five-point Likert scale ranging from low to high levels of agreement or priority, as appropriate.

In addition to the closed-ended questions, the questionnaire incorporated three open-ended questions (F1–F3). These questions explored respondents' main challenges in pursuing homeownership, the types of support they considered necessary, and additional comments concerning gig workers and housing. The open-ended component was included to provide contextual explanations for the quantitative findings rather than being treated as a separate interview phase.

**Quantitative Data Analysis**

The quantitative data were analysed using descriptive statistics, Relative Importance Index (RII), Cronbach's alpha reliability analysis, and Spearman's rank-order correlation. Descriptive statistics were used to summarise the respondents' demographic characteristics and response patterns. The Relative Importance Index (RII) was employed to rank the relative importance of lifestyle spending and financial-related factors based on the respondents' five-point Likert-scale responses. The RII provides a standardised index between 0 and 1, where a higher value indicates greater relative importance of a particular factor. The ranking was subsequently used to identify the factors most strongly prioritised by respondents.

Reliability analysis was conducted using Cronbach's alpha to assess the internal consistency of the multi-item constructs. The analysis covered the constructs of income instability, savings behaviour, lifestyle spending behaviour, homeownership readiness, and institutional/financing support. Single-item indicators were analysed individually and were not subjected to Cronbach's alpha analysis. Given the exploratory nature and small sample size of the study, the reliability results were interpreted cautiously. To examine the relationships between financial and lifestyle-related factors and homeownership readiness, Spearman's rank-order correlation was employed. This non-parametric technique was considered appropriate given the small sample size and ordinal nature of the Likert-scale data. The analysis examined the associations between income instability, savings behaviour, lifestyle spending behaviour, financial literacy/spending control, and homeownership readiness. Multiple regression analysis was not conducted because the final sample consisted of only 22 valid respondents. A multivariate regression model with such a small sample would


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have limited statistical power and could produce unstable estimates. Therefore, the inferential analysis was limited to Spearman's correlation to provide an exploratory assessment of the direction and strength of associations between the selected variables. The results are interpreted as associations rather than causal relationships.

**Qualitative Analysis**

The responses to the three open-ended questions were analysed using thematic analysis. The analysis identified recurring themes concerning the challenges experienced by gig workers, the support required to facilitate homeownership, and respondents' additional views regarding housing affordability, financing, documentation, and financial management. The responses were coded into major themes and sub-themes based on recurring issues. As respondents could identify multiple issues within a single response, thematic frequencies represent the number of mentions rather than mutually exclusive respondent categories. Selected verbatim quotations were used to illustrate the themes and provide direct evidence of respondents' perspectives. The quantitative and qualitative findings were integrated during the interpretation stage. The quantitative analysis was first used to identify the relative importance of lifestyle and financial factors and the statistical associations between these factors and homeownership readiness. The open ended responses were then used to **c**ontextualise, explain, and complement the quantitative findings. For instance, where quantitative results indicate an association between income instability and homeownership readiness, respondents' open-ended comments provide further insight into practical issues such as fluctuating income, difficulties in demonstrating financial stability, documentation requirements, loan accessibility, and housing affordability. Similarly, respondents' views regarding flexible financing and alternative forms of housing support provide contextual evidence for interpreting the quantitative findings on institutional and financing support. Through this integration, the study provides a more comprehensive understanding of the relationship between financial insecurity, lifestyle spending behaviour, and homeownership readiness among gig worker**s**. However, given the small, non-probability sample and the concentration of respondents in selected urban areas, the findings are interpreted as exploratory and context-specific and should not be generalised to the entire Malaysian gig worker population.

**Reliability Analysis**

To assess the internal consistency of the measurement items, Cronbach's alpha (α) was calculated for each multi-item construct. Cronbach's alpha is used to determine whether the items within a construct consistently measure the same underlying concept. In this exploratory study, the reliability results were

interpreted with consideration of the relatively small sample size of 22 valid respondents. Constructs with alpha values approaching or exceeding 0.70 were considered to demonstrate acceptable internal consistency, while slightly lower values were retained where theoretically relevant and appropriate for an exploratory study.

As shown in Table 1, the reliability analysis produced alpha values ranging from 0.639 to 0.824. The Institutional and Financing Support construct demonstrated the highest internal consistency ($\alpha = 0.824$), followed by Savings Behaviour ($\alpha = 0.790$) and Homeownership Readiness ($\alpha = 0.712$). These values indicate acceptable to good internal consistency among the items measuring these constructs. Income Instability recorded an alpha value of 0.677, which is slightly below the commonly referenced 0.70 level but remains reasonable for an exploratory study with a small sample. Similarly, Lifestyle Spending Behaviour recorded an alpha of 0.639. Given the exploratory purpose of the study and the relatively small number of respondents, these constructs were retained for subsequent analysis, with their results interpreted cautiously. Single-item measures, namely Financial Confidence, Property-Saving Orientation, and Financial Literacy/Spending Control, were not subjected to Cronbach's alpha analysis because internal consistency cannot be assessed meaningfully using a single item. These indicators were therefore analysed individually in the subsequent descriptive and correlation analyses.

**Table 1.** Reliability Analysis of the Study Constructs

| Construct | Measurement Items | No. of Items | Cronbach's Alpha (α) | Interpretation |
|---|---|---|---|---|
| Income Instability | B1–B3* | 3 | 0.677 | Marginal/acceptable for exploratory study |
| Savings Behaviour | B4–B6 | 3 | 0.790 | Good |
| Lifestyle Spending Behaviour | C1, C2, C3, C4, C6 | 5 | 0.639 | Marginal/acceptable for exploratory study |
| Homeownership Readiness | D1–D7* | 7 | 0.712 | Acceptable |
| Institutional and Financing Support | E3–E5 | 3 | 0.824 | Good |
| Financial Confidence | B7 | 1 | N/A | Single-item measure |
| Property-Saving Orientation | C5 | 1 | N/A | Single-item measure |
| Financial Literacy/Spending Control | C7 | 1 | N/A | Single-item measure |

Note: *B1 was reverse-coded in the construction of the Income Instability measure, while D5 and D6 were reverse-coded in the Homeownership Readiness measure.


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**Qualitative Analysis**

The qualitative component of the study comprised three open ended questions embedded within the structured questionnaire. The questions were designed to capture respondents' perspectives on the challenges associated with homeownership, the types of support required, and additional views concerning housing and financial issues among gig workers. The responses were analysed using thematic analysis to identify recurring patterns and key issues emerging from the respondents' experiences and perceptions. The analysis involved several stages. First, all responses were reviewed to obtain an overall understanding of the issues raised by respondents. The responses were subsequently coded according to recurring concepts and grouped into related themes and sub-themes. The frequency of each theme was then recorded to indicate the prominence of particular issues across the responses. As respondents were allowed to mention more than one issue in their answers, the reported frequencies represent the number of thematic mentions rather than mutually exclusive respondent counts.

For the first open-ended question concerning the main challenges in pursuing homeownership, the coding focused on issues such as income instability, difficulties in providing financial documentation, financing and loan accessibility, housing affordability and upfront costs, and housing suitability. For the second question concerning support required by gig workers, the analysis focused on financing accessibility and flexibility, financing costs, affordable housing, down-payment assistance, alternative tenure arrangements such as rent-to-own, income enhancement, and government support. The third question provided an opportunity for respondents to express additional comments and recommendations, particularly regarding housing prices, financial management, documentation, financing flexibility, financial assistance, and employment or income development.

To strengthen the credibility and transparency of the qualitative findings, selected verbatim quotations from respondents were retained as illustrative evidence for the identified themes. Respondents were anonymised using respondent codes rather than personal identifiers. The qualitative findings were subsequently compared with the quantitative results to identify areas of convergence, complementarity, or divergence between the two strands of evidence. Importantly, the qualitative component was not conducted as a separate interview stage. Instead, it functioned as an embedded qualitative component within the questionnaire survey, providing contextual explanations for the quantitative findings. This approach is particularly useful for an exploratory study of gig workers, as open-ended responses allow respondents to describe practical barriers and support needs that may not be fully captured through predetermined Likert-scale items.

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**Integration of Quantitative and Qualitative Findings**

The quantitative and qualitative findings were integrated at the interpretation stage to provide a more comprehensive understanding of homeownership readiness among gig workers. The quantitative analysis was used to identify the relative importance of lifestyle and financial factors and the associations between these factors and homeownership readiness, while the qualitative responses were used to contextualise and explain the observed patterns. Integration was conducted by comparing the findings according to key themes, including income instability, savings behaviour, lifestyle spending, financial literacy, homeownership readiness, and access to housing financing and institutional support.

The findings from both components were examined for convergence, complementarity, or divergence. For example, quantitative evidence of an association between income instability and homeownership readiness was interpreted alongside respondents' comments regarding fluctuating income, financial documentation, loan accessibility, and housing affordability. Similarly, respondents' expressed needs for flexible financing and financial assistance were used to contextualise the quantitative findings on financing and institutional support. This integrated approach provides both numerical evidence and contextual insights while recognising that the findings are exploratory and do not establish causal relationships.

## ANALYSIS AND DISCUSSIONS

The following Table 2 shows the descriptive findings based on the demographic details of gig workers in Malaysia as the respondents of this research.

**Table 2:** Descriptive findings based on the demographic details

| Characteristic | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| **Gender** | Male | 18 | 81.8 |
| | Female | 4 | 18.2 |
| **Age** | Below 25 | 2 | 9.1 |
| | 25–30 | 1 | 4.5 |
| | 31–35 | 4 | 18.2 |
| | 36–40 | 9 | 40.9 |
| | Above 40 | 6 | 27.3 |
| **Marital Status** | Single | 4 | 18.2 |
| | Married | 18 | 81.8 |
| **Education** | Diploma | 7 | 31.8 |
| | Bachelor's Degree | 11 | 50.0 |


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| Characteristic | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| | Master's Degree | 2 | 9.1 |
| | Other | 2 | 9.1 |
| **Duration as Gig Worker** | 1–3 years | 7 | 31.8 |
| | 4–6 years | 2 | 9.1 |
| | More than 6 years | 13 | 59.1 |
| **Average Monthly Income** | Below RM2,000 | 2 | 9.1 |
| | RM2,001–4,000 | 6 | 27.3 |
| | RM4,001–6,000 | 4 | 18.2 |
| | RM6,001–8,000 | 4 | 18.2 |
| | Above RM8,000 | 6 | 27.3 |
| **Current Housing Status** | Renting | 6 | 27.3 |
| | Own under mortgage | 11 | 50.0 |
| | Own, fully paid | 1 | 4.5 |
| | Living with family | 4 | 18.2 |

*Source: Author (2026)*

Table 2 presents the socio-demographic and employment characteristics of the 22 valid respondents included in the analysis. The respondents were predominantly male (81.8%) and married (81.8%). In terms of age, the largest group was aged 36–40 years (40.9%), followed by those aged above 40 years (27.3%). Half of the respondents held a Bachelor's degree, while 31.8% had a Diploma qualification.

In terms of gig work experience, 59.1% had been engaged in gig work for more than six years, indicating that a substantial proportion had relatively long exposure to non-standard employment arrangements. Monthly income varied considerably, with 27.3% earning between RM2,001 and RM4,000 and another 27.3% reporting income above RM8,000. Regarding housing status, half of the respondents currently owned a house under mortgage, while 27.3% were renting and 18.2% were living with family. These characteristics indicate that the respondents represented different stages of housing circumstances and income capacity, which provides useful context for interpreting their homeownership readiness.

**Lifestyle Spending and Financial Priorities**

The Relative Importance Index (RII) results indicate that daily living expenses were the most strongly prioritised factor among respondents, with a mean score of 3.77 and an RII of 0.755, followed by property-saving priority and financial

literacy/spending control, both recording a mean of 3.68 and an RII of 0.736. Transportation and commuting expenses ranked fourth (mean = 3.14; RII = 0.627), while immediate lifestyle satisfaction (RII = 0.436), discretionary lifestyle spending such as gadgets, dining and leisure (RII = 0.427), and social media or peer influence (RII = 0.373) recorded comparatively lower rankings. These findings suggest that although gig workers place considerable emphasis on meeting immediate living expenses, they also recognise the importance of saving towards future property ownership and exercising financial control. Importantly, the relatively low ranking of discretionary lifestyle spending and social influence indicates that excessive lifestyle consumption may not be the dominant financial priority among the respondents; rather, managing everyday expenses and securing financial capacity for future homeownership appear to be more prominent concerns. The results are illustrated in Table 3.

**Table 3.** Relative Importance Index (RII) of Lifestyle Spending and Financial Priorities

| Code | Factors | Mean | RII | Rank |
|---|---|---|---|---|
| C1 | Prioritising daily living expenses over long-term savings | 3.77 | **0.755** | 1 |
| C5 | Prioritising savings for future property ownership | 3.68 | **0.736** | 2 |
| C7 | Financial literacy helps control unnecessary spending | 3.68 | **0.736** | 2 |
| C2 | Transportation and commuting expenses | 3.14 | **0.627** | 4 |
| C6 | Prioritising immediate lifestyle satisfaction over long-term investments | 2.18 | **0.436** | 5 |
| C3 | Spending on lifestyle items (gadgets, dining and leisure) | 2.14 | **0.427** | 6 |
| C4 | Social media and peer influence on spending | 1.86 | **0.373** | 7 |

**Note:** RII = Weighted Score / (5 × N), where $N = 22$ valid respondents.

## Relationship between Financial and Lifestyle Factors and Homeownership Readiness

Spearman's rank-order correlation analysis was conducted to examine the relationships between selected financial and lifestyle factors and homeownership readiness.


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**Table 4.** Spearman's Rank-Order Correlation between Selected Factors and Homeownership Readiness

| Variable | Spearman's ρ | p-value |
|---|---|---|
| **Income Instability** | **−0.589** | **0.004** |
| Savings Behaviour | 0.307 | 0.165 |
| Lifestyle Spending Behaviour | −0.274 | 0.217 |
| Financial Literacy/Spending Control | 0.010 | 0.966 |

As shown in Table 4, income instability demonstrated a significant negative association with homeownership readiness (ρ = −0.589, $p$ = 0.004), indicating that greater income instability was associated with lower homeownership readiness. Savings behaviour showed a positive but non-significant association (ρ = 0.307, $p$ = 0.165), while lifestyle spending behaviour showed a negative but non-significant association (ρ = −0.274, $p$ = 0.217). Financial literacy/spending control demonstrated virtually no association with homeownership readiness (ρ = 0.010, $p$ = 0.966). Overall, the findings suggest that income instability is a more prominent factor associated with homeownership readiness than lifestyle spending, savings behaviour, or financial literacy within this sample. These findings are interpreted as associations rather than causal relationships given the exploratory nature and small sample size of the study.

**Integration of Quantitative and Qualitative Findings**

The integration of findings demonstrates that income instability, rather than discretionary lifestyle spending, represents the more prominent constraint on homeownership readiness among the respondents. The quantitative analysis showed a significant negative association between income instability and homeownership readiness (ρ = −0.589, p = 0.004), whereas lifestyle spending, savings behaviour and financial literacy/spending control did not demonstrate statistically significant relationships. This pattern is further supported by the qualitative responses, where income instability and insufficient income were the most frequently identified challenges, accounting for 13 mentions. Respondents repeatedly referred to fluctuating or uncertain monthly income, indicating that the ability to demonstrate consistent financial capacity may be more critical than lifestyle consumption itself.

The qualitative findings also provide further explanation for the relationship between income instability and homeownership readiness. Documentation and proof of income were identified in five responses, while financing and loan accessibility and housing affordability were each mentioned four times. Respondents highlighted difficulties in demonstrating financial stability to banks, obtaining loan approval and meeting documentation

requirements. These findings suggest that the challenge faced by gig workers extends beyond the level of income alone, as the non-standard and less predictable nature of gig income may create difficulties in conventional mortgage assessment. This is consistent with the quantitative finding that income instability is negatively associated with homeownership readiness, while the relatively low RII scores for discretionary lifestyle spending (0.427) and social media/peer influence (0.373) indicate that excessive lifestyle consumption was not the dominant concern in this sample.

**Implications for Housing Financing and Policy**

The findings point towards the need for a more flexible housing finance framework for workers with non-standard income arrangements. In the qualitative responses, flexible financing and improved accessibility were the most frequently requested forms of support, with 14 mentions, including requests to simplify loan approval and reduce eligibility requirements. Other suggestions included lower financing costs, affordable housing, rent-to-own arrangements and financial assistance for upfront costs. Accordingly, banks and housing finance institutions could consider alternative approaches to assessing repayment capacity, including more comprehensive income records and alternative credit assessment mechanisms, while government housing agencies could strengthen affordable housing and flexible tenure or financing programmes targeted at households with irregular income. Such measures should complement, rather than replace, appropriate affordability and repayment assessments.

**Overall Discussion and Contribution**

Overall, the findings indicate that gig workers continue to view homeownership as an important long-term financial objective, but income uncertainty and structural barriers to accessing housing finance may limit their ability to translate this aspiration into homeownership readiness. The study contributes to the literature by highlighting that the relationship between gig work and housing outcomes should not be examined solely through the lens of lifestyle spending. Instead, the findings suggest that the characteristics of gig employment including income fluctuation, documentation requirements and compatibility with conventional mortgage assessment are important considerations. For developers, this highlights the potential value of affordable housing products with realistic pricing and flexible payment or tenure options, while for policymakers and financial institutions, it emphasises the need to recognise non-standard income structures within housing finance policies.


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**Table 5.** Integrated Summary of Quantitative and Qualitative Findings

| Key Theme | Quantitative Finding | Qualitative Evidence | Overall Interpretation |
|---|---|---|---|
| Income instability | Significant negative association with homeownership readiness ($\rho = -0.589$, $p = 0.004$) | 13 mentions of unstable/insufficient income | Primary constraint |
| Savings behaviour | Positive but non-significant ($\rho = 0.307$, $p = 0.165$) | Requests for financial assistance and savings support | Financial capacity remains relevant, but evidence is inconclusive |
| Lifestyle spending | Negative but non-significant ($\rho = -0.274$, $p = 0.217$) | Low RII for lifestyle spending (0.427) | Not a dominant constraint |
| Financial literacy/spending control | No significant association ($\rho = 0.010$, $p = 0.966$) | Some comments emphasised better financial management | Potentially relevant behaviourally, but not statistically demonstrated |
| Financing & documentation | Reflected through homeownership-readiness indicators | 5 documentation mentions; 4 financing/loan-access mentions | Structural barriers affect mortgage accessibility |
| Flexible financing/support | D7 reflects willingness under flexible financing | 14 mentions requesting flexible/easier financing | Strong demand for more adaptable housing finance mechanisms |

**Note:** Qualitative frequencies represent thematic mentions and are not mutually exclusive; one respondent may contribute to more than one theme. Quantitative results are based on 22 valid respondents.

## CONCLUSION

This study concludes that homeownership remains an important long-term aspiration among gig workers, but their ability to achieve homeownership readiness is constrained primarily by income instability and related structural barriers. The quantitative findings indicate a significant negative association between income instability and homeownership readiness, while savings behaviour, lifestyle spending and financial literacy/spending control did not demonstrate statistically significant relationships within the sample. The qualitative findings further reinforce this pattern, highlighting fluctuating income, difficulties in providing financial documentation, loan accessibility and housing affordability as key challenges. These findings suggest that the housing challenges faced by gig workers should not be viewed primarily as a consequence

of excessive lifestyle spending, but rather in the context of the financial uncertainty and institutional limitations associated with non-standard employment. Nevertheless, the findings should be interpreted as exploratory and are limited to 22 purposively selected respondents from Johor Bahru, Kuala Lumpur and Selangor.

The findings provide implications for policymakers, financial institutions, housing developers and potential buyers. Policymakers and housing agencies should consider more inclusive housing policies that recognise non-standard income structures, including alternative approaches to income verification, flexible financing mechanisms, affordable housing initiatives and rent-to-own arrangements. Financial institutions could explore alternative credit assessment methods and more flexible mortgage products while maintaining appropriate affordability and repayment safeguards. Developers may also consider housing products that better reflect the financial capacity and preferences of households with irregular income. For gig workers themselves, strengthening financial planning, maintaining consistent financial records and building savings remain important in improving their preparedness for future homeownership. Future studies should involve larger and more geographically diverse samples and examine gig workers across different types of platforms and occupations to provide stronger evidence on the relationship between employment structure, financial behaviour and housing outcomes.

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# WOMEN'S HOUSING AFFORDABILITY IN SELANGOR: AN EXPENDITURE- BASED ANALYSIS BEYOND INCOME METRIC

**Nor Suzylah Sohaimi[1], Nur Syakiran Akmal Ismail[2], Rosfaraliza Azura Ramli[3], Nurzalyna Mohamed Zaki[4], Azlina Ismail[5]**

[1,3] *Department of Planning & Property, School of Government,*
[2]*Department of Public Management, School of Government,*
UNIVERSITI UTARA MALAYSIA
[4]*School of Business and Social Sciences,*
ALBUKHARY INTERNATIONAL UNIVERSITY, MALAYSIA
[5] LEMBAGA PERUMAHAN & HARTANAH SELANGOR, MALAYSIA

## Abstract

Rising housing and living costs challenge women's housing affordability in Selangor, yet income-based measures may conceal financial stress after essential expenditures. This study measures women's housing affordability and identifies expenditure commitments influencing it. A cross-sectional survey of 500 adult women from diverse marital statuses, household arrangements and income groups was analysed using the Residual Income Model (RIM) and Binary Logistic Regression (BLR), while Sankey analysis visualised income allocation. Household income significantly increased affordability (Wald = 125.147, $p < 0.001$), whereas household, housing, transportation and education expenditures significantly reduced it. B40 households earned an average of RM3,350 and spent RM930 (27.8%) on housing, yet saved only RM110 (3.3%). This reveals "false affordability", whereby households satisfy the conventional 30% benchmark but retain insufficient resources for essential needs. M40 and T20 households recorded higher savings rates of 18.1% and 25.0%, respectively. These findings support expenditure-sensitive assessments and targeted, gender-responsive housing interventions.

***Keywords***: Housing Affordability, Women's Housing Affordability, Residual Income, Binary Logistic Regression, Selangor

[2] Corresponding author. Email: suzysuhaimi@uum.edu.my

## INTRODUCTION

Affordable housing remains an unfulfilled aspiration for many women worldwide, particularly those living in rapidly urbanising areas where housing prices and living costs continue to outpace income growth. Women, especially female-headed households and those belonging to lower-income groups, face disproportionate barriers to homeownership due to persistent income inequality, limited financial resources, insecure employment, and greater caregiving responsibilities (Sohaimi, 2025). These structural disadvantages reduce their capacity to accumulate wealth and sustain housing payments, thereby increasing their vulnerability to housing insecurity. Consequently, housing affordability has emerged as a critical socio-economic issue requiring assessment beyond conventional income-based measures to better capture women's actual financial capacity to secure and maintain adequate housing.

Housing affordability has traditionally been measured using income-ratio indicators, such as the housing-cost-to-income ratio and the median multiple. While these measures remain widely adopted, they often underestimate housing stress because they ignore essential non-housing expenditures that households must meet before allocating income to housing. The RIM addresses this limitation by assessing whether households retain sufficient income after paying for housing and other basic living needs, including food, transportation, utilities, and childcare (Stone, 2006). Consequently, RIM provides a more realistic assessment of housing affordability, particularly for economically vulnerable households.

In Malaysia, housing affordability assessments continue to rely predominantly on ratio-based indicators despite growing recognition that affordability should reflect households' ability to meet both housing and non-housing necessities. The Ministry of Housing and Local Government (2023) acknowledges the residual income approach as a complementary measure alongside conventional affordability indicators. Similarly, the Department of Statistics Malaysia [DOSM] (2022), drawing on the Financial Stability Review, reports that persistent housing affordability problems are driven by slower income growth, rising household indebtedness, and house prices increasing faster than household income. These findings suggest that income alone is insufficient to explain affordability outcomes.

The affordability challenge is particularly evident in Selangor, where the average house price increased from RM540,704 in 2023 to RM557,425 in 2024 (preliminary) (National Property Information Centre [NAPIC], 2024). Concurrently, Malaysian households allocate a significant proportion of their monthly expenditure to housing and utilities (23.2%), food and beverages (16.3%), and transportation (11.3%), with average household expenditure in Selangor reaching RM6,770 per month (DOSM, 2023). These unavoidable

expenditures substantially reduce the income available for housing, making affordability increasingly dependent on residual income rather than gross household income.

The issue is more pronounced among women. Women, particularly female-headed households and single women, frequently experience lower earnings, interrupted employment due to caregiving responsibilities, and limited access to secure employment and housing finance. Beyond economic constraints, women also encounter legal, institutional, and socio-cultural barriers that restrict access to adequate housing, including unequal property ownership rights, discriminatory financing practices, and housing policies that inadequately address gender-specific needs (Sohaimi et al., 2025). These structural disadvantages increase women's vulnerability to housing insecurity even when they satisfy conventional income eligibility criteria.

Although previous Malaysian studies have demonstrated that total household expenditure and transportation costs significantly reduce housing affordability by eroding residual income (Sohaimi et al., 2018; 2022), existing research has largely examined housing affordability from a general household perspective, with limited attention to women's expenditure patterns and gender-specific financial constraints, particularly in Selangor. Furthermore, current affordable housing policies, including Rumah Selangorku, continue to emphasise income eligibility and creditworthiness, while giving insufficient consideration to the residual income available after essential living expenditures (Saleh et al., 2025). This creates an important policy and empirical gap, as women who meet formal income requirements may nevertheless remain unable to achieve sustainable homeownership.

## RESEARCH METHODOLOGY

A cross-sectional survey was conducted among 500 adult women residing in Selangor, representing diverse marital statuses, household arrangements, income groups (B40, M40 and T20), and housing circumstances. The term “women’s households” refers to households represented by women respondents, including single, married, divorced or widowed women and female-headed households. This broad representation captures variations in housing affordability across different socio-economic and household circumstances. To avoid double counting, Household Expenditure was defined as non-housing consumption expenditure excluding transportation, education and housing costs, which were entered separately in the BLR model. It comprises essential commitments such as food, utilities, clothing, healthcare, internet services, insurance, recreation and other routine household expenses. Residual income was computed as:


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Residual Income = Monthly Income − (Housing Cost + Non-Housing Expenditure).

The minimum living standard threshold represents the minimum level of residual income required for a household to meet essential non-housing needs after housing expenditure has been paid. The threshold was operationalised using essential household expenditure components derived from the DOSM cost of living framework. Accordingly, a respondent was classified as affordable (Yi = 1) when the residual income remaining after housing and essential non-housing expenditure was equal to or above the specified minimum living standard threshold, otherwise, the respondent was classified as not affordable (Yi = 0). This approach is consistent with the conceptual basis of Stone's RIM (2006), which evaluates affordability according to the adequacy of income remaining for necessary consumption rather than applying a uniform housing-cost-to-income ratio. Housing affordability was treated as a binary dependent variable, where

Yi = 1 if residual income ≥ minimum living standard threshold (Affordable)
Yi = 0 if residual income < minimum living standard threshold (Not Affordable)

Given the dichotomous nature of the dependent variable, a BLR model was employed to estimate the probability that a woman household attains housing affordability. The general logit specification is expressed as:

$$\text{logit}(Pi) = \ln[Pi / (1 - Pi)] = \beta 0 + \beta 1X1i + \beta 2X2i + ... + \beta kXki$$

where Pi refers to the estimated probability that housing is affordable for respondent i; (Pi / (1 − Pi) represents the odds of affordability; β0 is the intercept; βk are regression coefficients; and Xk represent the explanatory variables. The probability function is specified as:

$$Pi = e^{(\beta 0 + \Sigma \beta kXki)} / [1 + e^{(\beta 0 + \Sigma \beta kXki)}]$$

which constrains predicted probabilities between 0 and 1 and ensures econometric consistency when modelling affordability outcomes. The empirical model examining women's housing affordability is specified as:

$$\text{logit}(Pi) = \beta 0 + \beta 1(\text{HouseholdIncome}i) + \beta 4(\text{HouseholdExpenditure}i) + \beta 5(\text{Transporatationi}) + \beta 6(\text{EducationCost}i) + \beta 7(\text{HousingCost}i) + \varepsilon i$$

where HouseholdIncome represents monthly gross household income (MYR), HouseholdExpenditure captures total non-housing expenditures based on DOSM cost-of-living indicators, Transportation indicates monthly transportation expenditure, EducationCost reflects monthly education repayment commitments, HousingCost refers to monthly housing repayment obligations, and $\varepsilon_i$ denotes the stochastic error term. A positive coefficient ($\beta_k$) indicates that an increase in the corresponding explanatory variable increases the log-odds of housing affordability, holding other factors constant, while the exponentiated coefficient, $\exp(\beta_k)$, represents the odds ratio, values greater than 1 indicate an increased likelihood of affordability and values less than 1 indicate a reduced likelihood. For example, if $\exp(\beta_3) = 1.50$, a one-unit increase in household income increases the odds of attaining housing affordability by 50%, ceteris paribus. Model adequacy was evaluated using goodness-of-fit statistics, including the Hosmer–Lemeshow test, classification accuracy, and pseudo-$R^2$ measures to ensure robustness and reliability of the estimated model.

To complement the regression analysis, Sankey flow analysis was employed to visualise household income allocation and expenditure patterns, identifying major cost of living components that reduce residual income. This integrated approach provides a more comprehensive and policy-relevant assessment of women's housing affordability and financial vulnerability in urban Malaysia.

## RESULTS

### Measuring Women's Housing Affordability in Selangor

Prior to estimating the BLR model, multicollinearity diagnostics were performed. All predictor variables recorded tolerance values above 0.10 and VIF values below 10 (Table 1), indicating the absence of multicollinearity and confirming that the model satisfies the independence assumption among the explanatory variables.

**Table 1:** Collinearity Statistics

| PREDICTORS | COLLINEARITY STATISTICS | |
|---|---|---|
| | TOLERANCE | VIF |
| Household Income | .758 | 1.336 |
| Household Expenditure | .556 | 1.799 |
| Transportation Cost | .755 | 1.325 |
| Education Cost | .704 | 1.420 |
| Housing Cost | .954 | 1.048 |

*Source: Author, (2026)*


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The BLR results presented in Table 2 indicate that all five financial variables are statistically significant predictors of women's housing affordability. Monthly household income recorded the largest Wald statistic (B = 0.001640, S.E. = 0.000147, Wald = 125.147, $p < 0.001$, Exp(B) = 1.002, 95% CI [1.001, 1.002]). The positive coefficient indicates that higher household income increases the odds of achieving housing affordability, holding the other variables constant.

In contrast, monthly household expenditure shows a statistically significant negative association with housing affordability (B = −0.001986, S.E. = 0.000229, Wald = 75.421, $p < 0.001$, Exp(B) = 0.998, 95% CI [0.998, 0.998]). This indicates that increasing non-housing expenditure reduces the odds of achieving housing affordability by eroding the residual income available after meeting essential living expenses.

Monthly transportation cost also has a statistically significant negative association with housing affordability (B = −0.002160, S.E. = 0.000644, Wald = 11.259, $p = 0.001$, Exp(B) = 0.998, 95% CI [0.997, 0.999]). This suggests that transportation commitments contribute to the overall cost-of-living burden and constrain the financial resources available for housing. Similarly, monthly education cost is negatively associated with affordability (B = −0.001302, S.E. = 0.000547, Wald = 5.668, $p = 0.017$, Exp(B) = 0.999, 95% CI [0.998, 1.000]), indicating that education-related commitments can further reduce household residual income.

Monthly housing cost is also a statistically significant negative predictor of housing affordability (B = −0.001548, S.E. = 0.000174, Wald = 79.577, $p < 0.001$, Exp(B) = 0.998, 95% CI [0.998, 0.999]). Higher housing repayment commitments therefore reduce the odds of maintaining housing affordability after other essential household expenditures are considered. This finding reinforces the conceptual foundation of the RIM, whereby affordability depends on whether sufficient income remains after meeting housing and other essential living costs, rather than solely on the proportion of income devoted to housing.

Collectively, the coefficients demonstrate a consistent pattern, household income positively influences affordability, whereas housing and non-housing expenditure commitments negatively influence affordability. Although the odds ratios appear small when expressed for a RM1 change, their cumulative effects are more meaningful at realistic expenditure levels. Based on the estimated coefficients, a RM100 increase in household income is associated with approximately 1.18 times the odds of being affordable, equivalent to about 17.8% higher odds, holding other variables constant. Conversely, a RM100 increase in household expenditure, transportation cost, education cost and housing cost is associated with approximately 18.0%, 19.4%, 12.2% and 14.3% lower odds of affordability, respectively. These cumulative effects demonstrate that relatively

small per-ringgit coefficients can translate into substantively meaningful affordability differences at realistic monthly income and expenditure levels.

**Table 2:** Variables in the Equation

| Description | Variables | B | S.E. | Wald | Sig. | Exp(B) | 95% CI Lower | 95% CI Upper |
|---|---|---|---|---|---|---|---|---|
| Constant | Constant | 0.425 | 0.300 | 2.011 | 0.156 | 1.529 | 0.850 | 2.752 |
| Monthly household income | Household Income | 0.001640 | 0.000147 | 125.147 | <0.001 | 1.002 | 1.001 | 1.002 |
| Monthly household expenditure (non-housing cost) | Household Expenditure | −0.001986 | 0.000229 | 75.421 | <0.001 | 0.998 | 0.998 | 0.998 |
| Monthly transportation cost | Transportation Cost | −0.002160 | 0.000644 | 11.259 | 0.001 | 0.998 | 0.997 | 0.999 |
| Monthly education cost | Education Cost | −0.001302 | 0.000547 | 5.668 | 0.017 | 0.999 | 0.998 | 1.000 |
| Monthly housing cost | Housing Cost | −0.001548 | 0.000174 | 79.577 | <0.001 | 0.998 | 0.998 | 0.999 |

*Source: Author, (2026)*

## Expenditure Patterns Affecting Housing Affordability

Sankey flow analysis was used as a descriptive visualisation to illustrate income distribution across key expenditures and savings among B40, M40 and T20 households. It complements the BLR by visually demonstrating how competing expenditure commitments affect residual income across income groups.

### i. B40 Group

The expenditure pattern of the B40 income group in Selangor, as illustrated in Figure 1, highlights significant challenges in balancing the rising cost of living with limited household income. The average household income recorded in this study is RM3,350, consisting of contributions from wives amounting to RM2,020 (60%) and husbands contributing RM1,330 (40%). These figures represent the overall average across the dataset. The relatively lower contribution from husbands can be attributed to the presence of respondents who are single mothers or households where the husband is not employed.

The findings further reveal that only RM110, or approximately 3.3% of total household income, is allocated to savings. This minimal level of savings reflects the substantial financial pressure faced by B40 households. Housing instalment payments represent the largest expenditure component, averaging RM930 per month. This amount alone exceeds the commonly recommended housing affordability threshold of 30% of household income, indicating that B40 households are experiencing considerable housing cost burdens.


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In addition to housing costs, expenditure on other essential needs further constrains the financial capacity of B40 households. A total of RM1,635 is allocated to general household expenditures, which include food and beverages (RM680), utilities (RM250), clothing (RM100), medical expenses (RM110), internet services (RM100), recreation and tourism (RM150), entertainment (RM160), and insurance (RM85). Transportation costs amount to RM465 per month, covering vehicle instalments as well as related transportation expenses such as petrol, tolls, and public transport fares. Meanwhile, education expenditure reaches RM300 per month, reflecting households' prioritisation of their children's education despite increasing financial constraints.

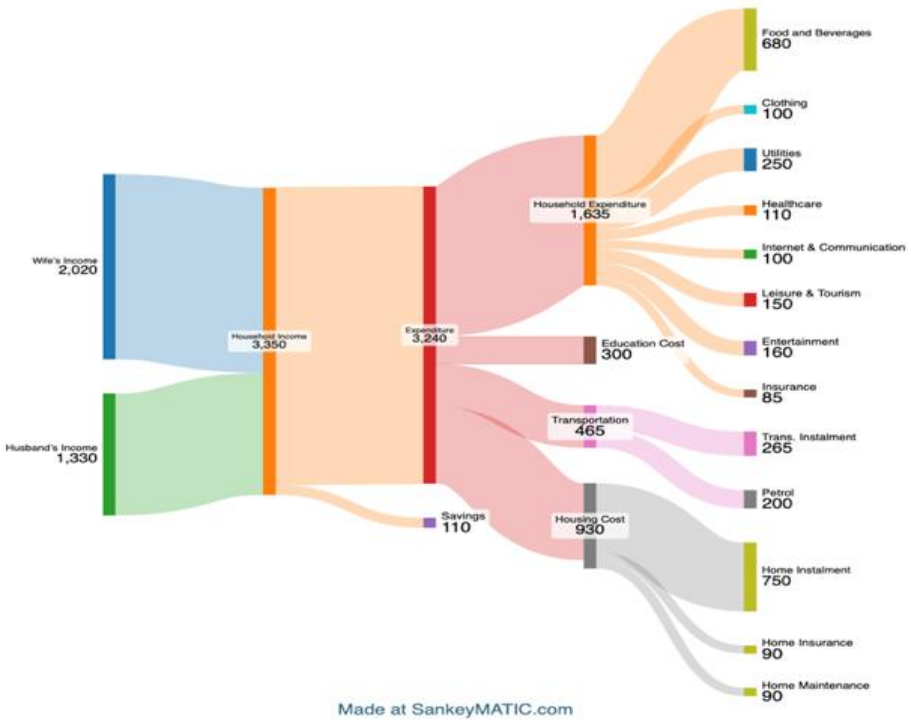



**Figure 1:** B40's household expenditure
*Source: Author, (2026)*

### ii. M40 Group

The M40 households demonstrate relatively stronger financial capacity than the B40 group, although rising living costs continue to place pressure on their household budgets. The average monthly household income is RM7,934, with

wives contributing RM3,850 (48.5%) and husbands RM4,084 (51.5%), indicating relatively balanced income contributions. Approximately RM1,434 (18.1%) of household income is allocated to savings, suggesting greater financial resilience and long-term planning compared with lower-income households. Nevertheless, a substantial proportion of income remains committed to meeting essential living expenses.

Housing represents the largest single expenditure, averaging RM1,900 per month (24.0%) of household income. Although this remains below the widely accepted affordability threshold of 30%, housing continues to constitute a significant financial commitment that limits disposable income available for other necessities. Monthly household expenditure totals approximately RM3,400, with food and beverages accounting for the largest share (RM1,500; 44.1%), followed by recreation and tourism (RM400; 11.8%), insurance (RM350; 10.3%), utilities (RM300; 8.8%), entertainment (RM250; 7.4%), and clothing, medical care, and internet services (each RM200; 5.9%). This expenditure pattern reflects a balance between fulfilling essential needs and maintaining a reasonable standard of living.

Transportation expenditure averages RM750 per month, largely associated with vehicle financing and commuting costs, highlighting continued dependence on private vehicles. In addition, households allocate RM500 (6.3%) of monthly income to education, demonstrating a commitment to investing in children's human capital despite increasing living expenses.

The findings indicate that M40 households generally maintain sustainable housing affordability and possess stronger financial capacity to achieve and retain homeownership than B40 households. However, the concentration of expenditure on housing, food, and transportation illustrates that rising living costs continue to constrain disposable income and reduce financial flexibility. While affordable housing assistance remains essential for lower-income groups, policy attention for the M40 segment should focus on improving housing supply, enhancing housing quality, promoting financial resilience, and mitigating cost-of-living pressures to ensure sustainable homeownership over the long term.


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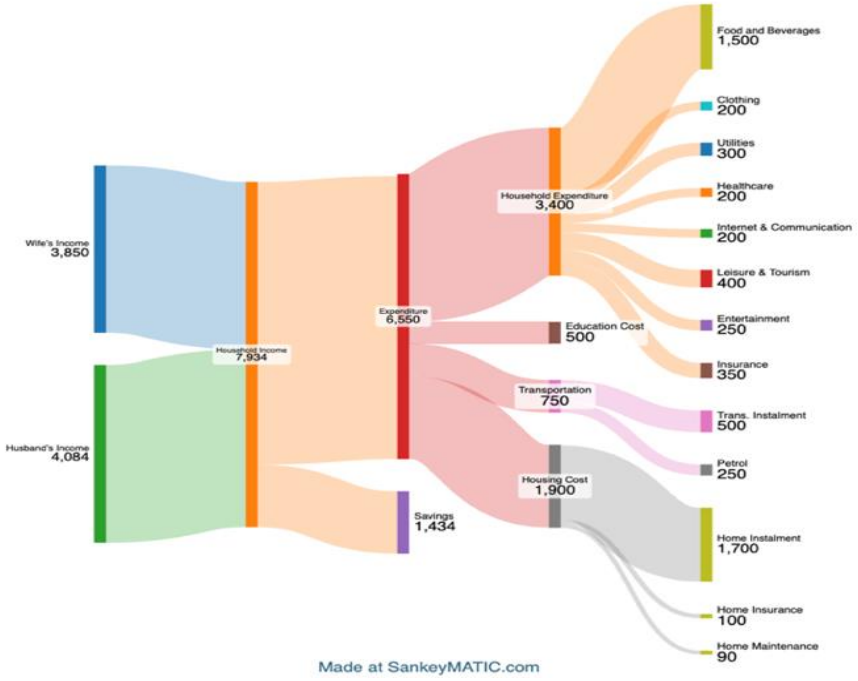



**Figure 2:** M40's household expenditure
*Source: Author, (2026)*

### iii. T20 Group

The T20 households exhibit the strongest financial position among the three income groups, characterised by higher income, greater savings capacity, and stronger housing affordability. The average monthly household income is RM17,457, with wives contributing RM7,465 (42.8%) and husbands RM9,992 (57.2%). Approximately RM4,367 (25%) of total household income is allocated to savings, indicating substantial financial resilience and a greater capacity for long-term wealth accumulation compared with the B40 and M40 groups.

Housing expenditure averages RM2,890 per month, representing only 16.6% of household income, well below the commonly accepted affordability threshold of 30%. This suggests that housing costs impose a relatively low financial burden on T20 households. Transportation expenditure is RM1,900 per month (10.9% of household income), reflecting reliance on private vehicles and vehicle financing. However, this remains financially manageable given the group's higher earning capacity.

Total household expenditure averages approximately RM7,000 per month, with food and beverages accounting for the largest share at RM2,500

(35.7%). Other expenditure categories include insurance (RM1,000; 14.3%), utilities (RM900; 12.9%), recreation and tourism (RM700; 10.0%), medical expenses (RM600; 8.6%), clothing and entertainment (RM500 each; 7.1%), and internet services (RM300; 4.3%). In addition, households allocate RM1,300 (7.4% of household income) to education, reflecting continued investment in children's human capital and future opportunities. Overall, the expenditure profile indicates that T20 households experience relatively low financial stress and possess sufficient financial flexibility to balance housing commitments, daily living expenses, savings, and discretionary spending. Their high savings rate further enhances resilience against economic uncertainty while supporting long-term asset accumulation.

From a housing perspective, T20 households generally achieve high levels of homeownership and require fewer affordable housing interventions than lower-income groups. However, from a gender perspective, promoting independent property ownership among women remains essential. Ownership of housing assets in their own names enhances women's financial autonomy, strengthens long-term economic security, and provides greater protection against divorce, widowhood, or unexpected financial hardship, contributing to more equitable and resilient housing outcomes.

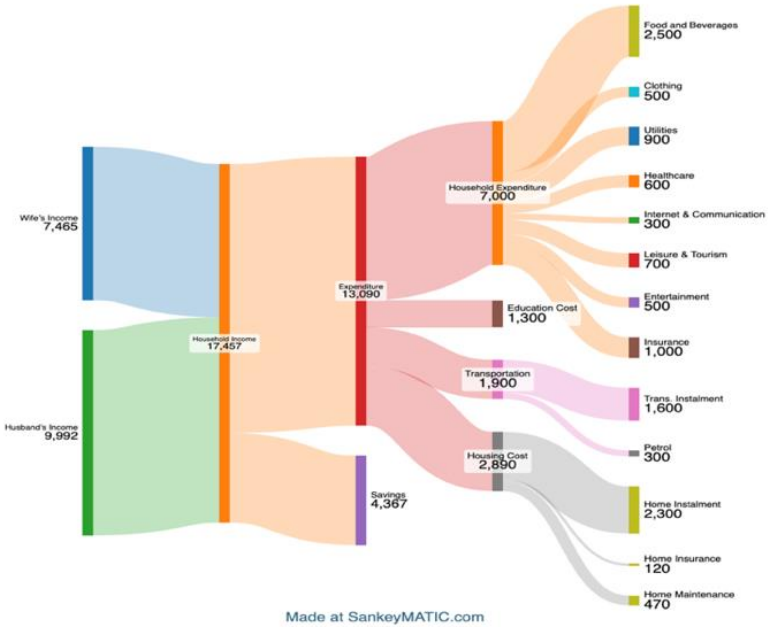



**Figure 3:** T20's household expenditure
*Source: Author, (2026)*


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The analysis of household expenditure patterns across income groups demonstrates that housing affordability is shaped not only by housing costs but also by the capacity of households to retain sufficient income after meeting essential living expenses. Using the RIM, affordability is assessed based on the income remaining after deducting housing costs and other unavoidable expenditures, providing a more comprehensive measure of financial well-being than conventional housing cost-to-income ratios.

The findings reveal substantial disparities across income groups. B40 households experience the greatest financial pressure, with an average monthly income of RM3,350 and housing expenditure of RM840, exceeding the recommended affordability threshold of 30% of household income. After accounting for essential expenses, including food, utilities, transportation, education, and healthcare, only a minimal residual income remains. Their average monthly savings of RM110 (3.3% of income) reflect limited financial resilience and a high vulnerability to housing stress and unexpected economic shocks.

In comparison, M40 households demonstrate relatively better financial stability. With an average income of RM7,934, housing expenditure represents 24% of income, remaining within the affordability threshold. Although most households retain positive residual income after meeting essential expenditures and save approximately 18.1% of their income, increasing living costs continue to constrain long-term wealth accumulation.

T20 households exhibit the strongest financial resilience. Their average household income of RM17,457, combined with housing expenditure of only 16.6% of income, enables them to maintain substantial residual income while allocating 25% of their earnings to savings. This financial flexibility supports greater economic security and long-term asset accumulation.

Collectively, the findings demonstrate that rising living costs disproportionately affect lower-income households by reducing residual income available for housing and savings. These results reinforce the importance of adopting expenditure-based affordability measures, such as the RIM, which account for both housing and essential non-housing expenditures to provide a more accurate assessment of household financial capacity and housing affordability.

## DISCUSSION

The findings demonstrate that women's housing affordability in Selangor is shaped by the interaction between household income and essential living expenditures rather than housing costs alone. Consistent with the RIM, higher household income significantly increases the likelihood of affordability, whereas rising housing, transportation, education and other essential expenditures reduce

residual income and constrain women's capacity to sustain homeownership. This supports Stone's (2006) proposition that affordability should be assessed according to the resources remaining after essential needs are met rather than solely through housing cost-to-income ratios.

The B40 findings demonstrate the analytical advantage of the RIM particularly clearly. Average housing expenditure of RM840 represents approximately 25.1% of the group's average household income of RM3,350, which falls below the conventional 30% affordability benchmark. Under a ratio-based assessment, these households could therefore appear affordable. However, once food, utilities, transportation, education, healthcare and other essential expenditures are considered, B40 households retain minimal residual income and save only RM110 per month. This reveals a form of "false affordability", whereby a household satisfies the conventional housing-cost threshold but lacks sufficient resources to maintain an adequate standard of living. In contrast, M40 and T20 households retain progressively greater residual income and savings, demonstrating that similar housing-cost ratios can mask substantial differences in actual financial capacity. These findings reinforce previous Malaysian evidence that non-housing expenditures, particularly transportation, can significantly affect affordability (Sohaimi et al., 2018; 2022), consistent with international findings by Makarewicz et al. (2020) and Crowe and Rowley (2024).

The findings have particular significance from a gender perspective because affordability pressures are not necessarily experienced uniformly within households. Women's residual income may be disproportionately constrained by caregiving responsibilities, childcare expenditure, interrupted employment and lower or less stable earnings. Single mothers and female-headed households may face greater vulnerability where housing and essential household expenses must be sustained from fewer income sources. Women's housing security also extends beyond access to a dwelling to encompass financial autonomy, housing stability and independent property ownership. As highlighted by Sohaimi et al. (2025a), legal, institutional and socio-economic barriers may restrict women's access to adequate housing and property ownership. Therefore, meeting household-level income eligibility does not necessarily indicate that an individual woman possesses sufficient financial capacity or housing security.

**Policy Implications**

These findings have important implications for housing policy in Selangor. First, Selangor Housing and Property Board (LPHS) and *Rumah Selangorku scheme* could complement existing household-income eligibility criteria with expenditure-sensitive assessments that consider residual income after essential living costs. This would help identify women who satisfy formal income thresholds but remain financially vulnerable. Second, financial institutions could


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develop gender-responsive financing mechanisms that recognise non-linear employment histories, particularly career interruptions associated with caregiving, rather than assessing affordability exclusively through conventional employment and credit profiles.

Third, affordable housing policy should be better integrated with transport planning, as high commuting expenditure can offset the financial benefits of lower-priced housing in peripheral locations. Affordable housing should therefore be planned with greater accessibility to employment centres and public transportation. Fourth, affordable childcare and education support could indirectly improve housing affordability by reducing essential expenditure burdens while strengthening women's labour-market participation. Finally, women-targeted financial literacy, homeownership advisory services and flexible financing mechanisms could enhance financial autonomy and encourage independent property ownership.

Collectively, these measures would shift policy from simply delivering lower-priced housing towards achieving sustainable affordability, whereby women can acquire, maintain and retain adequate housing without sacrificing essential household needs. Such an approach connects housing affordability with social sustainability by strengthening economic resilience, reducing gender inequality and promoting more inclusive and liveable urban communities.

## CONCLUSION

This study demonstrates that women's housing affordability in Selangor cannot be adequately assessed through income or housing-cost ratios alone, as affordability depends on the balance between household resources and essential expenditures. Using the RIM, the findings show that higher household income improves affordability, whereas housing, transportation, education, and other living costs reduce residual income and increase housing stress. The integration of BLR and Sankey flow analysis further demonstrates that conventional measures may produce "false affordability", particularly among B40 households whose housing costs remain below the 30% benchmark but whose residual income is insufficient after essential expenses. From a gender perspective, sustainable housing affordability requires policies that recognise caregiving responsibilities, employment interruptions, financial autonomy, and independent property ownership through expenditure-sensitive assessments, gender-responsive financing, affordable childcare, accessible transportation, and targeted financial support. Improving women's housing affordability can strengthen economic independence, household resilience, asset accumulation, and residential stability, thereby contributing to inclusive and sustainable urban development and SDG 11: Sustainable Cities and Communities (Sohaimi et al.,

2025b). Nevertheless, the cross-sectional design limits causal interpretation and generalisability beyond Selangor. A significant research gap remains in understanding how women's housing affordability changes over time and varies across geographical and socio-institutional contexts, as existing cross-sectional evidence cannot capture these dynamics. Future research should therefore employ longitudinal and comparative designs incorporating housing quality, neighbourhood conditions, spatial accessibility and institutional factors to inform more robust, gender-responsive and sustainable housing policies in Malaysia.

## ACKNOWLEDGEMENT

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# SOCIO-ECONOMIC INDICATORS TOWARDS SMART AND RESILIENT RURAL DEVELOPMENT

**Low Wai Wah[1], Priscilla Awing Stengle[2], Wong Kwong Soon[3], Wang Chen[4], Wong Shi Yee[5], Loo Siaw Chuing[6], Tay Ai Chen[7]**

[1]*Department of Construction Management, Faculty of Built Environment,*
TUNKU ABDUL RAHMAN UNIVERSITY OF
MANAGEMENT AND TECHNOLOGY
[2,3]*Department of Civil and Construction Engineering,*
*Faculty of Engineering and Science,*
CURTIN UNIVERSITY MALAYSIA
[4]*Department of Construction Management, College of Civil Engineering,*
HUAQIAO UNIVERSITY
[5]*Department of Quantity Surveying, School of Built Environment,*
UNIVERSITY OF TECHNOLOGY SARAWAK
[6]*Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[7]*School of Engineering and Science,*
*Faculty of Engineering, Computing and Science*
SWINBURNE UNIVERSITY OF TECHNOLOGY SARAWAK

## Abstract

Over the years, the United Nations' Sustainable Development Goals (UNSDG) have included rural development as one of the UNSDG indicators. Rural development is important, especially for developing countries with higher rural population. Limited existing literature focus on the underlying indicators in developing a smart and resilience rural. Therefore, this study aims to identify the underlying indicators of smart rural and rural resilience between two rural categories in Sarawak based on the rural communities' perspective. Likert-Scale questionnaires were distributed to seven village communities. This yields a total of 675 valid responses. The study demonstrates that rural categories significantly influence the perceived underlying indicators, emphasising the need for specific strategies to address development gaps between the different rural categories. Adaptive rural policies are needed to cater different characteristics of rural areas to close the rural development gaps.

***Keywords***: Smart Rural, Rural Resilience, Sustainable, Rural Development, Indicators, Sarawak

[1] Corresponding author. Email: lowww@tarc.edu.my

## INTRODUCTION

Rural development is a priority focus on some global sustainability agendas, such as United Nations' Sustainable Development Goals (UNSDG) (Liu et al., 2024). The aim is to deal with the socioeconomic disparity to strive towards sustainability. Sarawak is the largest state in the Borneo Islands, Malaysia with majority of its population residing in rural areas (Abdullah, 2021). As such, it is indeed important to improve its socioeconomic condition, especially with various rural categories encompassing the region.

Resilience of rural community plays a pivotal role to improve the sustainability of socioeconomic condition of rural areas. In view of the recent trends in smart and resilience direction towards a sustainability urban development. It is worth to look into the smart and resilience concepts in the rural development context. Smart rural is defined as the incorporation of smart technologies towards innovation and promoting a sustainable future for rural communities (Gerli et al., 2022; Guzal-Dec, 2018; Mukti et al., 2022). While rural resilience refers to the rural community's ability to adapt towards socioeconomic changes to improve living quality (Heijman et al., 2019; Li, 2023). Both concepts could contribute to a sustainable rural development. According to Wilson et al. (2018), rural resilience is particularly important in developing countries that are experiencing the transition of the economy such as Malaysia.

Limited existing studies are focused on smart and rural resilience in sustaining the socioeconomic of rural areas. This paper aims to identify the underlying indicators of smart, rural resilience, and sustainable rural development of two rural categories in Sarawak, namely Pedalaman 1 (P1) and Pedalaman 2 (P2). The underlying indicators in this study refer to the fundamental indicators that are likely to influence the development of smart rural and rural resilience. The study is important as it might support the local government in planning the rural development strategies that is tailored to the unique characteristics of the region. The following sections of this paper include literature review, research methodology, results and discussions, and conclusion and future research.

## LITERATURE REVIEW

Similar to the smart city concept, smart rural aims to enhance the quality of life of rural communities through governance, social inclusion, and rural economy to achieve sustainable rural development (Aziiza & Susanto, 2020; Shcherbina & Gorbenkova, 2018). The European Union (EU) has demonstrated that smart rural initiatives have the potential to improve rural livelihoods. Past studies such as Naldi et al. (2015) and Panciszko (2021) had derived smart rural indicators that can help to achieve successful implementation of the smart rural initiatives in the EU. Additionally, Indonesia has contributed to numerous studies smart rural studies. For example, Aziiza and Susanto (2020) had proposed a smart rural

model and indicators that is tailored to the unique characteristic of Banyuwangi Regency in Indonesia.

Rural resilience studies are mainly focused on China (Fan et al., 2021; Huang et al., 2018). Past studies have identified rural resilience indicators in various aspects such as economic, governance, social, livelihood, environmental, and technology (Li et al., 2021; Yang et al., 2022; Ye et al., 2023). Review of past studies indicates that the topic of rural resilience is not captured much attention in Malaysia compared to other countries, namely, China and Western regions. Consistently, Zhou et al. (2021) studied on smart cities and they argued that resilience in smart development is relatively a new concept in sustainability development and hence there is lack of studies on how smart development can promote resilience. They also discovered that smart cities development can improve urban resilience but will cause different resilient level. Existing literature in rural resilience is mostly focused on developed countries instead of developing countries or developing countries that are experiencing urban and rural transition (Wilson et al., 2018).

## SMART RURAL AND RURAL RESILIENCE INDICATORS

The indicators of smart rural and rural resilience are extracted from relevant literature as shown in Table 1 and 2. The identification of indicators are based on 5 dimensions, namely, resources, technology, environmental, social and economic.

**Table 1:** References for smart rural indicators.

| **Indicators** | **References** |
|---|---|
| Sufficient budget allocated for road construction by the government or municipal | [1], [5] |
| Sufficient budget allocated for innovation programmes for smart rural development | [1], [6] |
| Availability of banking or financial infrastructures in the village (e.g.: ATMs) | [1], [7] |
| Access for employment in recent years | [2], [4] |
| High job availability within rural area | [3], [7] |
| Using social media platform to boost business/livelihood | [1], [4] |
| Wide usage of online or mobile banking among rural residents | [1], [4] |
| Encouragement of entrepreneurship within rural community | [1], [4] |
| Income stability | [1], [4] |
| High employment rate of rural residents | [4], [2] |
| Business/industry improvement | [1], [4] |
| Sufficient number of books in the village library | [1], [5] |
| Efficient online database in the village library | [1], [5] |
| Active government participation in the village's development | [2], [9] |
| Digitalisation of governance (e.g.: Malaysia Digital Coordinating Committee (MD-CC) for MyDIGITAL) | [2], [5] |


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| **Indicators** | **References** |
|---|---|
| Active public rural participation with government initiatives | [2], [5] |
| Access to education | [3], [8] |
| Access to health facilities | [1], [3] |
| Governance effectiveness (e.g.: policies, etc.) | [2], [9] |
| Available ICT services in rural area (e.g.: optimisation of telco towers/ energy grid, etc.) | [1], [3] |
| Good quality ICT services in rural area | [1], [3] |
| Digitally empowered rural community | [1], [2], [4] |
| High number of rural residents voting | [2], [8] |
| Low dependency ratio of rural area | [2], [8] |
| Having an emergency plan for natural disasters | [1], [5] |
| High number of trained people to conduct the emergency plan during natural disasters | [1], [5] |
| Having domestic animals owned by rural community to be uniquely marked or having a tracking device | [1], [5] |
| Efficient waste management (domestic waste and sewage) | [1], [2], [3] |
| Efficient wildlife protection | [1], [3] |
| Early warning systems for drastic climate changes | [1], [5] |
| Access to fresh water | [2], [3] |
| Usage of solar panels within rural housing for personal use | [1], [5] |
| Abundance in agricultural produce (e.g.: livestock, fishery, farming etc.) | [3], [6] |
| Having buildings that can withstand harsh weather conditions | [1], [2] |
| Availability of communication infrastructures (e.g.: telco towers) | [1], [2] |
| Available internet access with high coverage | [1], [3] |
| Available multiple mobile networks (e.g.: Digi, Celcom, etc.) reception with cellular/voice/data coverage | [1], [10] |
| Availability of main road connecting to the village road | [1], [3] |
| Availability of public transport to the village | [1], [2] |
| Sufficient storage capacity of village's substation/energy grid (KWh) | [1], [3] |
| Wide usage of solar powered devices in the village (e.g.: solar panels, solar powered streetlights, etc.) | [1], [5] |
| Using smart and digital equipment in agriculture production | [2], [4] |
| Connectivity of village to the national grid | [1], [7] |
| Predictable and reliable General Practitioner schedule in visiting village clinic or mobile clinic | [1], [7] |
| Sufficient number of mobile clinics visiting the village | [1], [7] |
| Using efficient electricity meters (comparing conventional meters, pre-paid meters, and smart meters) | [1], [7] |
| Large land area earmarked for residential/agricultural/commercial development | [1], [3] |
| Receiving high level of education | [3], [8] |

*Note: [1] Maja et al. (2020), [2] Abu-Rayyash & Dincer (2023), [3] Aziiza & Susanto (2020), [4] Mukti et al. (2022), [5] Hussain et al. (2023), [6] Lin & Hou (2023), [7] Kim et al. (2020), [8] Kaye-Blake et al. (2019), [9] Ye et al. (2023), [10] Lopez-Penabad et al. (2022)*

**Table 2:** References for rural resilience indicators.

| Indicators | References |
|---|---|
| Sufficient public security for rural area | [4], [7] |
| Sufficient financial expenditure on employment in the village | [1], [4] |
| High savings rate of rural residents | [4], [8] |
| Income dependence | [1], [2], [4] |
| Overcoming assets and income poverty | [2], [3] |
| Diverse economy | [3], [4] |
| Encouragement of entrepreneurship in agriculture sector | [6], [7] |
| Stable income | [1], [2], [3] |
| High employment rate of rural residents | [1], [4] |
| Business/industry improvement over recent years | [4], [5] |
| High rural community spirit | [1], [3] |
| Low crime rate and safety of village | [1], [7] |
| High rural area population | [1], [2] |
| Sufficient investment in social services from government (e.g.: rehabilitation for drugs, counselling and psychological support, private sector protection and self-employment protection) | [5], [9] |
| Access to education | [1], [2], [4] |
| Access to health facilities | [1], [4] |
| Governance effectiveness (e.g.: policies, etc.) | [1], [10] |
| Fast recovery of rural population affected from extreme weather condition | [1], [5] |
| Low proportion of rural population over 65 years old | [5], [10] |
| Sufficient number of rural residents voting | [3], [10] |
| Low dependency ratio of rural | [5], [10] |
| Food security | [1], [12] |
| High greenery coverage around the rural area | [4], [9] |
| Efficient early warning systems for drastic climate changes | [1], [8] |
| Access to fresh water | [1], [2] |
| Awareness of rural community towards any change in rural environment | [1], [9] |
| Having irrigated arable land (land that can be used for agriculture) | [4], [5] |
| Large area of arable land | [4], [5] |
| Fast recovery of crops affected from extreme weather condition | [5], [13] |
| High water resources per capita | [1], [5] |
| Sufficient usage of fertiliser/pesticides per arable land | [4], [13] |
| Short commuting distance/ Availability of roads | [4], [8] |
| Available internet access with high coverage | [1], [2] |
| Rural household with access to cable, radio, and TV | [2], [4], [5] |
| Sufficient number of telephones per household | [2], [4] |
| Sufficient and efficient infrastructure development (e.g.: transportation systems, communication networks, sewage, school systems, etc.) | [1], [2] |
| Access to electricity via energy grid | [1], [5] |
| Access to public transport in the rural area | [1], [8] |
| Available vehicle for personal use | [1], [9] |
| Sufficient natural disaster relief expense per capita | [5], [7] |
| Sufficient power generation per capita | [1], [5] |
| High housing supply | [1], [2] |

*Note: [1] Kim et al. (2020), [2] Kaye-Blake et al. (2019), [3] Ye et al. (2023), [4] Yang et al. (2022), [5] Li (2023), [6] Mukti et al. (2023), [7] Aziiza & Susanto (2020), [8] Maja et al. (2020), [9] Hussain et al. (2023), [10] Abu-Rayyash & Dincer (2023), [12] Lacirignola et al. (2012), [13] Lin & Hou (2023)*


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## RESEARCH METHODOLOGY

Case study method was used in this research. This method was adopted by past literature in rural development (Abdul-Latiff et al., 2022; Aziiza & Susanto, 2020). The case study was conducted through questionnaires with five-point agreement's Likert Scale. The questionnaires were administered through drop and pick method. The drop-and-pick method enables respondents to fully answer the questionnaire aside from encouraging high response rates (Junod & Jacquet, 2023).

This research compares the rural categories of Pedalaman 1 (P1) and Pedalaman 2 (P2) in Sarawak. P1-category village is a more advanced rural area compared to P2-category village but very few in number. To assure the samples are representative, the case studies for P2-category villages are selected based on the four (4) main geographical regions in Sarawak, namely, Northern (Marudi), Central (Sarikei), Western (Lundu) and Southern (Simunjan) of Sarawak. In view of the research and accessibility constraints as well as limited numbers of P1-category villages, Bario was identified as the main representative P1-category village with the intensive government support in many significant ICT, digitalization and sustainability initiatives such as eBario project.

Respondents were selected through purposive and convenience sampling methods. Convenience sampling is a common sampling method adopted in previous rural studies (Fennell et al., 2018; Mukti et al., 2022). Rural communities from the selected rural areas are invited to participate the survey through the help and consent from the village head or village head representative. An independence sample T-test was used to compare the mean scores of smart rural and rural resilience indicators in improving the socioeconomic of their villages for two rural categories.

## ANALYSIS AND DISCUSSION

### Demographic Background

A total of 105 responses was received from P1 village while 570 responses were collected from P2 villages. Demographic information of respondents is shown in Table 3. Respondents from both rural categories were quite consistent with low differences in terms of gender and age between the two village categories. Approximately 40% of the respondents are male and 59% are female. Approximately 40% - 50% of the respondents are 50 years old and below. Respondents aged 60 years old and above contributed 51% - 60% of the total responses. The older adults in rural areas usually constituted larger population and they play an important role in driving social innovation in rural areas (Noack & Federwisch, 2020). Additionally, Weck et al. (2022) concluded that engagement of senior citizens play a role in developing a smart living environment. The underlying indicators were analysed through mean and

ranking. High mean value signifies higher ranking, whereas lower mean value signifies lower ranking.

**Table 3:** Demographic information.

| **Category** | **P1** | | **P2** | |
|---|---|---|---|---|
| **Demographic details** | **Frequency (F)** | **Percentage (%)** | **Frequency (F)** | **Percentage (%)** |
| *Age:* | | | | |
| 31 – 39 years old | 5 | 4.77% | 32 | 5.61% |
| 40 – 49 years old | 10 | 9.52% | 86 | 15.09% |
| 50 – 59 years old | 27 | 25.71% | 159 | 27.89% |
| ≥ 60 years old | 63 | 60.00% | 293 | 51.40% |
| *Gender:* | | | | |
| Male | 43 | 40.90% | 230 | 40.35% |
| Female | 62 | 59.10% | 340 | 59.65% |
| *Education level:* | | | | |
| Primary School | 44 | 41.90% | 390 | 68.42% |
| Secondary School | 21 | 20.00% | 164 | 28.77% |
| Technical School | 0 | - | 0 | - |
| Diploma | 36 | 34.28% | 16 | 2.81% |
| Undergraduate | 4 | 3.81% | 0 | - |
| Postgraduate or higher | 0 | - | 0 | - |
| Others (none) | 0 | - | 0 | - |

*Source: Authors' Own Source*

## Results and Discussion

### *Underlying Indicators of Smart Rural and Rural Resilience*

P1 village and P2 villages had perceived different smart rural indicators for its underlying indicators as shown in Table 4. "Access to education" (Mean=3.23), "Connectivity to the national grid" (Mean=3.20), "Information and Communication Technologies (ICT) services" (Mean=3.19), and "Businesses/industries improvement" (Mean=3.19) are the smart rural underlying indicators with higher mean scores for P1 village. Cooke (2006) stated the importance of education and infrastructure for rural development in Sarawak.

Meanwhile, P2 villages prioritised "ICT services" (Mean=3.33), "Sufficient budget for road construction" (Mean=3.32), and "Access to health facilities" (Mean=3.32) and "Sufficient mobile clinics visitation" (Mean=3.32). These indicators were probably chosen due to it being related to the common challenges in less developed rural parts of Sarawak. Wong (2012) pointed out that poor or non-existent roads served as a significant obstacle for rural development, as it restricts the rural communities from access to healthcare and economic opportunities. This shows that the underlying smart rural indicators perceived by P2 villages also reflects this rural categories' need for road and healthcare improvements as part of their rural development goals.


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**Table 4:** Smart rural underlying indicators.

| Dimensions | Indicators | Village categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | | | P2 | | |
| | | Mean | SD | Rank | Mean | SD | Rank |
| Economic | Sufficient budget allocated for road construction by the government or municipal | 2.89 | 1.48 | 35 | 3.32 | 1.42 | 2 |
| | Sufficient budget allocated for innovation programmes for smart rural development | 3.03 | 1.38 | 20 | 3.23 | 1.48 | 28 |
| | Availability of banking or financial infrastructures in the village (e.g.: ATMs) | 2.88 | 1.34 | 36 | 3.16 | 1.41 | 44 |
| | Access for employment in recent years | 3.17 | 1.40 | 5 | 3.25 | 1.48 | 21 |
| | High job availability within rural area | 2.86 | 1.39 | 39 | 3.17 | 1.46 | 40 |
| | Using social media to improve business | 2.98 | 1.43 | 27 | 3.27 | 1.49 | 15 |
| | Wide usage of online or mobile banking among rural residents | 3.13 | 1.41 | 10 | 3.31 | 1.44 | 8 |
| | Encouragement of entrepreneurship within rural community | 3.11 | 1.37 | 13 | 3.28 | 1.48 | 12 |
| | Income stability | 2.94 | 1.42 | 31 | 3.30 | 1.47 | 11 |
| | High employment rate of rural residents | 2.95 | 1.39 | 30 | 3.25 | 1.42 | 21 |
| | Business/industry improvement | 3.19 | 1.39 | 3 | 3.28 | 1.45 | 13 |
| Social | Sufficient books in the village library | 2.81 | 1.43 | 44 | 3.00 | 1.36 | 48 |
| | Efficient online database in the village library | 2.88 | 1.47 | 36 | 3.15 | 1.43 | 46 |
| | Active government participation in the village's development | 3.02 | 1.37 | 21 | 3.26 | 1.46 | 17 |
| | Digitalisation of governance | 2.91 | 1.40 | 32 | 3.05 | 1.42 | 47 |
| | Active public rural participation with government initiatives | 2.77 | 1.41 | 46 | 3.24 | 1.50 | 23 |
| | Access to education | 3.23 | 1.38 | 1 | 3.20 | 1.44 | 31 |
| | Access to health facilities | 3.15 | 1.45 | 9 | 3.32 | 1.46 | 3 |
| | Governance effectiveness | 2.88 | 1.39 | 36 | 3.16 | 1.46 | 43 |
| | Available ICT services in rural area | 3.19 | 1.53 | 3 | 3.33 | 1.49 | 1 |
| | Good quality ICT services in rural area | 3.12 | 1.31 | 11 | 3.25 | 1.43 | 19 |
| | Digitally empowered rural community | 3.09 | 1.47 | 15 | 3.21 | 1.48 | 30 |
| | High number of rural residents voting | 3.07 | 1.36 | 17 | 3.32 | 1.47 | 5 |
| | Low dependency ratio of rural area | 3.01 | 1.35 | 23 | 3.24 | 1.48 | 24 |
| Environmental | Having an emergency plan for natural disasters | 3.08 | 1.47 | 16 | 3.19 | 1.46 | 36 |

| Dimensions | Indicators | Village categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | | | P2 | | |
| | | Mean | SD | Rank | Mean | SD | Rank |
| | High number of trained people to conduct the emergency plan during natural disasters | 2.96 | 1.43 | 29 | 3.24 | 1.46 | 24 |
| | Efficient waste management (domestic waste and sewage) | 3.17 | 1.43 | 5 | 3.24 | 1.48 | 24 |
| | Efficient wildlife protection | 3.07 | 1.37 | 17 | 3.17 | 1.41 | 39 |
| | Early warning systems for drastic weather condition | 2.85 | 1.35 | 40 | 3.25 | 1.50 | 20 |
| | Usage of solar panels for personal use | 2.79 | 1.52 | 45 | 3.26 | 1.44 | 16 |
| | Having buildings that can withstand harsh weather conditions | 3.01 | 1.45 | 23 | 3.32 | 1.46 | 5 |
| **Technology** | Availability of communication infrastructures (e.g.: telco towers) | 3.02 | 1.50 | 21 | 3.30 | 1.46 | 10 |
| | Having domestic animals owned by rural community to be uniquely marked or having a tracking device | 2.72 | 1.34 | 47 | 3.20 | 1.50 | 31 |
| | Available internet access with high coverage | 3.04 | 1.43 | 19 | 3.18 | 1.49 | 38 |
| | Available multiple mobile networks (e.g.: Digi, Celcom, etc.) reception with cellular/voice/data coverage | 2.83 | 1.39 | 42 | 3.16 | 1.46 | 41 |
| | Availability of main road connecting to the village road | 3.17 | 1.41 | 5 | 3.27 | 1.44 | 14 |
| | Availability of public transport to the village | 2.85 | 1.47 | 40 | 3.18 | 1.41 | 37 |
| | Sufficient storage capacity of village's substation/energy grid (KWh) | 2.90 | 1.49 | 34 | 3.24 | 1.47 | 27 |
| | Wide usage of solar powered devices | 2.83 | 1.45 | 42 | 3.25 | 1.47 | 18 |
| | Using smart and digital equipment in agriculture production | 3.12 | 1.45 | 11 | 3.20 | 1.47 | 31 |
| | Efficient electricity meters | 3.10 | 1.39 | 14 | 3.19 | 1.45 | 35 |
| | Connectivity to the national grid | 3.20 | 1.49 | 2 | 3.21 | 1.45 | 29 |
| **Resources** | Reliable General Practitioner (GP) | 2.91 | 1.47 | 32 | 3.16 | 1.51 | 41 |
| | Sufficient mobile clinics visitations | 3.01 | 1.44 | 23 | 3.32 | 1.44 | 3 |
| | Access to fresh water | 3.17 | 1.40 | 5 | 3.19 | 1.43 | 34 |
| | Abundance in agricultural produce | 3.01 | 1.33 | 23 | 3.15 | 1.45 | 45 |
| | Large land area earmarked for multiple development | 2.72 | 1.47 | 47 | 3.30 | 1.46 | 9 |
| | Receiving higher educational level | 2.98 | 1.40 | 27 | 3.31 | 1.42 | 7 |

** Note: SD = Standard Deviation* *Source: Authors' Own Creation*

Table 5 shows the underlying rural resilience indicators perceived by P1 and P2 villages. P1 village perceived "Overcoming rural poverty"


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(Mean=3.23), "High community spirit" (Mean=3.21), "Economic diversity" (Mean=3.17) and "High forest coverage" (Mean=3.17) are the important underlying indicators to enhance rural resilience of their village. Bischoff et al. (2018) highlighted that cooperation and community support are vital for overcoming rural poverty and coping with the challenges of remote living.

Furthermore, having economic diversity is underlying indicator for enhancing rural resilience especially in terms of socioeconomic aspect. Past studies on Sarawak's rural areas showed that combining traditional economic activities such as farming, with other non-conventional economic activities such as tourism, handicraft, and small businesses might help rural communities handle economic changes (Denham et al., 2015).

For P2 villages, the rural resilience underlying indicators were "Quick recovery from extreme weather" (Mean=3.36), "Irrigation systems in farmlands" (Mean=3.34), and "Direct access to electricity" (Mean=3.34). Floods and other extreme weather conditions frequently disrupt agriculture and livelihoods in Sarawak (Abid et al., 2021). The underlying indicators perceived by P2 villages seem to focus on farming or agriculture as it is the main source of income for these villages, aside from the lack of basic infrastructures. This shows that villages in the P2 category need to explore other economic activities and not solely depend on farming to become more resilient

**Table 5:** Rural resilience underlying indicators.

| Dimension | Indicators | Village categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | | | P2 | | |
| | | Mean | SD | Rank | Mean | SD | Rank |
| Economic | Sufficient financial expenditure on employment in the village | 2.71 | 1.37 | 42 | 3.24 | 1.46 | 17 |
| | High savings rate | 3.05 | 1.49 | 19 | 3.32 | 1.48 | 5 |
| | Dependency on income | 2.93 | 1.38 | 33 | 3.23 | 1.48 | 19 |
| | Overcoming rural poverty | 3.23 | 1.43 | 1 | 3.21 | 1.42 | 25 |
| | Economic diversity | 3.17 | 1.41 | 3 | 3.18 | 1.49 | 34 |
| | Entrepreneurship in agriculture | 2.98 | 1.42 | 27 | 3.11 | 1.39 | 42 |
| | Income stability | 3.02 | 1.38 | 22 | 3.19 | 1.47 | 32 |
| | High employment rate | 2.94 | 1.42 | 32 | 3.26 | 1.47 | 11 |
| | Improvement in business or industry | 3.03 | 1.32 | 21 | 3.30 | 1.50 | 8 |
| Social | High community spirit | 3.21 | 1.43 | 2 | 3.30 | 1.44 | 7 |
| | Lower crime rate | 3.06 | 1.39 | 18 | 3.21 | 1.52 | 25 |
| | Sufficient public security | 3.12 | 1.35 | 11 | 3.12 | 1.43 | 40 |
| | High rural population | 3.12 | 1.39 | 11 | 3.23 | 1.39 | 20 |
| | Sufficient investment in social services from government | 3.00 | 1.47 | 25 | 3.21 | 1.53 | 28 |
| | Access to education | 3.05 | 1.49 | 19 | 3.16 | 1.40 | 36 |
| | Access to health facilities | 3.00 | 1.37 | 25 | 3.25 | 1.48 | 13 |
| | Governance effectiveness | 3.07 | 1.49 | 17 | 3.24 | 1.47 | 15 |

| Dimension | Indicators | Village categories | | | | | |
|---|---|---|---|---|---|---|---|
| | | P1 | | | P2 | | |
| | | Mean | SD | Rank | Mean | SD | Rank |
| | Low proportion of elderly population (> 65 years old) | 3.12 | 1.46 | 11 | 3.19 | 1.46 | 33 |
| | Sufficient voting residents | 2.73 | 1.32 | 41 | 3.24 | 1.49 | 16 |
| | Low dependency ratio | 3.15 | 1.38 | 5 | 3.11 | 1.37 | 41 |
| Environment | Efficient early warning systems for weather condition | 3.14 | 1.41 | 7 | 3.15 | 1.49 | 38 |
| | Quick recovery from extreme weather | 3.08 | 1.44 | 15 | 3.36 | 1.44 | 1 |
| | High forest coverage | 3.17 | 1.42 | 3 | 3.25 | 1.48 | 12 |
| | Awareness on changes | 2.95 | 1.41 | 31 | 3.14 | 1.40 | 39 |
| | Irrigation systems infarmlands | 3.15 | 1.47 | 5 | 3.34 | 1.41 | 2 |
| | Quick recovery of affected crops from extreme weather | 3.08 | 1.46 | 15 | 3.20 | 1.41 | 31 |
| | Sufficient usage of fertiliser or pesticides | 2.91 | 1.35 | 35 | 3.20 | 1.44 | 29 |
| Technology | Short commuting distance to nearest town | 3.14 | 1.34 | 7 | 3.29 | 1.48 | 9 |
| | Available internet access | 2.97 | 1.38 | 28 | 3.20 | 1.45 | 30 |
| | Rural household with digital devices | 3.02 | 1.43 | 22 | 3.16 | 1.52 | 37 |
| | Sufficient and efficient infrastructure development | 2.97 | 1.40 | 28 | 3.23 | 1.48 | 20 |
| | Access to public transport in the rural area | 2.96 | 1.50 | 30 | 3.28 | 1.49 | 10 |
| | Sufficient number of telephones per household | 2.88 | 1.42 | 37 | 3.24 | 1.45 | 17 |
| Resources | Food security | 3.14 | 1.37 | 7 | 3.22 | 1.48 | 23 |
| | Direct access to electricity | 2.77 | 1.38 | 39 | 3.34 | 1.41 | 3 |
| | Available vehicle for personal use | 2.90 | 1.49 | 36 | 3.22 | 1.47 | 22 |
| | Sufficient natural disaster relief expense per capita | 2.81 | 1.40 | 38 | 3.17 | 1.48 | 35 |
| | Sufficient power generation per capita | 2.75 | 1.40 | 40 | 3.24 | 1.41 | 14 |
| | High water resources per capita | 3.12 | 1.42 | 11 | 3.33 | 1.41 | 4 |
| | Access to fresh water | 3.13 | 1.41 | 10 | 3.22 | 1.47 | 24 |
| | Larger farmland area | 2.93 | 1.36 | 33 | 3.30 | 1.46 | 6 |
| | High housing supply | 3.01 | 1.41 | 24 | 3.21 | 1.47 | 25 |

** Note: SD = Standard Deviation* *Source: Authors' Own Creation*

### *Comparison of Mean Differences Between 2 Rural Areas*

Before running the independent sample T-test analysis, the skewness and kurtosis for all the indicators were checked for data distribution. Table 6 and 7 indicate the values of skewness and kurtosis are fall within the acceptable range, with skewness values between -1 and +1 and kurtosis values between -2 and +2 (Hair et al., 2027). Smart rural shows minimum and maximum skewness ranged from


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-0.304 to 0.002, while the minimum and maximum kurtosis ranged from -1.469 to -1.25. On the other hand, the skewness values for rural resilience ranges from -0.295 to -0.052, while the kurtosis values ranges from -1.448 to -1.211.

Tables 6 indicates the results of independent sample t-test of P1 and P2 rural areas on smart rural. There are significant differences between P1 and P2 rural area on smart rural mainly on economic (EC), environment (EV), technology (TG) and resources (RC) dimensions with 3 or more indicators exhibits differences. Only one indicator under the social (SC) dimension shows significantly difference between the rural areas. The indicators include "Sufficient budget allocated for road construction by the government or municipal" (EC) (t=-2.865, p=0.004), "High job availability" (EC) (t=-2.019, p=0.044), "Income stability" (EC) (t=-2.290, p=0.022), "Active public rural participation with government initiatives" (SC) (t=-2.980, p=0.003), "Early warning systems for drastic weather condition" (EV) (t=-2.738, p=0.007), "Usage of solar panels for personal use" (EV) (t=-3.062, p=0.002), "Buildings that can withstand harsh weather conditions" (EV) (t=-1.974, p=0.049), "Domestic animals to be uniquely marked or having a tracking device" (TG) (t=-3.258, p=0.001), "Available multiple mobile networks" (TG) (t=-2.187, p=0.029), "Availability of public transport" (TG) (t=-2.194, p=0.029), "Sufficient storage capacity of substation/energy grid (KWh)" (TG) (t=-2.196, p=0.028), "Wide usage of solar powered devices" (TG) (t=-2.656, p=0.008), "Sufficient mobile clinics visitations" (RC) (t=-2.013, p=0.044), "Large land area earmarked for multiple development" (RC) (t=-3.725, p<0.000) and "Receiving higher educational level" (RC) (t=-2.203, p=0.028).

Tables 7 indicates the results of independent sample t-test of P1 and P2 rural areas on rural resilience. There are significant differences between P1 and P2 rural area on smart rural mainly on economic (EC), technology (TG) and resources (RC) dimensions with 3 or more indicators exhibits differences. Only one indicator under the social (SC) dimension shows significantly difference between the rural areas. The rural communities from both rural areas demonstrate no difference for indicators under the environment dimension. Indicators that exhibit significantly difference with p-value less than 0.05 include "Sufficient financial expenditure on employment" (EC) (t=-3.395, p=0.001), "Dependency on income" (EC) (t=-2.021, p=0.045), "High employment rate" (EC) (t=-2.041, p=0.042), "Sufficient voting" (SC) (t=-3.536, p=0.001), "Access to public transport in the rural area" (TG) (t=-2.018, p=0.044), "Sufficient number of telephones per household" (TG) (t=-2.345, p=0.019), "Direct access to electricity" (RC) (t=-3.796, p<0.000), "Available vehicle for personal use" (RC) (t=-2.082, p=0.038), "Sufficient natural disaster relief expense per capita" (RC) (t=-2.302, p=0.022), "Sufficient power generation per capita" (RC) (t=-3.286, p=0.001) and "Large farmland area" (RC) (t=-2.520, p=0.013). The negative t-

test values demonstrate that the mean values of these indicators for P1 village are significantly lower than P2 villages.

**Table 6:** Independent sample t-test on smart rural.

| Dimensions | Indicators | Skewness | Kurtosis | t-value | p-value (2-tailed) |
|---|---|---|---|---|---|
| Economic | Sufficient budget allocated for road construction by the government or municipal | -0.227 | -1.293 | -2.865 | 0.004* |
| | Sufficient budget allocated for innovation programmes for smart rural development | -0.171 | -1.351 | -1.282 | 0.200 |
| | Availability of banking or financial infrastructures in the village (e.g.: ATMs) | -0.174 | -1.258 | -1.909 | 0.057 |
| | Access for employment in recent years | -0.228 | -1.348 | -0.477 | 0.633 |
| | High job availability within rural area | -0.068 | -1.355 | -2.019 | 0.044* |
| | Using social media to improve business | -0.218 | -1.348 | -1.853 | 0.064 |
| | Wide usage of online or mobile banking among rural residents | -0.247 | -1.293 | -1.136 | 0.256 |
| | Encouragement of entrepreneurship within rural community | -0.222 | -1.337 | -1.155 | 0.250 |
| | Income stability | -0.199 | -1.359 | -2.290 | 0.022* |
| | High employment rate of rural residents | -0.190 | -1.281 | -1.955 | 0.051 |
| | Business/industry improvement | -0.217 | -1.315 | -0.601 | 0.548 |
| Social | Sufficient books in the village library | 0.002 | -1.259 | -1.306 | 0.192 |
| | Efficient online database in the village library | -0.149 | -1.316 | -1.792 | 0.074 |
| | Active government participation in the village's development | -0.175 | -1.331 | -1.551 | 0.121 |
| | Digitalisation of governance | -0.048 | -1.320 | -0.931 | 0.352 |
| | Active public rural participation with government initiatives | -0.120 | -1.425 | -2.980 | 0.003* |
| | Access to education | -0.160 | -1.316 | 0.210 | 0.833 |
| | Access to health facilities | -0.230 | -1.332 | -1.069 | 0.286 |
| | Governance effectiveness | -0.091 | -1.347 | -1.851 | 0.065 |
| | Available ICT services in rural area | -0.304 | -1.333 | -0.878 | 0.380 |
| | Good quality ICT services in rural area | -0.253 | -1.250 | -0.886 | 0.377 |
| | Digitally empowered rural community | -0.190 | -1.362 | -0.786 | 0.432 |
| | High number of rural residents voting | -0.212 | -1.348 | -1.701 | 0.091 |
| | Low dependency ratio of rural area | -0.128 | -1.358 | -1.588 | 0.114 |
| Environment | Having an emergency plan for natural disasters | -0.152 | -1.339 | -0.707 | 0.480 |
| | High number of trained people to conduct the emergency plan during natural disasters | -0.192 | -1.344 | -1.805 | 0.072 |
| | Efficient waste management (domestic waste and sewage) | -0.165 | -1.377 | -0.441 | 0.659 |


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| Dimensions | Indicators | Skewness | Kurtosis | t-value | p-value (2-tailed) |
|---|---|---|---|---|---|
| | Efficient wildlife protection | -0.178 | -1.281 | -0.716 | 0.474 |
| | Early warning systems for drastic weather condition | -0.157 | -1.393 | -2.738 | 0.007* |
| | Usage of solar panels for personal use | -0.177 | -1.350 | -3.062 | 0.002* |
| | Having buildings that can withstand harsh weather conditions | -0.267 | -1.322 | -1.974 | 0.049* |
| **Technology** | Availability of communication infrastructures (e.g.: telco towers) | -0.243 | -1.316 | -1.809 | 0.071 |
| | Having domestic animals owned by rural community to be uniquely marked or having a tracking device | -0.116 | -1.374 | -3.258 | 0.001* |
| | Available internet access with high coverage | -0.151 | -1.381 | -0.874 | 0.383 |
| | Available multiple mobile networks (e.g.: Digi, Celcom, etc.) reception with cellular/voice/data coverage | -0.057 | -1.363 | -2.187 | 0.029* |
| | Availability of main road connecting to the village road | -0.201 | -1.303 | -0.671 | 0.502 |
| | Availability of public transport to the village | -0.167 | -1.299 | -2.194 | 0.029* |
| | Sufficient storage capacity of village's substation/energy grid (KWh) | -0.177 | -1.394 | -2.196 | 0.028* |
| | Wide usage of solar powered devices | -0.127 | -1.412 | -2.656 | 0.008* |
| | Using smart and digital equipment in agriculture production | -0.153 | -1.372 | -0.467 | 0.640 |
| | Efficient electricity meters | -0.245 | -1.298 | -0.542 | 0.588 |
| | Connectivity to the national grid | -0.186 | -1.334 | -0.080 | 0.937 |
| **Resources** | Reliable General Practitioner (GP) | -0.079 | -1.467 | -1.570 | 0.117 |
| | Sufficient mobile clinics visitations | -0.244 | -1.297 | -2.013 | 0.044* |
| | Access to fresh water | -0.235 | -1.268 | -0.143 | 0.887 |
| | Abundance in agricultural produce | -0.105 | -1.319 | -1.009 | 0.315 |
| | Large land area earmarked for multiple development | -0.197 | -1.374 | -3.725 | 0.000* |
| | Receiving higher educational level | -0.168 | -1.316 | -2.203 | 0.028* |

** Note: p-value = Significant level* *Source: Authors' Own Creation*

**Table 7:** Independent sample t-test on rural resilience.

| Dimensions | Indicators | Skewness | Kurtosis | t-value | p-value (2-tailed) |
|---|---|---|---|---|---|
| **Economic** | Sufficient financial expenditure on employment in the village | -0.110 | -1.356 | -3.395 | 0.001* |
| | High savings rate | -0.238 | -1.381 | -1.757 | 0.079 |
| | Dependency on income | -0.137 | -1.374 | -2.021 | 0.045* |
| | Overcoming rural poverty | -0.265 | -1.253 | 0.108 | 0.914 |
| | Economic diversity | -0.142 | -1.388 | -0.081 | 0.935 |
| | Entrepreneurship in agriculture | -0.118 | -1.266 | -0.889 | 0.374 |

| Dimensions | Indicators | Skewness | Kurtosis | t-value | p-value (2-tailed) |
|---|---|---|---|---|---|
| | Income stability | -0.143 | -1.330 | -1.103 | 0.271 |
| | High employment rate | -0.197 | -1.366 | -2.041 | 0.042* |
| | Improvement in business or industry | -0.210 | -1.372 | -1.870 | 0.063 |
| **Social** | High community spirit | -0.226 | -1.308 | -0.580 | 0.562 |
| | Lower crime rate | -0.156 | -1.429 | -1.038 | 0.301 |
| | Sufficient public security | -0.139 | -1.301 | 0.053 | 0.958 |
| | High rural population | -0.233 | -1.227 | -0.728 | 0.467 |
| | Sufficient investment in social services from government | -0.168 | -1.448 | -1.291 | 0.197 |
| | Access to education | -0.182 | -1.281 | -0.780 | 0.436 |
| | Access to health facilities | -0.191 | -1.358 | -1.711 | 0.089 |
| | Governance effectiveness | -0.218 | -1.363 | -1.120 | 0.263 |
| | Low proportion of elderly population (> 65 years old) | -0.156 | -1.366 | -0.400 | 0.689 |
| | Sufficient voting residents | -0.138 | -1.364 | -3.536 | 0.001* |
| | Low dependency ratio | -0.151 | -1.211 | 0.263 | 0.793 |
| **Environment** | Efficient early warning systems for weather condition | -0.140 | -1.369 | -0.051 | 0.959 |
| | Quick recovery from extreme weather | -0.295 | -1.268 | -1.843 | 0.066 |
| | High forest coverage | -0.259 | -1.332 | -0.531 | 0.595 |
| | Awareness on changes | -0.169 | -1.260 | -1.276 | 0.203 |
| | Irrigation systems infarmlands | -0.271 | -1.261 | -1.246 | 0.213 |
| | Quick recovery of affected crops from extreme weather | -0.207 | -1.307 | -0.798 | 0.425 |
| | Sufficient usage of fertiliser or pesticides | -0.128 | -1.294 | -1.890 | 0.059 |
| **Technology** | Short commuting distance to nearest town | -0.244 | -1.329 | -0.988 | 0.325 |
| | Available internet access | -0.141 | -1.336 | -1.484 | 0.138 |
| | Rural household with digital devices | -0.120 | -1.423 | -0.891 | 0.373 |
| | Sufficient and efficient infrastructure development | -0.161 | -1.376 | -1.669 | 0.096 |
| | Access to public transport in the rural area | -0.232 | -1.381 | -2.018 | 0.044* |
| | Sufficient number of telephones per household | -0.162 | -1.336 | -2.345 | 0.019* |
| **Resources** | Food security | -0.186 | -1.334 | -0.492 | 0.623 |
| | Direct access to electricity | -0.208 | -1.283 | -3.796 | 0.000* |
| | Available vehicle for personal use | -0.154 | -1.374 | -2.082 | 0.038* |
| | Sufficient natural disaster relief expense per capita | -0.052 | -1.392 | -2.302 | 0.022* |
| | Sufficient power generation per capita | -0.201 | -1.265 | -3.286 | 0.001* |
| | High water resources per capita | -0.284 | -1.243 | -1.394 | 0.164 |
| | Access to fresh water | -0.175 | -1.349 | -0.530 | 0.596 |
| | Larger farmland area | -0.203 | -1.327 | -2.520 | 0.013* |
| | High housing supply | -0.135 | -1.347 | -1.308 | 0.191 |

** Note: p-value = Significant level* *Source: Authors' Own Creation*


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## CONCLUSION

The findings show that the different rural development advancements levels between Pedalaman 1 (P1) and Pedalaman 2 (P2) in Sarawak was reflected in the perceived underlying indicators. The underlying indicators perceived by P1 village community reflect its advanced development, compared to P2 villages that the perceived underlying indicators are related to agriculture and basic infrastructures. This shows that the differences in rural categories affect the underlying indicators in the context of smart rural and rural resilience.

The implications of this study provide insight to the relevant government agencies in strategizing appropriate initiatives in implementing rural development policies. For example, to improve smart and rural resilience of P2-category villages, rural development initiatives should be focused on improving accessibility through ICT and new technologies, agriculture practices and technologies, improving social and physical infrastructure and improving the accessibility and facilities of rural health facilities. On the other hand, smart and rural resilience of P1-category villages can be enhanced by prioritising initiatives focus on improving accessibility through ICT and new technologies, intensify and diversity rural economy, strengthening community cohesion, forest conservation and improving educational access and facilities. The academic implication of this study includes the contribution towards identifying the smart rural and rural resilience underlying indicators in different rural categories in Sarawak.

Moreover, future studies can consider other rural categories in Sarawak such as the Pedalaman 3 (P3) category since this study only include the P1 and P2 categories. Besides, future studies may need to include more villages in the P1 category for a more comprehensive finding as this study only include one village in this category.

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# GOVERNMENT INTERVENTIONS AND HOUSING PRICES: CAN POLICIES STABILIZE MALAYSIA'S RESIDENTIAL PROPERTY MARKET?

**Nur Hafizah Ismail[1], Sr. Rosliza Ramli[2], Mohd Zaini Abd Karim[3], Mahyudin Ahmad[4]**

[1]*Economic and Financial Policy Institute (ECOFI),*
*School of Economics, Finance and Banking,*
UNIVERSITI UTARA MALAYSIA
[2]*Institut Penilaian Negara (INSPEN), Jabatan Penilaian dan Perkhidmatan Harta,*
KEMENTERIAN KEWANGAN MALAYSIA
[3]*School of Economics, Finance and Banking,*
UNIVERSITI UTARA MALAYSIA
[4]*Faculty of Business and Management,*
UNIVERSITI TEKNOLOGI MARA CAWANGAN PERLIS
[4]*Finance and Economics Research Society SIG,*
UNIVERSITI TEKNOLOGI MARA CAWANGAN PERLIS

## Abstract

Malaysia's residential property market faces a long-standing affordability problem because house prices have risen faster than household incomes. Government housing programmes are the main policy response, but there is little evidence on whether they significantly affect market prices. This study examines how government housing intervention and state economic conditions affect residential property prices across all 13 Malaysian states and the Federal Territory of Kuala Lumpur, using a balanced panel of 14 units observed annually from 2010 to 2022. In this study, government intervention is measured by the number of completed Program Perumahan Rakyat (PPR) units. The model is estimated using fixed effects with year effects and Driscoll-Kraay standard errors. Two findings emerge. First, state economic conditions are associated with house prices in the expected directions: a one per cent larger population is associated with a house price index about 1.55 points higher and a one per cent higher income per capita with about 0.22 points higher. Second, government housing policy is positively and significantly associated with the price index, with a coefficient of 10.926 and a Driscoll-Kraay standard error of 3.009, significant at the 1% level. This association is not uniform: once the government policy variable is interacted with state economic conditions, all three interaction terms are significant, indicating that the relationship between public housing provision and house prices varies with a state's income level, population size and labour-market conditions. For planning practice, these results imply that targeted affordable housing program should be assessed using sub-market affordability, access and delivery indicators rather than an aggregate state house price index, which covers all market segments.

***Keywords***: Housing prices, government interventions, macroeconomic factors, panel data, Malaysia

[1] Corresponding author. Email: hafizah19@live.com

## INTRODUCTION

The real estate market plays a crucial role in Malaysia's economic development within the residential property sector. Over recent years, various studies have reported growing concerns about the affordability and accessibility of housing for the Malaysian population (Daud et al., 2022; Hassan, Ahmad & Hashim, 2021; Liu & Ong, 2021; Musaddad, Maamor & Zainol, 2023; Yap & Ng, 2018). One of the most pressing issues is the mismatch between housing supply and demand in urban areas where property prices have escalated rapidly (Kamal, Lai & Yusof, 2020; Olanrewaju & Idrus, 2020; Tobi, Jasimin & Rani, 2020). Residential properties in high-demand locations have become increasingly out of reach for many, leading to concerns about housing affordability for low- and middle-income households.

Previous reports have highlighted several challenges related to the residential property market in Malaysia, including an oversupply of high-end properties, an increasing number of unsold homes, and a rising property overhang in Kuala Lumpur and other cities (Khazanah Research Institute, 2019; NAPIC, 2024). The growing gap between house prices and household income further worsens these issues, making it difficult for first-time homebuyers to enter the market. Additionally, rapid urbanization and population growth have increased the pressure on housing demand, leading to further inflation in property prices.

Given these challenges, government intervention is essential to address market inefficiencies and ensure the availability of affordable housing. Policy tools such as the introduction of housing affordability schemes have proven to be critical in mitigating price volatility and ensuring that housing remains accessible to the broader population. Government initiatives like Program Perumahan Rakyat (PPR), Perumahan Penjawat Awam 1 Malaysia (PR1MA), Perumahan Mesra Rakyat (PMR) and Program Kediaman SPNB are examples of interventions designed to promote homeownership among lower and middle-income groups (KPKT, 2022). However, the effectiveness of these programs in impacting house prices is often debated, and whether continuous adjustments in government interventions are necessary to respond to evolving market conditions and demographic shifts remains a key concern.

Program Perumahan Rakyat (PPR) is a government initiative through the Ministry of Local Government Development (KPKT) to provide comfortable, safe, and affordable housing for low-income groups in Malaysia, consisting of two distinct categories. The rented PPR programme was introduced in February 2002, aimed at being rented out to target groups, especially for low-income households and squatter communities, at a rate of RM124.00 per month, allowing families to temporarily secure housing while building financial capacity for homeownership. The Government is also implementing the owned PPR, which aims to enable lower income earners to have their own homes, with selling prices


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between RM35,000 and RM42,000 per unit depending on location (National Housing Department, 2022).

Review of past studies indicates that the topic of housing issues and macroeconomic factors has become one of the leading issues explored by researchers worldwide and in Malaysia. Those studies found that macroeconomic factors such as money supply, bank lending rate, gross domestic product, inflation, and stock market have a significant effect on residential property prices. This shows that macroeconomic factors have a significant contribution to the rising trend in the property market (Mohan et al., 2019; Tripathi, 2019; Leung & Ng, 2019; Maynou et al., 2021; Plakandaras et al., 2020). In Malaysia, many studies have examined the relationship between macroeconomic factors and housing prices (Pinjaman & Kogid, 2020; Baharuddin, Isa & Zahari, 2019; Camara, 2023; Zulkifli, Pinjaman & Malin, 2022). However, these studies focused only on national-level causal relationships between macroeconomic variables and house prices, without examining the role of government intervention in Malaysia's real estate market. Existing studies on government intervention through housing affordability programmes with respect to property prices remain scarce (Hashim, 2010).

Therefore, it is pertinent to study how sensitive Malaysia's housing market is to government interventions and macroeconomic factors. This study explores the relationship between government housing policies and macroeconomic factors to better understand the effects of these elements on property prices across Malaysian states. The role of government policies in regulating housing prices and stabilizing the real estate market in response to macroeconomic shifts, is critical in ensuring balanced market growth. This study contributes to new knowledge by not only assessing the impact at the national level but also conducting a state-level evaluation, providing deeper insights into state disparities in Malaysia's residential property market. Hence, it is essential to investigate how government interventions and macroeconomic factors shape Malaysia's real estate market within the residential property sector. The analysis covers all 13 Malaysian states, including Sabah and Sarawak, together with the Federal Territory of Kuala Lumpur, giving 14 cross-sectional units observed annually from 2010 to 2022.

## LITERATURE REVIEW

Government housing interventions represent a critical policy path for addressing market inefficiencies and affordability challenges. Hashim (2010) notes that research specifically examining the relationship between government housing affordability programmes and property prices remains scarce, pointing to a significant gap in the empirical literature. Recent evidence by Liu and Ong (2021) demonstrates that Malaysia's existing government housing scheme including the

Program Perumahan Rakyat (PPR), Perumahan Penjawat Awam 1 Malaysia (PR1MA), and rent-to-own arrangements, have proven insufficient in adequately addressing the escalating demand for affordable housing. These programmes face substantial implementation challenges such as bureaucratic delays, limited supply relative to demand, and restrictive eligibility criteria that constrain their effectiveness. Understanding how this policy interventions interact with macroeconomic conditions to influence housing price movements is therefore essential for developing more targeted and effective housing policy strategies that can stabilize Malaysia's residential property market while promoting both affordability and accessibility.

Previous studies have also highlighted that the effectiveness of government interventions may vary considerably across geographical contexts. For example, Cheong, Ngui and Beatrice (2020) found that while targeted affordability programmes like the PPR scheme aim to improve housing accessibility, they may unintentionally increase overall market prices through indirect market effects. This observation is relevant in the Malaysian context, where significant spatial disparities exist across states. Urban states such as Selangor, Kuala Lumpur and Johor exhibit markedly different housing market dynamics compared to less urbanized states in the north and east of Peninsular Malaysia (Kamal et al., 2020; Olanrewaju & Idrus, 2020). These geographical variations present the need for state-level analysis rather than national-level aggregation, as uniform national housing policies may produce heterogeneous outcomes across states with different levels of urbanization, income profiles and housing demand pressures. From a spatial planning perspective, understanding these state-level disparities is critical for designing land use policies and regional development strategies that are sensitive to local market conditions (Liu et al., 2024; Reiner & Musil, 2023).

Based on the discussion above, it is hypothesized that:
*H1: Government housing interventions have a significant effect on residential property prices.*

The empirical relationship between macroeconomic variables and housing prices has been extensively documented in academic literature. A substantial body of research demonstrates that macroeconomic indicators such as gross domestic product (GDP), money supply, inflation rates, and lending rates exert significant influence on residential property prices both in the short and long term. Internationally, Mohan et al. (2019), Tripathi (2019), Leung and Ng (2019), and Maynou et al. (2021) provide evidence that macroeconomic factors are critical determinants of property market dynamics. In the Malaysian context specifically, numerous studies have examined the causal relationships between


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macroeconomic variables and housing prices, including those by Pinjaman and Kogid (2020), Baharuddin, Isa and Zahari (2019), and Zulkifli, Pinjaman and Malin (2022). These studies collectively suggest that macroeconomic fluctuations create significant effects throughout the residential property sector, affecting affordability and market accessibility across different income groups.

Population growth and demographic pressure are consistently identified as among the most robust drivers of housing price appreciation. Rapid urbanization concentrates demand in specific geographic corridors, creating upward price pressure in urban and peri-urban areas and contributing to affordability stress for low- and middle-income households (Jun, Song & Selvaratnam, 2025; Ong, 2013). Similarly, exchange rate movements have been shown to influence housing prices through their effects on construction costs, foreign investment flows, and broader macroeconomic conditions (Pinjaman & Kogid, 2020). These findings carry significant implications for planning policy: spatial planning frameworks that fail to account for population distribution and global economic exposure risk worsening housing affordability challenges at the state level.

Based on the discussion above, it is hypothesized that:
*H2: Macroeconomic factors have a significant effect on residential property prices.*

## METHODOLOGY

### Variable Choices

This study aims to determine how government housing policy and macroeconomic factors affect residential property prices across 13 Malaysian states, including Sabah and Sarawak, together with the Federal Territory of Kuala Lumpur. The coverage is therefore national rather than confined to Peninsular Malaysia which has not been examined before in this context. To achieve this objective, this study identifies variables that can proxy for government housing policies, as well as the established macroeconomic factors previously shown in the literature to have significant influence housing prices in Malaysia (see studies by Jun, Song & Selvaratnam, 2025; Ong, 2013; and Pinjaman & Kogid, 2020). Thus, the selected variables capture three key areas namely government policy interventions, demand-side macroeconomic factors (such as GDP, population growth, and unemployment), and capital cost factors (like base lending rate and consumer price inflation, and exchange rate). The dependent variable is the Malaysian House Price Index (MHPI) for each state, published by the National Property Information Centre (NAPIC). State economic conditions are captured by three variables: gross domestic product per capita, population, and the unemployment rate, all measured at state level and obtained from the Department

of Statistics Malaysia. In contrast, the base lending rate, the consumer price index and the exchange rate, are national aggregate series

This study examined every annual statistics report published by the Ministry of Housing and Local Government (KPKT) from 2010 to 2022 in order to build a consistent measure of the policy portfolio. However, PR1MA, PPA1M, the SPNB residential programme and Rumah Mesra Rakyat do not appear in any KPKT statistics report before 2020. They appear for the first time in the 2020 edition, and only as cumulative totals to that date, with no annual breakdown. PPA1M is then dropped from the 2022 edition altogether. State-level schemes such as Rumah Selangorku, and rent-to-own arrangements, cannot be used either. State schemes are not compiled in national statistics on a comparable basis, and a scheme operating in a single state cannot be separated from that state's own time path in a fixed-effects model. Meanwhile rent-to-own is a financing and tenure mechanism rather than a supply intervention. It adds no units to the housing stock, and take-up is recorded by participating institutions rather than published by state and year.

Therefore, Program Perumahan Rakyat (PPR) is used as the primary measure of government housing intervention. PPR is selected as the proxy variable for several reasons. First, it is the flagship and longest-running government housing programme in Malaysia, with the widest spatial distribution across all Malaysia states, making it the most appropriate programme for state-level panel analysis. Second, unlike PR1MA and other affordability programmes, consistent state-level data on PPR completed units is available throughout the study period (2010–2022), ensuring balanced panel data. Third, PPR is explicitly targeted at the lowest income group which the households most affected by housing affordability, making it the most direct policy instrument for studying government intervention in the housing market. Fourth, the use of PPR as a proxy for government intervention is consistent with prior literature, including Hashim (2010) and Liu and Ong (2021), who identify PPR as the primary instrument of government housing intervention in Malaysia. Cheong, Ngui and Beatrice (2020) further highlight an important policy trade-off while targeted affordability programmes like the PPR scheme aim to improve housing accessibility, they may unintentionally increase overall market prices through indirect market effects.

**Data and Model Specification**

This study employs balanced panel data consisting of 13 Malaysian states and the Federal Territory of Kuala Lumpur observed over 13 years from 2010 to 2022, yielding 182 observations. The following regression model is proposed:

$$hpi_{it} = \alpha_i + \lambda_t + \beta_1 lngovpol_{it} + \beta_2 lngdppc_{it} + \beta_3 lnpop_{it} + \beta_4 unemp_{it} + \beta_5 blr_{it} + \beta_6 cpi_{it} + \beta_7 exrate_{it} + \gamma MP_{it} + + \varepsilon_{it}$$


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Where $\alpha_{\mathrm{i}}$ denotes state fixed effects and $\lambda_{\mathrm{t}}$ denotes year fixed effects. $hpi_{\mathrm{it}}$ is the housing price index for state $i$ at time $t$ and $lngovpol$ is the government policy variable measured via the number of completed Program Perumahan Rakyat (PPR) units in each state and year. Meanwhile, three variables for the demand-side macroeconomic factors are $lngdppc$ capturing the gross domestic product per capita, $lnpop$ is the population, and $unemp$ is the unemployment rate for each state. For capital cost factors, $blr$, $cpi$, and $exrate$ are included as control variables to capture base lending rate, consumer price index, and exchange rate, respectively. $MP$ is the vector of three interaction terms where the interaction variables were generated as $(lngdppc \times lngovpol)$ , $(lnpop \times lngovpol)$ and $(unemp \times lngovpol)$. $\varepsilon_{\mathrm{it}}$ is the error term. Six models are estimated where Models 1 to 3 add the policy variable and then the interactions to the state economic variables. Models 4 to 6 repeat these three specifications with the control variables added. All six models are estimated in levels rather than in first differences. The dependent variable is the state house price index measured in index points. The government policy, gross domestic product per capita and population variables are measured in natural logarithms, while the unemployment rate is measured in percentage points. The level specification is retained because the study is concerned with the long-run relationship between affordable housing provision, state economic conditions and house prices. First differencing would remove this long-run information and would instead measure short-run year-to-year changes, which does not correspond to the objective of this study.

**Preliminary Diagnostic Tests**

Given the panel nature of the data and the potential presence of unobserved heterogeneity across states, multiple diagnostic tests were conducted prior to model estimation including the Multicollinearity Test, the Pesaran Cross-Sectional Dependence (CSD) Test and the Model Selection Test.

## RESULTS OF TESTS AND ESTIMATION

This section presents and discusses the diagnostic tests, and estimated regression results. The presence of multicollinearity among the independent variables was assessed using the Variance Inflation Factor (VIF), the results of which are reported in Table 1.

**Table 1:** Multicollinearity Test

| Variable | VIF | 1/VIF |
|---|---|---|
| Government Housing Policy (lnGOVPL) | 2.26 | 0.442409 |
| GDP per capita (lnGDPPC) | 1.48 | 0.674600 |
| Population (lnPOP) | 1.28 | 0.779471 |
| Unemployment Rate (UNEMP) | 1.68 | 0.595618 |
| Base Lending Rate (BLR) | 1.36 | 0.734831 |
| Consumer Price Index (CPI) | 7.43 | 0.134643 |
| Exchange Rate (EXRATE) | 7.03 | 0.142306 |
| Mean VIF | 3.22 | |

*Note: VIF > 5 for Consumer Price Index and Exchange Rate indicate a moderate collinearity for these variables; however, both remain below the conservative threshold of 10 (Hair et al., 2010).*

Based on the Table 1 above, the theoretical importance of CPI and exchange rate in housing price determination is well-established in the literature and both are national data series that trend upward over the sample period, so they move together almost mechanically. Thus, their exclusion would risk omitted variable bias. The Driscoll-Kraay robust standard errors applied in the final model is expected to further mitigate the influence of collinearity on statistical inference. The mean VIF of 3.22 confirms that multicollinearity is not a systemic concern across the model.

**Table 2:** Panel Unit Root Test (Im-Pesaran-Shin W-statistic)

| Variable | Level W-stat | p-value | Decision | 1st Diff W-stat | p-value |
|---|---|---|---|---|---|
| Housing Price Index (HPI) | 2.982 | 0.999 | *I*(1) | -3.002 | 0.001*** |
| lnGOVPL | 3.028 | 0.999 | *I*(1) | -3.484 | 0.000*** |
| lnGDPPC | 4.010 | 1.000 | *I*(1) | -2.873 | 0.002*** |
| lnPOP | 6.552 | 1.000 | *I*(1) | -3.387 | 0.000*** |
| UNEMP | -0.287 | 0.393 | *I*(1) | -9.820 | 0.000*** |
| BLR | 7.860 | 1.000 | *I*(1) | -3.681 | 0.000*** |
| CPI | 3.685 | 1.000 | *I*(1) | -2.984 | 0.001*** |
| EXRATE | 4.261 | 1.000 | *I*(1) | -2.133 | 0.016** |

**Note: H0: All panels contain a unit root. W-statistic follows standard normal N(0,1) under H0. Level tests use intercept and trend; first-difference tests use intercept only. All variables are I(1), non-stationary in levels but stationary in first differences.*


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The IPS unit root test results in Table 2 above confirm that all variables are non-stationary in levels but become stationary after first differencing, indicating that all series are integrated of order one, *I*(1). This finding is important because when all variables share the same order of integration, long-run cointegrating relationships may exist between them. The use of a fixed effects estimator with Driscoll-Kraay standard errors, which is explicitly robust to serial correlation and heteroskedasticity, both of which are common features of *I*(1) processes, therefore appropriate for estimating the long-run relationship between housing prices and the explanatory variables.

Two qualifications apply to this result. First, the panel has a short time dimension of only 13 annual observations per state. The Im-Pesaran-Shin test is designed for panels with a relatively large time dimension, so at T = 13 it has limited power to detect unit roots. The *I*(1) classifications in Table 2 are therefore better read as evidence that the series are trending than as strong evidence of unit roots and they do not on their own require the model to be estimated in first differences. Second, panel cointegration tests such as Pedroni (1999) and Westerlund (2007) likewise require a longer time dimension than the 13 annual observations available here, and their reliability at this sample length would be limited.

The trending nature of the data is consequently addressed through the design of the model rather than through a cointegration test. Year fixed effects captured common trends and common shocks over time, state fixed effects control for permanent differences across states, and Driscoll-Kraay standard errors computed with a maximum lag of 2 remain valid in the presence of serial correlation, heteroskedasticity and cross-sectional dependence. This combination is the reason a two-way fixed-effects estimator with Driscoll-Kraay standard errors is considered sufficient for the panel used in this study.

**Table 3:** Pesaran Cross-Sectional Dependence Test

| Variable | CD-Test | p-value | Mean $\rho$ | Mean abs($\rho$) |
|---|---|---|---|---|
| HPI | 20.773 | 0.000 | 0.60 | 0.64 |
| lnGOVPOL | 28.472 | 0.000 | 0.95 | 0.95 |
| lnGDPPC | 27.424 | 0.000 | 0.80 | 0.83 |
| lnPOP | 23.349 | 0.000 | 0.68 | 0.71 |
| UNEMP | 15.172 | 0.000 | 0.44 | 0.47 |
| BLR | 34.395 | 0.000 | 1.00 | 1.00 |
| CPI | 34.395 | 0.000 | 1.00 | 1.00 |
| EXRATE | 34.395 | 0.000 | 1.00 | 1.00 |

*Note: All variables are significant at the 1% level with p-value of 0.000, confirming cross-sectional dependence across states.*

The Pesaran CSD test results in Table 3 above indicate statistically significant cross-sectional dependence across all variables at the 1% significance level, confirming highly dependent and interconnected housing market conditions across Malaysian states. This finding is important in the Malaysian context, where housing markets in urban states like Kuala Lumpur and Selangor are likely to influence neighbouring states through price spillovers. This is in line with Lean and Smyth (2013) that found evidence of price spillovers from the most developed states to less developed ones. Similarly, Fereidouni et al. (2016) also showed the existence of price spillover effects from Malaysia's major economic regions such as Kuala Lumpur, Selangor, Pulau Pinang, and Johor onto the neighbouring housing markets.

The mean correlation reported in Table 3 reaches 1.00 for the base lending rate, the consumer price index and the exchange rate because these are national data series that take the same value in every state in a given year, so their cross-state correlation is mechanical rather than behavioural. This pattern is precisely why a two-way fixed-effects specification is adopted. Year fixed effects absorb the common time-varying component that generates this dependence, while Driscoll-Kraay standard errors account for the remaining cross-sectional dependence, heteroskedasticity and serial correlation in the residuals.

**Table 4:** Model Selection Test

| | **Statistics** | **p-value** | **Decision** |
|---|---|---|---|
| Poolability test (FE vs POLS) | F(13, 131) = 2.93 | 0.0009 | Rejects POLS at 1% |
| Hausman test (FE vs RE) | $\chi^2(16) = 19.11$ | 0.2629 | Does not reject RE |
| Breusch–Pagan LM test (RE vs POLS) | $\text{chibar}^2(01) = 2.02$ | 0.0777 | Rejects POLS at 10% only |
| Joint test - year effects | F(9, 131) = 12.41 | 0.0000 | Year effects required |

The Poolability test in Table 4 above provides stronger evidence against the pooled specification. The FE estimation produces an F-test of 2.93 with a p-value of 0.0009 for the null hypothesis that all state-specific effects are zero. The null is rejected at the 1% level, indicating the presence of statistically significant state-specific heterogeneity. This reflects geographic characteristics, local housing policies, and regional economic structures, and heterogeneity is also of direct relevance to spatial planning practitioners and policymakers operating at the state level. This is in line with some studies done by Suh (2023) and Liu et al. (2024). For example, Suh (2023) found that regional housing cycles differ substantially due to idiosyncratic regional shocks, and argues explicitly that


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uniform national policies are inadequate, hence, stabilization tools such as property tax and housing policy are needed to address the heterogeneity.

Besides that, the result detects significant time effects. The joint test of the year dummy variables produces an F-statistic of 12.41 with a p-value of 0.0000, rejecting the null hypothesis that the year effects are jointly zero. Accordingly, year fixed effects are included in all principal specifications to control for common time shocks affecting the Malaysian housing market. Taken together, the diagnostic evidence supports the use of a two-way fixed-effects with state and year effects, while the presence of cross-sectional dependence motivates the use of Driscoll–Kraay standard errors for statistical inference.

Table 4 also reports a Hausman test comparing fixed and random effects, which returns a chi-square statistic of 19.11 with 16 degrees of freedom and a p-value of 0.2629 and therefore does not reject the random-effects specification. The fixed-effects estimator is nonetheless retained for three reasons. A failure to reject is not positive evidence that the state effects are uncorrelated with the regressors in a panel with only 13 time periods in which the test has low power. The poolability test already confirms that state-specific effects are jointly significant at the 1% level. Finally, the fixed-effects estimator remains consistent whether or not the orthogonality condition required by random effects holds, and it is the specification under which Driscoll-Kraay standard errors are applied here.

**Table 5:** Fixed Effects Estimation with Driscoll–Kraay Standard Errors

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| lnGOVPOL | | 10.926*** | −25.154 |
| | | (3.009) | (33.380) |
| lnGDPPC | 21.396* | 22.145** | 77.223** |
| | (11.006) | (8.470) | (28.334) |
| lnPOP | 154.692* | 155.360** | 14.191 |
| | (72.216) | (67.468) | (32.145) |
| UNEMP | −4.424* | −3.610 | 42.467*** |
| | (2.144) | (2.952) | (11.246) |
| MP1 (lnGOVPOL × lnGDPPC) | | | −7.888** |
| | | | (3.371) |
| MP2 (lnGOVPOL × lnPOP) | | | 9.892** |
| | | | (4.208) |
| MP3 (lnGOVPOL × UNEMP) | | | −5.378*** |

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| | | | (1.489) |
| Constant | −1028.568* | −1133.608** | −370.660 |
| | (527.961) | (505.114) | (279.662) |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 182 | 161 | 161 |
| Number of states | 14 | 14 | 14 |
| Within $R^2$ | 0.5346 | 0.5497 | 0.5912 |

*Note: Within $R^2$ measures the proportion of within-state variation in the house price index explained by the model. Driscoll–Kraay standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Maximum lag = 2. Dependent variable: house price index.*

Based on the Table 5 above, Model 1 is significant overall, with an F-statistic of 114.80 ($p < 0.001$). All three signs are as expected where higher income raises the ability of households to buy, population concentration and migration towards economically attractive states increase demand where supply does not adjust quickly, and a weaker labour market reduces household purchasing power and effective demand. Overall, Model 1 shows that housing prices are closely associated with the economic and demographic conditions of Malaysian states.

Model 2 extends the baseline specification by incorporating the housing-policy variable. The inclusion of housing policy increases the within R-squared from 0.5346 to 0.5497, suggesting that housing policy contributes additional explanatory power beyond the macroeconomic variables. The positive policy coefficient should, however, be interpreted as an association rather than evidence that housing policy causes prices to rise, since programmes may be introduced or expanded in response to market conditions, which raises the possibility of reverse causality. Nevertheless, the statistically significant positive coefficient indicates that housing-policy measures are systematically associated with housing-price movements across Malaysian states. The coefficient on lnGOVPOL is 10.926 with a Driscoll-Kraay standard error of 3.009 and is significant at the 1% level (Model 2). The policy series is constructed from every Ministry of Housing and Local Government (KPKT) annual statistics report from 2010 to 2022, giving a consistent series for all 14 units.

Three interaction terms are introduced in Model 3 to investigate whether housing policy changes the relationship between macroeconomic conditions and housing prices. Model 3 produces a within R-squared of 0.5912, compared with Model 1 and Model 2. The increase in explanatory power indicates that allowing the effects of macroeconomic conditions to vary with


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government housing policy provides a better representation of the observed within-state variation in housing prices. All three interactions are significant. This indicates that housing policy does not operate independently of macroeconomic conditions. Instead, its association with housing prices varies according to the underlying economic and demographic environment. The significant interaction terms therefore provide evidence against a simple assumption that housing policy has a uniform effect across states and over time. Because each marginal effect depends on the value of the other variables, these coefficients cannot be interpreted in isolation.

**Table 6:** Estimation with Control Variables

| Variable | Model 4 | Model 5 | Model 6 |
|---|---|---|---|
| lnGOVPOL | | 10.926*** | −25.154 |
| | | (3.009) | (33.380) |
| lnGDPPC | 21.396* | 22.145** | 77.223** |
| | (11.006) | (8.470) | (28.334) |
| lnPOP | 154.692* | 155.360** | 14.191 |
| | (72.216) | (67.468) | (32.145) |
| UNEMP | −4.424* | −3.610 | 42.467*** |
| | (2.144) | (2.952) | (11.246) |
| MP1 (lnGOVPOL × lnGDPPC) | | | −7.888** |
| | | | (3.371) |
| MP2 (lnGOVPOL × lnPOP) | | | 9.892** |
| | | | (4.208) |
| MP3 (lnGOVPOL × UNEMP) | | | −5.378*** |
| | | | (1.489) |
| BLR | −132.891* | −140.417** | −56.115* |
| | (62.237) | (57.585) | (30.069) |
| CPI | −2.285 | −2.883* | −0.328 |
| | (1.536) | (1.589) | (1.010) |
| EXRATE | omitted | omitted | omitted |
| 2022 year dummy | omitted | omitted | omitted |
| Constant | omitted | omitted | omitted |
| Year fixed effects | Yes | Yes | Yes |

| Variable | Model 4 | Model 5 | Model 6 |
|---|---|---|---|
| Observations | 182 | 161 | 161 |
| Number of states | 14 | 14 | 14 |
| Within $R^2$ | 0.5346 | 0.5497 | 0.5912 |

*Note: Driscoll–Kraay standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. The exchange rate is omitted because of collinearity.*

The within $R^2$ values are identical across the paired specifications: Model 1 and Model 4 both give 0.5346, Model 2 and Model 5 both give 0.5497, and Model 3 and Model 6 both give 0.5912. The explanation lies in the nature of the three control variables. The base lending rate, the consumer price index and the exchange rate are national data series, thus, every state records the same value in a given year. A full set of year dummies already captures everything that varies over time but not across states, which means these three variables lie entirely within the space spanned by the year dummies. Adding them therefore cannot change the fit of the model.

A direct consequence is that the base lending rate, the consumer price index and the exchange rate are not separately identified once year fixed effects are included. The estimator drops the exchange rate, the 2022-year dummy and the constant because of exact collinearity and the surviving coefficients on the base lending rate and the consumer price index should therefore not be interpreted as separately identified macro-financial effects. Common national macro-financial conditions are instead controlled for through the year fixed effects themselves. This also serves as the robustness check on the moderate collinearity reported in Table 1 where the coefficients of interest on government housing policy and the state economic variables are unchanged whether the three national controls are included or excluded, which shows that the collinearity between the consumer price index and the exchange rate does not affect the main findings of the study.

## DISCUSSION OF THE MAIN FINDINGS

The results in Table 5 reveal three key findings. First, government policy is statistically significant in explaining housing-price movements. Second, housing prices across Malaysian states are strongly associated with macroeconomic and demographic conditions. Third, the interaction results indicate that government policy modifies the relationship between macroeconomic conditions and housing prices.

The coefficient on government policy is positive, and this does not support a supply-and-demand expectation in which public housing lowers market prices. Diamond and McQuade (2019) found that subsidised development raises


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house prices by 6.5 per cent in low-income neighbourhoods while lowering them by 2.5 per cent in higher-income ones. Similarly, Baum-Snow and Marion (2009) report the same pattern where a neighbourhood was already in decline, building subsidised housing raised nearby property values. The possible explanations are as follows: (1) affordable housing program may be located where prices are already rising, thus the relationship reflects where government chooses to build rather than what building does; (2) affordable housing is usually accompanied by roads, utilities, schools and public transport, and these may raise the value of surrounding property; and (3) the units delivered may be too few relative to total stock to move an aggregate index. In Malaysia context, Liu and Ong (2021) report that 32.4 per cent of the 30,664 unsold residential units in 2019 were affordable housing, which suggests a mismatch between delivery and effective demand rather than a supply expansion large enough to depress prices.

These explanations point to a limited effect on the aggregate state house price index rather than to an ineffective policy. The house price index covers all market segments, whereas PPR is targeted specifically at the lowest income group, so a programme of this size need not move a broad state-level index even where it succeeds in its own terms. The performance of targeted public housing is accordingly better assessed against sub-market affordability, accessibility and delivery indicators than against the aggregate price index alone.

Higher GDP per capita and a larger population are associated with higher housing prices, whereas unemployment is negatively associated with them. This result is consistent with the previous studies done by Adams and Fuss (2010), Mankiw and Weil (1989) and Gan, Wang and Zhang (2018). For example, Adams and Fuss (2010) found that a one per cent rise in economic activity raises house prices by about 0.6 per cent in the long run. Mankiw and Weil (1989) established the demographic channel, showing that changes in the size of the house-buying population produce large and predictable movements in real house prices. Gan, Wang and Zhang (2018) reported that a three-percentage point rise in unemployment lowers house prices by about 10.7 per cent, working through both weaker demand and thinner market activity.

The significant interaction coefficients show that the association of income, population and unemployment with prices is not constant across levels of government policy. The negative GDP per capita interaction means that higher income is associated with smaller price increases where housing policy is more intensive. Diamond and McQuade (2019) and Baum-Snow and Marion (2009) find property values rising in weaker local markets. The positive population interaction means that the price pressure associated with a larger population is stronger where policy is more intensive. Tajrishy and Vesal (2024) found that the price effect of Iran's Mehr housing project depended on whether schools and other public facilities expanded alongside the new housing. The results are reported in

Model 3 of Table 5, where $lnGOVPOL\ x\ lnGDPPC$ is -7.888, $lnGOVPOL\ x\ lnPOP$ is 9.892 and $lnGOVPOL\ x\ UNEMP$ is -5.378, and all three interaction terms are statistically significant. The relationship between government policy and house prices therefore depends on a state's income level, population size and labour-market conditions.

Overall, housing prices are shaped by the interaction of economic fundamentals, demographic pressures, labour-market conditions and government policy interventions. The results suggest that an affordable housing programme applied on identical terms across states that differ widely in income, population and employment is therefore unlikely to produce uniform price outcomes. A state-level housing policy framework should therefore account for both state-specific structural conditions and broader national housing-market dynamics.

## CONCLUSION AND POLICY IMPLICATIONS

This study employs a quantitative approach to examine the determinants of residential property prices across Malaysian states. The main objective of this study is to investigate the effect of government housing interventions and macroeconomic factors on housing prices in Malaysia. The results indicate that government housing policy significantly affect aggregate housing prices. The findings of this study present several policy implications for housing developers, policymakers, and development authorities in Malaysia:

First, housing planning should be more closely linked to population growth and the availability of developable land. Population is the strongest measured driver of state-level house prices in this study. The interaction results also show that the price pressure from population growth is stronger where government housing intervention is more intensive. Therefore, building more affordable housing alone may not be sufficient to reduce housing pressure. The amount and location of land available for housing should also be considered. State and local planning authorities should set housing targets based on expected population growth, household formation and local housing demand, rather than applying the same target to all states. Land for affordable housing should be identified early in the planning process and protected for this purpose. New housing areas should also be supported by basic infrastructure such as roads, water supply, schools and health facilities. This is important because housing supply does not always match actual demand.

Second, housing targets should be planned together with facilities, public transport and urban development. People tend to live near jobs, schools, services and transport facilities. Affordable housing located far from these facilities may result in higher transport costs and longer commuting times for households. Planning authorities should therefore identify suitable public transport corridors and encourage higher-density and mixed-income housing in


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these areas. Evidence from Tajrishy and Vesal (2024) also shows that the impact of large-scale affordable housing can depend on the availability of public facilities, such as schools. Urban containment can also be used to manage outward expansion and encourage more efficient use of land within existing urban areas. However, such measures should be supported by sufficient development capacity within the designated areas. If development is restricted without allowing sufficient housing supply and higher-density development, housing shortages and price pressures may increase. Therefore, urban containment, appropriate density and efficient development approval should be considered together.

Third, housing supply should be planned at the regional level. The cross-sectional dependence results show that housing markets across Malaysian states are strongly connected. This suggests that housing demand and price pressures in one area may also affect neighbouring areas. High-demand areas should therefore not be expected to provide all additional housing within their own boundaries where land is limited or expensive. Housing supply can instead be planned across wider city regions, with affordable housing and public transport better connected across state and district boundaries. The results also suggest that a single national housing programme may not produce the same outcomes in every state. States could therefore be grouped according to their level of housing demand and price pressure, such as high-, medium- and low-pressure areas. Housing targets, land release and government housing allocations could then be adjusted according to local conditions. Finally, because government intervention is associated with higher aggregate housing prices in the model, the success of affordable housing programmes should not be assessed using the overall house price index alone. Instead, programmes should also be evaluated based on whether they improve housing affordability, accessibility and access to suitable housing for the households they are intended to support.

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# UNDERSTANDING DIGITAL DATA ECOSYSTEMS ACROSS MALAYSIA'S SURVEYING PROFESSIONS: A TWO ROUND DELPHI STUDY

**Umi Kalsum Zolkafli @Zulkifly[1], Elia Syarafina Abd Shakur[2], Saipol Bari Abd Karim[3], Hasnan Hashim[4], Ali Sunandar[5]**

[1,3,5]*Department of Quantity Surveying, Faculty of Built Environment,*
[2]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA
[4]*Department of Built Environment Studies & Technology,*
*Faculty of Built Environment,*
UNIVERSITI TEKNOLOGI MARA
[5]*Department of Civil Engineering, Faculty of Engineering,*
UNIVERSITAS MERCU BUANA

## Abstract

This study investigates the digital data ecosystem across Malaysia's surveying professions using a two-round Delphi study involving experts from Building Surveying, Property Surveying, Geospatial and Land Surveying, and Quantity Surveying. The first round employed semi-structured interviews with ten experts to explore professional roles, project lifecycle involvement, digital information management, and data sharing practices. The interview data were analysed using thematic analysis, resulting in three themes comprising seven categories. The second round involved nine independent experts who validated the findings through a structured Delphi consensus process. A total of 65 of the 69 statements achieved the predefined consensus threshold of at least 80 percent agreement, demonstrating strong expert convergence. The validated framework identifies three interconnected dimensions, namely professional roles and lifecycle involvement, data types, organisation and digital tools, and data sharing practices and cross-disciplinary exchange. The findings demonstrate that an effective digital data ecosystem depends on the integration of professional responsibilities, structured information management, and collaborative data exchange throughout the built environment lifecycle. The study provides an empirically validated framework that supports digital transformation and interdisciplinary collaboration across Malaysia's surveying professions.

***Keywords***: Built environment; Delphi study; Digital data ecosystem; Malaysia; Surveying professions

[1] Corresponding author. Email: umi@um.edu.my

## INTRODUCTION

Surveying professionals are among the principal producers and custodians of digital information throughout the built environment lifecycle. Construction projects generate substantial volumes of discipline-specific information, including spatial measurements, cost estimates, building condition assessments, and asset information (Niu et al., 2026; Yin, 2025). These data support technical, commercial, legal, and operational decision-making across the planning, design, construction, operation, and maintenance stages (Jacob et al., 2025; Ojiako et al., 2025). Although each surveying profession produces distinct datasets according to its professional responsibilities, these information resources collectively contribute to project delivery and require effective management throughout the project lifecycle (Cao et al., 2025; Li et al., 2025).

The increasing digitalisation of the construction industry has substantially expanded the volume, diversity, and complexity of surveying data. Digital technologies have transformed the ways in which professional information is generated, organised, stored, analysed, and exchanged (Cheng & Hu, 2026; Shakur et al., 2026). Consequently, understanding contemporary surveying practice requires consideration not only of individual technologies but also of the broader digital data ecosystem, which encompasses professional activities, information resources, digital platforms, data management processes, and interactions among surveying disciplines.

A digital data ecosystem provides a holistic perspective for examining how digital information supports professional practice (Berlato et al., 2025b). Rather than focusing solely on technology adoption, it considers the interrelationships among professional services, project lifecycle involvement, data types, digital platforms, data management practices, and information exchange activities that collectively shape the creation, management, and utilisation of digital information. Examining these interconnected components provides a more comprehensive understanding of digital information management across surveying professions.

In Malaysia, the four principal surveying professions, namely Quantity Surveying (QS), Property Surveying (PS), Geospatial and Land Surveying (GLS), and Building Surveying (BS), have increasingly adopted digital technologies within their respective areas of practice. Despite the important role of these professions in supporting the built environment, there remains limited empirical evidence that comprehensively describes the digital data ecosystem across Malaysia's surveying professions (Royal Institution of Surveyors Malaysia, 2021a, 2021b).

Previous research has primarily examined individual technologies or specific surveying disciplines, including Building Information Modelling (BIM), Geographic Information Systems (GIS), digital measurement technologies, and


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cloud-based information management (Berlato et al., 2025a; Nashruddin et al., 2024; Radman et al., 2025). Although these studies have advanced understanding of technology adoption within professional contexts, they provide only a partial view of digital information management. Limited attention has been devoted to investigating the broader digital data ecosystem across multiple surveying disciplines. Thus, there is insufficient empirical evidence regarding the professional services performed, project lifecycle involvement, data generated, digital platforms utilised, data management practices, and interdisciplinary data sharing across Malaysia's surveying professions. Furthermore, expert consensus on these dimensions of digital practice has not been systematically established.

In this study, the term digital data ecosystem refers to the interconnected professional activities, digital information resources, platforms, management practices, and exchange processes across surveying disciplines. Data exchange refers specifically to the transfer and sharing of digital information between project participants, while cross-disciplinary collaboration refers to the professional interaction required to use and coordinate such information across surveying disciplines. These terms are used consistently throughout the study to distinguish the broader ecosystem from its specific exchange and collaborative processes. To address these gaps, this study employs a two-round Delphi study involving experts from the QS, PS, GLS, and BS professions in Malaysia. The first research objective explores the digital data ecosystem across Malaysia's surveying professions through semi-structured expert interviews. The second research objective establishes expert consensus on the identified components of the digital data ecosystem by evaluating the level of agreement among experts using the Delphi technique. The findings provide a comprehensive empirical understanding of the current digital data ecosystem across Malaysia's surveying professions and establish a baseline for future research on digital transformation within Malaysia's built environment.

## RESEARCH METHODOLOGY

### *Round One: Semi-Structured Interviews*

The first Delphi round comprised semi-structured interviews (Sunandar et al., 2025c; Sunandar, Karim, et al., 2026). Participants were selected through purposive sampling from members of the Royal Institution of Surveyors Malaysia (RISM) based on their professional experience and active involvement in digital surveying practice. Data saturation was achieved after interviewing ten experts. The expert panel consisted of three participants, each from BS, PS, and QS, together with one participant from GLS. The smaller representation of GLS was primarily due to the more limited accessibility of eligible GLS professionals with direct experience in digital surveying practice during the data collection period.

This constraint was considered when interpreting the findings, and the Delphi process was used to assess whether the themes identified from Round One were supported across the wider expert panel. All interviews were transcribed verbatim and analysed using thematic analysis to identify recurring patterns and themes (Sunandar, Abd Karim, et al., 2026; Sunandar et al., 2025a, 2025d). The analysis followed an iterative coding process comprising data familiarisation, initial coding, category development, and theme generation (Braun & Clarke, 2021; Saldana, 2021; Sunandar, Andriyanti, Karim, et al., 2026). The demographic profile of the Round One expert panel is presented in Table 1.

**Table 1:** Details of Experts Round One

| Code | Surveying Discipline | Professional Status |
|---|---|---|
| A1 | BS | Business Practice, Academic, Consultant |
| A2 | BS | Academic, Consultant |
| A3 | BS | Government Officer |
| A4 | GLS | Consultant, Director |
| A5 | PS | Academic, Government Officer |
| A6 | PS | Business Practice |
| A7 | PS | Business Practice, Consultant |
| A8 | QS | Business Practice |
| A9 | QS | Business Practice, Director |
| A10 | QS | Business Practice |

*Source: Author's Own Creation* (2026)

### *Round Two: Delphi Consensus*

The second Delphi round was conducted to validate the findings from the semi-structured interviews and establish expert consensus. A separate panel of nine RISM members was purposively selected to provide an independent evaluation of the Round One finding. The Delphi statements were developed directly from the seven categories identified through the Round One thematic analysis. Interview codes and supporting participant statements were reviewed and consolidated into concise statements representing the recurring characteristics of each category. These statements were then organised under the three overarching themes and reviewed for clarity and conceptual alignment before being presented to the Round Two panel. This process resulted in 69 statements for Delphi evaluation. Using a different expert panel introduced an additional level of verification and strengthened the credibility and trustworthiness of the study (Sunandar, Andriyanti, Abd Karim, et al., 2026; Sunandar et al., 2025b). Consensus was evaluated using simple frequency analysis to determine the proportion of experts who agreed with each statement. Statements receiving more than 80 percent agreement were considered to have achieved a high level of consensus and were retained, whereas statements with agreement below 80 percent were excluded from the final consensus (Nasa et al., 2021; Zarghani et


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al., 2024). This consensus threshold also strengthened methodological triangulation by demonstrating convergence of expert perspectives across different surveying disciplines and professional backgrounds. The demographic profile of the Round Two expert panel is presented in Table 2.

**Table 2:** Details of Experts Round 2

| Code | Surveying Discipline | Professional Status |
|---|---|---|
| V1 | BS | Academic/ Consultant |
| V2 | BS | Academic/ Consultant |
| V3 | BS | Academic/ Consultant |
| V4 | PS | Business Practice |
| V5 | PS | Business Practice |
| V6 | PS | Business Practice |
| V7 | QS | Academic/ Consultant |
| V8 | QS | Government Service |
| V9 | GLS | Business Practice |

*Source: Author's Own Creation* (2026)

## ANALYSIS AND DISCUSSION

### *Round One Analysis*

The first Delphi round explored the digital data ecosystem across Malaysia's surveying professions through semi-structured interviews with ten experts. Thematic analysis identified recurring patterns describing professional roles, project lifecycle involvement, digital information management, and data sharing practices. The coding process resulted in three overarching themes comprising seven categories that collectively explain the digital data ecosystem across the four surveying professions. For example, interview statements concerning "building inspection", "defect identification", and "compliance checks" were initially coded as building condition assessment activities and subsequently grouped under the Professional Services category within Theme 1. Similarly, references to "project-based folders", "cloud-based document management", and "version control" were coded as digital information organisation and consolidated under Data Organisation and Storage within Theme 2. This iterative process ensured that the Delphi statements remained grounded in the interview evidence. The thematic structure derived from the interview analysis is presented in Table 3.

**Table 3:** Themes and Categories Identified from Round One Interviews

| Theme | Category |
|---|---|
| Theme 1: Professional Roles and Lifecycle Involvement | Professional Services; Project Lifecycle Stages |
| Theme 2: Data Types, Organisation, and Digital Tools | Data Types; Data Organisation and Storage; Digital Tools and Platforms |

| Theme | Category |
|---|---|
| Theme 3: Data Sharing Practices and Cross Disciplinary Exchange | Data Sharing Practices; Cross Disciplinary Data Exchange |

*Source: Author's Own Creation* (2026)

The first theme demonstrates that the digital data ecosystem is fundamentally shaped by the professional responsibilities of each surveying discipline and their involvement throughout the project lifecycle. Building Surveyors primarily focus on building inspection, defect assessment, compliance evaluation, and maintenance planning. For example, A1 explained that the profession is centred on "building inspection, including condition assessment, defect identification, compliance checks, and advisory services for building performance and safety," while A3 highlighted responsibilities extending to "policy maker, building inspection, management." GLS concentrated on spatial data preparation to support engineering design, with A4 stating, "I process field survey data and prepare survey drawings such as topographical plans." Property Surveyors emphasised valuation, feasibility studies, and property management, whereas Quantity Surveyors focused on pre-contract and post-contract cost management, contract administration, and commercial control. Interview findings also revealed that surveying disciplines contribute at different project stages rather than participating uniformly throughout the lifecycle. Building Surveyors were involved from pre-construction condition surveys to post construction performance assessment, while Quantity Surveyors participated from project inception through construction and handover. A8 described this involvement as "inception to hand over to end user," whereas A9 noted participation during the "design stage by providing cost information and tendering and construction." Collectively, these findings indicate that professional roles determine not only the services delivered but also the timing and nature of digital information generated across the built environment lifecycle.

The second theme illustrates the diversity of digital information managed by surveying professionals, together with the digital infrastructure supporting information management. The interviews revealed considerable variation in data types according to disciplinary responsibilities. Building Surveyors generated inspection reports, photographic evidence, defect records, condition ratings, and maintenance information. A2 described these as "condition and pathology data," "geometric and spatial data," and "regulatory and compliance data." GLS primarily managed "GNSS coordinate data, topographical and utility survey data, boundary information" (A4), while Property Surveyors handled legal, market, financial, planning, and valuation datasets. Quantity Surveyors managed commercial information, including "Bills of Quantities, interim valuations, variation records, cost reports, and final account


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documentation" (A10). Despite these differences, participants consistently reported structured approaches to organising digital information using project-based folders, centralised servers, cloud storage, and standardised naming conventions. A2 explained that data are organised using "project-based folders" and "cloud-based document management systems to ensure version control," while A6 described a "centralized digital storage" system supported by an internal "master list database" and documented quality assurance procedures. A1 additionally reported using "AI generative tools such as Gemini, and NotebookLM" to improve reporting efficiency, illustrating the gradual integration of emerging artificial intelligence technologies into surveying practice. Overall, the findings demonstrate that digital information management has evolved beyond simple document storage towards integrated digital environments combining specialised software, cloud infrastructure, and collaborative information systems.

The third theme highlights that digital information exchange remains essential for multidisciplinary project delivery but continues to rely heavily on conventional document-based communication. Participants consistently reported that information is shared through emails, cloud storage platforms, organisational servers, and formal documentation rather than interoperable digital databases. A1 explained that information is distributed through "hardcopy printed reports, email, and digital platforms such as Google Drive," while A4 reported sharing "DWG and PDF formats through email or cloud storage." Larger projects increasingly utilise common data environments, with A2 referring to "Viewpoint, Aconex, or Procore" for collaborative document exchange. Nevertheless, several participants acknowledged persistent fragmentation in cross-disciplinary information management. A6 observed that data sharing is "currently fragmented and largely manual" because "the raw data remains locked away, meaning stakeholders often have to recreate the data for their own systems." The interviews further demonstrated that the types of exchanged information vary according to project stages. During planning and design, spatial surveys, feasibility studies, market information, and cost estimates are frequently exchanged. During construction, valuation reports, variation assessments, inspection records, and progress information support project coordination and contract administration. At project completion, as-built drawings, operation and maintenance documentation, final accounts, and asset information are transferred to facilitate operational management. These findings suggest that while multidisciplinary collaboration is well established, opportunities remain to improve interoperability and integrated digital data exchange across Malaysia's surveying professions.

***Round Two Analysis***

The second Delphi round was undertaken to validate the findings generated from the semi-structured interviews and to establish expert consensus regarding the components of the digital data ecosystem across Malaysia's surveying professions. Nine independent experts representing BS, PS, QS, and GLS evaluated the statements derived from the thematic analysis conducted in Round One. Following the predefined Delphi protocol, statements receiving at least 80 percent agreement were retained, whereas statements below the threshold were excluded from the final framework. The consensus results are summarised in Table 4.

**Table 4**

| Statement 1 (Theme 1) | Statement 2 (Theme 2) | Statement 3 (Theme 3) |
|---|---|---|
| 1.1.1 (89%) | 2.1.1 (89%) | 3.1.1 (89%) |
| 1.1.2 (89%) | 2.1.2 (100%) | 3.1.2 (78%) |
| 1.1.3 (89%) | 2.1.3 (100%) | 3.1.3 (89%) |
| 1.1.4 (89%) | 2.1.4 (100%) | 3.1.4 (89%) |
| 1.1.5 (89%) | 2.1.5 (89%) | 3.1.5 (89%) |
| 1.1.6 (89%) | 2.1.6 (100%) | 3.1.6 (78%) |
| 1.1.7 (100%) | 2.1.7 (89%) | 3.1.7 (89%) |
| 1.1.8 (100%) | 2.1.8 (89%) | 3.1.8 (89%) |
| 1.2.1 (100%) | 2.1.9 (100%) | 3.1.9 (89%) |
| 1.2.2 (100%) | 2.1.10 (100%) | 3.2.1 (89%) |
| 1.2.3 (100%) | 2.2.1 (100%) | 3.2.2 (100%) |
| 1.2.4 (100%) | 2.2.2 (89%) | 3.2.3 (100%) |
| 1.2.5 (100%) | 2.2.3 (100%) | 3.2.4 (89%) |
| 1.2.6 (100%) | 2.2.4 (100%) | 3.2.5 (100%) |
| 1.2.7 (100%) | 2.2.5 (100%) | 3.2.6 (89%) |
| 1.2.8 (100%) | 2.2.6 (89%) | 3.2.7 (89%) |
| 1.3.1 (89%) | 2.2.7 (100%) | 3.2.8 (89%) |
| 1.3.2 (89%) | 2.2.8 (100%) | 3.3.1 (78%) |
| 1.3.3 (100%) | 2.2.9 (89%) | 3.3.2 (78%) |
| 1.3.4 (89%) | 2.2.10 (89%) | 3.3.3 (100%) |
| 1.3.5 (100%) | | 3.3.4 (89%) |
| 1.3.6 (100%) | | 3.3.5 (89%) |
| 1.3.7 (100%) | | 3.3.6 (89%) |
| 1.3.8 (100%) | | 3.3.7 (89%) |
| | | 3.3.8 (100%) |

*Source: Author's Own Creation* (2026)

The findings demonstrate a high degree of agreement among the expert panel. Of the 69 statements evaluated, 65 achieved the required consensus level, with agreement ranging from 89 to 100 percent. Specifically, 27 statements received unanimous agreement from all experts, while 38 statements obtained 89 percent agreement. These findings indicate strong convergence of expert opinions


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regarding the professional roles, project lifecycle involvement, digital information resources, digital platforms, data management practices, and interdisciplinary information exchange that collectively characterise the digital data ecosystem within Malaysia's surveying professions.

Only four statements failed to satisfy the predetermined consensus threshold, each obtaining 78 percent agreement. Two statements concerned technical challenges during information exchange, namely data loss and geometric inconsistencies during model exchange, while the other two concerned information loss associated with static document formats such as PDF documents. The remaining two statements concerned behavioural dimensions of collaboration, specifically low levels of trust among professionals and disciplinary silo mentalities. Although these issues were recognised by several experts during the interviews, their exclusion from the validated framework reflects the predefined 80 percent consensus criterion rather than indicating that they are absent from practice. They are therefore considered emerging issues that warrant further investigation, particularly because their occurrence may vary according to organisational context, project characteristics, and professional experience.

### *Final Consensus*

The validated statements confirm the three thematic dimensions identified during Round One and establish the fundamental components of the digital data ecosystem across Malaysia's surveying professions. Theme 1, Professional Roles and Lifecycle Involvement, achieved consistently high levels of consensus, demonstrating that surveying practices are fundamentally shaped by discipline-specific responsibilities and participation throughout the built environment lifecycle. The findings confirm that BS, PS, GLS, and QS contribute distinct forms of professional expertise and digital information from project inception, through design and construction, to operation and maintenance stages. This finding supports previous studies emphasising that digital transformation in the built environment requires recognition of professional roles, information responsibilities, and lifecycle-based collaboration rather than technology adoption alone (Berlato et al., 2025b; Parece et al., 2025; Yin, 2025).

Theme 2, Data Types, Organisation, and Digital Tools, also achieved strong validation, indicating that digital surveying practices are characterised by diverse information resources supported by specialised software, cloud-based platforms, and structured data management approaches. The consensus demonstrates a transition from fragmented and isolated digital tools towards integrated information environments, where data quality, accessibility, consistency, and organisation directly influence decision-making throughout project delivery. This finding aligns with existing research on digital information

management, which identifies effective data structuring, information exchange, and interoperability as critical elements of successful digital transformation within the construction industry (Cheng & Hu, 2026; Swe Myat & Malla, 2026).

Theme 3, Data Sharing Practices and Cross-Disciplinary Exchange, was generally validated by the expert panel; however, several statements related to interoperability limitations, information loss, and professional collaboration challenges did not achieve consensus. This indicates that although digital information exchange is widely recognised as an essential component of contemporary surveying practice, the maturity of collaborative digital processes remains influenced by organisational capability, project requirements, regulatory conditions, and established professional workflows. Similar challenges have been identified in digital construction research, where fragmented information systems, limited interoperability, and organisational resistance continue to constrain the implementation of integrated information management practices (Abdeen et al., 2025; Binamungu & Kimaro, 2025; Zohourian et al., 2026) .

Overall, the Delphi findings establish an empirically validated framework comprising three interconnected dimensions: professional responsibilities, digital information management, and interdisciplinary data exchange, as presented in Figure 1. From a practical perspective, the framework can support several stakeholder groups. For RISM, the three dimensions provide a basis for developing professional guidance on digital information management and interdisciplinary data exchange. Surveying firms can use the framework to review their internal data structures, platform use, and information-sharing workflows, while public agencies can consider these dimensions when developing digital project requirements and information governance arrangements. For BIM and GIS users, the framework highlights the importance of aligning discipline-specific information with shared project environments and exchange requirements. More broadly, the findings suggest that digital data governance should address not only technology and interoperability, but also professional responsibilities, information ownership, data quality, and cross-disciplinary workflows. The validated framework highlights that the effectiveness of a digital data ecosystem depends not only on technological capabilities but also on the alignment of professional roles, structured information practices, and collaborative mechanisms that facilitate reliable data exchange across surveying disciplines.


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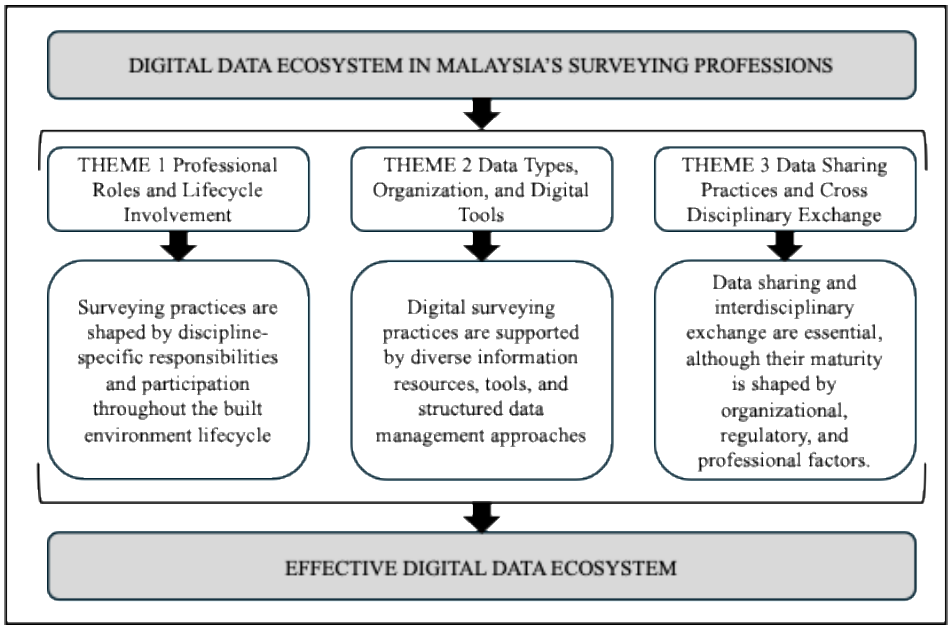



**Figure 1:** Final Consensus
*Source: Author's Own Creation* (2026)

## CONCLUSION

This study explored and validated the digital data ecosystem across Malaysia's surveying professions through a two-round Delphi study involving experts from BS, PS, GLS, and QS. The findings identified three interconnected dimensions, namely professional roles and lifecycle involvement, digital information management, and cross-disciplinary data sharing. The high level of expert consensus demonstrates that an effective digital data ecosystem extends beyond technology adoption and is fundamentally supported by the alignment of professional responsibilities, structured information management, and collaborative data exchange throughout the built environment lifecycle.

This study contributes to the literature by developing an empirically validated framework that conceptualises the digital data ecosystem across multiple surveying disciplines within the Malaysian context. The framework provides a holistic understanding of how professional functions, digital information resources, and collaborative practices collectively shape digital transformation in surveying services. The findings also offer practical implications for professional institutions, industry practitioners, and policy makers by identifying key elements that can strengthen interoperability, improve information management, and support the implementation of integrated digital practices across the surveying profession.

Several limitations should be acknowledged. The expert panel was confined to Malaysian surveying professionals and included limited representation from the GLS discipline. In addition, the findings are based on expert perspectives and therefore do not capture variations in organisational practices across different project settings. Future research should examine the applicability of the proposed framework in different national and organisational contexts through empirical case studies. Further investigation is also needed to examine governance arrangements, interoperability standards, and emerging technologies, including artificial intelligence and digital twins, to advance a multidisciplinary data ecosystem and strengthen digital collaboration within the built environment.

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## DISCLOSURE

The authors declare that there is no conflict of interest associated with this research.

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# SMART ACCESSIBILITY IN MELAKA'S HERITAGE BUILDINGS FOR PERSONS WITH DISABILITIES: A TECHNOLOGY-DRIVEN APPROACH

**Nik Fatma Arisya Nik Yahya[1], Suhaida @ Suhana Kamarudin[2], Hon Yin Cheng[3], Mazura Mahdzir[4], Tariq Umar[5]**

[1,2,3]*Department of Quantity Surveying,*
*Faculty of Engineering and Quantity Surveying,*
INTI INTERNATIONAL UNIVERSITY
[4]*Centre for Building, Construction & Tropical Architecture (BuCTA),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA
[5]*School of Architecture and Environment, College of Arts,*
*Technology and Environment,* UWE BRISTOL

## Abstract

This study investigates the accessibility of public heritage buildings in Melaka for persons with disabilities (PwDs). Despite Melaka's designation as a UNESCO World Heritage Site, many heritage buildings remain inaccessible due to historical architectural designs that do not meet modern accessibility standards. Employing semi-structured interviews with PwDs and a review of local and international literature, the research identifies key challenges, including inaccessible ramps, narrow doorways, inaccessible toilets, and low staff awareness. The study also explores the potential of integrating adaptive technologies, such as mobile applications and virtual reality (VR), alongside Universal Design (UD) principles. Findings indicate that combining physical upgrades with digital solutions can significantly enhance accessibility while preserving historical authenticity. By addressing these issues, the study contributes to Sustainable Development Goals (SDG), i.e., SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), and SDG 9 (Industry, Innovation, and Infrastructure), promoting inclusive heritage tourism and ensuring equitable access to Malaysia's rich cultural heritage. The study concludes with actionable strategies for local authorities and stakeholders to foster a more inclusive and accessible artistic environment.

***Keywords***: persons with disabilities (PwDs), heritage buildings, smart accessibility, sustainable development goals, universal design, technology

[4] Corresponding author. Email: mazuramahdzir@um.edu.my

## INTRODUCTION

Heritage tourism is a rapidly growing segment of the global tourism industry, offering visitors the opportunity to explore a destination's cultural and historical landmarks (Geçikli et al. 2024). As a designated UNESCO World Heritage Site (Amir et al. 2015; UNESCO no date), Melaka boasts a profound cultural and historical heritage that attracts a significant influx of tourists each year. Since receiving UNESCO's recognition, Melaka has become a central designation for both domestic and international tourists, recording 13.711 million tourists in 2012 (Amir et al. 2015). Ensuring that all tourists, particularly PwDs, can fully experience these heritage landmarks is therefore of paramount importance. The United Nations Convention on the Rights of Persons with Disabilities (CRPD) emphasizes that people with disabilities should have equal access to cultural heritage sites, just like all other members of society (Equality Act 2010). Despite this, many PwDs reported dissatisfaction with the facilities provided at heritage buildings, including public toilets, transportation infrastructure, services, hotel management, and information maps, which often fail to meet their accessibility needs (Ang Kean Hua 2019). To attract a wider range of local and international tourists, it is essential to provide high-quality services, facilities, and accessible environments that cater to both tourists with and without impairments. Accessible heritage tourism not only fosters inclusivity but also enhances the overall visitor experience and promotes Malaysia's rich cultural heritage.Heritage buildings have gained popularity due to their historical significance, architectural value, and cultural knowledge, attracting tourists eager to explore them. However, accessing these sites remains challenging for PwDs due to physical, informational, and attitudinal barriers. Often, the presence and needs of visitors with disabilities are overlooked when discussing accessibility (Nurul Fadzila Zahari et al. 2023). Urban planning and heritage site design frequently prioritize the general population, neglecting the specific requirements of PwDs. Consequently, PwDs have fewer opportunities to engage in tourism and cultural activities(Ikhwan Ali Wazani, Diana Mohamad & Mastura Jaafar 2021). Moreover, most historic heritage sites were constructed before the establishment of accessibility standards and disability rights. As a result, these sites were not originally designed to accommodate PwDs, who continue to face significant physical and social barriers (Ruiz-Rodrigo et al. 2024). Lastly, PwDs have expressed dissatisfaction with the existing facilities, which include public restrooms, transportation, and insufficient accommodations by site management. Many believe that instead of relying solely on basic disability amenities, public facilities should be modernized and enhanced to provide more advanced accessibility solutions (Ang Kean Hua 2019)

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## LITERATURE REVIEW

### Public Heritage Buildings in Melaka

The preservation and conservation of Malaysia's cultural heritage are governed by the National Heritage Act 2005 (Act 645). This legislation covers national treasures, underwater cultural heritage, natural heritage, tangible and intangible cultural heritage, and other related matters. According to the Act, the term heritage broadly encompasses national heritage, including sites, objects, and underwater cultural assets, regardless of their listing in the National Heritage Register. A building is defined as a structure, or a group of connected or separate structures, that possesses outstanding universal value in terms of history, art, or science due to architectural significance (National Heritage Act 2005 no date). For a building to qualify as an archaeological relic, it must be at least 50 years old (Clause 2.1), encompassing preserved remnants of past landscapes, vegetation, structures, artifacts, and site features. To be gazetted as a heritage building, a structure must meet criteria outlined in Clause 67 of the Act, including historical significance, architectural or aesthetic value, technical achievements, social or cultural associations, educational or research potential, uniqueness, and representativeness (National Heritage Act 2005, Clause 67). The Commissioner ensures that all declared heritage sites are officially listed in the National Heritage Register (Clause 71) and maintains public access under specified conditions (Clause 23). To educate future generations about Malaysia's rich historical background, promote conservation-friendly practices, and enhance community awareness regarding built heritage, Jabatan Warisan Negara (JWN) and Badan Warisan Malaysia (BWM) plays a crucial role.

Melaka, situated on the southwest coast of Peninsular Malaysia in the Strait of Malacca, comprises three districts: Melaka Tengah, Alor Gajah, and Jasin, covering an area of 1,658 square kilometers. The state is accessible by car from Kuala Lumpur (approximately two hours) and Singapore (approximately three hours). Jabatan Warisan Negara (2008) notes that Melaka and George Town are the historical cities that have developed over more than 500 years through trade activities and cultural exchanges between the East and the West. Its rich historical background has made Melaka a prominent tourist destination (Amir et al. 2015). Melaka's public heritage buildings reflect the influence of Portuguese (1511), Dutch (1641), and British (1824) colonization, with the latter being the longest period of foreign rule (Dutch Trading Post Heritage Network 2021). Historically, Melaka served as a major trading port connecting Arabia, China, India, and Europe, facilitating the exchange of goods such as porcelain, silk, spices, and gold (Tourism Melaka no date). UNESCO formally recognized Melaka as a World Heritage Site on July 7, 2008, highlighting over 500 years of East-West trade and cultural interactions along the Straits of Melaka (Amir et al. 2015). This historical significance makes Melaka an ideal case study for assessing


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accessibility in heritage sites. Additionally, the Persons with Disabilities Act 2008 (Clause 26, Subsection 2) mandates that facilities for PWD conform to Universal Design (UD) principles, ensuring accessibility and usability for all.

**Persons with Disabilities (PWDs)**

PwDs in Malaysia are classified into seven categories under the Persons with Disabilities Act 2008 (Act 685), namely hearing, visual, speech, physical, learning, mental, and multiple disabilities. In 2024, the Department of Statistics Malaysia (DOSM) reported that 805,509 individuals with disabilities were registered nationwide, representing approximately 2.4% of the total population. Of this number, 286,634 individuals (35.6%) were identified as having physical disabilities. In light of this significant proportion, this research investigates the experiences and challenges faced by individuals with physical disabilities who use wheelchairs when accessing public heritage sites. The Act establishes the National Council for Persons with Disabilities, ensuring PwD's registration, protection, rehabilitation, development, and overall well-being. Clause 26 emphasizes accessibility to public facilities, amenities, services, and buildings, mandating that these environments conform to Universal Design principles to facilitate access for all. Research by (Ang Kean Hua 2019) indicates that wheelchair users in Kuala Lumpur expressed dissatisfaction with public toilets, transportation, and hotel management. Participants recommended improvements beyond basic accessibility, including better staff training to foster a more inclusive and welcoming environment. NGOs such as the Damai Disabled Person Association Malaysia, established in 1998, further support PwDs by advocating for independence, reintegration into society, and equitable employment opportunities. These organizations also raise awareness among authorities and the public about the necessity for structural, social, and educational reforms for the disabled community (Damai Disabled Person Association Malaysia 2023).

**Adaptive Technologies for Wheelchair Accessibility**

Virtual Reality (VR) immerses users in a simulated environment, allowing interaction through head-tracking technology, while Augmented Reality (AR) overlays digital images onto real-world surroundings. Both technologies have significantly impacted tourism for individuals with accessibility challenges (GCF Global no date). The global VR industry, valued at USD 25.11 billion in 2023, is projected to reach USD 244.84 billion by 2032, with a CAGR of 28.6% (Fortune Business Insights 2024). VR and AR enhance tourism experiences by providing immersive, memorable interactions, improving social engagement, and enabling access to otherwise restricted environments (Loureiro, Guerreiro & Ali 2020; Bailey, Bryant & Hemsley 2021). Paladini et al. (2019) demonstrated the potential of VR in improving access to fragile or restricted cultural heritage sites.

Using the Myin-pya-gu Temple in Bagan as a case study, VR applications offered engaging and educational experiences, increasing visitor interest and awareness of heritage conservation. Adjustments in contrast, lighting, and interactive features further enhance visual clarity and appreciation of architectural details, emphasizing VR's role in heritage education and preservation. Mobile applications utilizing semantic linked data, such as WEMAP, facilitate accessible travel planning for wheelchair users (Liu et al. 2017). Features include real-time accessibility information, route planning, crowd-sourced facility ratings, audio descriptions, emergency assistance, and visual guidance. Such apps serve as practical tools for enhancing accessibility, allowing PwDs to navigate heritage sites independently and safely.Universal Design (UD) aims to create products, environments, and services usable by people of all ages and abilities without the need for adaptation (Burgstahler 2009). Developed by a multidisciplinary team led by Ronald Mace in 1997, UD is grounded in seven principles: equitable use, flexibility, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and appropriate size and space. UD principles can guide the evaluation of existing designs, inform the development of new environments, and educate designers on inclusive practices (Centre for Excellence in Universal Design no date). Accessible design emphasizes fairness and a deep understanding of diverse user needs, contributing to inclusive societies (Crook 2023). The Persons with Disabilities Act 2008, Clause 26(2), reinforces the requirement that facilities and equipment for PwDs comply with UD principles. Consequently, the study of accessible built environments integrates legal mandates, design theory, and technological solutions to remove barriers and promote equitable access for all individuals (Ikhwan Ali Wazani et al. 2021).

**International Practices in Universal Design for Heritage Accessibility**

Internationally, several countries have adopted Universal Design (UD) strategies to improve accessibility in heritage contexts while preserving historical authenticity. In Sweden, the Royal Palace in Stockholm provides virtual reality (VR) and 360° virtual tours, enabling visitors with mobility impairments to access otherwise inaccessible areas (Kungliga Slotten, 2023). Such digital interventions demonstrate how technology can complement physical accessibility measures in heritage buildings where structural modifications are constrained. Similarly, the European Union initiated the European Cultural Heritage Online (ECHO) project in 2002, coordinated by the Max Planck Institute for the History of Science, to digitize cultural heritage and provide open-access online platforms (ECHO 2015). Although the project concluded in 2004, it highlighted the potential of digital infrastructure in preserving heritage while improving accessibility for diverse user groups. These international practices provide valuable benchmarks for Malaysia, particularly in heritage cities such as Melaka. Adopting digital


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platforms that integrate historical documentation, architectural data, virtual tours, and accessibility information could enhance inclusivity while supporting conservation objectives. Such approaches would enable PwDs to plan visits effectively and reduce reliance on physical access alone. Comparative studies further support the adoption of UD principles. Saito (2006) reported that facility managers in the United States and Japan widely recognize the benefits of Universal Design, implementing them at varying levels. These findings suggest that learning from international best practices can inform the development of more inclusive heritage environments in Malaysia.

**Strategies for Integrating Adaptive Technologies into Universal Design (UD)**

Accessibility is a fundamental component of inclusive environments, particularly for PwDs. However, the absence of adequate accessibility features remains a significant barrier. (Nuratiqah Aisyah Awang et al. 2024) identified that the limited provision of ramps, elevators, handrails, and accessible sanitary facilities often restricts independent access and increases dependence on assistance. Malaysia's ratification of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) in 2006 reinforces the obligation to ensure equal access to social, cultural, and tourism activities (Nurul Fadzila Zahari et al. 2023). This commitment is further supported by national policies aligned with the National Policy on Equalization of Opportunities for Persons with Disabilities. Consequently, the integration of adaptive technologies within UD principles should be viewed as both a policy requirement and a social responsibility. Effective implementation requires multi-stakeholder collaboration. Wu et al. (2023) emphasized the involvement of governments, non-governmental organizations, industry stakeholders, professionals, and local communities in tourism planning. Given Malaysia's tourism performance, recording 20.14 million arrivals and RM71.30 billion in receipts in 2023, ensuring accessibility at heritage destinations is critical for sustainable and inclusive tourism development. Furthermore, Alshafeey et al. (2019) argued that greater integration of virtual environments addressing diverse disabilities could enhance accessibility outcomes. Adaptive solutions such as portable ramps, temporary lifting devices, and trained assistance personnel offer practical strategies to improve access in heritage buildings without compromising conservation values. Regular assessments by local authorities are therefore essential to balance accessibility compliance with heritage preservation.

**Accessibility Challenges in Public Heritage Buildings in Melaka for PWD**

This section presents an overview of the accessibility challenges identified at selected public heritage buildings and sites in Melaka. The information was compiled by the authors from previous research and publicly available secondary

sources, including photographs and visitor feedback, to provide contextual evidence of the physical accessibility conditions reported at these heritage sites. The discussion focuses primarily on barriers affecting persons with physical and mobility impairments, particularly wheelchair users, such as stepped entrances, steep terrain, inaccessible circulation routes, and the absence of alternative means of vertical access. As no independent site observation was undertaken for these locations, the findings presented in this section should be interpreted as secondary evidence of reported accessibility conditions rather than as a direct assessment of their current compliance or accessibility status.

Heritage buildings contribute significantly to the architectural identity of a society, as they embody unique historical and cultural values that are both significant and irreplaceable (Abd Rahim et al., 2026). Previous research has identified significant accessibility limitations at the Baba & Nyonya Heritage Museum, particularly for wheelchair users due to the lack of ramps. As noted by Aurélie (2017), the museum entrance is accessible only via steps, and visitor circulation requires movement between the ground, first, and second floors, all of which are connected solely by steep staircases. Figure 1 shows photos of the entrance and the interior of the museum. The lack of alternative vertical circulation or assistive facilities significantly restricts access for people with mobility impairments.



**Figure 1**: Baba & Nyonya Heritage Museum
*Source: Google image,2026*

Saint Paul's Hill is one of the most popular tourist attractions in Melaka; however, it presents significant accessibility challenges for wheelchair users. According to Aurélie (2017), the site is located at the top of a hill, making access


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to several historical buildings physically demanding and largely impractical for persons with mobility impairments. The steep terrain and lack of accessible pathways substantially limit independent access for wheelchair users. Figure 2 shows the photos of Saint Paul's Hill.

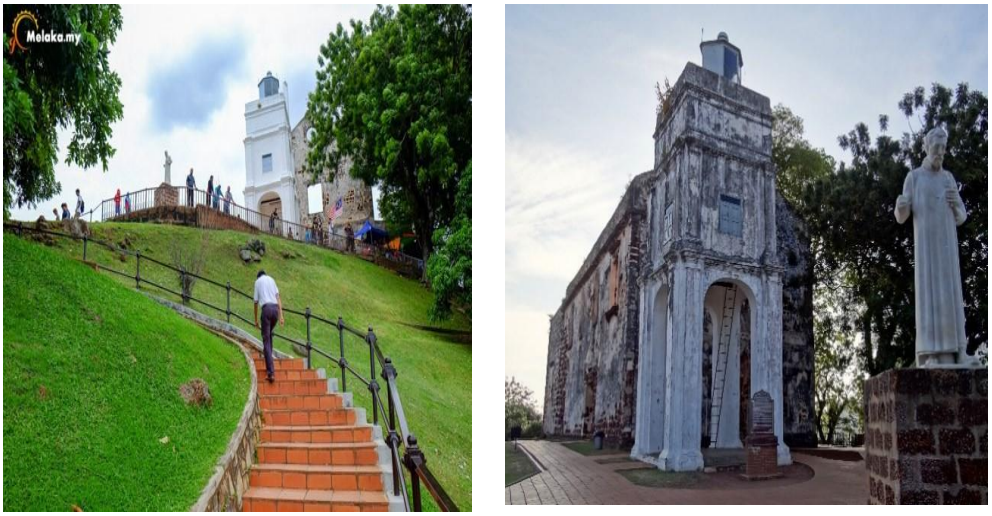



**Figure 2**: Saint Paul's Hill
*Source: Google image,2026*

The design of the Melaka Sultanate Palace Museum was inspired by descriptions of Sultan Mansur Shah's palace in the *Malay Annals*. Constructed between 1984 and 1986 in Melaka City, the museum was developed based on historical annotations found in the ancient *Malay Annals*. Despite its cultural and historical significance, the Melaka Sultanate Palace Museum remains largely inaccessible to PwDs. Visitor feedback reported in Google Reviews indicates that the main entrance is accessible only via steps, which discourages wheelchair users and individuals with mobility impairments from visiting. Figure 3 shows photos of Melaka Sultanate Palace Museum. Furthermore, the absence of designated facilities or ticketing provisions for PwDs suggests limited consideration of inclusive access, contributing to an environment that is not fully welcoming to visitors with disabilities.

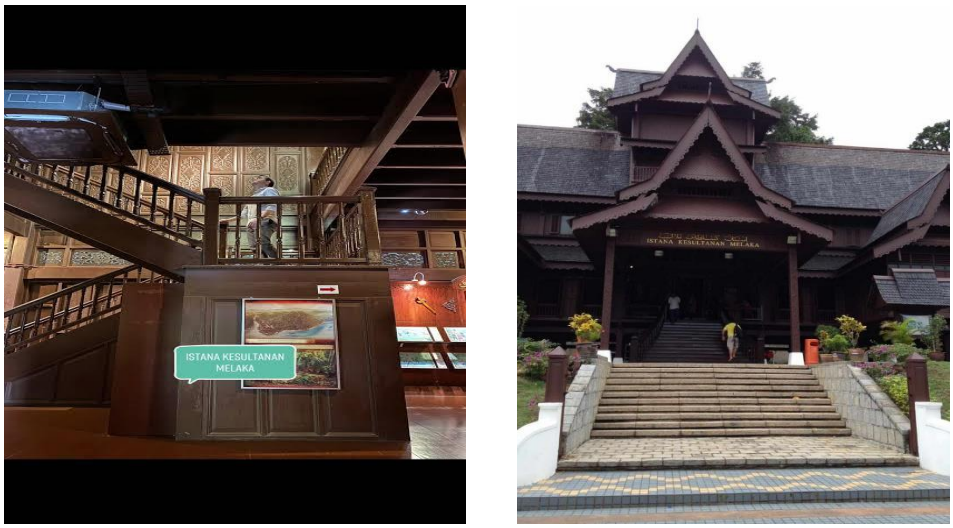



**Figure 3**: Melaka Sultanate Palace Museum
*Source: Google image,2026*

## RESEARCH METHODOLOGY

This study adopts a qualitative research approach to explore the accessibility experiences, perceptions, and challenges faced by persons with disabilities (PwDs) in accessing public heritage buildings in Melaka. The study specifically focuses on persons with physical disabilities, particularly those with mobility limitations, as the accessibility issues examined relate primarily to the physical environment, such as entrances, pathways, ramps, stairs, and circulation within heritage buildings. Therefore, the findings should be interpreted within the context of physical disability access and are not intended to represent the experiences of all categories of PwDs.

Qualitative research is well-suited for understanding human behavior and social phenomena within real-life contexts, allowing for the collection of rich, in-depth insights (Ahmad et al. 2019). This approach is particularly appropriate for investigating complex, context-dependent issues such as heritage accessibility, where users lived experiences and perspectives are central to the research objectives. Data was collected through online semi-structured interviews conducted via digital platforms, including Google Meet and WhatsApp, enabling participants to engage remotely. This approach improves flexibility and accessibility, particularly for those with mobility challenges, while reducing logistical and time-related issues associated with in-person interviews. It offers a valid alternative to in-person approaches as it captures both visual and auditory signals, preserves a sense of co-presence, and offers flexibility and convenience for those involved. (Wakelin, et al., 2024). All interviews were conducted with


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informed consent, audio-recorded, and transcribed verbatim, providing a comfortable environment that encouraged open and reflective discussions. Interview transcripts were systematically reviewed to identify key statements aligned with the research objectives.

The three heritage sites introduced in the Background section (Baba & Nyonya Heritage Museum, St Paul' s Hill, Melaka Sultanate Palace Museum) were referenced throughout the interviews as examples of accessibility barriers in Melaka's heritage settings. These three were not defined as a set group of case-study sites for all respondents to evaluate. Rather respondents were asked questions about sites they visited in Melaka; the sites they mentioned are listed separately in Table 2. As such, comments relating to access barriers are understood as descriptions of each respondent's perceived visit, and comments relating to adaptive technology or recommendations are understood as their opinions. These interviews do not document the accessibility status of all sites mentioned in the background. Six wheelchair users were interviewed to provide rich descriptions about their personal experiences accessing heritage sites in Melaka. The sample size allows for an exploratory examination of challenges faced by participants; however, conclusions cannot be generalized to all wheelchair users or other types of persons with disabilities. The concept of data saturation was not used operationally in this study. As such, the authors do not suggest that interviewing additional people would not lead to new themes emerging.

Data were manually organized by grouping similar responses, facilitating the identification of common accessibility barriers, user experiences, and suggested improvements. Selected verbatim quotations were included to enhance analytical credibility. This type of content or findings is intended to be illustrative, providing examples that support the theoretical assertions (Eldh, et al., 2020; Thorne 2020). Ethical considerations were rigorously addressed. Participation was voluntary, with participants provided clear information regarding the study's purpose, data usage, and the right to withdraw at any time without penalty. Informed consent was obtained before the interviews, and participant anonymity and confidentiality were maintained by removing identifying information from transcripts and research outputs. All data were securely stored and used solely for academic purposes.

## ANALYSIS AND DISCUSSION

### Respondents' Profile

Six PwDs in wheelchairs, i.e., four males and two females, have been interviewed via Google Meet. The respondents are 28 to 45 years old. The respondents are expected to answer all questions based on their opinions and experiences visiting

the heritage buildings in Melaka. The profile of the respondents is depicted in Table 1. The respondents were labelled according to the numbers.

**Table 1**: Details of the respondents

| Participant | Designation | Age | Frequency of Visiting Heritage Buildings in Melaka |
|---|---|---|---|
| P1 | Male | 49 | Frequently |
| P2 | Female | 37 | Rarely |
| P3 | Male | 32 | Frequently |
| P4 | Female | 28 | Occasionally |
| P5 | Male | 45 | Rarely |
| P6 | Male | 40 | Rarely |

**Accessibility Barriers in Heritage Buildings**

Table 2 summarizes the experiences of PwDs when visiting and accessing heritage buildings in Melaka. Despite Melaka's prominence as a heritage tourism destination, respondents reported persistent physical barriers that limit independent access, including narrow doorways, the absence of ramps and elevators, inaccessible toilets (P1, P3, P4, P6), and uneven floor surfaces that require caregiver assistance, thereby reducing autonomy (P6). In addition, a lack of staff awareness of PwDs needs was identified (P4), indicating that accessibility challenges extend beyond physical infrastructure to include social and operational factors. These findings are consistent with previous studies highlighting that heritage buildings constructed before modern accessibility standards continue to present physical and social barriers for PwDs (Nuratiqah Aisyah Awang et al. 2024; Ruiz-Rodrigo et al. 2024). External access issues, such as uneven surfaces and narrow pathways, further exacerbate these challenges, while inadequate accessibility in supporting facilities, including public toilets and transportation, limits the overall inclusiveness of heritage destinations (Ang Kean Hua 2019; Ikhwan Ali Wazani et al. 2021).

Participants proposed several strategies to improve accessibility, emphasizing the enforcement of accessibility standards to prevent misuse of PwDs facilities (P1, P3), regular inspection and maintenance of lifts (P2), and the proper provision and upkeep of accessible toilets (P3). Design-related recommendations included smooth, bump-free pathways and additional wheelchair-friendly ramps and lifts to enhance independent mobility (P4, P6). Human factors were also highlighted, with calls for staff training to improve awareness and responsiveness to PwDs needs (P4), alongside policy-level support such as free parking for PwDs to reduce access barriers and encourage participation in heritage activities (P5). Collectively, these findings underscore the need for an integrated accessibility approach that combines physical improvements, effective management, staff capacity building, and supportive policies to ensure heritage environments are both preserved and inclusive.


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**Table 2**: Experience difficulties when accessing heritage buildings in Melaka

| Experience/ respondents | P1 | P2 | P3 | P4 | P5 | P6 |
|---|---|---|---|---|---|---|
| Facing difficulties | Yes | Yes | Yes | Yes | No | Maybe |
| Buildings visited | Muzium Kapal | Famosa Area | Stadhuys & Menara Taming Sari | Menara Taming Sari, Dutch Square & Porta De Santiago | Stadhuys & Muzium Kapal | Dataran Pahlawan |
| Barriers faced | Ramps Doorways Toilet | Ramps (old building) | Lack of ramps | Ramps Narrow door Toilet | Ramps Narrow door Toilet | Quite accessible |
| Suggestion for improvement | Local authority and government | Lift | PWD toilet | Smooth pathways Lift Wheelchair friendly | Parking free | Accessible pathway |

**Adaptive technology and Universal Design in Heritage Buildings**

Table 3 indicates cautious optimism among participants regarding the use of adaptive technologies to enhance accessibility in heritage buildings in line with Universal Design principles. Most participants (5 of 6; P1, P3–P6) supported the use of Virtual Reality (VR) as an alternative access tool for virtual visitation and historical education, particularly for fragile or physically inaccessible sites. This finding aligns with Paladini et al. (2019), who highlight VR's potential to improve access for PwDs while promoting conservation awareness. However, concerns regarding financial feasibility and long-term government funding were noted (P2). Mobile real-time wheelchair accessibility information applications were also viewed as beneficial for supporting independent navigation, with several participants expressing support (P2, P3, P6), although others raised concerns about data reliability and user adoption (P1, P4, P5). Existing studies demonstrate that crowdsourcing-based systems using semantically linked data can enhance trip planning efficiency and the accuracy of accessibility information (Liu et al. 2017). Participants identified key application features, including real-time navigation, accessibility details, user reviews, emergency functions, and photographic documentation. While most participants expressed willingness to use such applications, hesitation among some users reflects broader challenges related to technological acceptance, particularly among older adults and users who perceive accessibility features as complex or stigmatizing (Kuerbis et al.

2017; Franz et al. 2019). Overall, the findings suggest that adaptive technologies can significantly enhance heritage accessibility, provided they are supported by user-centered design, reliable data systems, and adequate policy and funding support.

**Table 3**: Adaptive Technology and Universal Design in Heritage Buildings

| Theme/Respondent | P1 | P2 | P3 | P4 | P5 | P6 |
|---|---|---|---|---|---|---|
| Virtual Reality | Good alternative | Government fundings | Yes | Yes | Possible | Interesting idea |
| Mobile real-time wheelchair accessibility information application | Not sure | Yes | Yes | Maybe | No | Yes, great start |
| Features to be included | Real-time navigation assistance | Real-time navigation, route info, emergency button, user reviews, picture of place. | Yes, Agree to R2. | Information on wheelchair accessible routes | Real-time navigation, user review and location photos. | Yes. All features are important |
| Willingness to adopt a mobile real-time wheelchair accessibility application. | Yes | Yes | Yes | Maybe – I am old-fashioned | Yes | Yes |

**Strategies for Integrating Adaptive Technologies into Universal Design**

Table 4 highlights the critical role of governance, inclusive design, and capacity building in integrating adaptive technologies within Universal Design (UD) frameworks for heritage buildings. Participants emphasized the need for stronger policy enforcement related to PwDs, regular accessibility inspections, and targeted government funding to support adaptive technologies such as Virtual Reality (VR) and accessible infrastructure, including properly designed ramps (P1, P2, P3, P6). These views align with Wu et al. (2023), who highlight the importance of multi-stakeholder collaboration among government, industry, non-governmental organizations, local communities, and built environment professionals. At the policy level, Malaysia's National Policy on Equalization of Opportunities for Persons with Disabilities provides a foundation for accessibility enforcement, while international studies highlight the shared responsibility of governments, companies, and researchers in developing inclusive virtual and adaptive environments (Alshafeey et al. 2019). Beyond regulation, participants


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stressed the importance of inclusive design processes that actively involve PwDs in design oversight and decision-making (P4), consistent with the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), which affirms the right of PwDs to participate in cultural and tourism activities (Nurul Fadzila Zahari et al. 2023). Training and awareness were also identified as key enablers, with calls for systematic accessibility and UD education for heritage staff and broader public awareness initiatives (P1, P5), supporting previous findings on the role of trained personnel in inclusive environments (Ang Kean Hua 2019). Overall, the findings suggest that integration of adaptive technologies in heritage contexts requires a holistic approach combining policy enforcement, inclusive design participation, staff capacity building, public awareness, and sustained multi-stakeholder collaboration.

**Table 5**: Strategies and Further Recommendations for Integrating Adaptive Technologies into UD

| Theme/Respondent | P1 | P2 | P3 | P4 | P5 | P6 |
|---|---|---|---|---|---|---|
| Government enforcement/relevant authority (rules and policies) | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Government funding | ✓ | | ✓ | ✓ | | |
| Training to be provided to the museum staff (how to assist PWD) | | | | | ✓ | |
| PWD community should be included in discussing and overseeing the design features | | | | ✓ | | |
| Public awareness | | | | ✓ | | ✓ |
| Encourage PWD to visit Melaka | | | | | ✓ | |
| Modify the heritage building – free accessibility, ramps | | ✓ | ✓ | | | |
| Welfare Exco (State Executive Councilor) – address the accessibility issue | ✓ | | | | | |

## CONCLUSION

This study highlights persistent accessibility challenges faced by PwDs in Melaka's heritage buildings, largely due to physical and social barriers embedded

in structures built before modern accessibility standards. Consistent with existing literature, participants reported narrow doorways, the absence of ramps and elevators, inaccessible toilets, and uneven flooring, which restrict independence and discourage visitation to inaccessible sites. The findings demonstrate strong support for adaptive technologies, particularly Virtual Reality (VR) and mobile real-time accessibility applications, as complementary tools to enhance access, heritage education, and independent navigation. Participants also endorsed the adoption of Universal Design (UD) principles informed by international best practices, emphasizing practical features such as portable ramps, wider doorways, and staff training. While the study is limited by a small sample size, a short study duration, and the absence of prototype testing, it confirms that integrating adaptive technologies with globally informed UD strategies and effective policy enforcement can significantly improve accessibility in heritage contexts. To advance inclusive heritage tourism, the study recommends strengthening accessibility enforcement, funding assistive technologies, involving PwDs in design and decision-making processes, enhancing staff training, and increasing public awareness through targeted education and media initiatives. Collectively, these measures support a holistic approach to creating inclusive, equitable, and socially sustainable heritage environments. This study identifies persistent accessibility challenges faced by PwDs in Melaka's heritage buildings, primarily due to physical and social barriers in structures developed before modern accessibility standards. Participants reported narrow doorways, the lack of ramps and elevators, inaccessible toilets, and uneven flooring, which limit independence and discourage visits to inaccessible heritage sites. The findings demonstrate strong support for the integration of adaptive technologies, particularly Virtual Reality (VR) and mobile real-time accessibility applications, as complementary mechanisms for enhancing accessibility, heritage education, and independent navigation. The findings further suggest that these technologies can contribute to more inclusive heritage experiences by supporting diverse user needs through immersive learning, real-time access to accessibility information, and greater autonomy in navigating heritage environments. Collectively, the findings highlight the potential of adaptive technologies to complement existing accessibility measures and strengthen the inclusivity and usability of heritage sites. Participants also endorsed the adoption of Universal Design (UD) principles informed by international best practices, emphasizing practical features such as portable ramps, wider doorways, and staff training. The study recommends stronger enforcement of accessibility regulations, dedicated funding for assistive technologies, the meaningful participation of PwDs in design and decision-making processes, continuous capacity building for staff, and sustained public awareness initiatives. More specifically, Historical Melaka City Council, Department of National Heritage, museum operators, tourism agencies, and


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building owners should strengthen accessibility through regular audits and maintenance, integrate universal design principles into planning and conservation practices, provide appropriate assistive facilities and technologies, enhance staff competency in disability-inclusive services, and establish mechanisms for ongoing consultation with PwDs. These coordinated efforts are essential to ensuring that heritage environments are not only compliant with accessibility requirements but also inclusive, equitable, and sustainable for all visitors.

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# CYBERSICKNESS ASSOCIATED WITH DIGITAL TOOL USE AMONG CONSTRUCTION PRACTITIONERS: SYMPTOM PATTERNS, ASSOCIATED FACTORS AND COPING STRATEGIES

**Najwa Nabiha[1], Nurshuhada Zainon[2*], Azlan Helmy Abd Samat[3], Eric Lou[4], Nur Mardhiyah Aziz[4], Loo Siaw Chuing[5]**

[1,2,4,5]*Department of Quantity Surveying*,
*Faculty of Built Environment,*
[2,4,5]*Centre for Building, Construction & Tropical Architecture (BUCTA)*,
*Faculty of Built Environment,*
UNIVERSITI MALAYA, 50603 Kuala Lumpur, Malaysia.
[3]*Department of Emergency Medicine, Faculty of Medicine,*
*Hospital Canselor Tuanku Muhriz*,
UNIVERSITI KEBANGSAAN MALAYSIA, 56000, Kuala Lumpur, Malaysia.
[4]*Faculty of Science and Engineering*,
MANCHESTER METROPOLITAN UNIVERSITY,
Manchester, United Kingdom

## Abstract

Digital technologies have transformed the way construction work is planned, coordinated and executed, resulting in increasingly digital and screen-intensive work environments. However, prolonged digital exposure has also raised concerns regarding cybersickness and occupational well-being. Although generally not considered a serious medical condition, cybersickness may adversely affect user comfort and potentially hinder the sustainable adoption of digital technologies. Despite the industry's growing digitalisation, empirical evidence on cybersickness among construction practitioners remains limited, leaving a lack of evidence-based guidance to promote healthier Construction 4.0 work environments. Therefore, this study investigated the self-reported occurrence and severity of cybersickness among Malaysian construction practitioners, examined demographic and digital usage factors associated with symptom severity, and explored coping strategies adopted to mitigate discomfort. A quantitative approach was employed using a structured questionnaire survey involving 109 construction practitioners in Malaysia. The findings revealed that more than half of the respondents experienced cybersickness symptoms intermittently, predominantly in the form of oculomotor discomfort, including eye strain, headaches and difficulty focusing. Higher symptom severity was observed among female and younger practitioners and was associated with

[1] Corresponding author. Email: zshuhada@um.edu.my

prolonged continuous screen exposure rather than overall daily digital exposure. To alleviate discomfort, practitioners primarily adopted behavioural and ergonomic measures, with regular breaks, screen adjustment and ergonomic posture emerging as the most common coping strategies. This study extends cybersickness research beyond gaming and laboratory settings by providing empirical evidence from professional construction practice and offering insights for industry practitioners, organisations, and policymakers to develop healthier, more sustainable digital work environments.

***Keywords***: Industry 4.0, cybersickness, digital tools, digital well-being, construction practitioners, construction industry

## INTRODUCTION

The global construction industry is undergoing rapid digital transformation driven by Industry 4.0 technologies and the emerging transition to more human-centred, sustainable Industry 5.0 paradigms. Consequently, investments in digital construction technologies, including Building Information Modelling (BIM), artificial intelligence (AI), cloud computing, digital twins and extended reality (XR), have increased substantially over the past decade as organisations seek to enhance operational efficiency and competitiveness (McKinsey Global Institute, 2017; Deloitte, 2025). Global investment in construction technologies reached approximately US$50 billion between 2020 and 2022, driven by the potential of digital transformation to improve productivity by 14-15% and reduce project costs by 4-6% (Koeleman et al., 2019; McKinsey Global Institute, 2024).

While the widespread adoption of digital technologies has significantly improved productivity, collaboration and project delivery, it has also inevitably increased workers' exposure to screen-based and immersive digital environments. Consequently, new occupational health concerns have emerged. Among these, cybersickness has become an increasingly important issue as digital technologies become integral to everyday construction practice.

Cybersickness refers to a collection of physiological and psychological symptoms experienced during or after interaction with digital and virtual environments. Prior studies have demonstrated that immersive environments and prolonged screen exposure may negatively affect physical comfort, concentration and task performance (Dennison et al., 2016). In occupational settings, these effects may contribute to mental fatigue, reduced work efficiency, and decreased cognitive performance, particularly in professions that require prolonged visual attention and precision-based decision-making. These concerns are increasingly relevant within the construction industry, where practitioners frequently engage

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in digitally intensive workflows involving modelling, coordination, visualisation, and remote collaboration.

Within the construction industry, empirical evidence concerning cybersickness among construction practitioners remains limited. Existing cybersickness research has predominantly focused on gaming environments, simulator systems, healthcare applications and controlled laboratory settings, with particular emphasis on immersive virtual reality (VR) systems and head-mounted displays (HMDs) (Rebenitsch & Owen, 2016; Weech et al., 2019). Consequently, relatively little is known about cybersickness associated with the routine use of conventional screen-based digital tools in professional construction practice. As digital technologies become increasingly integrated into construction practice, the impact of cybersickness on practitioners remains poorly understood. This knowledge gap may compromise worker well-being, productivity, and the long-term sustainability of Construction 4.0 initiatives.

Therefore, this study investigates cybersickness among Malaysian construction practitioners using digital tools within Construction 4.0 environments. Specifically, the study examines the occurrence and severity of cybersickness symptoms, identifies demographic and digital-use factors that influence cybersickness, and evaluates coping strategies practitioners use to mitigate discomfort.

This study addresses an important knowledge gap by providing baseline empirical evidence on self-reported cybersickness among construction practitioners. Extending existing research beyond gaming and laboratory settings, it examines symptom occurrence, associated factors, and coping strategies in real-world digital construction environments. As a perception-based study, it does not aim to provide a clinical or physiological diagnosis of cybersickness but rather to describe practitioners' self-reported symptoms and perceived digital well-being. The findings contribute to the emerging literature on digital well-being and occupational health while informing ergonomic guidelines and human-centred digital work practices.

## LITERATURE REVIEW

### Construction 4.0 and Digital Tool Adoption

Construction 4.0, derived from the broader Industry 4.0 paradigm, integrates advanced digital technologies, automation and data-driven processes into construction to enhance productivity, efficiency and project performance (Oesterreich & Teuteberg, 2016). Its adoption has been driven by the need to overcome fragmented workflows, inefficient information exchange and low productivity within the construction industry (McKinsey Global Institute, 2017). Consequently, digital technologies have become integral to modern construction practice. As practitioners increasingly rely on these technologies throughout the


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project lifecycle, prolonged interaction with screen-based digital environments has become an inherent feature of contemporary construction work.

**Cybersickness and Construction**

While these technologies have substantially improved collaboration and operational performance, they have also increased practitioners' exposure to screen-based and digitally intensive work environments. Prolonged interaction with digital interfaces has been associated with visual fatigue, cognitive strain, reduced concentration and other ergonomic-related discomforts, highlighting growing concerns regarding the occupational implications of digital work (Dennison et al., 2016; Chen et al., 2022).

Cybersickness refers to a collection of physiological and psychological symptoms experienced during or after interaction with digital or virtual environments. Common symptoms include nausea, dizziness, headaches, eye strain, visual fatigue, disorientation and general discomfort (Rebenitsch & Owen, 2016). As digital technologies become increasingly embedded in construction workflows, these symptoms have attracted growing attention due to their potential effects on user comfort, cognitive performance, and workplace productivity (Dennison et al., 2016; Stanney et al., 2020).

One of the principal explanations of cybersickness is the Sensory Conflict Theory, originally proposed by Reason and Brand (1975). The theory suggests that cybersickness arises when discrepancies occur between visual, vestibular and proprioceptive sensory inputs. Although such sensory conflicts are most evident in immersive virtual environments, prolonged interaction with visually demanding screen-based applications may also contribute to eye strain, visual fatigue and cognitive discomfort (Keshavarz et al., 2015; Rebenitsch & Owen, 2016). Another widely recognised explanation is the Postural Instability Theory (Riccio & Stoffregen, 1991), which proposes that cybersickness results from prolonged difficulties in maintaining postural stability and spatial orientation. Within construction practice, extended engagement with digital modelling, visualisation and other visually intensive applications may increase visual and cognitive demands, thereby contributing to discomfort during prolonged work sessions.

**Cybersickness Symptoms**

Cybersickness symptoms are commonly classified into three dimensions: oculomotor, nausea-related, and disorientation (Kennedy et al., 1993). This classification is widely adopted in cybersickness and simulator sickness research and provides the conceptual framework for assessing symptom severity in the present study.

Oculomotor symptoms involve visual discomfort associated with prolonged interaction with digital systems, including eye strain, headaches, blurred vision, difficulty focusing and visual fatigue (Kaur et al., 2022). Prolonged screen exposure and visually demanding tasks have been shown to increase digital eye strain and reduce visual comfort (Beeson et al., 2024; Jahangiri et al., 2023). These symptoms are particularly relevant to construction practitioners who routinely engage with BIM, digital modelling and project coordination platforms.

Nausea-related symptoms comprise physiological discomfort such as dizziness, stomach awareness, sweating and motion-related uneasiness (Kennedy et al., 1993; Rebenitsch & Owen, 2016). They are commonly associated with immersive virtual environments, where sensory conflicts between the visual and vestibular systems are more pronounced (Oh & Son, 2022). Although less common in conventional screen-based applications, prolonged digital interaction may still contribute to discomfort and reduced concentration during digitally intensive construction tasks.

Disorientation symptoms include vertigo, balance disturbances and spatial confusion arising from inconsistencies between visual perception and physical movement (Kennedy et al., 1993; Rebenitsch & Owen, 2016). While these symptoms are typically associated with immersive virtual environments (Jochmann et al., 2025), prolonged engagement with visually intensive digital workflows may also contribute to cognitive fatigue and spatial discomfort among construction practitioners.

**Factors Influencing Cybersickness**

Previous studies have identified both demographic characteristics and technology usage patterns as important factors influencing the occurrence and severity of cybersickness (Rebenitsch & Owen, 2016; Stanney et al., 2020; Saredakis et al., 2020).

Demographic characteristics, including gender, age, professional experience and job role, have been associated with variations in cybersickness susceptibility. Female users generally report greater symptom severity than males, potentially due to physiological, perceptual and ergonomic differences (Stanney et al., 2020; Fulvio et al., 2021). Age may also influence susceptibility, as visual adaptation, cognitive response and familiarity with digital technologies vary across age groups (Weech et al., 2019). In addition, greater professional experience and familiarity with digital systems have been associated with improved adaptation and reduced discomfort during prolonged digital interaction (Saredakis et al., 2020). Consequently, practitioners with limited experience using advanced digital technologies may be more vulnerable to cybersickness.


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Technology usage patterns also influence symptom severity. Prolonged screen exposure and sustained visual concentration have consistently been associated with visual fatigue, headaches and cognitive strain (Dennison et al., 2016; Sheppard & Wolffsohn, 2018). Within construction, practitioners engaged in BIM modelling, project coordination and digital visualisation are likely to experience greater digital exposure than those performing less screen-intensive tasks.

Finally, the type of digital technology may affect the severity of cybersickness. Immersive technologies, such as VR and augmented reality (AR), are generally associated with greater sensory conflict and motion-related discomfort than conventional screen-based systems (Rebenitsch & Owen, 2016; Weech et al., 2019). Nevertheless, prolonged use of non-immersive digital tools may also contribute to cybersickness through continuous visual engagement and repetitive screen-based interaction.

**Coping and Mitigation Strategies**

Various strategies have been proposed to reduce cybersickness symptoms and improve user comfort during digital interaction (Stanney et al., 2020; Saredakis et al., 2020). Behavioural strategies, particularly taking regular breaks, are among the most effective approaches for reducing visual fatigue, cognitive strain and prolonged sensory exposure, thereby improving comfort and concentration.

Ergonomic interventions, including appropriate screen brightness, viewing distance, display positioning and workstation design, can further minimise eye strain and visual discomfort associated with prolonged screen use (Moore et al., 2024; Sheppard & Wolffsohn, 2018). Optimising ambient lighting and reducing screen glare have also been shown to improve visual comfort during digitally intensive tasks.

In immersive digital environments, gradual exposure and adaptation training may enhance users' tolerance to virtual systems and reduce susceptibility to cybersickness (Saredakis et al., 2020). In addition, training and awareness programmes that promote symptom recognition, ergonomic practices and digital wellness can encourage healthier technology-use behaviours and support occupational well-being among construction practitioners.

**Conceptual Framework**

Based on the reviewed literature, a conceptual framework was developed to examine the relationships between demographic characteristics, digital usage patterns and cybersickness severity among construction practitioners (Figure 1). The framework proposes that demographic characteristics and digital usage patterns influence the occurrence and severity of cybersickness, while coping strategies can mitigate symptom severity.

Demographic characteristics include gender, age, professional experience, and job role, whereas digital usage patterns include screen exposure, digital tool usage, and exposure to immersive technologies. Cybersickness severity is represented by three symptom dimensions: **oculomotor, nausea-related** and **disorientation**, adapted from the Simulator Sickness Questionnaire (SSQ) framework (Kennedy et al., 1993). Coping strategies, including regular breaks, screen adjustment, and ergonomic practices, are incorporated as mitigating factors and illustrated with a dashed arrow to indicate their buffering role in reducing cybersickness associated with prolonged digital interaction.

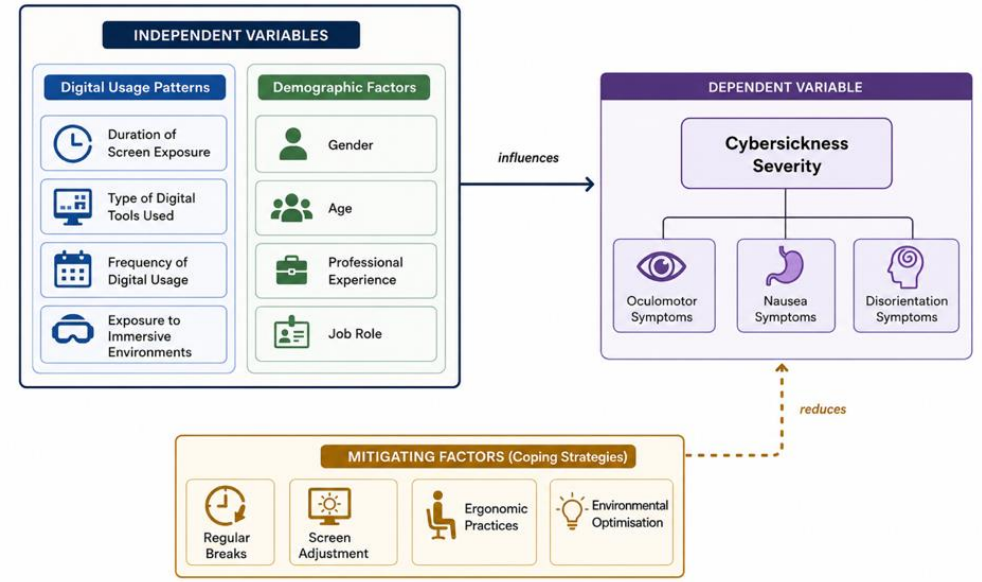



**Figure 4:** Conceptual Framework of Cybersickness Among Construction Practitioners
*Source: Developed by the authors based on the research questions and synthesis of the existing literature. The visual layout and graphical elements were refined using Gemini (January 2026).*

## RESEARCH METHODOLOGY

This study employed a quantitative research design to investigate self-reported cybersickness among construction practitioners in Malaysia. A structured questionnaire survey was developed based on an extensive review of the literature on cybersickness, digital ergonomics, occupational health and digital construction. The literature review informed the development of the conceptual framework and questionnaire, with particular emphasis on identifying factors associated with cybersickness and on existing approaches to its assessment and mitigation.


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The questionnaire comprised four sections. Section A collected respondents' demographic information, including gender, age, professional background, job role and years of professional experience. Section B assessed cybersickness severity using symptom-related items adapted from the SSQ (Kennedy et al., 1993). The original SSQ symptom items were reviewed and adapted to reflect routine digital technology use among construction practitioners, with items retained and organised under the three SSQ dimensions of oculomotor, nausea-related, and disorientation. Terminology referring specifically to simulator- or headset-based experiences was contextualised to broader digital work environments where necessary, while the underlying symptom constructs were retained.

Section C examined digital usage patterns, including the types of digital tools used, frequency of use, daily screen exposure and interaction with immersive technologies. Section D assessed the coping strategies adopted by respondents to alleviate cybersickness-related discomfort.

A stratified purposive sampling approach was adopted to obtain responses from construction practitioners representing a range of professional disciplines, including architects, engineers, quantity surveyors, project managers and site supervisors. Eligible respondents were required to be actively involved in construction-related work and routinely use digital technologies, such as BIM software, project management platforms, communication tools and other screen-based applications.

The questionnaire was administered online using Google Forms and distributed via email and professional social media networks between 9 October and 12 December 2025. Prior to the main survey, a pilot study was conducted to evaluate the clarity, reliability and relevance of the questionnaire, and minor revisions were made based on participant feedback.

This study complied with the university's ethical guidelines. Participation was voluntary, informed consent was obtained from all respondents prior to data collection, and all responses were anonymised to ensure confidentiality.

The collected data were analysed using IBM SPSS Statistics. Descriptive statistics (frequency, percentage, mean and standard deviation) were used to summarise respondents' demographic characteristics, digital usage patterns, cybersickness occurrence and severity, perceived contributing factors and coping strategies. Pearson correlation analysis was performed to examine the relationships between digital usage variables and overall cybersickness severity, while independent-samples t-tests were used to determine differences in cybersickness severity across demographic groups. These analyses provided a descriptive and exploratory understanding of cybersickness and the factors associated with symptom severity among construction practitioners.

## ANALYSIS AND DISCUSSION

### Response Rate and Reliability Analysis

A total of 111 survey responses were received for this study. After screening for consent, 109 responses (98.2%) were retained for analysis, while 2 responses (1.8%) were excluded due to the absence of participant consent. The sampling frame comprised construction practitioners in Malaysia who were actively engaged in construction-related work and routinely used digital technologies as part of their professional activities. Respondents from different construction-related professional roles and experience levels were recruited through email and professional online networks using a stratified purposive sampling approach. The final sample of 109 respondents provided an adequate basis for descriptive and exploratory quantitative analysis, enabling meaningful interpretation of cybersickness experiences and group comparisons the study objectives. Given the purposive sampling approach, the findings are interpreted as empirical evidence of cybersickness experiences within the sampled construction practitioners rather than as statistically representative of the entire Malaysian construction workforce.

Prior to analysis, all retained cases (n = 109) were examined for completeness and data quality. Overall, the responses were suitable for statistical analysis, with only minor missing values identified in a small number of questionnaire items. Missing data were handled using valid response analysis, which automatically excluded incomplete entries from statistical calculations for the respective variables.

The internal consistency of the survey instrument was assessed using Cronbach's alpha reliability analysis. The overall questionnaire achieved a Cronbach's alpha of 0.960, indicating excellent reliability and strong internal consistency.

### Respondent Profile and Digital Usage

Figures 2 and 3 summarise the demographic and digital usage characteristics of the respondents. The sample comprised 109 construction practitioners representing diverse demographic backgrounds, professional roles and experience levels. Male respondents accounted for 53.2% of the sample, while females represented 46.8%. The respondents spanned a broad age range, with the largest proportion aged 45-54 years (27.5%), followed by 25-34 years (25.7%). Nearly half (49.5%) had more than 10 years of professional experience, and the sample included a range of occupations, led by quantity surveyors (25.7%), followed by engineers (11.9%), site supervisors (8.3%) and project managers (7.3%), providing perspectives across multiple construction disciplines.


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The findings indicate extensive reliance on digital technologies in routine construction practice. More than half of the respondents (55.0%) reported using digital tools for over six hours per day, while a further 22.0% reported 4-6 hours of daily use. Word-processing, communication, and spreadsheet applications were the most frequently used digital tools, whereas Computer-Aided Design (CAD)/BIM applications were used moderately, and VR applications were used least frequently. Digital technologies were primarily employed for communication and collaboration (63.3%), project management and coordination (57.8%), design and drafting (48.6%), site monitoring (47.7%), and quantity take-off and cost estimation (45.9%), while only 24.8% reported using immersive technologies for training and simulation. The findings demonstrate that construction practitioners routinely engage with screen-based technologies, although immersive applications remain relatively uncommon.

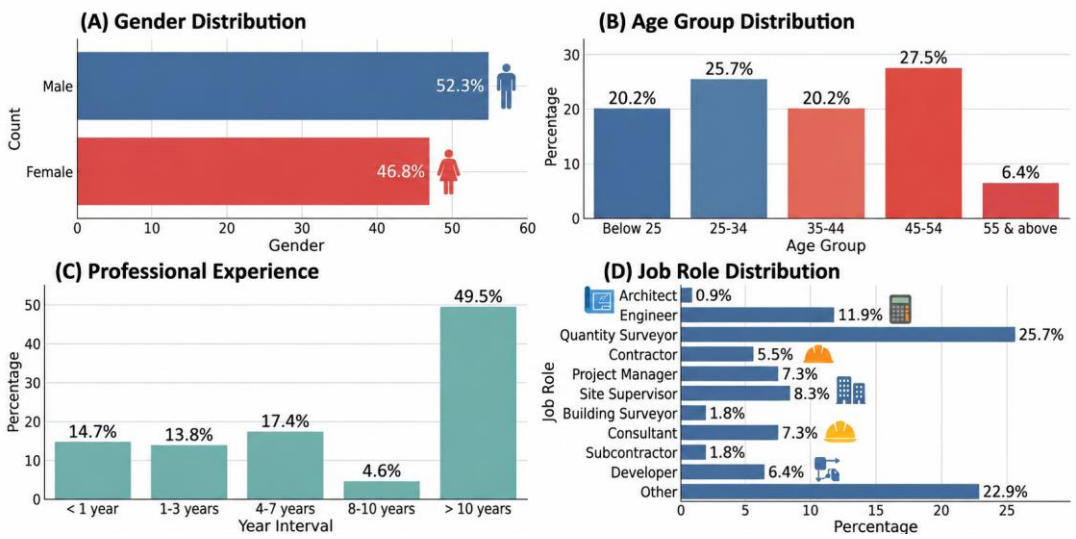



**Figure 2:** Demographic Profile of Sample Population (N=109), illustrating percentage distributions across: (A) gender breakdown, (B) age group distribution, (C) professional experience intervals, and (D) organisational job positions.
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

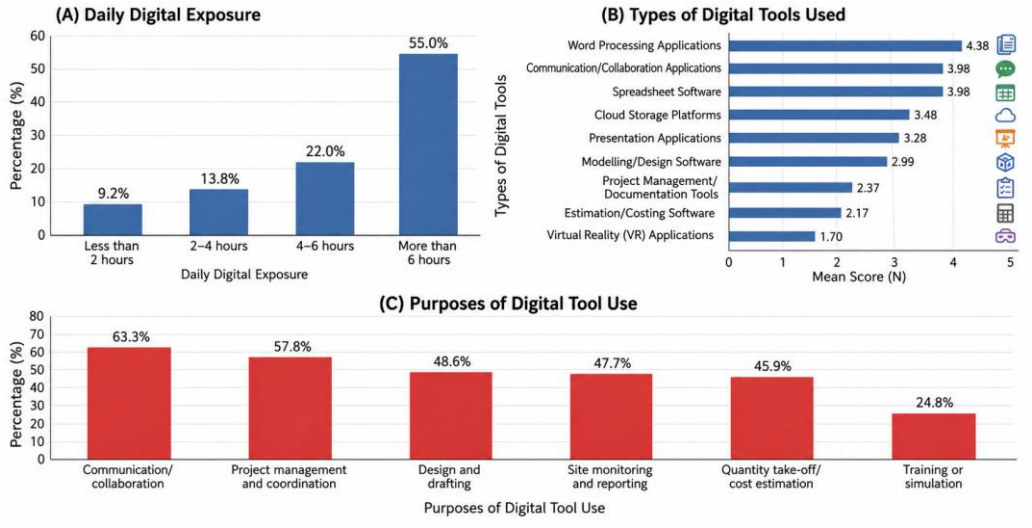



**Figure 3:** Digital Usage Characteristics of Sample Population (N=109), showing the distribution of (A) daily digital exposure, (B) mean frequency of use across different categories of digital tools, and (C) the primary purposes of digital tool use among construction practitioners.

*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

## Occurrence and Severity of Cybersickness

### *Frequency of Cybersickness Occurrence*

Figure 4 presents the frequency of cybersickness among construction practitioners. Slightly more than half of respondents (50.5%) reported experiencing cybersickness symptoms at least occasionally, whereas 49.5% had never experienced them. Frequent symptoms were uncommon, with fewer than 10% reporting weekly or more frequent occurrences. These findings indicate that cybersickness is generally intermittent rather than chronic, suggesting that digital tool use in construction is more likely to result in recurring discomfort than persistent health problems. This pattern is consistent with previous studies reporting that prolonged digital interaction primarily causes temporary visual and cognitive discomfort rather than severe physiological effects (Rebenitsch & Owen, 2016).


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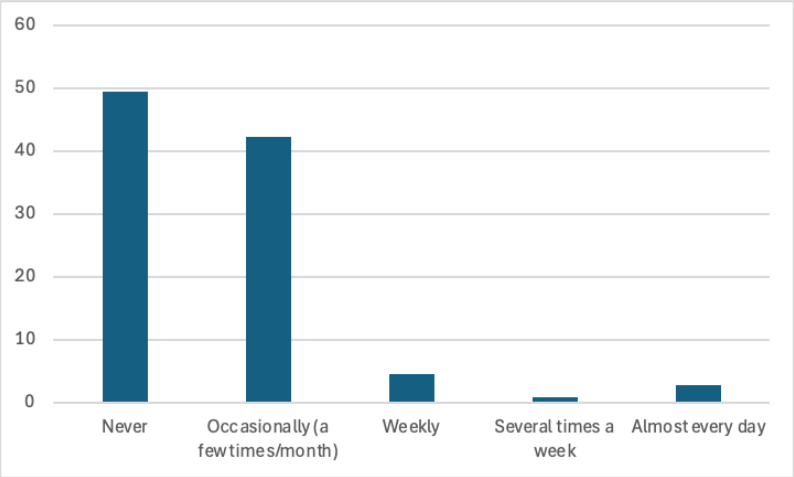



**Figure 4:** Frequency of Cybersickness (%)
*Source: Developed by the authors based on the survey results.*

***Overall Severity of Cybersickness***

To further characterise these experiences, Figure 5 presents the mean severity scores for the three symptom dimensions. Oculomotor symptoms were rated as the most severe (M = 2.30), followed by disorientation (M = 1.72) and nausea-related symptoms (M = 1.59), with an overall mean score of 1.87, corresponding to symptoms rated "Rarely" to "Sometimes". These findings indicate that cybersickness associated with routine construction work is predominantly characterised by visual discomfort, whereas vestibular and gastrointestinal symptoms remain relatively mild. The greater variability observed for oculomotor symptoms further suggests that visual fatigue differs according to individual work patterns and digital exposure.

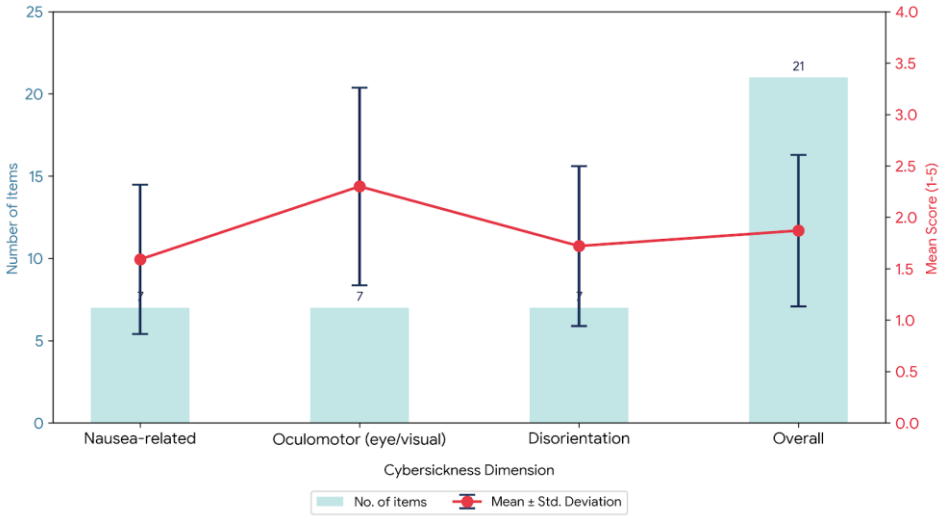



**Figure 5:** Mean Severity Scores Across Cybersickness Dimensions
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

### *Symptom Profiles*

Figure 6 presents the severity of individual cybersickness symptoms. Oculomotor symptoms emerged as the predominant manifestation, with eye strain, headaches and difficulty focusing recording the highest severity, whereas disorientation- and nausea-related symptoms, including vertigo, spatial confusion, nausea and vomiting, were reported less frequently. This symptom profile suggests that cybersickness among construction practitioners is primarily associated with prolonged visual workload arising from routine use of conventional screen-based technologies rather than the motion-induced sensory conflicts typically observed in immersive virtual environments. The relatively low prevalence of vestibular and gastrointestinal symptoms is consistent with respondents' limited use of immersive technologies. These findings extend previous research by demonstrating that conventional digital tools used in construction practice may also induce cybersickness symptoms, particularly visual fatigue, even in non-immersive settings (Rebenitsch & Owen, 2016; Rosenfield, 2016; Oh & Son, 2022).


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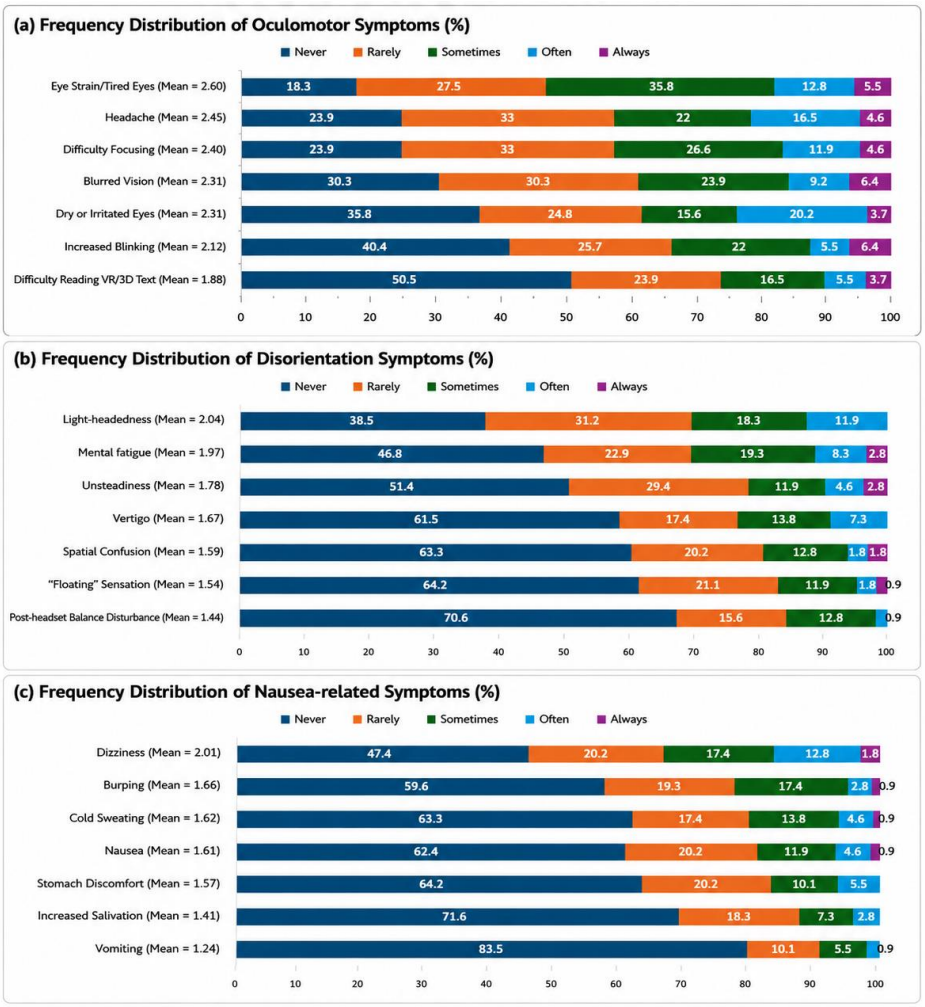



**Figure 6:** Frequency Distribution of Cybersickness Symptoms (%)
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

## Demographic Associated with Cybersickness

### *Gender*

Figure 7 compares cybersickness severity between male and female respondents. An independent-samples t-test examined differences in overall cybersickness severity between male and female respondents. A statistically significant difference was observed, with female respondents reporting higher mean severity

(M = 2.05, SD = 0.85) than male respondents (M = 1.70, SD = 0.58), t(106) = −2.50, p = 0.014. The magnitude of the difference was moderate (Cohen's d = 0.49). This finding is consistent with previous studies reporting greater susceptibility to cybersickness among females, which has been associated with differences in visual processing, motion sensitivity and physiological factors (Golding, 2006; Stanney et al., 2020). The finding suggests that gender-related differences in cybersickness susceptibility may warrant consideration when developing digital well-being and ergonomic interventions for construction practitioners.

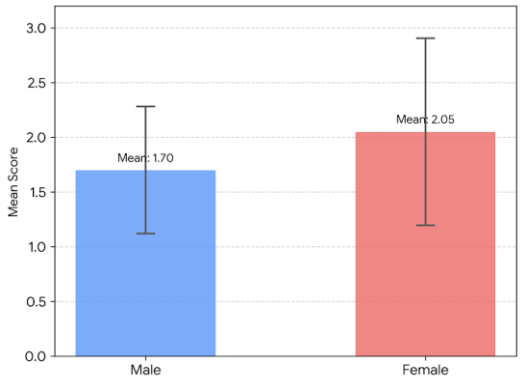



**Figure 7:** Mean Cybersickness Severity by Gender
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

### *Age and Professional Experience*

Figure 8 illustrates cybersickness severity across age groups and professional experience. A declining trend was observed for both variables, with younger practitioners and those with fewer years of experience reporting higher symptom severity. Respondents aged 20-25 years reported the highest mean severity (≈2.15), whereas those aged 35+ reported the lowest (≈1.62). Likewise, respondents with less than 1 year of professional experience exhibited the highest severity (≈2.40), while those with 8-10 years of professional experience reported the lowest (≈1.53).

These findings suggest that greater age and professional experience may enhance adaptation to digitally intensive work environments. Previous research similarly reported that repeated exposure to digital systems improves user tolerance and reduces cybersickness over time (Fernandes & Feiner, 2016). Consequently, younger and less experienced practitioners may benefit from greater guidance on healthy digital work practices and ergonomic awareness.


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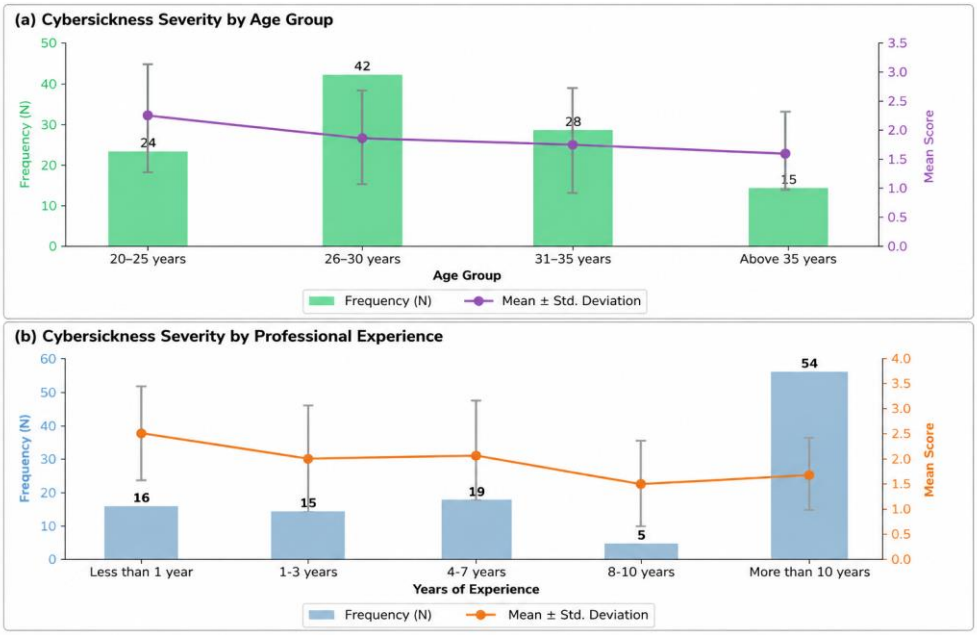



**Figure 8:** Cybersickness Severity by Age Group, and Professional Experience
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

## Perceived Contributing Factors Associated with Cybersickness

Figure 9 presents respondents' perceptions of factors contributing to cybersickness, grouped into display and visual factors, motion and interaction factors, user-related factors, and environmental and physical factors. Overall, respondents perceived these factors as exerting low to moderate influence on symptom severity, with environmental and visual factors receiving the highest ratings.

Among the display and visual factors, display brightness and contrast emerged as the most influential (M = 2.82), followed by low frame rate/image smoothness (M = 2.49), text legibility (M = 2.46), motion blur/visual latency (M = 2.44) and field-of-view mismatch (M = 2.40). These findings suggest that display quality and visual presentation play an important role in user comfort during prolonged digital interaction.

For motion and interaction factors, system response latency recorded the highest perceived influence (M = 2.32), followed by camera/viewpoint motion and navigation method (both M = 2.23), whereas virtual movement speed had the lowest mean score (M = 2.21). Although the perceived influence was modest, the findings indicate that smooth system responsiveness reduces discomfort during digital tool use.

Regarding user-related factors, pre-use fatigue emerged as the most influential factor (M = 2.46), followed by exposure duration (M = 2.19), while motion sickness susceptibility (M = 1.99) and prior immersive experience (M = 1.90) were perceived as less influential. This suggests that temporary physical and mental conditions may have a greater impact on cybersickness than individual predisposition.

Among all categories, environmental and physical factors recorded the highest overall ratings. Ergonomic posture (M = 2.78), ambient lighting (M = 2.74) and environmental distractions (M = 2.67) were perceived as the principal contributors, highlighting the importance of ergonomic workstation design and appropriate working environments in reducing cybersickness.

These findings shows that cybersickness among construction practitioners is primarily influenced by visual demands, ergonomic conditions, and user fatigue, rather than by motion-related characteristics typically associated with immersive virtual environments. This pattern is consistent with the predominance of oculomotor symptoms observed in the present study and suggests that improving display quality, workstation ergonomics and working conditions may be more effective than technology-specific interventions alone.

Pearson correlation analysis was conducted to examine the relationships between digital usage patterns and overall cybersickness severity (Table 1). Continuous screen use without breaks showed a significant positive association with cybersickness severity ($r = 0.295$, $p = 0.002$), indicating that longer uninterrupted periods of screen use were associated with greater symptom severity. The correlation was small to moderate. In contrast, the interval between breaks was negatively associated with cybersickness severity ($r = -0.254$, $p = 0.008$), also representing a small-to-moderate association. This indicates that longer intervals between breaks were associated with higher reported severity. Total daily digital-tool use was not significantly associated with cybersickness severity ($r = 0.147$, $p = 0.127$), indicating a small and statistically non-significant relationship. The findings suggest that the pattern of screen exposure, particularly uninterrupted use and break intervals, may be more closely associated with cybersickness severity than total daily exposure alone. The results reinforce recommendations in digital ergonomics literature advocating regular breaks to reduce visual fatigue and cognitive strain during prolonged digital work (Sheppard & Wolffsohn, 2018).


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**Table 2:** Pearson Correlation between Digital Usage Patterns and Overall Cybersickness Severity

| Usage pattern | Pearson correlation, *r* | *p*-value | Effect Interpretation |
|---|---|---|---|
| Continuous screen exposure | 0.295 | 0.002 | Small-to-moderate positive association |
| Break interval | -0.254 | 0.008 | Small-to-moderate negative association |
| Daily digital exposure | 0.147 | 0.127 | Small, non-significant association |

*Source: Developed by the authors based on the survey results.*

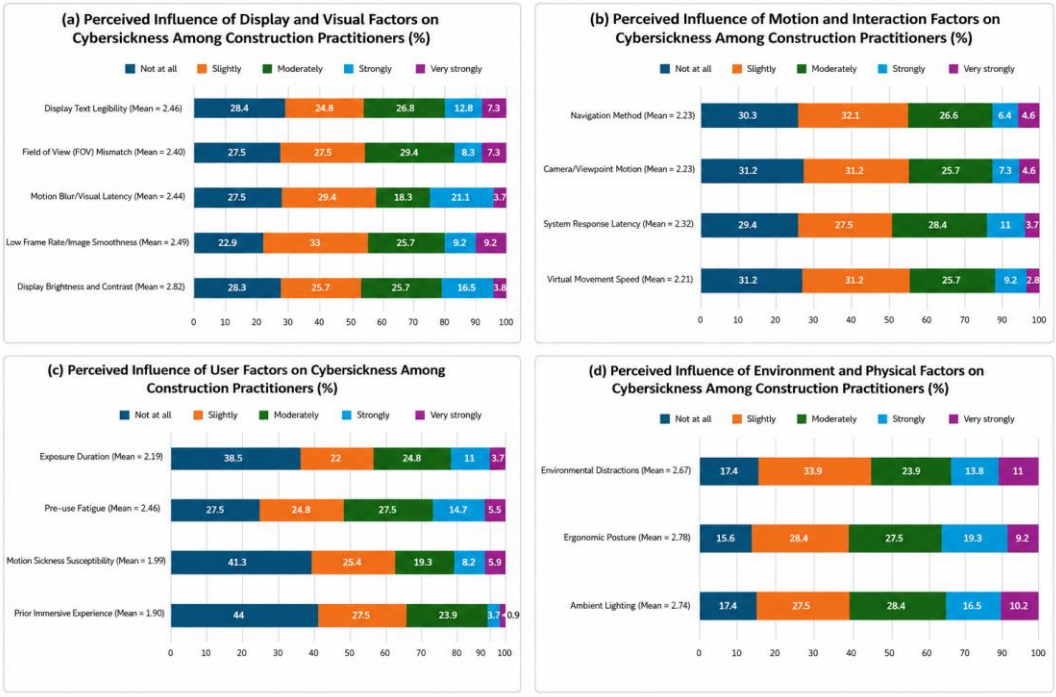



**Figure 9:** Perceived Contributing Factors Associated with Cybersickness
*Source: Developed by the authors based on the survey results. The visual layout and graphical elements were refined using Gemini (June 2026).*

## Perceived Effectiveness of Coping Strategies

Having identified the factors associated with cybersickness, the study further examined the coping strategies adopted by construction practitioners to manage digital-related discomfort. As shown in Figure 10, most strategies were adopted moderately to frequently (mean = 2.39-3.27). Regular breaks emerged as the most frequently adopted and effective strategy (M = 3.27), followed by screen adjustment (M = 3.17) and maintaining ergonomic posture (M = 3.17). Visual

rest practices (M = 3.00) and hydration and wellness measures (M = 2.97) were also commonly adopted, indicating that practitioners primarily relied on simple behavioural and ergonomic approaches to alleviate discomfort.

In contrast, digital exposure management (M = 2.85) and the use of ergonomic aids (M = 2.69) demonstrated moderate levels of adoption, whereas immersive technology reduction (M = 2.39) and blue-light protection (M = 2.39) were perceived as the least effective strategies. This pattern likely reflects the relatively limited use of immersive technologies among respondents, together with mixed evidence regarding the effectiveness of blue-light filters.

Overall, the findings suggest that construction practitioners manage cybersickness primarily through behavioural and ergonomic interventions rather than technology-specific solutions. The prominence of regular breaks, screen adjustment and ergonomic posture aligns with the factors identified as contributing to symptom severity and supports previous recommendations that periodic breaks and ergonomic practices are effective in reducing cybersickness and visual fatigue during prolonged digital work (Parry et al., 2013; Keshavarz et al., 2014).

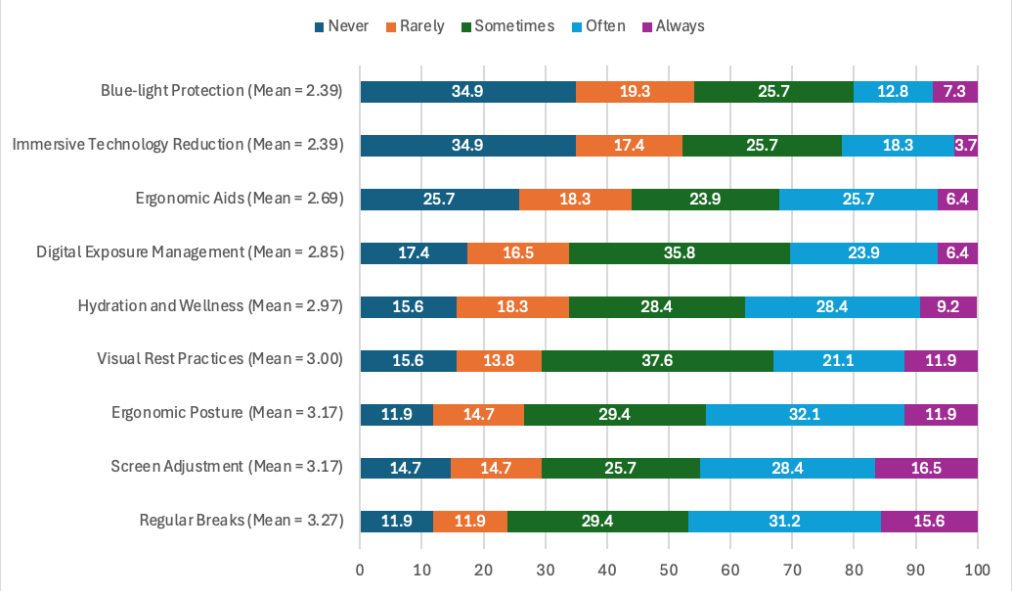



**Figure 10:** Perceived Coping Strategies for Cybersickness Mitigation Among Construction Practitioners (%)

*Source: Developed by the authors based on the survey results.*


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### Practical Implications

The findings have important implications for the management of occupational health in increasingly digital construction workplaces. Although digital technologies have become indispensable for project delivery, the results demonstrate that prolonged screen-based interaction may adversely affect practitioners' visual comfort and well-being, even in predominantly non-immersive work environments. Cybersickness should therefore be recognised as a broader digital ergonomics issue rather than a concern confined to virtual reality applications.

The findings further suggest that organisations should prioritise human-centred digital work practices alongside technological implementation. Given that continuous screen exposure, ergonomic posture and display conditions were identified as important contributors to cybersickness, workplace interventions should extend beyond technology adoption to include ergonomic workstation design, optimised display settings and structured work–rest schedules. Such measures may reduce visual fatigue, improve user comfort, and support sustained cognitive performance during digitally intensive tasks.

From an organisational perspective, integrating digital well-being into occupational health and safety policies, employee training and digital transformation initiatives may enhance both workforce well-being and operational performance. Particular attention should be directed towards younger and less experienced practitioners, who demonstrated greater susceptibility to cybersickness. As digital technologies continue to reshape construction practice, embedding ergonomic and human-centred considerations into digital transformation strategies will be essential to achieving sustainable, productive digital workplaces.

## CONCLUSION

This study investigated self-reported cybersickness among Malaysian construction practitioners engaged in digitally intensive work. Specifically, it examined the occurrence and severity of cybersickness symptoms, identified demographic and digital-use factors associated with symptom severity, and evaluated coping strategies used to mitigate digital-related discomfort.

The findings indicate that a substantial proportion of sampled practitioners reported cybersickness symptoms, although symptoms are generally intermittent rather than chronic. Oculomotor symptoms, particularly eye strain, headaches and difficulty focusing, were the predominant manifestations, whereas nausea-related and disorientation symptoms were comparatively less severe. Female and younger practitioners reported greater symptom severity, while continuous screen exposure and inadequate break intervals were associated with increased discomfort. In contrast, total daily digital exposure was not

significantly associated with symptom severity, suggesting that different patterns of digital use may be associated with cybersickness symptoms beyond total exposure duration alone.

The study further indicates that practitioners perceived ergonomic, behavioural and environmental factors as relevant to their cybersickness experiences. Display conditions, ambient lighting, posture and fatigue were perceived as key contributors, whereas regular breaks, screen adjustment and ergonomic practices were among the more frequently adopted coping strategies. These findings suggest that cybersickness experiences may be related not only to digital technologies but also to how they are used and the working conditions in which they are deployed

This study contributes to the growing literature on cybersickness by providing empirical evidence from construction practitioners engaged in routine digital work, extending the context beyond the gaming and immersive virtual-reality settings commonly examined in previous research. Within the context of the sampled Malaysian practitioners, the findings provide an initial basis for further research on digital well-being, ergonomic practices and human-centred approaches to digital work in construction.

**Limitation and Future Research**

Several limitations should be considered when interpreting the findings. First, the study relied on self-reported measures of cybersickness symptoms, digital usage patterns and coping strategies. Although the questionnaire demonstrated excellent reliability, self-reported data are subject to recall bias and individual differences in symptom perception. Future studies should complement subjective assessments with objective measures, such as eye-tracking, physiological monitoring or digital activity logs.

Second, the cross-sectional design limits causal inference. Although significant associations were identified among continuous screen exposure, break intervals, and cybersickness severity, the temporal relationships among these variables cannot be established. Longitudinal and experimental research is therefore needed to examine the causal mechanisms underlying cybersickness in occupational settings.

Finally, the study was based on a moderate sample of Malaysian construction practitioners. Although respondents represented diverse professional roles and experience levels, some occupational subgroups were relatively small, limiting detailed comparisons within subgroups and broader generalisation. Future studies involving larger samples, multiple construction disciplines and cross-country comparisons would strengthen the robustness and generalisability of the findings.


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Despite these limitations, this study provides one of the first empirical investigations of cybersickness among construction practitioners engaged in routine digital work. By establishing baseline evidence on symptom patterns, associated factors and coping strategies, it provides a foundation for future research and supports the development of healthier, more human-centred digital workplaces in the construction industry.

**Declaration of Generative AI and AI-assisted Technologies in the Manuscript Preparation Process**

During the preparation of this manuscript, the authors used ChatGPT to assist with language refinement and readability. Selected figures were visually enhanced using Gemini. However, all underlying data, analyses, interpretations and scientific content were produced and verified by the authors, with AI use acknowledged in the relevant figure captions. The authors reviewed and edited all AI-assisted outputs and take full responsibility for the content of this publication. No AI tools were used for data collection, statistical analysis, interpretation of results or the formulation of scientific conclusions.

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# THE IMPACT OF INTEGRATING ACOUSTIC SURFACE MATERIAL DESIGN INTO INTERIOR SPACE PLANNING FOR HYBRID LEARNING ENVIRONMENTS

**Abdul Wafi Razali[1], Asrul Sani Abdul Razak[2], Raha Sulaiman[3], Musli Nizam Yahya[4], Nazli Bin Che Din[2*]**

[1]*Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYSIA SARAWAK
[2]*Department of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA
[3]*Department of Building Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[4]*Department of Transportation Engineering Technology,*
*Faculty of Engineering Technology,*
UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## Abstract

The adoption of hybrid teaching and learning has transformed the planning and design of higher education learning environments, requiring classroom interiors to support both face-to-face and remote instruction. However, inadequate acoustic conditions remain a major challenge, reducing speech intelligibility and limiting effective communication. This study investigates the role of interior surface material design in integrating acoustic considerations into the space planning of hybrid classrooms that accommodate conventional and collaborative learning. A combination of field measurements and acoustic simulations was conducted to evaluate the effects of wall and ceiling treatments on reverberation time (RT), speech transmission index (STI), and speech clarity ($C_{50}$). The findings demonstrate that strategically designed surface materials significantly improve acoustic performance and speech intelligibility. The study provides evidence-based design strategies for interior space planning to create hybrid learning environments that enhance communication and teaching and learning experiences.

***Keywords***: Hybrid Classroom, Classroom Acoustic, Space Planning

[*]Corresponding author. Email: nazlichedin@um.edu.my

## INTRODUCTION

The design of higher education learning environments has evolved considerably in response to advances in educational technology and changing pedagogical practices. Contemporary learning spaces are no longer viewed merely as physical settings for knowledge delivery but as active environments that influence teaching effectiveness, student engagement, and learning outcomes (Cheung et al., 2021). These environments may be physical or virtual (Zhong et al., 2023), and are increasingly expected to accommodate diverse instructional approaches, ranging from teacher-centred lectures to student-centred collaborative learning (Murphy et al., 2021). Consequently, learning space design has become a multidisciplinary endeavour that integrates principles from architecture, interior design, learning sciences, and environmental psychology to create environments that support evolving educational needs (Ellis & Goodyear, 2016).

The transformation of pedagogical practices has challenged the suitability of conventional classroom layouts, where rows of desks facing a lecturer primarily support one-way knowledge transmission. Such configurations are increasingly inadequate for interactive, collaborative, and technology-enabled learning activities (Cheung et al., 2021). However, despite significant advances in learning space design, there remains limited consensus regarding interior planning strategies capable of supporting the wide range of pedagogical activities expected in future learning environments (Rands & Gansemer-Topf, 2017). This challenge highlights the need for evidence-based design approaches that integrate spatial planning with environmental quality, including lighting, ventilation, and acoustic performance (Suraini & Aziz, 2023).

The rapid adoption of hybrid teaching has further accelerated the transformation of higher education learning spaces. Hybrid classrooms enable face-to-face and remote students to participate simultaneously, offering greater flexibility while extending educational access beyond the physical classroom (Li et al., 2023). Numerous studies have reported positive educational outcomes associated with hybrid learning, including improved student autonomy, flexibility, and overall satisfaction (Monk et al., 2020; Wei et al., 2023).

Although advances in educational technology have enhanced hybrid teaching delivery, maintaining equivalent learning experiences for both face-to-face and remote participants remains a significant challenge. Previous studies have reported that remote learners frequently experience reduced engagement due to technological limitations, ambiguous group membership, and diminished interaction with instructors and peers (Olt, 2018; Zydney et al., 2019). Audio quality has consistently been identified as one of the most critical determinants of successful hybrid learning. Remote participants rely almost exclusively on microphone-captured audio to understand classroom discussions, making speech intelligibility essential for effective participation (Cunningham, 2014).


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Consequently, inadequate classroom acoustics can substantially reduce communication quality, impair student engagement, and negatively affect learning performance (Otčenášek et al., 2022).

Classroom acoustic performance is fundamentally influenced by the interior environment. Excessive reverberation and poor speech transmission reduce speech intelligibility, increase listening effort, and negatively influence students' concentration, cognitive performance, and learning outcomes (Dockrell & Shield, 2012; Mogas et al., 2021). While considerable research has focused on improving classroom acoustics for conventional teaching environments, relatively limited attention has been given to how interior surface material design can support the dual instructional requirements of hybrid classrooms. Furthermore, existing studies primarily emphasise technological solutions, such as microphones and audiovisual systems, while comparatively few have investigated the contribution of interior space planning through strategic surface material design.

Therefore, this study investigates the role of interior surface material design in supporting acoustically favourable space planning for hybrid classrooms. Specifically, the study evaluates the effects of highly absorptive ceiling and wall surface treatments on three key acoustic performance indicators namely reverberation time (RT), speech transmission index (STI), and speech clarity ($C_{50}$) under two instructional settings: conventional lecture-based teaching and collaborative learning, across two different classroom sizes. The findings contribute evidence-based design strategies that integrate acoustic considerations into interior space planning to support effective communication and enhance learning experiences in hybrid higher education environments.

## LITERATURE REVIEW

### Classroom Space Design

The design of learning environments extends beyond functional and aesthetic considerations, as spatial architecture influences how users think, feel, and behave within a space (Warburton & Mor, 2022). Consequently, effective learning spaces should be designed based on a comprehensive understanding of users' needs while integrating principles from architecture, learning sciences, and environmental psychology (Ellis & Goodyear, 2016). Barrett et al. (2013) proposed the Stimulation–Individualisation–Naturalness (SIN) model, which identifies three spatial design dimensions that contribute to improved learning outcomes. Among these, naturalness encompasses environmental quality attributes such as lighting, thermal comfort, indoor air quality, and acoustics, highlighting the importance of integrating these elements into the planning and design of contemporary learning environments.

### Teaching and Learning Approaches

Instructional approaches are closely linked to the spatial and functional requirements of learning environments. Face-to-face (F2F) learning, the conventional mode of instruction, involves direct interaction between instructors and students within the same physical space and time (Eidenberger & Nowotny, 2022; Ramnarine, 2018). In higher education, the physical learning environment complements pedagogical practices by influencing teaching effectiveness, student engagement, and learning experiences (Anggrawan et al., 2019). As pedagogical approaches continue to evolve from teacher-centred to student-centred and collaborative learning, classroom design has similarly shifted towards more flexible learning environments that support active participation, interaction, and technology-enhanced teaching and learning (Pearlman, 2010).

### Classroom Acoustic

Architectural acoustics examines the behaviour of sound within enclosed spaces and its influence on human communication, comfort, and performance (Rossing, 2007). In educational environments, acoustic quality is essential for supporting effective speech communication and facilitating teaching and learning processes. Recognising its importance, several countries have established classroom acoustic standards and guidelines, including American National Standards Institute (2010), Building bulletin 93 (2015), and AS/NZS 2107:2000 (2000). These guidelines specify recommended criteria for key acoustic parameters, such as background noise, reverberation time, and speech intelligibility. Razali et al. (2024) proposed a comprehensive conceptual framework comprising six key design enablers that govern acoustic comfort in classroom environments.

## RESEARCH METHODOLOGY

Two classrooms at a public university in Malaysia were purposively selected to represent different spatial scales while retaining common characteristics of university teaching spaces, including rectangular room geometry, lecturer-oriented teaching areas, and student seating zones. Although originally designed for conventional face-to-face teaching, these classrooms reflect the practical adaptation of existing teaching spaces for technology-assisted and hybrid learning. Therefore, they serve as relevant case-study representations rather than statistically representative samples of all Malaysian hybrid learning spaces. The measurements were conducted under unoccupied conditions to evaluate the acoustic characteristics of the rooms. Three key acoustic parameters were assessed: background noise (BN), reverberation time (RT), and speech transmission index (STI). The physical characteristics of the selected classrooms are summarised in Table 1.


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**Table 1:** Classroom geometrical characteristics

| Classroom | Width (m) | Length (m) | Height (m) | Floor Area ($m^2$) | Volume ($m^3$) |
|---|---|---|---|---|---|
| C1 | 8.6 | 6 | 2.5 | 51.6 | 129 |
| C2 | 8.2 | 8.7 | 2.8 | 71.3 | 200 |

## Field Measurement

Background noise level (BNL) was measured by recording the equivalent continuous A-weighted sound pressure level (LAeq) in unoccupied classrooms with the heating, ventilation, and air conditioning (HVAC) system operating under normal conditions. The receiver positions were located at representative student seating positions and at each measurement location, the background noise level was recorded continuously for two minutes with a sampling interval of one second. Measurements were conducted using a Cirrus CR:171B sound level meter (SLM) positioned 1.2 m above the finished floor level, corresponding to the average ear height of seated students.

Reverberation time (RT) was measured using an omnidirectional dodecahedron loudspeaker as the sound source. The loudspeaker was driven by a Crown XLS1000 power amplifier to generate the test signal. The acoustic response was captured using a GRAS 46AE ½-inch measurement microphone positioned 1.2 m above the finished floor level and connected to a Scarlett 2i4 audio interface, and the recorded impulse responses were analysed using ODEON Room Acoustics Software (Version 17) to determine the RT values. The receiver positions were identical to those used for the background noise measurements to ensure consistency throughout the acoustic assessment.

Speech transmission index (STI) measurements were conducted using a BOSE M101 loudspeaker positioned 1.5 m above the finished floor level within the designated lecturer teaching zone to represent the instructor's position. A sweep signal generated by a Minirator MR2 signal generator was used to simulate an amplified speech source. The signals received were measured using a Blue Solo 01dB sound level meter integrated with dBBati acoustic measurement software for STI analysis.

## Acoustic Simulation

Three-dimensional (3D) models of the selected classrooms were developed using SketchUp Pro® based on the measured room dimensions. Accurate representation of the room geometry and surface areas is essential to minimise modelling errors and ensure reliable acoustic simulations. Previous studies have reported that model verification generally permits a maximum surface area deviation of 20%, equivalent to a minimum geometric accuracy of 80%, although this may vary depending on modelling techniques, software configurations, and

the accuracy of the assigned material absorption and scattering coefficients (Jalil et al., 2019).

Prior to the simulation, the acoustic models were validated by comparing the simulated RT and STI with the corresponding field measurement results using ODEON Room Acoustics Software (Version 17). During the validation process, the surface material properties, sound source locations, and receiver positions were iteratively refined to achieve similarity between the measured and simulated acoustic parameters. Model validation was considered acceptable when the relative differences in RT and STI satisfied the recommended just noticeable difference (JND) criteria. Due to limitations of the existing measurement equipment, C50 could not be measured during the field investigation and was therefore excluded from the validation process. The close agreement between the measured and simulated RT and STI values indicates that the developed models adequately represent the actual acoustic conditions of the classrooms. Although C50 was not independently validated through field measurements, the successful validation of RT and STI provides confidence in the overall reliability of the acoustic models. Therefore, the simulated C50 results were considered appropriate for evaluating the effects of the proposed surface treatments on speech clarity, while acknowledging the absence of direct field validation for this parameter.

Acoustic simulations were performed to evaluate the effects of wall and ceiling surface treatments on RT, STI, and $C_{50}$ under different learning settings. The surface treatment simulation focused on two major interior surfaces, namely the ceiling and wall surfaces. Three scenarios were evaluated for each classroom and learning configuration: (i) the existing condition, representing the original interior surface materials; (ii) the ceiling treatment scenario, in which the treatment was applied to the entire ceiling surface area; and (iii) the wall treatment scenario, in which the treatment was applied to the entire wall surface area. The sound absorption coefficients of the selected materials across the relevant frequency bands, together with the total surface area covered by each treatment, are presented in Table 2.

**Table 2:** Sound absorption coefficient (SAC) of surface materials and treatment area for each element and classroom

| **Surface Element** | **Frequency (Hz)** | | | | | | **Treatment Area ($m^2$)** | |
|---|---|---|---|---|---|---|---|---|
| | **125** | **250** | **500** | **1000** | **2000** | **4000** | **C1** | **C2** |
| Wall | 0.15 | 0.35 | 0.65 | 1.00 | 0.9 | 1.00 | 44 | 74 |
| Ceiling | 0.34 | 0.43 | 0.54 | 0.67 | 0.65 | 0.64 | 46 | 77 |


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Virtual microphone receivers were positioned 2.0 m above the finished floor level and were arranged in a 1 m × 1 m grid, resulting in 35 and 70 receiver positions in the small and medium classrooms under two instructional configurations. The first represented a conventional arrangement with students seated in rows facing the lecturer, while the second represented a collaborative learning arrangement using modular group seating. For the conventional learning configuration, a single sound source representing the lecturer's natural raised voice was positioned within the designated teaching area. For the collaborative learning configuration, four sound sources representing students' natural raised voices were positioned at the centre of each discussion group. The surface materials assigned to the wall, ceiling, and floor elements were identical for both classroom configurations, with their acoustic properties.

## ANALYSIS AND DISCUSSION

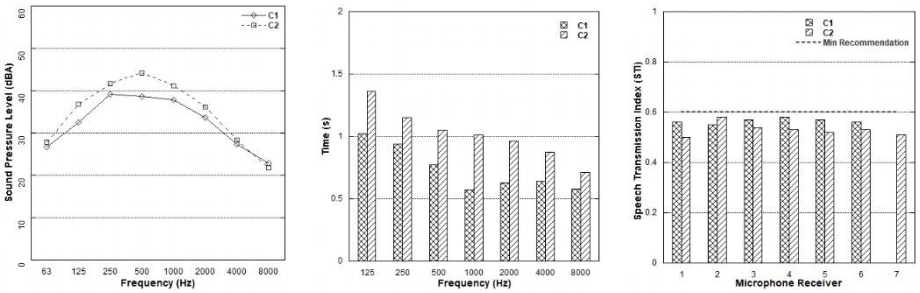
### Field Measurement Results

Figure 1(a) presents the measured equivalent continuous A-weighted sound pressure level (LAeq) in the two classrooms under unoccupied conditions with the HVAC system operating. The mean LAeq values were 44.3 dBA for C1 and 47.7 dBA for C2. Both values exceeded the maximum recommended BN level of 35 dBA for unoccupied classrooms specified by American National Standards Institute (2010) and Building bulletin 93 (2015). The elevated background noise levels indicate that the existing acoustic environment may adversely affect speech perception and increase listening effort during classroom activities.

The measured RT values are presented in Figure 1(b). According to American National Standards Institute, (2010) classrooms with a volume of less than 283 $m^3$ should achieve a maximum RT of 0.6 s. The average RT values recorded for C1 and C2 were 0.74 s and 1.01 s, corresponding to room volumes of 129 $m^3$ and 198 $m^3$, respectively. Both classrooms exceeded the recommended RT criterion, indicating inadequate sound absorption within the existing interior environment. Although the measured RT values complied with the maximum limits recommended by Building bulletin 93, (2015), the predominantly reflective surface finishes contributed to prolonged sound decay. Previous studies have demonstrated that improving the sound absorption characteristics of wall and ceiling surfaces is an effective strategy for reducing RT and enhancing classroom acoustic performance (Razali et al., 2023).

Figure 1(c) illustrates the distribution of the STI across the receiver positions in both classrooms. The average STI values were 0.56 for C1 and 0.53 for C2, corresponding to a fair rating according to the IEC 60268-16 classification. These results indicate that the existing acoustic conditions provide only moderate speech intelligibility, which may affect verbal communication during teaching and learning activities. Overall, the measured background noise

level, reverberation time, and speech transmission index indicate that the existing classrooms do not fully satisfy the recommended acoustic performance criteria for educational spaces. These findings establish the baseline acoustic conditions and provide the basis for evaluating the effectiveness of the proposed interior surface material treatments.




(a) (b) (c)

**Figure 1:** Field measurement findings for (a) BN, (b) RT, and (c) STI

## 3D Model Verification

The acoustic models were validated by comparing the RT and STI obtained from the simulations with the corresponding on-site measurement results. Model accuracy was evaluated by calculating the relative differences between the measured and simulated acoustic parameters. Previous studies recommend just noticeable difference (JND) of less than 5% for RT and 0.03 for STI to ensure perceptually insignificant differences (Christensen & Koutsouris, 2013). However, Bistafa & Bradley (2000) reported that a maximum relative difference of 10% for RT is generally considered an acceptable level of accuracy for engineering applications.

The validation was performed by comparing the mean RT values over the frequency range of 125–8000 Hz and the STI values at the corresponding receiver locations. As summarised in Table 3, the simulated RT and STI values for both models were in close agreement with the field measurements. The relative differences were below 10% for RT and 0.03 for STI, confirming that both acoustic models adequately represented the measured acoustic conditions and were therefore considered suitable for the subsequent simulation analyses.


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**Table 3:** Validation results based on the just noticeable difference (JND) for RT and STI

| Parameter | Classroom | | | | | |
|---|---|---|---|---|---|---|
| | C1 | | | C2 | | |
| | Field | Simulation | JND | Field | Simulation | JND |
| Reverberation time | 0.74 | 0.75 | 2% | 1.01 | 1.00 | 2% |
| STI | 0.56 | 0.56 | 0 | 0.53 | 0.54 | 0.01 |

## Surface Treatment Simulation

### *a) Reverberation time (RT)*

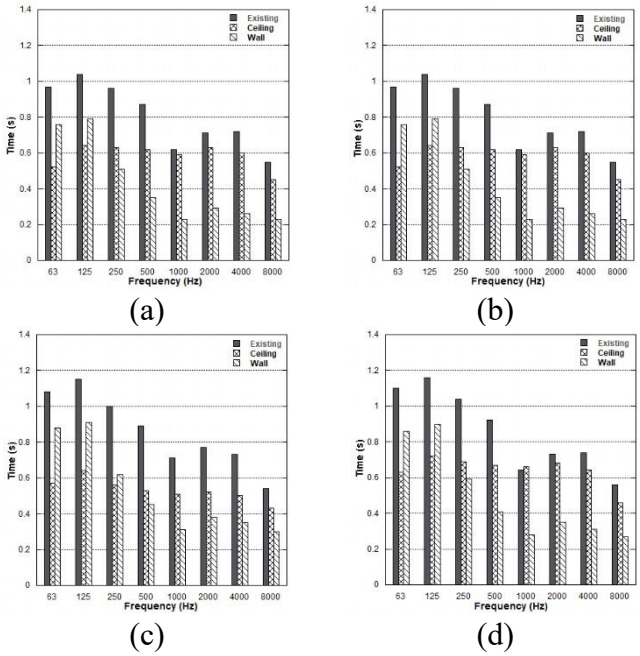



**Figure 2:** Impact of surface treatments on RT under conventional and collaborative learning settings (a & b) in small classroom, (c & d) medium classroom

According to Building Bulletin 93 (2015), the maximum recommended RT for unoccupied and furnished classrooms is 0.8 s. In comparison, American National Standards Institute (2010) specifies a more stringent RT criterion of 0.6 s for classrooms with a volume of less than 283 m³ and 0.7 s for volumes exceeding 283 m³. Figures 2(a) and 2(b) present the RT results for the small classroom under collaborative and conventional learning configurations, respectively. Under the existing conditions, the average RT values were 0.80 s for collaborative learning and 0.79 s for conventional learning. Although both configurations complied with the BB93 recommendation, they exceeded the RT

limit specified by ANSI/ASA S12.60. Following the application of absorptive ceiling materials, the average RT decreased to 0.59 s and 0.48 s for the collaborative and conventional configurations, respectively. Further reductions were achieved after treating all wall surfaces with absorptive materials, resulting in average RT values of 0.43 s for collaborative learning and 0.44 s for conventional learning. These findings demonstrate that both ceiling and wall treatments substantially improved the acoustic performance of the small classroom.

As illustrated in Figures 2(c) and 2(d), under the existing conditions, the average RT was 0.86 s for both collaborative and conventional learning configurations in medium classroom. The application of absorptive ceiling materials reduced the RT to 0.53 s and 0.64 s for collaborative and conventional learning, respectively. Following wall treatment, the average RT further decreased to 0.51 s and 0.50 s, respectively. The consistent reduction in RT across both room sizes indicates that increasing the acoustic absorption of ceiling and wall surfaces effectively reduced sound reflections and shortened sound decay time.

### *b) Speech Transmission Index (STI)*
### *Collaborative Learning*

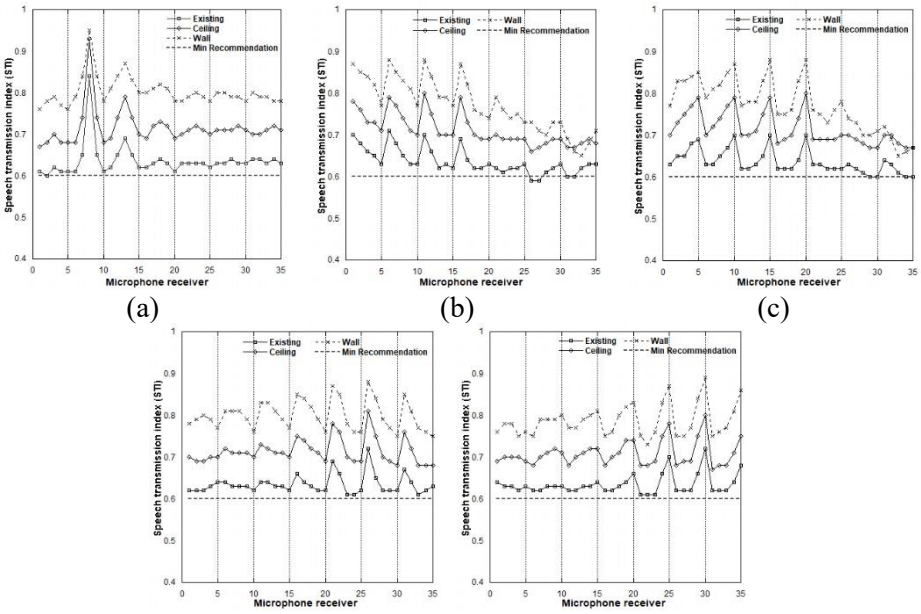



**Figure 3:** STI distribution in small classroom for different sound source locations: (a) lecturer, (b) S1, (c) S2, (d) S3, and (e) S4


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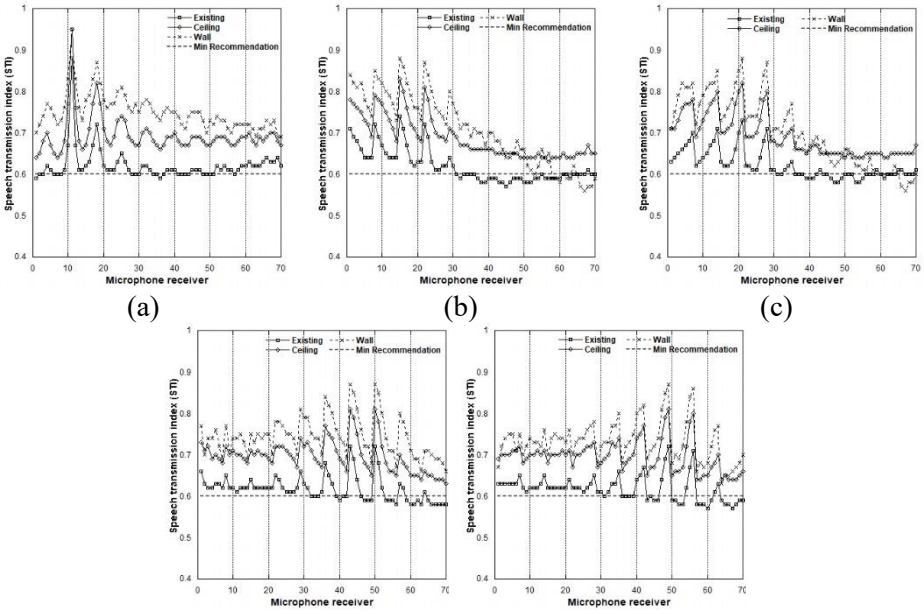



**Figure 4:** STI distribution in medium classroom for different sound source locations: (a) lecturer, (b) S1, (c) S2, (d) S3, and (e) S4

Figures 3 and 4 present the spatial distribution of STI values for the various surface treatment scenarios in the small and medium classrooms, respectively. Previous studies recommend a minimum STI value of 0.60 to achieve satisfactory speech intelligibility in educational environments. Under the existing room conditions, most receiver locations in the small classroom achieved STI values close to or exceeding this threshold. The application of absorptive ceiling materials increased the STI values across most receiver positions, while further improvements were observed following the treatment of the wall surfaces.

The greatest enhancement occurred at receiver locations within approximately 1.5 m of the active sound source, where the reduction in reverberant sound increased the proportion of direct sound, thereby improving speech intelligibility. A similar trend was observed in the medium classroom, where both ceiling and wall treatments consistently improved STI compared with the existing room condition. However, a slight reduction in STI was observed at several receiver locations associated with S1 and S2. This reduction can be attributed to the orientation of the sound source, which was positioned near the front of the classroom and directed towards the front wall. Consequently, receiver locations situated farther from the source experienced a lower direct-to-reverberant sound ratio, resulting in slightly reduced STI values.

***Conventional Learning***

Figure 5 presents the spatial distribution of STI values for the existing room condition and the proposed surface treatment scenarios. Under the existing conditions, most receiver locations achieved the minimum recommended STI value of 0.60, indicating satisfactory speech intelligibility for conventional instruction. The application of absorptive ceiling materials resulted in a noticeable increase in STI across most receiver locations, while further improvements were achieved following the installation of absorptive wall panels. At several receiver positions, the STI classification improved from "Good" to "Excellent", demonstrating the effectiveness of increasing the acoustic absorption of the interior surfaces. The enhanced STI performance can be attributed to the reduction in reverberation time, which increased the direct-to-reverberant sound ratio and improved speech transmission throughout the room. These findings indicate a strong relationship between reverberation time and speech intelligibility, whereby lower RT values consistently resulted in higher STI ratings.

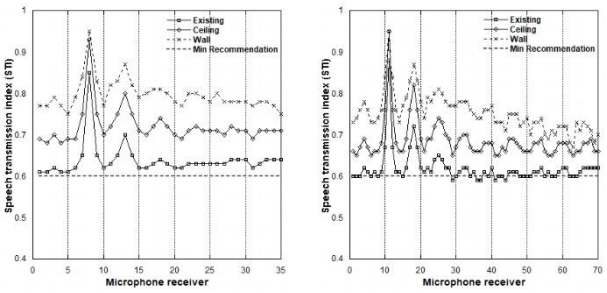



**Figure 5:** STI distributions for conventional learning in (a) small and (b) medium classrooms

***c) Speech Clarity ($C_{50}$)***

***Collaborative Learning***

Under the existing room conditions, only a limited number of receiver locations situated close to the sound source achieved the recommended minimum value of 3 dB as presented in Figures 6 and 7. Following the application of absorptive ceiling materials, $C_{50}$ values increased across most receiver locations, while further improvements were achieved after the wall surfaces were treated with absorptive materials. In both classrooms, the majority of receiver locations exceeded the recommended 3 dB threshold after the surface treatments were applied. The improvement in $C_{50}$ can be attributed to the reduction in reverberation time resulting from the increased acoustic absorption of the ceiling and wall surfaces. The shorter sound decay time reduced the influence of late


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reflections and increased the proportion of early sound energy reaching the receivers, thereby enhancing speech clarity throughout the rooms. These findings are consistent with the STI results, indicating that improvements in reverberation control contribute to enhanced speech intelligibility and overall acoustic performance.

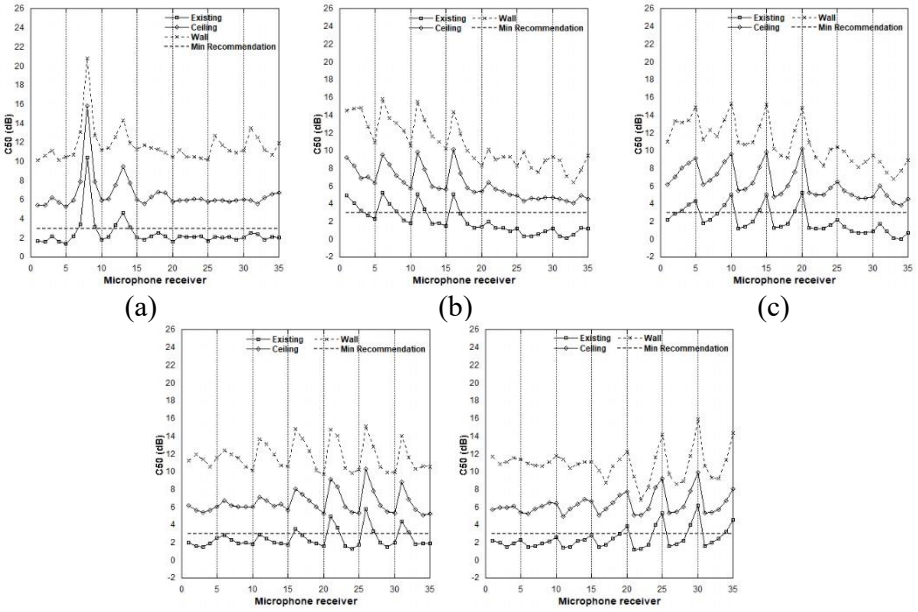



**Figure 6:** $C_{50}$ performance in small classroom for different sound source locations: (a) lecturer, (b) S1, (c) S2, (d) S3, and (e) S4

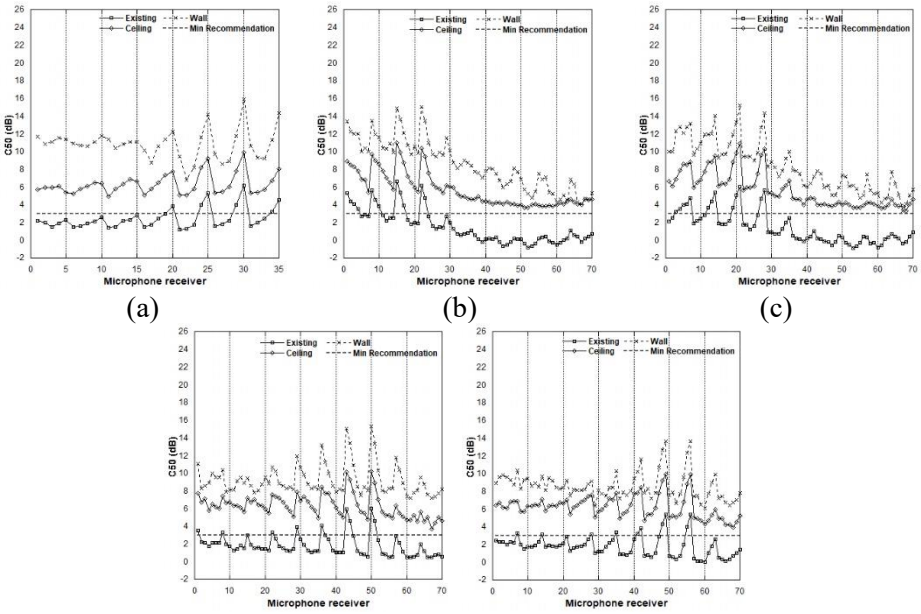



**Figure 7:** $C_{50}$ performance in medium classroom for different sound source locations: (a) lecturer, (b) S1, (c) S2, (d) S3, and (e) S4

### *Conventional Learning*

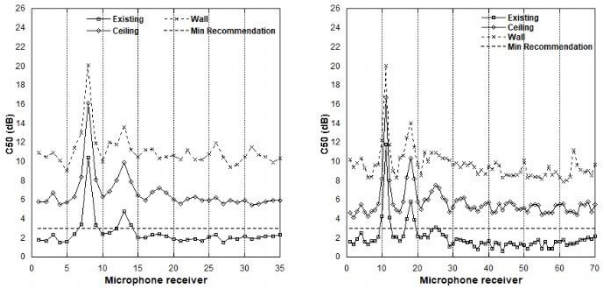



**Figure 8:** $C_{50}$ performance for conventional learning in (a) small and (b) medium classrooms

A similar trend was observed under conventional learning conditions. Figure 8 presents the spatial distribution of $C_{50}$ values for the small and medium classrooms under the existing condition and the proposed surface treatment scenarios. Under the existing room conditions, only a limited number of receiver locations situated close to the sound source achieved the recommended minimum


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$C_{50}$ value of 3 dB. This indicates that speech clarity decreased with increasing distance from the lecturer due to the influence of reflected sound.

The application of absorptive ceiling materials resulted in noticeable improvements in $C_{50}$ across most receiver locations, while further enhancement was achieved following the installation of absorptive wall treatments. After the surface treatments were applied, the majority of receiver locations exceeded the recommended $C_{50}$ threshold of 3 dB, indicating improved speech clarity throughout the room. The improvement in $C_{50}$ was consistent with the reduction in reverberation time observed following the application of the absorptive surface treatments. By reducing sound reflections and increasing the proportion of early arriving sound energy, the surface treatments enhanced speech clarity across the classroom. These findings are consistent with the STI results, demonstrating that improved reverberation control contributes to enhanced speech intelligibility in conventional learning environments.

Comparison between the two learning configurations shows that their influence varies according to the acoustic parameter. For RT, only minor differences were observed between conventional and collaborative configurations. In contrast, STI and C50 showed greater spatial variation due to differences in sound source location, orientation, and source-to-receiver distance. This effect was more evident in the collaborative configuration, where multiple student sound sources were distributed throughout the classroom, compared with the single lecturer source in the conventional configuration. The findings demonstrate that surface absorption primarily controls reverberation, while the spatial arrangement of sound sources and receivers has a greater influence on speech transmission and clarity.

## CONCLUSION

The simulation results demonstrated that absorptive wall and ceiling treatments significantly improved the three key acoustic parameters, namely reverberation time (RT), speech transmission index (STI), and speech clarity ($C_{50}$), in both small and medium classrooms. Similar trends were observed across both instructional configurations, with reductions in reverberation time consistently accompanied by improvements in speech intelligibility and speech clarity. Among the proposed interventions, wall and ceiling treatments effectively enhanced the overall acoustic performance by increasing sound absorption and reducing sound reflections within the rooms. The findings highlight the importance of incorporating acoustic considerations into interior space planning through appropriate surface material selection to support contemporary learning environments. From an operational perspective, university facilities managers should incorporate acoustic performance into classroom refurbishment and maintenance planning, including assessment of background noise, reverberation,

and speech intelligibility before and after major interior modifications. Interior designers and classroom planners should similarly coordinate acoustic material selection with spatial layout at the design stage. Such an integrated approach can reduce the likelihood that acoustics are addressed only after problems in speech communication become apparent during classroom operation. Future studies should investigate the combined influence of other interior design variables, such as room geometry, ceiling height, furniture configuration, and seating layout, on the acoustic performance of learning spaces to establish comprehensive design strategies for hybrid teaching environments.

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# LEARNING ORGANISATION FOR ORGANISATIONAL RESILIENCE IN TIMES OF UNCERTAINTY: EVIDENCE FROM QUANTITY SURVEYING CONSULTANT FIRMS IN MALAYSIA

**Nur Mardhiyah Aziz[1*], Loo Siaw Chuing[2], Nurshuhada Zainon[3], Zafira Nadia Maaz[4], Izatul Laili Jabar[5]**

[1,2,3,4] *Department of Quantity Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[5] *Studies for Building Surveying, Faculty of Built Environment,*
UNIVERSITI TEKNOLOGI MARA

## Abstract

In today's rapidly changing business environment, organisations must navigate through various disruptions, including pandemics, geopolitical conflicts, economic uncertainties, and other unforeseen events. These challenges highlight the need for resilience, adaptability, and continuous learning to maintain business continuity. For Quantity Surveying (QS) consultant firms, valuable knowledge and expertise are often embedded within experienced professionals. Therefore, developing a Learning Organisation is essential to support knowledge sharing, employee development, and organisational improvement. This study examines the key characteristics, critical success factors, and benefits of Learning Organisation practices among QS consultant firms in Malaysia. A quantitative approach was adopted using a questionnaire survey distributed to QS consultant firms registered with the Board of Quantity Surveyors Malaysia (BQSM). The survey achieved a 38% response rate, providing sufficient data for analysis. The findings identified Dynamic Learning as the most prominent characteristic, high personal competencies as the key success factor, and continuous improvement and innovation as the main organisational benefit. This study contributes to existing knowledge by providing empirical evidence on Learning Organisation practices within the QS profession, which remains limited in current research. The findings also provide industry practitioners with key areas to strengthen organisational resilience, particularly through employee capability development, knowledge sharing, and continuous improvement.

***Keywords***: Learning Organisation; Organisational Resilience; Quantity Surveying Consultant Firms; Organisational Learning; Knowledge Sharing; Innovation

[1] Corresponding author. Email: nurmardhiyah@um.edu.my

# INTRODUCTION

In today's rapidly changing business environment, organisations are increasingly exposed to various disruptions, including economic uncertainty, technological advancements, geopolitical conflicts, natural disasters, and other unforeseen events. These challenges require organisations to become more resilient, adaptable, and committed to continuous learning in order to sustain their performance and remain competitive. The construction industry is no exception. Quantity Surveying (QS) consultant firms play a vital role in delivering professional services related to cost management, procurement, and contractual administration throughout the project lifecycle (Yap & Aziz, 2020). As knowledge-intensive organisations, QS firms depend heavily on the expertise, experience, and professional judgement of their employees. However, workforce challenges such as employee turnover, changing career expectations, and early retirement have increased the risk of knowledge loss, making it more difficult for organisations to maintain their expertise and organisational performance (Fuller & Kerr, 2022; Gaines, 2022).

In response to these challenges, developing a Learning Organisation (LO) culture has become increasingly important. A Learning Organisation promotes continuous learning, knowledge sharing, collaboration, and innovation, enabling organisations to adapt more effectively to changing business conditions while preserving valuable organisational knowledge. Such culture helps organisations strengthen employee capabilities, improve organisational resilience, and sustain long-term performance in an increasingly volatile business environment. Despite the growing importance of organisational learning, studies examining Learning Organisation culture within Malaysian QS consultant firms remain limited, highlighting the need for further investigation in this context.

# LITERATURE REVIEW

## Learning Organisation (LO)

Despite decades of research, there is still no universally accepted definition of a learning organisation. The concept was first popularised by Senge (1990), who described a learning organisation as one in which individuals continuously expand their capabilities, develop new ways of thinking, and learn collectively to achieve shared aspirations. Marquardt (1996) defined a learning organisation as an organisation that continuously acquires, creates, and applies knowledge to improve its performance and achieve business success. Similarly, Pedler (1991) viewed a learning organisation as one that facilitates the learning of all its members and continuously transforms itself, while Dulaimi & Ang, (2009) emphasised an organisation's ability to embed learning, adaptation, and change into its culture and operations.

Although the terms *learning organisation* and *organisational learning* are often used interchangeably, they represent different concepts. Tsang (1997) distinguished learning organisation as the desired state or characteristic of an organisation, whereas organisational learning refers to the processes and activities through which learning occurs. In other words, organisational learning is the mechanism that enables an organisation to become a learning organisation.

Among the various learning organisation models proposed in the literature, Marquardt's (1996) Systematic Learning Organisation Model is widely recognised for its comprehensive and practical approach. The model consists of five interrelated dimensions: dynamic learning, people empowerment, knowledge management, organisational transformation, and technology application. These dimensions collectively promote continuous learning, knowledge sharing, innovation, and adaptability, enabling organisations to respond effectively to changing business environments. In addition, successful implementation of a learning organisations is influenced by several critical success factors, including shared goals, a supportive learning environment, teamwork, personal competencies and dynamic leadership. Previous studies have also associated learning organisation practices with numerous organisational benefits such as continuous improvement, innovation, effective problem solving, stronger collaboration, employee retention and long-term organisational sustainability.

For professional service organisations such as quantity surveying (QS) consultant firms, developing a learning organisation culture has become increasingly important in navigating uncertainty and maintaining competitiveness. The construction industry continues to face rapid technological advancement, evolving client expectations, economic fluctuations, and unexpected disruptions, which place increasing demands on firms to develop appropriate organisational capabilities. Given these challenges, this study adopts Marquardt's (1996) Systematic Learning Organisation Model to examine the significance of learning organisation practices among Malaysian QS consultant firms. The model provides a suitable theoretical foundation for understanding how learning capabilities can strengthen organisational resilience and support long-term business performance.

## RESEARCH METHODOLOGY

This study adopted a quantitative research approach to examine the significance of learning organisation practices among Quantity Surveying (QS) consultant firms in Malaysia. The target population comprised QS consultancy firms registered with the Board of Quantity Surveyors Malaysia (BQSM), including sole proprietorships, partnerships, body corporates, joint ventures, and multidisciplinary practices. These firms were selected as the unit of analysis due


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to their role as professional service organisations that require continuous learning, knowledge sharing, and adaptation to respond to changes within the construction industry. Based on the list provided by BQSM website in 2026), a total of 424 registered QS consultancy firms were identified as the study population. The required sample size was determined using the sample size guideline proposed by Krejcie and Morgan (1970).

Data were collected through a structured questionnaire survey developed based on the extensive review of previous literature on learning organisation practices. The questionnaire consisted of four sections. Section A collected respondents' demographic and organisational background information using nominal-scale questions. Sections B, C, and D measured the significance of learning organisation dimensions, critical success factors, and organisational benefits, respectively. A five-point Likert scale was employed, where Section B measured significance levels (1 = Not Significant to 5 = Very Significant), while Sections C and D assessed respondents' agreement levels (1 = Strongly Disagree to 5 = Strongly Agree).

A reliability analysis was carried out to assess the internal consistency of the questionnaire items in Section B, C and D. Cronbach's alpha was used to assess the reliability of each section, where a value of more 0.70 is considered acceptable. The results show that section B had a Cronbach's alpha value of 0.91, Section C recorded a value of 0.88, and Section D recorded a value of 0.93. Overall, the results indicate good internal consistency across all three sections, suggesting the questionnaire items were sufficiently reliable for further analysis.

The questionnaire survey was conducted over a four-week period from March 2026 to April 2026 to provide sufficient time for participation. The collected data were analysed using descriptive statistics, including mean ranking and the Relative Importance Index (RII), to determine the relative significance of each learning organisation element. The RII method has been widely applied in construction management research to rank factors according to their perceived importance (Tan & Aziz, 2022). The RII was calculated using the following formula:

$$\mathbf{RII = \Sigma W / (A \times N)}$$

where:
W = weighting assigned by respondents based on the five-point Likert scale;
A = highest possible weighting (5); and
N = total number of respondents.

The calculated RII values were interpreted using five importance levels: high (H) ($0.8 \leq RII \leq 1.0$), high–medium (H–M) ($0.6 \leq RII < 0.8$), medium (M) ($0.4 \leq RII < 0.6$), medium–low (M–L) ($0.2 \leq RII < 0.4$), and low (L) ($0 \leq RII <$

0.2) (Tan & Aziz, 2022). This approach enabled the ranking and comparison of learning organisation dimensions, critical success factors, and benefits perceived by QS consultant firms in Malaysia.

In addition to the descriptive analysis, Spearman's rank correlation was conducted to show the strength of linear relationship between the three main construct of the study; learning organisation dimensions, critical success factors and organisational benefits. This analysis was used to determine whether there were significant relationships between the constructs. The correlations coefficient indicates the direction strength of the relationship between each pair of constructs.

## ANALYSIS AND DISCUSSION

### *Respondents' Background*

This study achieved a response rate of 38%, with a total of 161 responses. The responses obtained from QS consultant firms provided the basis for analysing the significance of learning organisation practices within the Malaysian QS consulting context. Table 1 presents the background characteristics of the respondents.

**Table 1**: General respondent's background

| **Parameters** | **Percentage** |
|---|---|
| **Types of QS Consulting Practice** | |
| Sole Proprietorship | 43 |
| Body Corporate | 24 |
| Partnership | 33 |
| **Organisation Size** | |
| 1-50 Employees (Small Scale) | 95 |
| 51-200 Employees (Medium Scale) | 5 |
| **Job Position** | |
| Director | 19 |
| Associate Director | 14 |
| Team Leader | 5 |
| Senior Project Executive | 14 |
| Project Executive | 9 |
| Quantity Surveyor | 38 |
| **Opinion Level on Significance of LO** | |
| Agree | 100.0 |
| Disagree | - |

In terms of the type of QS consulting practice, the majority of respondents were from sole proprietorship firms (43%), followed by partnership firms (33%) and body corporate firms (24%). No responses were received from joint venture or multidisciplinary QS practices.


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Regarding organisational size, the majority of participating firms were classified as small-scale organisations with 1–50 employees (95%), while the remaining firms were categorised as medium-scale organisations with 51–200 employees (5%). This classification is consistent with previous studies that recognise employee size as one of the key indicators in distinguishing organisational scale, particularly within the context of Malaysian organisations (Ramdan et al., 2022).

The respondents represented various professional positions within QS firms, with Quantity Surveyors forming the largest group (38%), followed by Directors (19%), Associate Directors and Senior Project Executives (14% each), Project Executives (9%), and Team Leaders (5%).

In terms of respondents' perception of the significance of learning organisation practices, all respondents (100%) agreed that learning organisation is significant within QS consulting firms. This reflects the recognition among QS professionals regarding the importance of continuous learning, knowledge development, and organisational adaptability in sustaining firm performance.

***Natures of Learning Organisation***

Section B of the questionnaire examined the significant natures of learning organisation practices among QS consultant firms in Malaysia. Table 2 summarises the highest and lowest ranked practices under each dimension based on the Relative Importance Index (RII). Overall, all dimensions recorded a high level of importance, with RII values ranging from 0.733 to 0.905. This indicates that QS professionals generally recognise the importance of developing a learning-oriented culture to support continuous improvement and organisational adaptability. This suggests that Malaysian QS consultant firms recognise that continuous learning is essential to remain competitive in an increasingly complex and uncertain construction environment. Recent studies have similarly arggued that organisations with stronger learning capabilities are better equipped to respond to technological change, market uncertainty, and evolving client expectations (Broekema et al., 2026; Basten & Haamann, 2018; Tortorella et al., 2020).

**Table 2:** Ranking of Significant Natures of Learning Organisation

| Learning Organisation Dimension | Highest Ranked Practice | RII | Lowest Ranked Practice | RII |
|---|---|---|---|---|
| **Dynamic Learning** | Encouraging employees to openly discuss experiences, successes, and mistakes to facilitate learning | 0.905 | Viewing continuous learning as a high business priority | 0.790 |

| Learning Organisation Dimension | Highest Ranked Practice | RII | Lowest Ranked Practice | RII |
|---|---|---|---|---|
| **Organisational Transformation** | Employees understand the importance of becoming a learning organisation | 0.848 | Learning from mistakes and failures is encouraged | 0.733 |
| **Empowering People** | Employees are empowered to coach, mentor, and facilitate learning with management support | 0.829 | Decentralised decision-making | 0.771 |
| **Knowledge Management** | Providing accessible systems to identify and collect information | 0.829 | Knowledge coding and systematic job rotation practices | 0.781 |
| **Technology Application** | Access to information technologies and digital connectivity | 0.848 | Use of groupware technology to support group processes | 0.733 |

Among all practices, encouraging employees to openly discuss experiences, successes, and mistakes recorded the highest RII value (0.905). This suggests that QS firms place strong emphasis on knowledge sharing and learning through daily work experiences. This finding supports Senge's (1990) view that learning organisations are built through collective learning and shared knowledge. Similarly, Liao et al. (2017) highlighted that knowledge transfer between experienced and new employees contributes to organisational learning. The result is consistent with recent studies confirming that knowledge exchange, open communication, and collaborative learning strengthen organisational learning capability and improve organisational performance (Broekema et al., 2026; Basten & Haamann, 2018; Hoa et al., 2022). Within professional service organisations such as QS firms, much technical expertise is developed through project experience rather than formal training. Therefore, creating opportunities for employees to exchange practical knowledge enables firms to retain valuable tacit knowledge and improve future project delivery (Orych, & Patora-Wysocka, 2026).

Although continuous learning is a fundamental element of a learning organisation, viewing continuous learning as a high business priority recorded the lowest ranking under the dynamic learning dimension (RII = 0.790). This may indicate that while QS firms acknowledge the value of learning, continuous learning activities may not yet be fully integrated into their strategic priorities. Similar observations have been reported by Tortorella et al. (2020), who found that many organisations encourage operational learning but struggle to institutionalise learning through formal strategic initiatives, structured training programmes, and long-term capability development. For many small and medium-sized QS firms, business priorities often focus on project delivery, client satisfaction, and cost management, leaving fewer resources for formal learning


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initiatives. Challenges such as resistance to change, uncertainty, and lack of confidence may influence employees' acceptance of continuous learning initiatives (Piderit, 2000; Furxhi, 2021).

For organisational transformation, understanding the importance of becoming a learning organisation was ranked highest (RII = 0.848). This highlights that awareness among employees and management is an important foundation for developing a learning culture. However, learning from mistakes and failures received the lowest ranking (RII = 0.733). Although mistakes can provide valuable learning opportunities, QS firms may perceive failures as having negative impacts on project outcomes, cost, and client satisfaction.

The findings also show that empowerment and knowledge accessibility are important elements of learning organisation practices. Employees being empowered to coach, mentor, and facilitate learning achieved the highest ranking under empowering people (RII = 0.829), indicating the importance of management support in encouraging employee development. This supports recent evidence that leadership support and employee empowerment create psychological safety, encourage knowledge sharing, and improve organisational learning capability (Hoa et al., 2022; Orych, & Patora-Wysocka, 2026). Similarly, providing accessible systems to identify and collect information was ranked highest under knowledge management (RII = 0.829), showing that QS firms recognise the need for effective information management to support learning and decision-making.

Technology application was also viewed as an important enabler of learning, particularly through access to information technologies and digital connectivity (RII = 0.848). This finding aligns with recent construction digitalisation research, which highlights that digital technologies improve knowledge accessibility, collaboration, and organisational learning (S Kannan & Abd Rahim, 2025). However, the use of groupware technology recorded the lowest ranking (RII = 0.733). This suggests that QS firms are more focused on using technology for information access rather than advanced collaborative learning platforms. The finding may be influenced by the characteristics of the participating firms, as most respondents were from small-scale QS organisations where investment in advanced technologies may require additional resources.

Overall, the findings indicate that learning within Malaysian QS consultant firms is primarily driven by interpersonal knowledge sharing, mentoring, and accessible information rather than formal organisational systems such as decentralised decision-making, systematic job rotation, or advanced collaborative technologies. This contrasts with the findings from larger multinational organisations, where formal learning structures and digital collaboration platforms play a greater role in organisational learning (Basten & Haamann, 2018). The results therefore suggest that Malaysian QS firms have

established a positive learning culture but still have opportunities to institutionalise learning through more structured organisational practices.

***Critical Success Factors of Learning Organisation***

Section C of the questionnaire examined the critical success factors for establishing a learning organisation among Quantity Surveying (QS) consultant firms. As shown in Table 3, all factors recorded high RII values (above 0.80), indicating that respondents generally agreed that these factors are important in developing a learning organisation. However, the ranking shows the different levels of importance perceived by the respondents.

The highest-ranked factor was **"**having a high level of personal competencies", with the highest mean score ($\bar{x}$ = 4.571) and RII value (0.914). This finding reflects the knowledge-intensive nature of QS consultancy, where service quality depends heavily on employees' technical expertise, professional judgement, and continuous skills development. Recent studies similarly conclude that employee competence remains one of the strongest determinants of organisational learning and innovation because knowledgeable employees are better able to acquire, share, and apply new knowledge (Broekema et al., 2026; Basten & Haamann, 2018; Hoa et al., 2022).

The second highest-ranked factor was "led by inspirational leaders who promote continuous learning" ($\bar{x}$ = 4.476, RII = 0.896). This finding aligns with Hoa et al. (2022), who demonstrated that transformational leadership strengthens organisational learning by encouraging knowledge sharing, employee motivation, and innovation. Leaders who actively support mentoring, learning opportunities, and knowledge exchange help establish an environment where employees feel confident to develop professionally.

The lowest-ranked factor was "encourage employees to have a feeling of interdependence among themselves" ($\bar{x}$ = 4.143, RII = 0.829). Although it remained an important factor, the lower ranking may be due to the working structure of QS consultant firms, where many employees are required to work independently and manage multiple responsibilities. Excessive dependency between team members may also create coordination issues, especially when delays in one task affect other related activities. Therefore, respondents may perceive individual competency as more critical than interdependence in supporting organisational learning.

Overall, the findings suggest that developing a learning organisation in QS consultant firms relies mainly on competent employees and supportive leadership. While collaboration and shared goals remain important, organisations should first focus on strengthening individual capabilities and creating an environment that encourages continuous learning.


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**Table 3:** Ranking of Critical Success Factors for Establishing a Learning Organisation

| Critical Success Factors | Mean | RII | Rank |
|---|---|---|---|
| Have a high level of personal competencies | 4.5714 | 0.914 | 1 |
| Led by inspirational leaders who promote continuous learning | 4.4762 | 0.896 | 2 |
| Create a learning environment that is engaging, participatory, hassle-free, and appreciative | 4.3810 | 0.876 | 3 |
| Have a mission statement that is widely displayed and regularly referenced | 4.2857 | 0.857 | 4 |
| Have common goals with all personnel | 4.1905 | 0.838 | 5 |
| Encourage employees to have a feeling of interdependence among themselves (e.g., cross-training/staff rotation) | 4.1429 | 0.829 | 6 |

### *Significant Benefits of Learning Organisation*

Section D of the questionnaire assessed the benefits of implementing a learning organisation among Quantity Surveying (QS) consultant firms. As presented in Table 4, all benefits achieved high RII values (above 0.80), showing that respondents generally recognised the positive impact of a learning organisation. However, the ranking reveals that QS firms prioritise improvements in organisational capability over employee-related benefits.

The highest-ranked benefit was "continuous improvement and innovation" ($\overline{x}$ = 4.476, RII = 0.895). This indicates that respondents view learning organisation practices as an important approach to encourage employees to share ideas, improve work processes, and adapt to changes. Similar findings have been reported by Tortorella et al. (2020), who concluded that organisational learning directly enhances innovation capability and organisational adaptability. For QS firms, where project requirements, technology, and industry practices continuously evolve, the ability to learn and innovate is essential for maintaining competitiveness.

Other highly rated benefits include building stronger teams ($\overline{x}$ = 4.429, RII = 0.886) and improving problem-solving capability ($\overline{x}$ = 4.381, RII = 0.876). These findings support research demonstrating that organisational learning enhances collective problem-solving by encouraging employees to share experiences, integrate diverse knowledge, and develop more effective solutions (Broekema et al., 2026; Basten & Haamann, 2018). In QS consultancy, where projects often involve complex contractual, financial, and technical decisions, collaborative learning contributes directly to improved decision quality. These findings suggest that respondents appreciate learning organisations as a platform to improve internal knowledge sharing and decision-making.

Interestingly, better collaboration and teamwork and employee retention were ranked lowest (RII = 0.848). This partially differs from studies conducted in other knowledge-intensive industries, where learning opportunities significantly influence employee retention and organisational commitment (Hoa et al., 2022). The difference may be explained by the characteristics of Malaysian

QS consultant firms. Employee retention often hinges primarily on external variables such as remuneration, career progression, and labour market opportunities than on organisational learning initiatives alone. Similarly, smaller firms may already experience close day-to-day collaboration, reducing the perceived additional benefit of learning organisation practices in improving teamwork (Orych, & Patora-Wysocka, 2026).

Overall, the findings indicate that respondents perceive Learning Organisation primarily as a strategic capability that enhances innovation, organisational adaptability, and continuous improvement rather than solely as a mechanism for improving employee satisfaction or retention. This reinforces the growing importance of organisational learning in enabling professional service firms to remain competitive under increasingly uncertain business environment.

**Table 4:** Ranking of Significant Benefits of Learning Organisation

| Benefits | Mean | RII | Rank |
|---|---|---|---|
| **Continuous improvement and innovation through employee learning, idea sharing, and feedback** | 4.4762 | 0.895 | 1 |
| **Building a strong team and strengthening relationships among personnel** | 4.4286 | 0.886 | 2 |
| **Improving problem-solving through discussion and new solutions** | 4.3810 | 0.876 | 3 |
| **Ensuring business longevity through continuous improvement and innovation** | 4.3333 | 0.867 | 4 |
| **Better collaboration and teamwork through shared understanding and involvement** | 4.2381 | 0.848 | 5 |
| **Retaining talented and loyal employees through employee growth and development** | 4.2381 | 0.848 | 5 |

### *Correlation Analysis*

To further examine the findings, a Spearman's correlation analysis was conducted to determine the relationships between learning organisation dimensions, critical success factors and organisational benefits. This analysis provides a clearer view of how these three aspects are related based on the responses from the 161 respondents. The results are presented in Table 5.

**Table 5:** Spearman's correlation analysis

| | Learning Organisation (B) | Critical Success Factors (C) | Organisational Benefits (D) |
|---|---|---|---|
| **Learning Organisation (B)** | 1.000 | .650 | .667 |
| **Critical Success Factors (C)** | .650 | 1.000 | .625 |
| **Organisational Benefits (D)** | .667 | .625 | 1.000 |

Note: Spearman's rank order correlation; N= 161. $p < 0.001$ (2-tailed).


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The results show positive and significant relationships among all three dimensions. Learning organisation had a strong positive relationship with critical success factors ($\rho = 0.650$, $p < 0.001$) and organisational benefits ($\rho = 0.667$, $p < 0.001$). Critical success factors also showed a strong positive relationship with organisational benefits ($\rho = 0.625$, $p < 0.001$). Overall, the findings suggest that learning practices, the factors that support them, and the benefits perceived by the organisations are closely related. However, these relationships should be understood as associations and do not indicate that one construct directly causes another.

***Overall Significance of Learning Organisation in QS Firms***

The findings of this study show that the elements of a Learning Organisation are already present and applicable in Quantity Surveying (QS) consultant firms. Table 5 presents the ranking of Learning Organisation categories based on respondents' perceptions. Among the five categories, Dynamic Learning was ranked the highest, with the highest group mean score ($\bar{x} = 4.274$) and RII value (0.855). This indicates that QS firms place strong emphasis on learning from experiences, sharing knowledge, and improving through continuous learning. This finding supports Marquardt (1996), who identified dynamic learning as one of the key foundations of a learning organisation.

Three core themes consistently manifested across the findings in this study. First, learning is primarily facilitated through open communication and knowledge sharing among employees. Second, developing highly competent professionals supported by inspirational leadership is considered essential for sustaining organisational learning. Third, organisations perceive continuous improvement and innovation as the most valuable outcomes of adopting Learning Organisation practices. Together, these findings align with recent organisational learning literature, which emphasises that sustainable organisational performance depends on integrating knowledge sharing, leadership support, employee capability, and innovation into everyday organisational practice (Basten & Haamann, 2018; Hoa et al., 2022; Tortorella et al., 2020).

Nevertheless, the study also reveals several areas where Malaysian QS firms can further strengthen their learning capability. Formal learning mechanisms, including structured learning strategies, systematic job rotation, collaborative digital platforms, and learning from organisational failures, received relatively lower rankings than interpersonal knowledge sharing. This suggests that while a positive learning culture already exists, many firms have yet to institutionalise learning through formal organisational systems (Stewart (2019). Strengthening these areas would enable QS consultant firms to build greater organisational resilience, enhance innovation capability, and improve long-term competitiveness in an increasingly dynamic construction industry.

**Table 5:** Ranking of Learning Organisation Categories in QS Firms

| Dimension | Key Finding | Mean/RII | Contribution |
|---|---|---|---|
| **Nature of LO** | Dynamic Learning | 4.274 / 0.855 | Encourages knowledge sharing and learning from experience |
| **Success Factor** | High Personal Competencies | 4.571 / 0.914 | Strengthens employee capability and professional performance |
| **Benefit** | Continuous Improvement and Innovation | 4.476 / 0.895 | Improves adaptability and organisational performance |

In this study, 95% of the respondents were from small firms, while only 5% were from medium-sized firms. Therefore, the findings largely reflect the experiences and practice of small QS consultant firms and may not fully capture the situation in larger firms, which may have different organisational structures, resources and approached to learning. Future studies could include more firms of different sizes to provide a broader view of Learning Organisation practices in the QS consulting sector.

## CONCLUSION

This study was conducted to establish the relevance and significance of Learning Organisation practices among Quantity Surveying (QS) consultant firms in Malaysia. The findings demonstrate that the key elements of a Learning Organisation are already present and applicable within QS firms.

The study identified Dynamic Learning as the most prominent nature of Learning Organisation, particularly through encouraging employees to openly discuss experiences, successes, and mistakes as opportunities for learning. This highlights the importance of knowledge sharing and continuous improvement in developing a learning culture. In addition, high personal competencies among employees were identified as the most important success factor, showing that capable and motivated employees are the foundation of organisational learning. The main benefit of Learning Organisation was found to be continuous improvement and innovation, indicating that learning practices can help QS firms adapt and improve their performance in a changing construction environment.

Overall, the findings confirm that Learning Organisation is a relevant approach for QS consultant firms in Malaysia. The study highlights that developing a learning culture is not only about implementing new systems or technologies, but also about strengthening employee capabilities, encouraging knowledge exchange, and creating an environment that supports continuous improvement. These findings provide a better understanding of how QS firms can embrace Learning Organisation practices to enhance their long-term competitiveness and sustainability.

From a practical perspective, the findings can benefit several stakeholders in the QS professions. Professional bodies like Board of Quantity


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Surveyors Malaysia (BQSM) could use these findings as input when planning professional development and continuous professional development activities. QS firms could encourage regular knowledge sharing, discussion of project experiences, monitoring and skills development among their staff. Education and training providers could also develop programmes that promote knowledge sharing, teamwork, problem-solving and continuous learning. These efforts can help QS firms develop a stronger learning culture and support the continued development of the QS profession.

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# THE PLANNED CAPITAL TRAP: HOUSING MARKET DISEQUILIBRIUM AND GOVERNANCE RISK IN PUTRAJAYA

**Mohd Azhar Ab Wahid, Amalina Azmi*, Zafirah Al Sadat Zyed, Noorame Mohd Foudzy**

*Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA

## Abstract

Planned administrative capitals are designed on the assumption that state-backed employment can be spatially concentrated without exposing public servants to severe housing pressure. This study develops the concept of the 'planned capital trap' to explain how controlled urban development and concentrated public employment can produce housing conditions that weaken the workforce base on which administrative efficiency depends. Focusing on Putrajaya, Malaysia's federal administrative capital, it examines the relationship between housing market disequilibrium, financial resilience, and workforce operational readiness. Drawing on survey evidence from 388 public servants, the findings show that perceived housing disequilibrium is strongly associated with weaker financial resilience and lower operational readiness. The association with operational readiness is partly accounted for by financial resilience, while the remaining direct association is consistent with additional non-financial pathways. The study contributes to urban-planning and governance debates by reframing workforce housing in planned capitals as administrative infrastructure rather than residual welfare.

***Keywords***: Housing market disequilibrium; spatial governance; planned administrative capitals; financial resilience; workforce operational readiness

* Corresponding author. Email: amalinaazmi@um.edu.my

## INTRODUCTION

Planned administrative capitals have long been conceived as instruments of state-building, territorial order, and administrative rationalisation. Purpose-built cities such as Brasília, Canberra, and Putrajaya were designed to project political authority, organise bureaucratic functions, and translate state vision into urban form (Hall, 2002; Holston, 1989; Scott, 1998; Vale, 2008). Central to this planning tradition is the assumption that government employment can be spatially concentrated within a dedicated urban footprint without weakening administrative stability. Within this framework, housing is not merely a social good but a spatial condition of effective governance, intended to keep civil servants within functional proximity to the institutions they serve.

This planning assumption becomes fragile when housing supply and affordability adjust more slowly than concentrated employment demand. In planned capitals such as Putrajaya, controlled land development, financing conditions, and limited supply responsiveness can intensify affordability pressure (Gyourko & Molloy, 2015; Malpezzi & Mayo, 1997; OECD, 2024a, 2024b, 2025). Nationally, 52.95% of serving Malaysian civil servants were reported as not owning a home in 2024 (Parliament of Malaysia, 2024). This suggests a 'planned capital trap': spatial concentration intended to support administrative order may coexist with housing conditions that weaken the workforce base on which that order depends.

Putrajaya exemplifies this tension. Established in the late 1990s to consolidate federal ministries and agencies within a planned administrative environment (Moser, 2010; Vale, 2008), it is supported by targeted mechanisms including the Malaysia Civil Servants Housing Programme (*Program Perumahan Penjawat Awam Malaysia,* PPAM) and public-sector housing financing through the Public Sector Home Financing Board (*Lembaga Pembiayaan Perumahan Sektor Awam*, LPPSA). Yet affordability pressure may persist where housing prices, available supply, financing capacity, and residential location do not align with workforce needs. The issue is therefore not policy absence but potential misalignment between housing support, market conditions, and a spatially concentrated workforce.

Existing scholarship illuminates parts of this problem but rarely connects them. Planned-capital and high-modernist research explains how state power is materialised through urban form (Hall, 2002; Holston, 1989; Scott, 1998; Vale, 2008); housing research identifies financialisation, regulatory constraint, land scarcity, and weak supply responsiveness as sources of affordability pressure (Aalbers, 2016; Fernandez & Aalbers, 2016; Glaeser & Gyourko, 2018; Gyourko & Molloy, 2015; OECD, 2024a; Saleh et al., 2025); and work on Sejong highlights difficulties aligning residence, commuting, and employment in new administrative capitals (Im & Jang, 2022; Shin et al., 2024).


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What remains less developed is the point at which housing pressure becomes relevant to state capacity. This paper therefore asks how housing market disequilibrium in a planned capital is associated with financial resilience and workforce operational readiness.

Drawing on Housing Market Disequilibrium Theory, the study treats persistent supply-demand imbalance as a structural condition associated with affordability pressure under constrained adjustment (Malpezzi & Mayo, 1997; Glaeser & Gyourko, 2018; OECD, 2024a). It advances a governance-transmission argument in which housing disequilibrium is associated with weaker financial resilience and, in turn, lower workforce operational readiness. Financial resilience captures capacity to meet obligations and absorb shocks (Brüggen et al., 2017; Netemeyer et al., 2018), while financial strain has been linked to concentration and work engagement (Kim & Garman, 2004). Putrajaya is used as the empirical case; comparative references to Canberra, Brasília, and Sejong establish the wider question rather than statistical generalisability.

## HOUSING DISEQUILIBRIUM AS SPATIAL GOVERNANCE RISK

Planned administrative capitals may exhibit a structural vulnerability that conventional housing analysis often overlooks. By concentrating governmental functions within a purpose-built city, the state constructs a specific urban and labour-market configuration shaped by planning, land governance, and employment policy (Hall, 2002; Scott, 1998; Vale, 2008). In such contexts, housing-market pressures may bear on the functioning of the administrative workforce, making housing outcomes relevant to institutional infrastructure as well as private welfare.

Planned administrative capitals concentrate public employment within a controlled spatial footprint while land and housing development remain strongly shaped by public planning. When regulation, land constraints, and development costs limit supply elasticity, rising demand can be transmitted into higher prices and weaker affordability rather than rapid supply adjustment (Glaeser & Gyourko, 2018; Gyourko & Molloy, 2015; Malpezzi & Mayo, 1997). This creates a distinctive governance problem because the workforce exposed to housing pressure is also the workforce sustaining the administrative centre.

Housing Market Disequilibrium Theory provides the analytical foundation: persistent imbalance between supply and demand can sustain affordability pressure beyond short-term market cycles (Malpezzi & Mayo, 1997). Housing-policy research further shows that land-use regulation, development bottlenecks, financing, and coordination across housing and transport shape these pressures (Gyourko & Molloy, 2015; OECD, 2024a, 2024b, 2025). Malaysian research similarly identifies interaction between demand-side affordability and supply-side development conditions (Saleh et al., 2024). In a

planned capital, institutional control over land release and development can therefore make housing adjustment a governance issue as well as a market outcome.

Comparative evidence from Canberra, Sejong, and Brasília shows that planned administrative capitals can experience affordability pressure or workforce displacement despite active state involvement in planning and provision (Yates, 2016; Im & Jang, 2022; Shin et al., 2024; Holston, 1989). The recurrence motivates comparative testing of how controlled development and concentrated public employment interact across different institutional settings.

Financial resilience provides the proposed intervening pathway. When housing costs absorb more income, residual resources and capacity to absorb shocks may weaken; research links financial stress to concentration, decision-making, and work engagement (Kim & Garman, 2004). In a spatially concentrated public-service workforce, such associations become governance-relevant rather than solely private household outcomes.

Where the state assumes a directive role in urban form, land allocation, and housing provision, spatial order may coexist with limited housing-supply responsiveness when market conditions shift faster than institutional adjustment. This study examines one associated pattern: housing market disequilibrium is associated with weaker financial resilience, which in turn is associated with lower workforce operational readiness. A remaining direct association is also estimated, but it is not treated as identifying a specific non-financial mechanism. Figure 1 illustrates the proposed pathway.

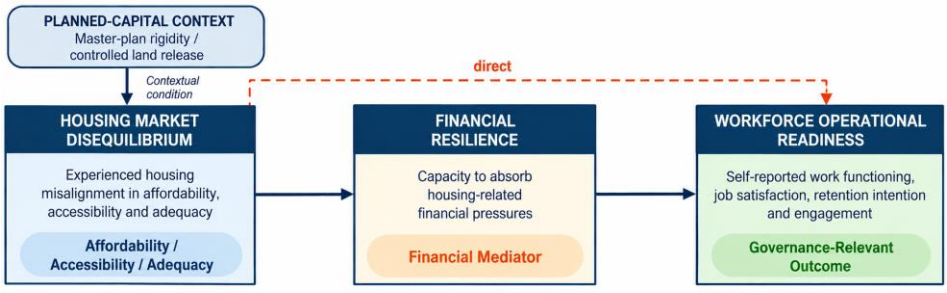



**Figure 1:** Conceptual Framework – Proposed Pathway Linking Housing Disequilibrium and Governance Risk
*Source: Author (2026)*

## INSTITUTIONAL CONTEXT AND ANALYTICAL EXPECTATIONS

Putrajaya's housing market reflects structural tensions that can arise in planned administrative capitals. Established in the late 1990s as Malaysia's federal administrative centre, the city was designed through a master plan that concentrated government functions within a deliberately planned residential


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environment (Moser, 2010; Vale, 2008). Public planning therefore strongly shapes the spatial context in which housing supply and concentrated public-sector employment interact.

Putrajaya's controlled residential development and concentrated public employment create a setting in which affordability pressure can persist despite formal support. Stable employment does not necessarily ensure access to suitably priced housing within the administrative capital, particularly where commercial prices, targeted provision, financing capacity, and location do not align (Ronald, 2008; Yates, 2016).

Malaysia has targeted civil-servant housing through preferential LPPSA financing and PPAM below-market provision. These instruments address different constraints: financing improves borrowing conditions, while PPAM expands access to designated housing. Their effectiveness nevertheless depends on the relationship among prices, borrowing capacity, project supply, and location; preferential finance alone cannot close an affordability gap if prices rise faster than salary-supported borrowing capacity (Malpezzi & Mayo, 1997; OECD, 2024a).

Nationally, more than half of serving Malaysian civil servants were reported as not owning a home in 2024 (Parliament of Malaysia, 2024). The relevant analytical expectation is therefore not that support is absent, but that housing pressure can persist where policy calibration, supply adjustment, and concentrated demand do not align. Sustained disequilibrium is expected to be associated with weaker financial resilience and lower operational readiness, while any residual direct association is treated as potentially reflecting unmeasured non-financial pathways rather than as evidence of a specific mechanism.

Against this institutional backdrop, sustained housing market disequilibrium is expected to be associated with weaker financial resilience among public servants through higher housing-cost pressure and lower residual resources available for savings and shock absorption (Malpezzi & Mayo, 1997; Glaeser & Gyourko, 2018; OECD, 2024a). Weaker financial resilience is in turn expected to be associated with lower workforce operational readiness, including task focus and work engagement (Kim & Garman, 2004). A residual association between housing disequilibrium and workplace functioning may also remain after financial resilience is accounted for. These expectations are examined empirically rather than formalised as hypotheses.

## DATA AND METHODS

### Analytical Strategy and Study Context

This study employs a quantitative diagnostic strategy to examine housing market disequilibrium as a governance-relevant risk. Unlike studies focused solely on household welfare or tenure-based equity, the analysis examines whether

respondents' experienced housing misalignment is associated with financial resilience and workforce operational readiness. The public servant is therefore considered both as a housing consumer and as part of the administrative workforce. Because the data are individual and cross-sectional, the analysis does not directly measure aggregate state capacity or establish housing conditions as an exogenous structural constraint.

The analysis is situated in Putrajaya, a mature planned administrative capital that provides a focused setting for examining how housing support interacts with market conditions. Primary data were collected through a cross-sectional survey administered between July and August 2025. Recruitment used an email distribution database made available under administrative permission from PPAM, together with social-media circulation through public-service agencies and related public-service networks. Participation was voluntary. Of 400 responses received, 12 were excluded because the respondents were not currently working as public servants in Putrajaya, leaving 388 eligible respondents. Among these respondents, 268 (69.1%) were in the support/service group (Grades 1–8) and 118 (30.4%) in the management and professional group (Grades 9–15), with two respondents in other classifications; 324 (83.5%) reported a net monthly income of RM5,000 or below. Housing arrangements comprised 197 government-quarters residents (50.8%), 90 owner-occupiers (23.2%), 72 private renters (18.6%), and 29 family-housing residents (7.5%). A total of 261 respondents (67.3%) lived inside Putrajaya, and 293 (75.5%) reported commutes of 30 minutes or less. Recruitment circulated across multiple ministries and departments, but ministry affiliation was not retained as an analytical field and ministry-specific shares cannot therefore be reported. Because recruitment was mixed-channel and non-probability based, the sample is not population-weighted and should not be treated as statistically representative of all public servants working in Putrajaya. The analysis therefore supports diagnostic inference about relationships within the surveyed workforce rather than population prevalence estimates.

**Operationalisation of Core Constructs**

Three constructs use five-point agreement scales. Housing market disequilibrium (HD) uses six affordability, access, adequacy and locational items informed by Stone et al. (2011); it measures respondents' experienced housing-market misalignment rather than market-level disequilibrium. Financial resilience (FR) uses nine residual-income, savings, shock-absorption and financial-strain items drawing on Prawitz et al. (2006) and Netemeyer et al. (2018). Workforce operational readiness (WR) uses nine task, concentration, satisfaction, engagement and retention items contextualised with reference to Borman and Motowidlo (1993). Table 1 reports the complete analysed item set.


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Composite scores were constructed after direction correction and reliability checks. Higher scores denote greater HD, FR and WR. Internal consistency was borderline for HD ($\alpha = 0.70$ after rounding) and stronger for FR ($\alpha = 0.88$) and WR ($\alpha = 0.77$).

**Table 1:** Construct Items

| Construct | Item | Item wording |
|---|---|---|
| Housing disequilibrium | HD1 | My current housing costs (rent or loan repayments) are reasonable relative to my income. |
| | HD2 | Putrajaya housing costs are reasonable for public servants' financial capacity. |
| | HD3 | I can afford to buy a home in Putrajaya based on my current income. |
| | HD4 | I have adequate and convenient transport access between home and work. |
| | HD5 | My current housing meets my household's needs. |
| | HD6 | My housing provides easy access to essential amenities such as schools, healthcare and shopping centres. |
| Financial resilience | FR1 | My income is sufficient for basic daily expenses, including food, transport and utilities. |
| | FR2 | After housing payments, I have enough money for other essential expenses. |
| | FR3 | Housing expenditure is a major obstacle to managing my monthly finances. |
| | FR4 | I can consistently save part of my monthly income for housing. |
| | FR5 | I have sufficient emergency savings for at least three months of expenses. |
| | FR6 | I often feel worried about my financial situation. |
| | FR7 | Housing-related costs are a major contributor to my financial stress. |
| | FR8 | I have to take on additional debt to manage housing expenses. |
| | FR9 | My existing level of debt is manageable. |
| Workforce operational readiness | WR1 | I can complete my work tasks efficiently and effectively. |
| | WR2 | My housing situation impairs my ability to focus at work. |
| | WR3 | My daily commuting time affects my productivity at work. |
| | WR4 | I am satisfied with my current job. |
| | WR5 | Housing-related financial worries affect my job satisfaction. |
| | WR6 | I intend to remain in my current position for the next five years. |

| Construct | Item | Item wording |
|---|---|---|
| | WR7 | I am enthusiastic about my work duties and responsibilities. |
| | WR8 | I can give my full attention when carrying out my work tasks. |
| | WR9 | Financial worries disrupt my concentration at work. |

*Note: Five-point agreement scale (1 = strongly disagree; 5 = strongly agree). HD1–HD6, FR3, FR6–FR8, and WR2, WR3, WR5 and WR9 were reverse-scored. Items were averaged within each construct so that higher scores denote greater HD, FR and WR. WR3 and WR5 use the directionally neutral wording "affects" in the original questionnaire and were treated as negatively oriented items in constructing WR.*

*Source: Author (2026)*

### Estimation Approach and Validity

The proposed pathway is estimated using regression-based simple mediation with 5,000 bootstrap resamples (Hayes, 2018). The model estimates HD–FR, FR–WR and the remaining direct HD–WR association after FR is included; the direct association is not treated as identifying a specific mechanism. Survey anonymity and item separation were used to reduce common method bias (Podsakoff et al., 2003). All constructs are self-reported, and some FR and WR items explicitly reference housing-related financial or commuting conditions, so common-source and item-content overlap may contribute to the observed associations. Independently observed workplace outcomes would provide a stronger test. The cross-sectional results are interpreted as diagnostic associations rather than causal proof and are confined to Putrajaya.

## EMPIRICAL FINDINGS

### Descriptive Patterns

Descriptive results show a consistent pattern of housing pressure, uneven financial resilience, and differentiated workforce functioning (Table 2). Housing disequilibrium is close to the scale midpoint (M = 2.95), while financial resilience records a mean of 2.63. Workforce operational readiness records the highest mean (M = 3.51). These descriptive patterns motivate examination of the associations among housing disequilibrium, financial resilience, and workforce operational readiness.

**Table 2:** Descriptive Statistics and Reliability

| Construct | Items | Mean | SD | Min | Max | α |
|---|---|---|---|---|---|---|
| Housing disequilibrium | 6 | 2.95 | 0.70 | 1.00 | 5.00 | 0.70 |
| Financial resilience | 9 | 2.63 | 0.79 | 1.00 | 4.67 | 0.88 |
| Workforce operational readiness | 9 | 3.51 | 0.62 | 1.44 | 5.00 | 0.77 |

*Source: Author (2026)*


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**Housing Disequilibrium and Financial Resilience**

Table 3 presents the proposed pathway model. Housing market disequilibrium is negatively associated with financial resilience: greater perceived housing misalignment corresponds with weaker financial resilience among surveyed public servants (B = −0.619, 95% CI [−0.712, −0.525]).

**Financial Resilience and Workforce Operational Readiness**

Financial resilience is positively associated with workforce operational readiness after housing disequilibrium is included in the model (B = 0.336, 95% CI [0.256, 0.416]; Table 3). This association is consistent with financial resilience being relevant to self-reported work-related functioning within the surveyed public-sector workforce.

**Transmission Mechanism and Governance Risk**

The mediation results are consistent with the proposed pathway (Table 3). The estimated indirect association through financial resilience is −0.208 (95% bootstrap CI [−0.268, −0.150]), approximately 59% of the total association between housing disequilibrium and workforce operational readiness (−0.353). A smaller negative direct association remains after financial resilience is included (B = −0.145, 95% CI [−0.235, −0.055]). This partition is descriptive rather than causal, and the residual direct association does not identify a specific mechanism.

A controlled specification was also estimated using income band, service grade, age, number of dependents, marital status, residence location, housing tenure, and commuting time as categorical controls in both equations. The housing-disequilibrium to financial-resilience association remained negative (B = −0.573, p < .001), as did the adjusted indirect association (B = −0.197, 95% bootstrap CI [−0.258, −0.141]). The associations therefore persisted after adjustment for these observed characteristics.

**Table 3:** Housing Disequilibrium, Financial Resilience, and Workforce Operational Readiness

| Path | B | SE | 95% CI |
|---|---|---|---|
| HD → Financial resilience | −0.619*** | 0.047 | [−0.712, −0.525] |
| FR → Workforce readiness | 0.336*** | 0.041 | [0.256, 0.416] |
| HD → Workforce readiness (direct) | −0.145** | 0.046 | [−0.235, −0.055] |
| Indirect effect (via FR) | −0.208 | 0.030 | [−0.268, −0.150] |
| Total effect | −0.353*** | 0.041 | [−0.434, −0.272] |

*Notes: N = 388. Bootstrap samples = 5,000. ** p < 0.01; *** p < 0.001. HD = Housing disequilibrium; FR = Financial resilience. For the indirect effect, SE and 95% CI are based on 5,000 case-resampling bootstrap draws; the interval does not cross zero.*

*Source: Author (2026)*

### Summary of Empirical Pattern

Taken together, housing disequilibrium is associated with weaker financial resilience, which is in turn associated with lower workforce operational readiness. The estimated indirect association represents approximately 59% of the total association, while a smaller direct association remains. These results are consistent with financial resilience accounting for an important part of the observed relationship without establishing a causal decomposition.

## DISCUSSION: HOUSING DISEQUILIBRIUM AS A SPATIAL GOVERNANCE RISK

### The Transmission to Governance Risk

The main contribution of this study is to reframe housing disequilibrium in planned administrative capitals as a condition relevant to the functional micro-foundations of public administration, not only to affordability or welfare. In Putrajaya, perceived housing misalignment is associated with weaker financial resilience among public servants and, in turn, with lower workforce operational readiness. The planned capital trap describes the potential tension created when the state spatially concentrates administrative labour while housing adjustment does not keep pace with the financial and locational capacity of that workforce. The findings are consistent with housing forming part of the institutional environment relevant to administrative functioning, rather than establishing a causal effect of housing conditions on state capacity.

### Dual Pathways: Financial and Residual Associations

The findings indicate that housing market disequilibrium is linked to workforce functioning through an estimated indirect association via financial resilience and a remaining direct association. Financial resilience accounts for a substantial share of the observed relationship, while a smaller direct association remains after accounting for it. That residual should not be interpreted as identifying a specific spatial mechanism: it may reflect additional unmeasured pathways, including commuting burden, residential instability, or housing-related uncertainty. Recent evidence indicates that longer commuting times can be associated with lower self-reported work productivity, while spatial mismatch can impose additional burdens on workers in high-cost urban environments (Ma et al., 2024; Meen & Whitehead, 2020). The present cross-sectional results do not test those mechanisms directly.

### The Planned Capital Trap

Putrajaya's experience identifies a broader vulnerability that may arise in planned administrative capitals under specific institutional conditions. Purpose-built capitals are designed to enhance administrative efficiency through spatial


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concentration, controlled development, and coordinated planning. A 'planned capital trap' becomes plausible where three conditions coincide: public employment is strongly concentrated spatially; housing development and land release are institutionally structured or relatively inflexible; and housing adjustment does not keep pace with the financial and locational capacity of the concentrated workforce. Evidence from Brasília and Sejong illustrates how planned administrative development can coexist with residential or locational tensions (Holston, 1989; Im & Jang, 2022; Shin et al., 2024). Putrajaya provides evidence consistent with the proposed configuration, but whether the same relationship operates elsewhere, and with what magnitude, requires comparative testing. The concept would be weakened where concentrated administrative employment is accompanied by housing supply and accessibility that adjust sufficiently to workforce needs. The emergence of new administrative capitals, most notably Indonesia's Nusantara, heightens the contemporary relevance of these scope conditions.

**Governance Misalignment in Planned Administrative Capitals**

The observed associations despite targeted housing interventions are consistent with governance misalignment rather than policy absence. Preferential financing and targeted provision may be insufficient when support adjusts more slowly than market conditions shaped by financialisation, constrained land release, and segmented supply (Aalbers, 2016; Fernandez & Aalbers, 2016). Treating workforce housing as a governance input therefore supports coordination across supply, finance, regulation, and transport rather than reliance on a single instrument (OECD, 2024a; Vale, 2008).

## POLICY IMPLICATIONS

The findings indicate that housing market disequilibrium should be considered a spatial governance risk. Policy responses should therefore treat workforce housing as spatial infrastructure rather than a residual social concern. For Putrajaya, the relevant response is institutional coordination rather than reliance on a single instrument: PPAM supports access to strategically located below-market homeownership, LPPSA administers public-sector housing financing, and Putrajaya Corporation exercises local-government, planning, infrastructure, and residential-development functions within Putrajaya. Three mutually reinforcing directions follow from the analysis.

First, supply-side recalibration through coordinated housing and land-use planning. The strong association between housing market disequilibrium and financial resilience suggests that affordability pressure should not be treated only as an individual financing problem. For Putrajaya, closer coordination between PPAM provision and Putrajaya Corporation's planning and residential-

development functions could place greater emphasis on the location, price, density, and tenure mix of workforce housing. Mixed-tenure development and spatial cross-subsidy may offer useful instruments where they are compatible with local market feasibility and developer incentives (Galster, 2007; Calavita & Mallach, 2010). The policy objective is not simply additional units, but supply that is financially and spatially usable by the workforce it is intended to serve.

Second, financing support should be calibrated alongside, rather than substituted for, supply reform. The indirect association through financial resilience indicates that household resource conditions remain relevant even where public servants have access to preferential financing. LPPSA can reduce financing frictions for eligible borrowers, but financing terms cannot by themselves correct a shortage of suitably priced and located housing. Periodic alignment between housing prices, public-sector borrowing capacity, and targeted support would therefore help identify where financing remains usable and where the binding constraint lies elsewhere in the housing system. Any location-specific or income-banded support should be assessed against fiscal capacity and the distribution of housing pressure (OECD, 2024a, 2025).

Third, transport-linked housing strategies may be relevant where residential proximity cannot be achieved, but this implication should not be read as a programme-effect estimate. The residual direct association does not identify commuting as its mechanism. Rather, the survey shows that housing disequilibrium remains associated with workforce operational readiness after financial resilience is accounted for. Putrajaya Corporation's planning role provides a basis for considering housing location together with transport accessibility, while public-transport connectivity and appropriate flexible-work arrangements may complement longer-term housing-supply and financing reforms (Ma et al., 2024; Meen & Whitehead, 2020; OECD, 2024a, 2024b).

## CONCLUSION

This study shows that perceived housing market disequilibrium in Putrajaya is associated with conditions relevant to governance as well as household welfare. Perceived housing misalignment is associated with weaker financial resilience and lower workforce operational readiness. Financial resilience accounts for a substantial part of the observed relationship, while a smaller residual direct association remains that is not assigned to a specific mechanism by the cross-sectional model.

By linking housing conditions to workforce readiness, the paper extends housing analysis beyond conventional concerns with affordability and access alone. The findings are consistent with workforce housing forming part of the institutional environment relevant to administrative functioning in planned capitals. The planned capital trap captures the potential contradiction between


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spatially concentrating government functions and housing conditions that do not adjust sufficiently to the needs of the concentrated workforce.

The implications may extend beyond Putrajaya, where concentrated public employment, institutionally structured urban development, and lagging housing adjustment coexist. In such settings, housing warrants consideration as a strategic governance asset rather than a residual welfare concern. Comparative and longitudinal research is needed to establish whether the Putrajaya pattern recurs and whether supply, financing, or transport responses alter these relationships over time.

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# DEVELOPING A SUSTAINABLE FEATURES OF AFFORDABLE HOUSING MODEL BASED ON OCCUPANTS' PERCEIVED HOUSEHOLD COST BURDEN REDUCTION

**Ahmad Fawwaz Saleh[1*], Noorame Mohd Foudzy[2], Mohammad Syahir Aiman Abd Khair[3], Mohammad Firdaus Ishak[4], Fadzilah Awg Bakar[5]**

[1*2,3,5]*Centre for Sustainable Planning and Real Estate (SUPRE),*
*Faculty of Built Environment,*
UNIVERSITI MALAYA, MALAYSIA
[4] *College of Built Environment,*
UNIVERSITI TEKNOLOGI MARA, MALAYSIA

## Abstract

Housing affordability has evolved beyond housing purchase prices to include long-term operating and maintenance costs. Although sustainable housing features are recognised for improving environmental performance, limited evidence exists on which features effectively reduce household cost burdens in stratified affordable housing. This study identifies the Sustainable Features of Affordable Housing that contribute to Perceived Household Cost Burden Reduction (PHCBR) among occupants of affordable housing schemes in the Klang Valley, Malaysia. A quantitative approach was adopted using a structured questionnaire administered to 385 respondents. Descriptive statistics and multiple regression analysis were employed to examine the influence of sustainable housing features on PHCBR. The findings indicate that 15 sustainable housing features significantly contribute to reducing occupants' perceived household cost burdens, with LED lighting in common areas, motion sensor lighting, and energy-efficient lifts emerging as the strongest predictors. The regression model explained 65.7% of the variance in PHCBR ($R^2 = 0.657$), indicating strong explanatory power. Based on these findings, the study proposes the Sustainable Features of Affordable Housing Model, comprising four sustainability pillars: Energy Efficiency, Water Efficiency, Materials and Resources, and Indoor Environmental Quality. The proposed model provides practical guidance for developers and policymakers in prioritising sustainable housing features that enhance long-term housing affordability and financial sustainability.

***Keywords***: Sustainable Features of Affordable Housing; Affordable housing; Perceived Household Cost Burden Reduction; Housing affordability; Malaysia.

[1] Corresponding author. Email: fawwaz@um.edu.my

## INTRODUCTION

Rapid urbanization, rising housing demand, and growing environmental concerns have intensified global efforts to promote sustainable housing development. The residential sector is recognized as a major consumer of energy, water, and construction materials, while simultaneously contributing significantly to greenhouse gas emissions and environmental degradation. Consequently, governments and international organizations are increasingly advocating for the adoption of sustainable housing features. Such as energy-efficient technologies, water conservation systems, eco-friendly building materials, and improved indoor environmental quality as essential components of sustainable urban development (United Nations, 2015; World Green Building Council, 2019). These sustainable features are expected not only to enhance environmental performance but also to reduce building operating costs and improve residents' quality of life.

Despite the growing emphasis on sustainable housing, integrating sustainability into affordable housing development remains a significant challenge. Gan et al. (2017) assert that affordable housing should strike a balance between economic affordability, environmental sustainability, and social well-being, rather than merely providing housing at a lower purchase price. Similarly, Chan and Adabre (2019) argue that sustainable affordable housing must go beyond construction costs to consider the building's lifecycle performance, operating expenses, housing management, and the long-term financial well-being of occupants. Previous studies have extensively examined aspects of sustainable housing, such as green feature adoption (Zulkepli & Rahman, 2025); the willingness to pay a price premium (Lee et al., 2025); environmental performance, green building certification, purchase intention, residential satisfaction, and consumers' willingness to pay a premium purchase price for green housing (Chan & Adabre, 2019a; Adabre et al., 2020; Tan et a., 2022) and far less attention has been invested to the role of sustainable housing features in alleviating the long-term financial burden associated with housing maintenance and household cost. Previous authors argued that investment in sustainable features in affordable housing is essential, considering the continuing operational management and positive externalities, such as neighborhood benefits (MacAskill *et al.*, 2021). In Malaysia, affordable housing programs primarily focus on increasing access to homeownership through various government initiatives on housing prices (Saleh et al. 2025a). However, growing evidence suggests that housing affordability cannot be assessed solely based on the initial purchase price. Homeownership entails ongoing financial commitments throughout the housing lifecycle, including mortgage repayments, utility bills, maintenance fees, sinking fund contributions, and repair costs (Chan & Adabre, 2019b)

Therefore, this study examines the relationship and impacts between sustainable housing features and the perceived reduction in housing cost burden among stratified affordable occupants in Klang Valley. Specifically, the study aims to identify sustainable housing features that contribute to reducing utility expenses, common area maintenance costs, and maintenance fee burdens, ultimately developing a Sustainable Affordable Housing Features Model to guide future stratified affordable housing developments. The findings are expected to provide valuable guidance for developers, property managers and policymakers in balancing sustainability objectives with long-term housing affordability while ensuring the financial sustainability of affordable housing management.

## LITERATURE REVIEW

### Sustainable Affordable Housing

Affordable housing is generally defined as housing that is financially accessible to low- and middle-income households without imposing excessive financial burdens that compromise their ability to meet other essential living needs. (Saleh et al., 2025a). Traditionally, housing affordability has been assessed based on the relationship between household income and housing costs, with particular emphasis on the purchase price or rental expenditure (Saleh et al., 2025b). However, this conventional definition has been increasingly criticised for overlooking the long-term financial commitments associated with homeownership, including utility bills, maintenance fees, repair costs, and other operational expenses incurred throughout the housing lifecycle. This issue is commonly observed in stratified residential developments governed by management bodies that are responsible for maintaining common property. Property owners are required to pay monthly maintenance and management fees to support the upkeep of these shared facilities. Such arrangements are typically found in high-rise or strata-titled residential government scheme; such as, PR1MA, Residensi Wilayah and Rumah Selangorku. Consequently, the concept of sustainable affordable housing has emerged, integrating the principles of environmental sustainability with long-term economic affordability and social well-being. Although, Jamaludin et al (2017) provides a detailed discussion on the challenges of integrating sustainability principles into affordable housing, this does not preclude the incorporation of sustainable housing features within government-subsidised affordable housing developments. Chan and Adabre (2019) defined sustainable affordable housing as housing that simultaneously satisfies affordability, environmental performance, and occupants' quality of life throughout its lifecycle. Similarly, Gan et al. (2017) argued that sustainable affordable housing should balance environmental, economic, social, institutional, and technological dimensions to ensure long-term housing sustainability.


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In practice, this is achieved through the incorporation of sustainable housing features such as energy-efficient technologies, water conservation systems, durable construction materials, and improved indoor environmental quality, which not only minimise the housing prices but also reduce long-term operational and household costs. Despite these recognised benefits, the adoption of sustainable housing features within stratified affordable housing scheme remains limited, highlighting the need to identify those features that can effectively reduce long-term household operating costs while enhancing the financial sustainability of affordable homeownership.

**Sustainable Features for Affordable Housing**

The findings suggest that sustainable development features improve residential affordability by reducing long-term household expenditure and building operational costs. Rather than providing environmental benefits alone, the integration of Energy Efficiency (EE), Water Efficiency (WE), Materials and Resources (MR), and Indoor Environmental Quality (IEQ) contributes to lower electricity and water consumption, reduced maintenance requirements, and improved lifecycle performance of residential buildings. These outcomes are consistent with previous studies, which argue that sustainable housing should be evaluated based on its ability to minimise both initial and recurring housing costs, thereby improving long-term affordability (Chan & Adabre, 2019; Zulkepli & Rahman, 2025).

Energy Efficiency (EE) features, including solar photovoltaic (PV) systems, LED lighting, energy-efficient lift systems, EV charging infrastructure, motion sensors and energy star rating appliance, directly reduce electricity consumption in residential buildings. Lower energy demand decreases utility bills and common area operational expenditure, allowing management bodies to maintain more stable maintenance fees. This is particularly important in affordable high-rise housing, where recurring electricity costs form a significant proportion of monthly household expenditure (Santamouris, 2014; Ramli et al., 2024). Similarly, Water Efficiency (WE) measures, such as rainwater harvesting, water-efficient fixtures, dual-flush toilets, Water saving landscaping, and water sub-metering, reduce potable water demand while encouraging responsible water consumption. Besides lowering monthly water bills, these systems reduce water losses and maintenance costs associated with plumbing infrastructure, contributing to better long-term resource management (Al-Qawasmi et al., 2019; Mandell & Wilhelmsson, 2011).

The Materials and Resources (MR) pillar contributes mainly through lifecycle cost reduction. The adoption of Industrialised Building Systems (IBS), durable construction materials, low-VOC products, universal design, and recycling facilities reduces repair frequency, replacement costs, and building

maintenance throughout the service life of the building. Previous studies indicate that sustainable housing should be assessed based on whole-life cost rather than initial construction cost alone (Iwuanyanwu et al., 2024; Olanrewaju & Tan, 2018). Indoor Environmental Quality (IEQ) features, including natural daylighting, natural ventilation, large windows, external views, and acoustic insulation, also contribute indirectly to housing affordability. Improved daylight and natural ventilation reduce dependence on artificial lighting and air-conditioning, while healthier indoor environments improve occupant comfort and satisfaction. Consequently, sustainable housing delivers both economic and social value by lowering energy consumption while enhancing residents' quality of life (Wang et al., 2025; Abdullah et al., 2025). Overall, the integration of EE, WE, MR, and IEQ improves resource efficiency, reduces utility bills and maintenance expenditure, and enhances housing affordability throughout the building lifecycle.

**Perceived household cost burden reduction (PHCBR)**

Perceived Household Cost Burden Reduction (PHCBR) refers to occupants' perception that sustainable housing features help reduce the overall financial burden of homeownership by lowering utility bills, common area maintenance costs, and recurring maintenance fees. In Malaysia, the problem is particularly severe in low-cost and affordable housing schemes, where approximately half of the residential units experience difficulties in making regular maintenance fee payments (Bernama, 2025). Meanwhile, Saleh et al. (2025b) and Adabre et al. (2020) noted that a major challenge in affordable housing lies in balancing sustainability objectives with financial affordability considerations. This concept extends housing affordability beyond the initial purchase price by recognising that homeowners or occupants continue to bear recurring housing-related expenses throughout the occupancy period.

## RESEARCH METHODOLOGY

### Data Collection and Sample Selection

A quantitative research approach was adopted, and a structured questionnaire was administered to 385 occupants of stratified affordable housing schemes in the Klang Valley. Respondents were selected from occupants residing in PR1MA, Residensi Wilayah and Rumah Selangorku developments, comprising both homeowners and tenants. Affordable Housing Scheme in Klang Valley was selected as the study area due to its high concentration of affordable housing developments and diverse housing schemes. The collected data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were first employed to summarise mean score for dependent variables of PHCBR. Subsequently, regression analysis was performed to examine the influence of


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sustainable housing features on occupants. The strength and significance of the relationships were assessed using the normality, correlation coefficient (r), coefficient of determination ($R^2$), standardized regression coefficient (β), significance level (p-value), and effect size ($f^2$), where appropriate. In the light of the following research, the hypothesis included;

- $H^1$ – *Sustainable housing features have a significant influence on occupants' Perceived Household Cost Burden Reduction (PHCBR)*

The proposed initial conceptual framework illustrating this relationship is presented in Figure 1.

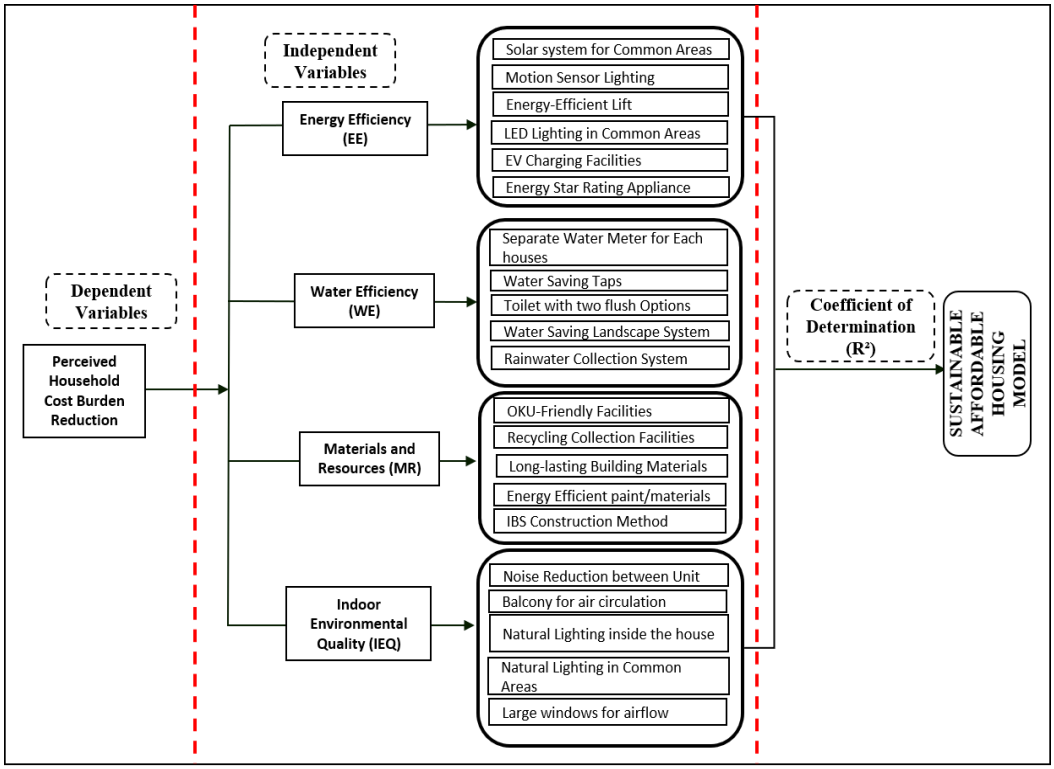



**Figure 5:** Conceptual and Research framework

The figure above presents the initial research framework, which was put together after considering previous studies that identified relevant attributes and integrated relationships between Sustainable Features of Affordable Housing as the independent variable and the Perceived Household Cost Burden Reduction

as the dependent variable. The selected initial attributes were classified into four categories, comprising a total of 21 attributes. The regression model formula for this research can be summarised as below;

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots + \beta\, \gamma\, X\, \gamma + \varepsilon$$

Where;
Y = *Dependent variable; Mean of PHCBR*
X = X1, X2,.. Xγ = *Independent variable; Sustainable Features of Affordable housing*
β0, β1, β2, β3, ...βγ = *Parameters of the variables* + ε = *Error estimation*

Therefore, the analysis commenced with the dependent variables by examining their composite mean scores to determine the overall level of respondents' perceptions.

## RESULT AND DISCUSSION

### Descriptive Statistics of Respondent Profiles

The basic distribution of respondents is presented in Table 1.

**Table 1**: Descriptive Statistics of Respondent Profiles

| Variables | Category | Frequency (n) | Percentage (%) |
|---|---|---|---|
| Tenure | Owner | 235 | 61.0 |
| | Tenant | 150 | 39.0 |
| Housing Scheme | PR1MA | 70 | 18.2 |
| | Residensi Wilayah | 150 | 42.9 |
| | Rumah Selangorku | 165 | 39.0 |
| | | **385** | **100.0** |

Table1 shows that the sample comprised respondents from three affordable housing schemes, with the largest proportion from Residensi Wilayah (42.9%), followed by Rumah Selangorku (39.0%) and PR1MA (18.2%). In terms of tenure, homeowners constituted 61.0% of the sample, while tenants accounted for 39.0%. This distribution provides a contextual profile of the study sample, encompassing both ownership and rental occupancy within Klang Valley's affordable housing sector.


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## Descriptive Statistics of Perceived Household Cost Burden Reduction

**Table 2**: Mean Score

| **Variables** | | |
|---|---|---|
| **Items** | **Mean** | **SD** |
| Sustainable housing features reduce monthly utility costs (e.g., electricity and water bills). | 4.188 | 0.742 |
| Sustainable housing features reduce monthly maintenance costs for common areas. | 4.113 | 0.754 |
| Sustainable housing features reduce the overall financial burden of maintenance fees for homeowners. | 4.061 | 0.701 |
| **Overall mean score: PHCBR** | 4.121 | 0.800 |

PHCBR was measured using three items related to perceived reductions in utility costs, common area maintenance costs, and maintenance fees payment. A composite mean score was calculated by averaging the responses to the three items. The overall mean score of 4.121 indicates a high level of perceived household cost burden reduction.

## Regression Analysis

### Normality test

Normality was assessed using skewness and kurtosis values. Following Hair et al. (2022), all four sustainability categories met the recommended thresholds of ±2.0 for skewness and ±7.0 for kurtosis, as shown in Table 2;

**Table 3**: Normality Result

| **Variables** | | | **Normal distribution** | | **Status** |
|---|---|---|---|---|---|
| **Categories** | **Mean** | **SD** | **Skewness** | **Kurtosis** | |
| Energy Efficiency (EE) | 3.938 | 0.742 | -0.503 | 0.049 | Normal |
| Water Efficiency (WE) | 3.832 | 0.754 | -0.660 | 1.161 | |
| Indoor Environmental Quality (IEQ) | 4.027 | 0.701 | -0.972 | 2.215 | |
| Materials and Resources (MR) | 3.983 | 0.800 | -0.849 | 0.883 | |

As presented in Table 3, skewness values ranged from -0.503 to -0.972, Meanwhile, the kurtosis values ranged from 0.049 to 2.215, indicating that the distributions were slightly more peaked than a normal distribution but remained well within the acceptable threshold. Since all skewness and kurtosis values met the recommended criteria proposed by Hair et al. (2022), the data were considered

approximately normally distributed. Meanwhile, multicollinearity was assessed based on tolerance and VIF values. The results showed acceptable values for all predictors, indicating no significant multicollinearity concern in the model.

**Correlation analysis with dependent variables**

Table 4 show the correlation between total of composite mean score for perceived household cost burden reduction and categories in Sustainable Features of Affordable housing;

**Table 4**: Correlation analysis

| Variables | Pearson Correlation (*r*) | Sig.2-Tailed | Relationship |
|---|---|---|---|
| **DV: Perceived Household Cost Burden Reduction** | | | |
| Energy Efficiency (EE) | 0.573 | | Moderate and Positive |
| Water Efficiency (WE) | 0.664 | <0.001 | Strong and Positive |
| Materials and Resources (MR) | 0.586 | | Moderate and Positive |
| Indoor Environmental Quality (IEQ) | 0.483 | | Moderate and Positive |

The Pearson correlation analysis revealed that all four sustainable development categories were positively and significantly associated with PHCBR ($p < 0.001$). Among the four predictors, Water Efficiency (WE) demonstrated the strongest positive relationship with perceived household cost burden reduction ($r = 0.664$), indicating that respondents perceived water-efficient features as having the greatest contribution to reducing household living costs. Next, Materials and Resources (MR) exhibited a moderate positive correlation ($r = 0.586$), followed closely by Energy Efficiency (EE) ($r = 0.573$). These findings suggest that respondents recognised the role of durable construction materials, resource-efficient building practices, and energy-saving technologies in lowering long-term maintenance expenses and utility costs. Meanwhile, Indoor Environmental Quality (IEQ) recorded the lowest, yet still statistically significant, positive correlation with perceived household cost burden reduction ($r = 0.483$). Although IEQ features primarily enhance occupants' comfort and well-being, respondents also acknowledged their indirect contribution to reducing household expenditure through improved natural lighting and ventilation, which may reduce reliance on artificial lighting and mechanical cooling. Overall, the statistically significant positive correlations support the proposition that greater implementation of sustainable housing features is associated with stronger perceptions of reduced household financial burden. Subsequently, Table 5 summarises the results of the path coefficients (B), t-values (T), and ranked of the 21 attributes.


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**Table 5**: Coefficient result of Sustainable Features of Affordable Housing with PHCBR

| **Regression Analysis DV: PHCBR** | | ***Beta*** | ***t*** | **Sig. A** | **Ranks** |
|---|---|---|---|---|---|
| Materials and Resources (MR) | OKU-friendly facilities (MR1) | -.032 | -0.492 | .632 | Not Sig |
| | Recycling collection facilities (MR2) | .178 | 2.725 | .004 | 12 |
| | High-quality and long-lasting building materials (MR3) | .174 | 2.601 | .004 | 13 |
| | Energy Efficient paint/materials (MR4) | .185 | 2.912 | .004 | 11 |
| | IBS construction method (MR5) | .281 | 4.332 | .002 | 7 |
| Indoor Environmental Quality (IEQ) | Noise reduction between units (IQ1) | -.029 | -0.482 | .338 | Not Sig |
| | Balcony for better air circulation (IQ2) | .249 | 3.814 | .002 | 8 |
| | Natural lighting inside the house (IQ3) | .224 | 3.448 | .003 | 9 |
| | Natural Lighting in Common Areas (IQ4) | .163 | 2.542 | .004 | 14 |
| | Large windows for better airflow (IQ5) | .198 | 3.052 | .003 | 10 |
| Energy Efficiency (EE) | Solar system for common areas (EE1) | -.375 | -4.72 | .003 | 5 |
| | Motion sensor lighting (EE2) | .401 | 5.031 | .000 | 2 |
| | Energy-efficient lifts (EE3) | .389 | 4.922 | .000 | 3 |
| | LED lighting in common areas (EE4) | .408 | 5.130 | .000 | 1 |
| | EV charging facilities (EE5) | -.045 | -.574 | .553 | Not Sig |
| | Energy Star Rating Appliance (EE6) | .381 | 4.845 | .000 | 4 |
| Water Efficiency (WE) | Separate water meter for each house (WE1) | .031 | 0.493 | .634 | Not Sig |
| | Water-saving taps (WE2) | -.054 | -0.501 | .671 | Not Sig |
| | Toilets with two flush options (WE3) | .324 | 4.52 | .001 | 6 |
| | Water-saving landscape system (WE4) | .151 | 2.312 | .004 | 15 |
| | Rainwater collection system (WE5) | .129 | 2.082 | .004 | 16 |

Coefficient analysis was conducted to examine the influence of sustainable housing features on perceived household cost burden reduction (PHCBR). The results indicate that 16 out of the 21 sustainable housing features significantly influenced occupants' perceptions of household cost burden reduction, while the remaining five attributes, namely EV charging facilities, separate water meters, water-saving taps, OKU-friendly facilities, and noise reduction between housing units, were not statistically significant.

A closer look, Among the significant predictors, LED lighting in common areas emerged as the most influential factor ($\beta = 0.408$, $t = 5.130$, $p < 0.001$), followed by motion sensor lighting ($\beta = 0.401$, $t = 5.031$, $p < 0.001$),

energy-efficient lifts (β = 0.389, $t$ = 4.922, $p$ < 0.001), Energy Star-rated appliances (β = 0.381, $t$ = 4.845, $p$ < 0.001), and dual-flush toilet systems (β = 0.324, $t$ = 4.520, $p$ = 0.001). These features directly contribute to reductions in electricity and water consumption, enabling households to experience immediate savings in monthly utility expenses. This finding is consistent with Gan et al. (2017) and Chan and Adabre (2019), who emphasised that sustainable affordable housing should prioritise technologies capable of lowering lifecycle operating costs while improving long-term housing affordability. Other sustainable housing features, including IBS construction methods, balconies for natural ventilation, natural lighting, large windows for better airflow, energy-efficient paint/materials, high-quality durable building materials, and recycling collection facilities, also demonstrated significant positive relationships with PHCBR. These findings suggest that occupants recognise the long-term economic benefits of passive design strategies and durable construction materials, which are associated with lower maintenance requirements and reduced household energy consumption.

Interestingly, solar systems for common areas demonstrated a significant negative relationship with PHCBR (β = –0.375, $t$ = –4.720, $p$ = 0.003). Although solar energy systems are generally recognised for reducing electricity consumption, occupants may perceive that the installation, operation, and long-term maintenance of solar systems for common facilities increase overall building management costs. Since the electricity savings generated from common-area solar systems are not always directly reflected in individual household utility bills, occupants may perceive that the financial benefits do not immediately outweigh the additional maintenance or replacement costs associated with the technology. Furthermore, EV charging facilities (β = –0.045, $p$ = 0.553) were found to have a negative but insignificant relationship with PHCBR. This finding suggests that occupants do not currently associate EV charging infrastructure with reductions in household expenditure. Instead, respondents may perceive EV charging infrastructure as an additional facility requiring higher installation, operational, and maintenance costs, which could ultimately increase maintenance charges rather than reduce household financial burdens. Similar observations were highlighted by Adabre et al. (2020), who noted that sustainable technologies should be prioritised based on their practical relevance and economic value to target users rather than solely on their environmental benefits.

Overall, the findings demonstrate that affordable housing occupants place greater emphasis on sustainable housing features that produce immediate and measurable reductions in utility bills and maintenance costs. From table below, the potential regression model was identified;


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**Table 6:** Regression Model Fit for Perceived Household Cost Burden Reduction

| **Regression Analysis between PHCBR and Sustainable Features of Affordable Housing** | | | | |
|---|---|---|---|---|
| **PHCBR** | EE2,EE3,EE4,EE6; WE3, WE4, WE5; MR2,MR3,MR4,MR5; IQ2,IQ3,IQ4,IQ5 | ***R*** 0.810 | ***Std. Error*** 0.623 | ***Sig.*** 0.000 |
| | ***R²*** | .657 | | |
| | ***F*** | 35.082 | | |

Multiple regression analysis was subsequently conducted to examine the relationship between sustainable housing features and PHCBR and to develop the proposed model. The final regression model identified 15 significant sustainable housing features, comprising four attributes from Energy Efficiency (EE) (EE2, EE3, EE4, and EE6), three from Water Efficiency (WE) (WE3, WE4, and WE5), four from Materials and Resources (MR) (MR2, MR3, MR4, and MR5), and four from Indoor Environmental Quality (IEQ) (IQ2, IQ3, IQ4, and IQ5). To further identify the relative contribution of these features to PHCBR, the standardized regression coefficients (β) were examined and used to rank the retained predictors. Based on the standardized regression coefficients, LED lighting in common areas (β = 0.408), motion sensor lighting (β = 0.401), energy-efficient lifts (β = 0.389), Energy Star-rated appliances (β = 0.381), and dual-flush toilets (β = 0.324) were the highest-ranked predictors of PHCBR. This pattern indicates that occupants placed greater perceived importance on features with a relatively direct connection to energy and water consumption. The remaining predictors demonstrated comparatively smaller but statistically significant contributions, extending across Materials and Resources, Water Efficiency, and Indoor Environmental Quality. The model demonstrated a strong relationship with PHCBR (R = 0.810) and explained 65.7% of the variance in occupants' perceived household cost burden reduction ($R^2 = 0.657$), suggesting that the selected sustainable housing features provide strong explanatory capability. Furthermore, the regression model was statistically significant ($F = 35.082$, $p < 0.001$). According to Cohen (2013), this exceeds the threshold for a large effect size ($f^2 \geq 0.35$), indicating that the selected sustainable housing features are significant predictors of household cost burden reduction. Although solar systems for common areas (EE1) demonstrated a statistically significant relationship, the negative regression coefficient indicates that occupants did not perceive this feature as contributing to household cost reduction. This may be because the financial benefits of common-area solar systems are not directly reflected in individual household utility bills, while installation and maintenance costs are perceived to increase overall building management expenses. Therefore, the proposed sustainable housing features framework focuses on features that are perceived to provide direct or indirect reductions in household costs, consistent

with the primary objective of this study and the argument of Chan and Adabre (2019) that the adoption of sustainable housing features is strongly influenced by occupants' perceived economic value.

## CONCLUSION

This study demonstrates that sustainable housing features play a significant role in reducing occupants' Perceived Household Cost Burden Reduction (PHCBR) within affordable housing developments scheme in Klang Valley. The model identified 15 sustainable housing features across the four sustainable categories including Energy Efficiency, Water Efficiency, Materials and Resources, and Indoor Environmental Quality as significant predictors of perceived household cost reduction. Among these, energy-efficient technologies, including LED lighting, motion sensor lighting, energy-efficient lifts, and Energy Star-rated appliances, exhibited the strongest influence, indicating that occupants place greater value on features that generate immediate and measurable reductions in household utility costs. These findings support the argument of Chan and Adabre (2019) and Gan et al. (2017) that sustainable affordable housing should prioritise features that improve lifecycle affordability rather than focusing solely on environmental performance.

The findings further reveal that not all sustainable housing features are perceived equally by affordable housing occupants. Features such as EV charging facilities and common-area solar systems were not perceived as directly contributing to household cost reduction, suggesting that occupants evaluate sustainable technologies based on their immediate economic benefits rather than their environmental advantages alone. This observation is consistent with Adabre et al. (2020), who emphasised that the successful adoption of sustainable housing features depends on their perceived affordability, practicality, and economic value to end users. Overall, this study extends the sustainable affordable housing literature by demonstrating that occupants prioritise sustainable housing features capable of reducing long-term household expenditure. These findings support previous research that sustainable housing and affordable housing are complementary concepts, where lower operational costs and improved building performance ultimately reduce the financial burden on residents (Chan & Adabre, 2019; Zulkepli and Rahman, 2025). The findings provide an evidence-based foundation for developers, management bodies and policymakers to prioritise cost-effective sustainable housing features in future affordable housing developments, thereby enhancing long-term housing affordability, financial sustainability, and residents' quality of life.


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# REAL ESTATE INVESTMENT DECISION-MAKING CHALLENGES AMONG GOVERNMENT-LINKED INVESTMENT COMPANIES IN MALAYSIA

**Fatin Aziz[1], Yasmin Mohd Adnan[2], Noorame Mohd Foudzy[3], Zarita Ahmad Baharum[4]**

[1,2,3]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI MALAYA MALAYSIA
[4]*Department of Real Estate, Faculty of Built Environment,*
UNIVERSITI TEKNOLOGI MARA MALAYSIA

## Abstract

Institutional real estate investment decisions in emerging economies remain underexplored, particularly among government-linked entities that must balance commercial returns with broader national development mandates. Although Malaysia government-linked investment companies (GLICs) are among the country's dominant institutional investors in the commercial real estate market, the challenges influencing their real estate investment decisions remain insufficiently understood. This study examines the challenges that influence real estate investment decisions among Malaysian GLICs. A qualitative study design was adopted, drawing on semi-structured interviews with 15 key informants directly involved in real estate investment decision-making. Thematic analysis identified challenges across two broad dimensions, namely internal and external. Internal challenges include organisational and structural constraints, behavioural biases such as herding and home bias, and social and sustainable challenges, including environmental, social, and governance (ESG) pressure and ambitious development. External challenges comprise political and geopolitical risk, macroeconomic challenges, real estate market constraints, and regulatory and legal requirements. These findings reveal a dual mandate tension between achieving risk-adjusted returns and fulfilling socio-political obligations. This study contributes to the limited literature on institutional real estate investment challenges in emerging economies and offers practical implications for fund managers, policymakers, and regulators seeking to enhance institutional real estate investment practices in Malaysia.

***Keywords***: Real Estate Investment, Government-Linked Investment Companies, Investment Decision-Making Challenges, Malaysia

[3] Corresponding author. Email: ameyfoudzy@um.edu.my

## INTRODUCTION

The rise of institutional investors in Malaysia's commercial real estate market has made effective investment decision-making even more critical. Government-Linked Investment Companies (GLICs) are key players, managing over RM2.06 trillion in assets, with RM138 billion specifically allocated to real estate. They must balance generating returns with meeting national development goals. However, GLICs face significant challenges in making real estate investment decisions. These challenges include governance inefficiencies, political influence, portfolio constraints, and behavioural biases. Research has shown that factors such as limited transparency, herding behaviour, and home bias distort rational decision-making.

GLICs struggle with additional complexities due to their dual mandate: they must comply with governance requirements while also fulfilling economic obligations. The impact of these challenges on their investment decisions is not well understood.

This paper aims to explore the internal and external factors influencing GLICs' investment choices in Malaysia's real estate market. It will provide insights to enhance institutional investment practices in the country.

## LITERATURE REVIEW

### Institutional Investors and Government-Linked Investment Companies (GLICs)

Institutional investors, particularly Government-Linked Investment Companies (GLICs) in Malaysia, play a crucial role in global real estate markets due to their significant capital and long-term focus. Collectively, GLICs control over a quarter of Bursa Malaysia’s market capitalisation, making them key players in the country's capital market (Tan, 2019). These entities, managing approximately RM2.06 trillion in assets, have a dual mandate: to achieve commercial returns while addressing national socio-economic objectives, which complicates their investment strategies (Gomez et al., 2018).

Notably, the federal government’s involvement in GLIC governance, including influence on board appointments, raises questions about accountability and transparency, especially since GLIC funding comes from public resources (Nasir et al., 2020). The allocation to real estate varies across GLICs, from 5.3% to 20% of total assets, reflecting diverse investment objectives and risk appetites (GLIC Annual Report, 2025).

Existing research has focused heavily on quantitative performance metrics, such as returns and diversification, often overlooking the internal and external challenges shaping investment decisions in the context of Malaysian GLICs (Baum & Hartzell, 2020). Internally, governance arrangements and varying institutional capabilities affect decision-making, while externally,

pressures from public fund management, policy alignment, and economic conditions limit strategic options. This interplay of factors remains insufficiently explored, highlighting a critical gap in understanding the complexities of GLIC investment decision-making in real estate.

**Challenges Influencing Real Estate Investment Decisions**

Institutional real estate investment decisions are shaped by interconnected macroeconomic, regulatory, market, organisational, behavioural, and sustainability factors. Although these decisions are supported by formal governance, financial modelling, and portfolio strategies, they remain vulnerable to external uncertainties and internal organisational constraints (Sirmans & Worzala, 2003; Wiegelmann & Schwab, 2025).

Macroeconomic conditions strongly influence investment performance. Interest rates affect financing costs, capitalisation rates, and property valuations, while inflation influences construction costs, rental growth, and financing uncertainty. Political stability and consistent economic policies further strengthen investor confidence, whereas volatile macroeconomic conditions increase investment risk and delay capital allocation (Huang & Wagner, 2025).

A transparent and stable regulatory environment is equally critical. Clear property rights, efficient planning systems, taxation policies, and legal enforcement reduce transaction costs and investment uncertainty. In contrast, regulatory inconsistency and policy uncertainty discourage long-term investment and weaken market confidence (Jones & Trevillion, 2022; Vashist et al., 2025).

Real estate market characteristics further complicate investment decisions due to information asymmetry, illiquidity, market cycles, and asset heterogeneity. Institutional investors, therefore, assess market fundamentals including occupancy, rental growth, liquidity, and sector performance to balance expected returns against investment risk. Weak market conditions typically encourage more conservative portfolio strategies (Baum & Hartzell, 2020; Lin et al., 2026).

Despite sophisticated analytical tools, investment decisions are not entirely rational. Behavioural biases such as overconfidence, anchoring, loss aversion, and herd behaviour may distort risk assessment and asset valuation. Consequently, institutional investors increasingly rely on investment committees, independent due diligence, and data-driven technologies, including artificial intelligence, to improve decision quality and reduce subjective bias (Gavrilakis & Floros, 2022; Vashist et al., 2025).

Finally, organisational capability and ESG integration have become strategic determinants of investment success. Strong governance, leadership, and investment expertise enhance organisational adaptability, while ESG considerations are increasingly embedded into acquisition, development, and


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portfolio management to improve long-term value, manage sustainability-related risks, and meet evolving stakeholder expectations (Basile, 2024; Christensen et al., 2021).

Critically, the literature largely examines these factors in isolation, despite their dynamic interactions in practice. Institutional investment decisions are rarely driven by a single determinant; rather, they reflect the combined influence of economic conditions, regulatory certainty, market dynamics, organisational capability, behavioural judgement, and sustainability priorities. This fragmented perspective highlights the need for an integrated decision-making framework that captures the interrelationships among these factors when evaluating institutional real estate investments. Table 1 shows the literature review matrix of challenges in institutional real estate investment.

**Table 1:** Matrix of Challenges in Institutional Real Estate Investment

| Factors | Authors (Year) |
|---|---|
| **Political & Geopolitical Challenges** | |
| Political stability | Newell and Marzuki (2023); Andonov et al. (2018); van Loon and Aalbers (2017); Lieser and Groh (2014) |
| Transaction risk | Sirmans and Worzala (2003) |
| Geopolitical constraints | Wiegelmann and Schwab (2025); Nnamani et al. (2025) |
| Government intervention | Andonov et al (2018) |
| **Macroeconomic Challenges** | |
| Economic stability and fluctuation | Newell and Marzuki (2023) |
| Taxation issues | Wiegelmann & Schwab (2025) |
| Monetary policy | Sirmans & Worzola (2003); Wan et al. (2010); ; Li et al. (2023). |
| Inflation and recession | Anastasopoulos and Varelas (2023) |
| **Regulatory and Legal Constraints** | |
| Legal and rule of law | Wiegelmann & Schwab (2025) |
| Transparency – legal framework | Lieser & Groh (2014); Sirmans & Worzola (2003) |
| Restriction of capital flows & ownership control | Lieser and Groh (2014) |
| Lengthy Transaction process: Ownership title | Agboola and Scofield (2018) |
| **Real Estate Market Challenges** | |
| Transparency of real estate market | Cvijanović et al. (2021); van Loon and Aalbers (2017) |
| Dynamic of market cycles | Wiegelmann & Schwab (2025); Razali et al. (2019). |
| Investment cycle | Wiegelmann & Schwab (2025) |
| Diversification challenge | Baum and Hartzell (2020); Chun et al. (2004) |
| **Behavioral Bias** | |
| Home bias | Lee et al. (2023) and Gaar et al. (2020) |
| Herding | van Loon and Aalbers (2017) |

| Factors | Authors (Year) |
|---|---|
| Information asymmetry | Aren et al., (2016); Gavrilakis & Floros, (2022); Vashist et al., (2025) |
| **Organization & Structural Challenges** | |
| Mission/ Mandate | Wiegelmann & Schwab (2025) |
| Investment capabilities | Wiegelmann & Schwab (2025) |
| Lack of experience (asset manager) | Read et al. (2016) |
| Deficiency of knowledge in real estate investment | Read et al. (2016) |
| **Social and Sustainability Challenges** | |
| Investment aligns with community goals | Wiegelmann & Schwab (2025) |
| Social & cultural challenges | Lieser & Groh (2014) |
| ESG | Jalil et al. (2026); Wiegelmann & Schwab (2025) |

*Source: Author's Compilation*

## RESEARCH METHODOLOGY

This study adopted a qualitative research approach to explore the challenges influencing real estate investment decisions among Malaysian GLICs. A qualitative approach was considered appropriate because it enables an in-depth understanding of participants' experiences and perspectives within their organisational contexts, particularly in areas where empirical evidence is limited (Creswell & Poth, 2018). Data were collected through semi-structured interviews with 15 senior professionals who were purposively selected based on their direct involvement in institutional real estate investment decision-making and possessing a minimum of 10 years of professional experience. Participants were identified through GLIC organisational structures, professional networks, industry linkages, and snowball sampling and were subsequently approached via telephone and email. The participants represented six categories of Malaysian GLICs, namely private pension funds, public pension funds, armed forces pension funds, savings fund institutions, public investment institutions, and sovereign wealth funds and held positions including real estate directors, vice presidents, and investment managers, with professional experience ranging from 10 to more than 30 years. This diversity of institutions and senior management positions enabled the study to capture a broad range of perspectives on institutional real estate investment practices. A summary of the participants is presented in Table 2.

**Table 2:** List of Participants

| Position | Years of Experience | Category of Institutional Investors | Code |
|---|---|---|---|
| Real Estate Director | 14 years | Private Pension Fund | P1 |
| Investment Manager | 15 years | Private Pension Fund | P2 |
| Real Estate Director | 15 years | Private Pension Fund | P3 |
| Vice President | 15 years | Public Pension Fund | P4 |


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| Position | Years of Experience | Category of Institutional Investors | Code |
|---|---|---|---|
| Investment Manager | 15 years | Public Pension Fund | P5 |
| Vice President | 15 years | Armed Forces Pension Fund | P6 |
| Real Estate Director | > 10 years | Armed Forces Pension Fund | P7 |
| Vice President | 12 years | Saving Fund | P8 |
| Investment Manager | > 10 years | Saving Fund | P9 |
| Vice President | 31 years | Public Investment Institution | P10 |
| Investment Manager | > 25 years | Public Investment Institution | P11 |
| Real Estate Director | 16 years | Public Investment Institution | P12 |
| Investment Manager | > 15 years | Sovereign Wealth Fund | P13 |
| Investment Manager | > 30 years | Sovereign Wealth Fund | P14 |
| Investment Manager | > 30 years | Sovereign Wealth Fund | P15 |

*Source: Author's Compilation*

Semi-structured interviews were selected because they provided a consistent interview structure while allowing flexibility to probe participants' experiences and elaborate on emerging issues (Osborne & Grant-Smith, 2021). The interview protocol was developed based on the research objectives and relevant literature, and ethical approval was obtained from the University of Malaya Research Ethics Committees (UMREC) prior to data collection. To ensure confidentiality, participants and their respective organisations were anonymised throughout the study. Each interview lasted approximately 40-50 minutes and was conducted either face-to-face or online, depending on participants' availability. With participants' consent, all interviews were audio-recorded. Based on Saunders et al. (2018) the data saturation was reached between the 14$^{th}$ and 15$^{th}$ interviews, as subsequent interviews yielded no new data. The interview data were analysed using thematic analysis following the six-phase framework proposed by Braun and Clarke (2006). The analysis began with transcript familiarisation and data cleaning, followed by coding and data management in Atlas.ti. Both inductive and deductive coding were employed, allowing themes to emerge from participants' narratives while being informed by the literature. The codes were organised, reviewed, and refined into higher-order themes. The identified themes were subsequently validated by a panel of four industry experts to assess their relevance and applicability.

## ANALYSIS AND DISCUSSION.

The thematic analysis identified two overarching themes that characterise the challenges influencing real estate investment decision-making among Malaysian GLICs: internal and external challenges. These themes comprise seven interrelated categories derived from the coding process, as illustrated in Figure 1. Internal challenges arise from organisational and governance constraints, behavioural biases, and social and sustainability considerations, while external

challenges stem from political and geopolitical risks, macroeconomic conditions, real estate market conditions, and regulatory and legal requirements.

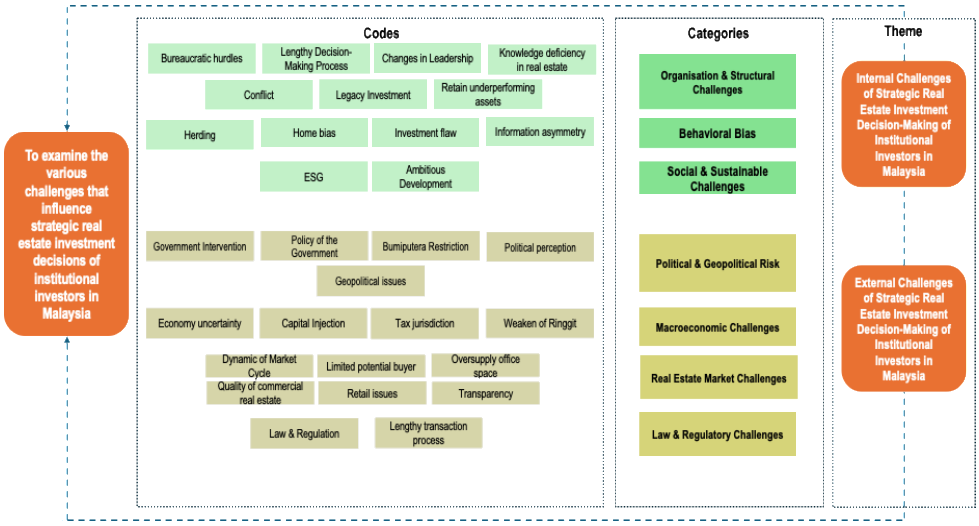



**Figure 1:** Thematic Framework of Challenges Influencing Real Estate Investment Decisions Among Malaysian GLICs
*Source: Author's 2026*

## *Internal Challenges*

### ***Organisational and Structural Challenges***

Organisational and structural challenges emerged as one of the most significant internal factors influencing real estate investment decisions among Malaysian GLICs. Participants consistently identified bureaucratic hurdles, lengthy approval processes, leadership changes, limited real estate expertise among decision-makers, internal conflicts arising from competing institutional objectives, and the persistence of legacy investments and retaining underperforming assets as major constraints on effective investment decisions. Bureaucratic hurdles were consistently cited as a challenge, with investment proposals required to undergo multiple layers of reviews and approval before receiving final endorsement. As one participant explained, *"the approval process can be lengthy, often taking up to a year"* (P8), while another noted that "*the proposal must pass through several committees, resulting in delayed feedback and slower decision-making*" (P3). These lengthy procedures reduce organisational responsiveness, making it difficult for GLICs to compete with private institutional investors that can respond quickly to market opportunities. Participants further observed that frequent changes in senior leadership,


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particularly chief executive officers and chief investment officers, disrupt strategic continuity as each new leadership team often introduce different priorities and investment directions. In addition, several participants highlighted that senior decision-makers possess strong financial expertise but limited knowledge of the real estate sector, which increases the likelihood of acquiring assets at above-market prices or overlooking attractive investment opportunities. Internal conflicts also arise from the GLIC's dual mandate of delivering commercial returns while supporting national socio-economic objectives, requiring investment decisions to balance financial performance with broader public policy considerations. Finally, participants explained that conservative governance practices, political sensitivities, and reputational concerns surrounding asset disposals often result in the retention of underperforming assets and legacy investments. These organisational and structural challenges reduce institutional responsiveness, delay investment execution, and constrain GLIC's ability to optimise portfolio performance within an increasingly competitive real estate market.

***Behavioural Biases***

Behavioural biases also emerged as another important internal challenge for GLICs. Although investment decisions are guided by formal governance frameworks, investment policies, and quantitative evaluation processes, participants acknowledged that behavioural tendencies continue to shape investment judgment. Home bias was identified as the most prominent bias, with Participants indicated a strong preference for domestic real estate investment due to policy direction, market familiarity, and information advantages. As participant P1 explained, "*sometimes, there are instructions from the MoF to invest in the local market,*" while P2 noted that *"we have the advantage of information when we invest in our home country"*. Although this preference supports national development objectives and reduces perceived investment risk, participants recognised that it may constrain international diversification and limit opportunities to optimise risk-adjusted portfolio returns. Participants also reported evidence of herding behaviour, whereby investment decisions are influenced by the strategies of leading institutional investors, such as Singapore's Government Investment Corporation (GIC) and Temasek, or by prevailing market trends, as these are perceived to reduce uncertainty and provide confidence in unfamiliar investment environments. Other participant P8 also noted that *"we sometimes follow the trends of other institutional investors. We invest in the market where other main players are, this is for liquidity"*. These findings are consistent with previous studies suggesting that institutional investors often regard peer investment activities as valuable informational signals under conditions of market uncertainty (Ahiadu et al., 2025). Furthermore,

information asymmetry was identified as a significant challenge, particularly in overseas investments where limited local knowledge and an unfamiliar regulatory environment increase investment uncertainty. One participant recalled an overseas investment in the United Kingdom that was unexpectedly affected by government land acquisition despite extensive due diligence, illustrating the limitations of available information. Participants further highlighted that investment flaws may arise from overly optimistic assumptions, premature market entry, and inadequate assessment of market fundamentals and tenant demand, especially when investment decisions are influenced by broader national development objectives rather than commercial considerations. These findings indicate that Malaysian GLICs exhibit several behavioural biases that influence investment judgement, portfolio diversification, and strategic real estate investment decisions.

***Social and Sustainable Challenges***

Social and sustainability challenges also emerged as an internal factor influencing real estate investment decisions among Malaysian GLICs. The findings indicate that institutional investors are under increasing pressure to align investment decisions with Environmental, Social, and Governance (ESG) principles while fulfilling their broader nation-building responsibilities. Participants acknowledged that ESG considerations, including green-certified buildings, energy-efficient operations, responsible governance, and sustainable developments, are becoming increasingly important in property investment decisions, as noted by P8, *"moving towards ESG, where we tend to invest in buildings that have green certification"*. However, the implementation of ESG remains uneven across institutions, with several GLICs having established sustainability frameworks while others are still in the early stages of integrating ESG into their investment strategies. Participants further highlighted that ambitious development projects, often undertaken to support national economic and regional development, may thus expose institutions to higher commercial risks when market demand and sector maturity are insufficient. These findings suggest that GLICs must balance financial performance with environmental and social responsibilities, reflecting the growing importance of sustainable investment practices in institutional real estate. This is consistent with previous studies, which argue that ESG considerations have become an integral component of institutional real estate investment due to their contribution to long-term value creation, risk management, and stakeholder expectations (Baum & Hartzell, 2020).


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### *External Challenges*

#### ***Political and Geopolitical Risk***

Political and geopolitical challenges have emerged as significant external factors influencing real estate investment decisions among Malaysian GLICs. Participants consistently emphasised that government intervention, policy uncertainty, Bumiputera ownership requirements, political expectations, and geopolitical developments shape investment strategies and portfolio allocation. Although GLICs function as independent institutional investors, several participants acknowledged that government policies and national development priorities continue to affect investment decisions. For example, one participant stated, *"We occasionally receive directives from MoF, for instance, a need to increase investment in Malaysia, particularly in ESG-related investment"* (P4). Another participant noted that frequent changes in government policies create uncertainty for long-term investment planning. Participants also identified the Bumiputera equity requirement as a significant constraint during property disposals, as it limits the pool of potential buyers and extends transaction periods, particularly for high-value commercial assets. While these policies support socio-economic objectives and protect national interest, participants recognised that they may reduce market liquidity and limit investment flexibility. This finding aligns with previous studies, which identify political stability, government policies, and regulatory intervention as important determinants of institutional real estate investment decisions (Bolomope et al., 2024; Nnamani et al., 2025).

Participants further explained that political perceptions and geopolitical developments influence both domestic and international investment strategies. Several participants observed that GLICs are sometimes expected to support government objectives through strategically important development projects, which can create tension between commercial objectives and broader public policy goals. Additionally, geopolitical uncertainty resulting from changing trade relations, foreign regulations, and global political instability was perceived to increase the risks associated with overseas real estate investment. As a result, participants indicate a preference for politically stable jurisdictions with predictable regulatory environments. Overall, the findings suggest that political and geopolitical challenges affect GLICs not only through formal government policies and regulatory requirements but also by shaping risk appetite, investment timing, and strategic allocation decisions, consistent with the observations of Baum and Hartzell (2020), and Brueggeman and Fisher (2021).

#### ***Macroeconomic Challenges***

Macroeconomic challenges represent a significant external factor influencing real estate investment decisions among Malaysian GLICs. Participants consistently emphasised that economic uncertainty, capital injection obligations, taxation, and

currency volatility shape investment strategies and portfolio performance. Economic uncertainty, characterised by fluctuating economic growth, inflation, interest rates, and declining investor confidence, was perceived to reduce occupancy rates, delay investment decisions, and encourage more conservative strategies focused on stable, income-generating assets. As one participant reflected, *"from a market perspective, the current investment climate is not very favourable due to economic uncertainty and reduced investors' confidence"* (P8). Participants further noted that GLICs are sometimes required to support national economic objectives by making capital injections during periods of financial distress, reflecting their dual mandate to achieve commercial returns and contribute to economic stability. As stated, *"In other cases, such as saving other companies, institutions must come in to buy over their building during a financial crisis".* Additionally, several participants highlighted the increasing impact of tax jurisdiction and newly introduced fiscal policies, such as the expansion of the service tax and property-related levies. One participant observed, *"The recently introduced service tax directly impacts retail services"* (P11). These tax adjustments affect operating margins and investment returns, particularly in the retail and commercial sectors, which are already under pressure from weak demand. Furthermore, currency volatility and the weakening of the Malaysian Ringgit present additional macroeconomic risk for institutional investors with foreign real estate exposure. As explained by the participant, *"The challenge is when the Ringgit is weakened, this is when Bank Negara Malaysia stepped in to control the Ringgit, any currency exchanged had to get their approval"* (P6). Such intervention measures, while stabilising the economy, constrain transaction flexibility and delay capital movement. These findings are consistent with Brueggeman and Fisher (2021) and Baum and Hartzell (2020), who note that exchange rate volatility is among the most critical risk factors for global institutional investors, particularly those from emerging markets.

***Real Estate Market Challenges***

Challenges within the real estate market emerged as a significant external factor. Participants identified property market cycles, limited market liquidity, oversupply of office space, the shortage of investment-grade assets, retail market weakness, and market transparency as key issues affecting portfolio performance and investment strategies. Liquidity constraints, particularly those resulting from Bumiputera ownership requirements, were noted to reduce the pool of potential buyers and prolong asset disposal, thereby limiting portfolio optimisation. Persistent oversupply of office space in major urban centres has increased vacancy rates and compressed rental growth, reducing the attractiveness of office investments. These findings align with previous studies indicating that market cycles, liquidity constraints, and structural imbalances are among the primary


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challenges facing institutional real estate investors in emerging markets (Huangfu et al., 2024). Participants further emphasised, *"most of our investment is in the global market because there is inadequate availability of good quality commercial assets in the local market"* (P2). The limited availability of high-quality commercial assets domestically has encouraged GLICs to expand investments into overseas markets that offer higher-quality tenants, better building standards, and more stable income streams. Additionally, the retail sector was perceived as increasingly challenging due to changing consumer behaviour, inflation pressures, and rising operating costs, prompting several institutions to diversify into sectors such as logistics, healthcare, and data centres. Market transparency was also identified as a critical consideration. As participants observed, "*we refrain from investing in countries with lower transparency"* (P 2). For international investments, reliable market information and transparent regulatory systems were seen to improve investment confidence and reduce due diligence risks. Overall, the findings suggest that real estate market conditions significantly influence asset selection, portfolio diversification, and long-term investment performance. This supports previous research demonstrating that institutional investors are more likely to allocate capital to markets characterised by greater transparency, liquidity, and the availability of investment-grade assets (Cvijanović et al., 2021; Fabozzi & Fabozzi, 2020).

***Regulatory and Legal Challenges***

Regulatory and legal factors are also identified as challenges in GLICs' real estate investment decisions. Participants consistently reported that complex legal frameworks, lengthy approval procedures, and multi-layered governance structures reduce investment efficiency and responsiveness. Although these regulatory mechanisms are designed to ensure transparency, accountability, and prudent investment decisions, they often prolong transaction processes and increase administrative costs. Participants noted that property acquisitions and disposals involving GLICs commonly require multiple approvals from internal committees, government agencies, and ministerial authorities, and that transactions often take between six months and one year to complete. As the participant explained, *"the transaction will take around six months to one year in the local market."* (P11). Such procedural delays reduce GLICs' ability to compete with private investors in securing time-sensitive investment opportunities. These findings are consistent with previous studies that identify regulatory complexity and legal requirements as significant constraints on institutional real estate investment decisions (Ahiadu et al., 2024; Bolomope et al., 2020).

The thematic analysis demonstrates that the challenges affecting real estate investment decisions are interrelated rather than independent. Internal organisational capabilities and governance structures determine how investment opportunities are assessed and executed, whereas external factors, such as political, economic, market, and regulatory conditions, shape the opportunities and constraints faced by institutional investors. These challenges require Malaysian GLICs to balance commercial investment objectives with statutory responsibilities and long-term portfolio resilience, illustrating the complexity of institutional real estate investment in an emerging market.

## CONCLUSION

This study examines the challenges affecting real estate investment decisions by Malaysian Government-Linked Investment Companies (GLICs) through interviews with experienced fund managers and professionals. The findings show that these decisions are influenced by both internal and external challenges. Internal challenges include organisational issues, behavioural biases, and considerations related to social responsibility and sustainability. External challenges encompass political risks, macroeconomic conditions, real estate market issues, and regulatory constraints. This indicates that institutional investment decisions go beyond traditional financial analysis and are shaped by governance, policy environments, market dynamics, and broader socio-economic goals.

The study adds to the literature on institutional real estate investment by providing insights from an emerging market where investors must balance commercial and public policy mandates. Unlike previous research that has looked at these challenges separately, this study offers a holistic view of how various factors interact in the decision-making process of Malaysian GLICs. From a practical perspective, the findings highlight the need for the GLIC board to strengthen corporate governance by enhancing oversight and organisational responsiveness in real estate investment decision-making. Fund managers should strengthen investment assessment, real estate expertise, and ESG integration, while regulators and policymakers should reform regulatory and approval processes to facilitate more effective real estate investment decisions. Addressing these challenges would enable GLICs to respond effectively to changing market conditions.

It is important to note that this study is limited to Malaysian GLICs and focuses on direct real estate investment, meaning the findings may not apply to other types of institutional investors or contexts. Future research could explore different institutional investors, such as insurance companies and state-owned enterprises (SOEs), to compare their real estate decision-making processes.


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# INTEGRATING FLEXIBLE WORK ARRANGEMENTS FEATURES INTO BANKING OFFICE ENVIRONMENTS: EVIDENCE FROM KUALA LUMPUR CITY CENTRE

**Shirley Jin Lin Chua[1], Kasturi Anpalanan[2], Azlan Shah Ali[3], Nik Elyna Myeda[4]**

[1,2,3,4]*Department of Building Surveying, Faculty of Built Environment,*
UNIVERSITI MALAYA
[1,3,4]*Centre for Building, Construction and Tropical Architecture (BuCTA), Faculty of Built Environment,*
UNIVERSITI MALAYA

## Abstract

The rapid adoption of Flexible Work Arrangements (FWAs) has transformed workplace planning and office design, requiring organisations to develop work environments that better support evolving employee needs. Although the banking sector has increasingly embraced hybrid and flexible working models, limited research has examined the integration of FWAs features within urban banking offices. This study investigates the implementation of FWAs features in commercial banking offices in Kuala Lumpur, Malaysia, to identify workplace characteristics associated with employee satisfaction and inform future workplace planning strategies. A quantitative approach was adopted using a structured questionnaire survey administered to 250 employees working in commercial bank headquarters located in Kuala Lumpur City Centre. Descriptive statistics were used to evaluate employees' perceived satisfaction and expectations, followed by gap analysis to identify discrepancies between current workplace provision and employee expectations. Pearson correlation analysis was subsequently conducted to examine the relationships between FWAs features and employee satisfaction, followed by multiple linear regression analysis to identify the unique predictive contribution of individual FWAs features. The findings indicate that although FWAs features are moderately available, employees consistently reported higher expectations than their current workplace experiences. Substantial expectation–experience gaps were identified across all six FWAs features, particularly in smart workplace technologies, wellness spaces, collaboration zones, and privacy and focus areas. Furthermore, all FWAs features demonstrated significant positive relationships with employee satisfaction, while multiple regression analysis showed that Smart Tools and

[1] Corresponding author. Email: shirleychua88@um.edu.my

Technology Support, Flexible Workstations, Privacy and Focus Areas, and Remote Work Support were significant positive predictors of employee satisfaction. This study contributes to workplace planning and office design literature by providing empirical evidence on the FWAs features associated with and significantly predicting employee satisfaction in the Malaysian banking sector. The findings offer practical guidance for office designers, facilities managers, HR departments and banking organisations in developing more flexible, employee-centred, and hybrid work supportive office environments through closer alignment between physical workplace design and FWA policies.

***Keywords***: Flexible Work Arrangement, workspace arrangements, employee satisfaction, banking, features

## INTRODUCTION

Flexible Work Arrangements (FWAs) have become an integral component of contemporary workplace strategies, particularly following the COVID-19 pandemic, which accelerated the transformation of traditional office practices (Chua et al., 2022). FWAs provide employees with greater autonomy over when and where work is performed through practices such as hybrid working, flexitime, teleworking, compressed workweeks, and job sharing (Allen et al., 2013). Beyond offering flexibility, FWAs are increasingly recognised as a strategic organisational approach that enhances employee satisfaction and productivity, while strengthening talent attraction and retention (Hasim et al., 2024). In Malaysia, this shift is further reinforced through amendments to the Employment Act 1955, which grant employees the right to request flexible working arrangements, reflecting the government's commitment to fostering more adaptive and resilient workplaces (Othman et al., 2019). Consequently, FWAs have evolved from temporary workplace responses into a long-term organisational strategy.

Despite the growing adoption of Flexible Work Arrangements (FWAs), their successful implementation extends beyond organisational policies and requires workplace environments that effectively support flexible working practices. Contemporary workplace research highlights that the physical office environment plays a critical role in shaping employee wellbeing, collaboration, productivity, and workplace experiences, particularly within hybrid working contexts (Kazlauskaitė et al., 2023). The effectiveness of FWAs therefore depends not only on employees having flexibility over when and where work is performed but also on the availability of workplace features that support diverse work activities, including collaboration spaces, quiet zones, digital connectivity, and areas for focused work (Wohlers & Hertel, 2017). Furthermore, although FWAs have been consistently associated with improved job satisfaction and

organisational commitment, these benefits are significantly reduced when office environments fail to provide appropriate spatial support and activity-based workplace settings (Chen & Fulmer, 2018). Recent evidence further suggests that well-designed activity-based offices can enhance collaboration and employee wellbeing, although careful workplace planning is required to balance interaction, privacy, and autonomy (Lauterbach & Borge, 2026). Inadequate workplace provisions, such as poorly designed hot-desking systems and insufficient supporting facilities, may reduce employee satisfaction and negatively affect work performance (Tulenheimo-Eklund et al., 2025). Consequently, integrating flexible workspace features—including activity-based workspaces, collaborative zones, quiet spaces, and hybrid working facilities—into office design has become increasingly important to maximise the effectiveness of FWAs (Davidescu et al., 2020).

The integration of FWAs supportive workplace features is particularly important in the banking sector, where operational efficiency, information security, regulatory compliance, and customer service must be balanced with evolving employee expectations. As digital transformation and hybrid work continue to reshape banking operations, financial institutions are increasingly required to redesign workplace environments that support both organisational performance and employee collaboration while maintaining high standards of security and service delivery (Lóska & Uotila, 2023). Nevertheless, although many banks have adopted flexible working practices, the physical design of office environments often continues to reflect conventional workplace layouts that inadequately support hybrid and activity-based work. Contemporary workplace research further highlights a growing shift towards employee-centred and activity-based workplace planning, emphasising the importance of providing diverse work settings that facilitate collaboration, focused work, wellbeing, and flexibility (Kazlauskaitė et al., 2023). Consequently, understanding employees' perceptions of existing FWAs supportive workplace features is essential for developing effective workplace strategies that align organisational objectives with evolving workforce expectations.

While previous studies have extensively examined the organisational benefits of Flexible Work Arrangements (FWAs), including enhanced employee commitment, retention, and performance (Hasim et al., 2024), comparatively little research has examined whether the physical workplace features intended to support FWAs adequately meet employees' expectations, particularly within the banking sector. Recent workplace studies suggest that the effectiveness of hybrid and activity-based work environments depends largely on employees' perceptions of how well workplace features support different work activities, collaboration, concentration, and overall productivity (Bergefurt et al., 2024). Moreover, empirical evidence from the banking sector indicates that employee acceptance


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of activity-based workplaces is closely related to the extent to which workplace design aligns with employees' work requirements and expectations (Jasińska-Słowik et al., 2023). These findings highlight a significant research gap regarding the alignment between FWAs supportive workplace features and employee expectations, particularly in highly regulated office environments such as banking.

Therefore, this study investigates the integration of Flexible Work Arrangement (FWA) features within banking offices in Kuala Lumpur, Malaysia. Specifically, the study aims to identify the key FWAs features incorporated into contemporary banking workplaces, evaluate employees' satisfaction by examining the gap between their expectations and perceived workplace experiences, and propose strategies to enhance the implementation of FWAs supportive workplace features. By providing empirical evidence from employees' perspectives, this research contributes to workplace planning and office design literature by offering practical recommendations for creating adaptive, employee-centred office environments that better support flexible working practices, improve workplace satisfaction, and enhance organisational performance within the banking sector.

## LITERATURE REVIEW

Flexible Work Arrangements (FWAs) refer to organisational practices that provide employees with greater flexibility regarding when, where, and how work is performed while maintaining organisational effectiveness (Shinde, 2024). FWAs have evolved from an employee benefit into a strategic organisational approach that enhances workforce flexibility, improves job satisfaction and work–life balance, and supports talent attraction and retention (Awang & Nadzri, 2023). Understanding the concept and dimensions of FWAs is therefore essential for designing workplace environments that effectively support contemporary work practices.

### A. FWAs Features

The successful implementation of FWAs depends not only on organisational policies but also on workplace environments that effectively support flexible work practices. As organisations increasingly adopt hybrid and flexible working models, office design has evolved from traditional fixed workspaces towards employee-centred environments that accommodate diverse work activities and preferences. Contemporary workplace planning emphasises the provision of adaptable spaces that support collaboration, individual concentration, digital connectivity, and employee well-being, enabling employees to select work settings that best suit their tasks (Kazlauskaitė et al., 2023; Schuller et al., 2025). This shift is particularly important in the banking sector, where workplace design

must balance operational efficiency, regulatory compliance, and evolving employee expectations (Tulenheimo-Eklund et al., 2025). Accordingly, several workplace features have been identified as essential for supporting FWAs, including remote work support, flexible workstations, collaboration zones, privacy and focus areas, wellness spaces, and smart technologies.

***a. Remote Work Support***

***Remote work areas to support private work activities***

Dedicated remote work areas provide employees with private and distraction-free environments for individual tasks and confidential activities. Such spaces support effective hybrid working by improving concentration and productivity. These facilities are particularly important in banking organisations where employees frequently handle sensitive information and require secure work settings (Chua et al., 2022).

***Phone booths or enclosed meeting pods to support short-duration virtual meetings and online communication***

Phone booths and enclosed meeting pods provide private spaces for virtual meetings and online discussions within shared workplaces. These facilities minimise noise disturbance and interruptions while improving communication effectiveness. They are especially valuable in hybrid workplaces where employees frequently participate in digital meetings requiring privacy and confidentiality (Babapour Chafi & Rolfö, 2019).

***b. Flexible Workstations***

***Hot-desking areas are available with ergonomic and comfortable setups***

Hot-desking areas allow employees to select workspaces based on their daily activities rather than assigned desks. Providing ergonomic furniture and comfortable workstation arrangements is essential to maintain employee satisfaction, physical comfort, and productivity in flexible working environments (Schuller et al., 2025).

***Shared workplace equipped with reliable booking or reservation system***

Workspace booking systems enable employees to reserve shared workstations efficiently while improving workplace utilisation. Such systems reduce uncertainty associated with hot-desking arrangements and support smoother implementation of flexible working practices through better workplace management and resource allocation (Hoendervanger et al., 2016).


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***c. Collaboration Zones***

***Designated collaboration spaces to support group interactions and teamwork***

Collaboration spaces facilitate teamwork, knowledge exchange, and face-to-face interaction through flexible layouts and supportive technologies. These areas are increasingly important in hybrid workplaces as they encourage meaningful interaction, collective problem-solving, and organisational connectivity among employees (Schuller et al., 2025).

***d. Privacy and Focus Areas***

***Individual work areas to support focused and independent work activities***

Quiet and individual work areas provide employees with suitable environments for concentration-intensive tasks and confidential activities. These spaces help reduce workplace distractions and improve productivity, particularly in open-plan offices where noise and interruptions may negatively affect employee performance (Seddigh et al., 2015).

***e. Wellness Spaces***

***Dedicated wellness spaces to support employee relaxation and recovery during working hours***

Wellness spaces provide employees with opportunities for relaxation, recovery, and stress reduction during working hours. Facilities such as relaxation areas and breakout spaces contribute to improved employee well-being, satisfaction, and engagement by supporting healthier workplace experiences (Kazlauskaitė et al., 2023).

***Wellness areas are functional, comfortable, and conveniently located***

The effectiveness of wellness facilities depends on their functionality, comfortability and accessibility. Conveniently located and well-designed wellness spaces encourage employee utilisation and contribute to workplace environments that support physical and psychological well-being (Appel-Meulenbroek & Danivska, 2021).

***f. Smart Tools and Technology Support***

***Smart workplace tools and digital solutions to support flexible working practices***

Smart workplace tools, including digital communication platforms and workplace management systems, enable employees to work effectively across different locations. These technologies enhance flexibility, communication, and coordination while supporting the implementation of hybrid working practices (Chua et al., 2022).

***Technology-enabled workplace facilities support hybrid working and virtual collaboration***

Technology-enabled facilities, such as video conferencing systems and digital collaboration platforms, support seamless communication between office-based and remote employees. Integrating workplace technologies enhances collaboration, productivity, and adaptability in hybrid work environments (Appel-Meulenbroek & Danivska, 2021).

### *B. Perceived Satisfaction with FWAs Features*

Employee satisfaction with FWAs features plays an important role in shaping workplace experiences, particularly in highly regulated sectors such as banking. In addition to policy-based flexibility, supportive workplace features further enhance employees' sense of empowerment and workplace value. Such environments can improve employee retention, reduce turnover intentions, and alleviate workplace stress, particularly in competitive labour markets (Berber et al., 2022). Therefore, satisfaction with FWAs features represents not only a functional workplace benefit but also a psychological factor influencing employee engagement, organisational loyalty, and well-being (Davidescu et al., 2020).

### *C. Expectations Towards Future FWAs Enhancements*

The continued evolution of work practices has increased expectations for workplaces that support FWAs through adaptive, human-centred, and digitally integrated environments. In the banking sector, where employees operate within high-pressure and compliance-driven conditions, future workplaces are expected to provide not only flexibility in work location and scheduling but also greater autonomy, comfort, and technological support (Khalequzzaman et al., 2025). Recent studies highlight the importance of diverse workplace configurations that allow employees to transition between collaborative areas and focused workspaces according to task requirements and personal preferences (Pan et al., 2023). Such flexibility enables employees to better manage cognitive demands and maintain performance in roles involving prolonged digital work, complex decision-making, and confidentiality requirements. Future banking workplaces are therefore expected to integrate advanced digital solutions, including smart scheduling systems, collaborative technologies, and intelligent workplace management platforms. Emerging technologies can further optimise workplace utilisation, environmental conditions, and employee comfort (Zhang et al., 2021). Additionally, incorporating ergonomic and psychological considerations into workplace design can promote inclusivity and employee well-being across diverse workforce groups (Simões et al., 2022). Consequently, future FWAs enhancements should move beyond flexible policies towards intelligent


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workplace ecosystems that dynamically support employee productivity, engagement, and long-term retention.

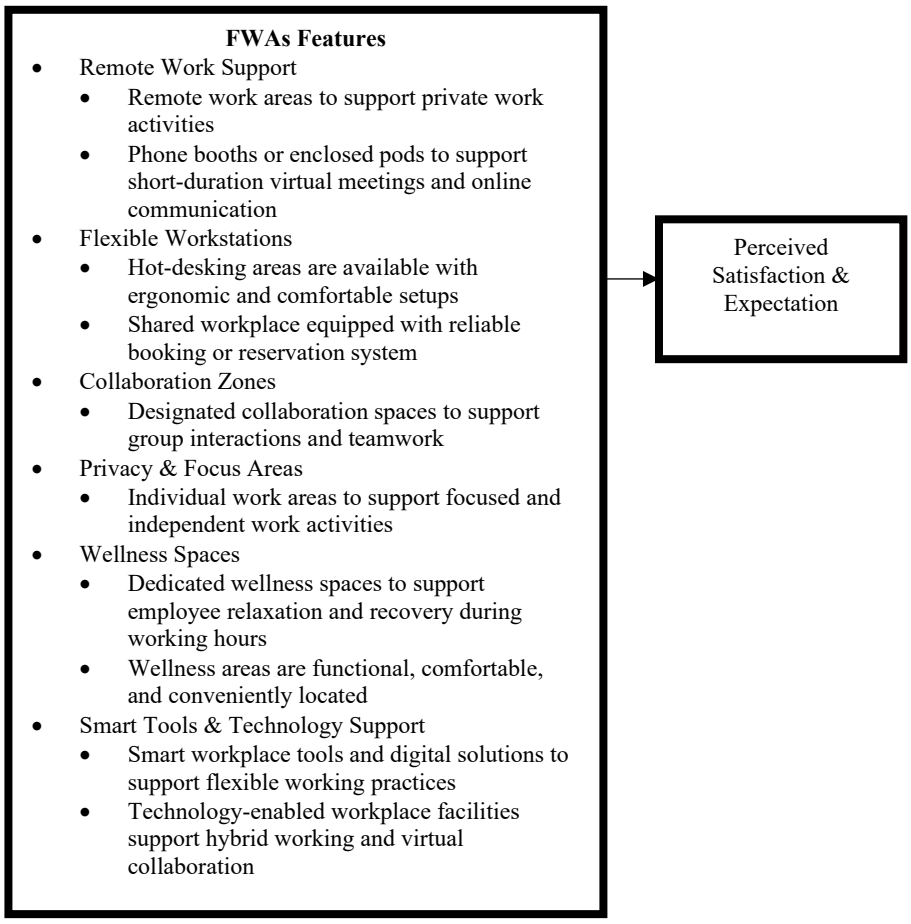



**Figure 1:** Conceptual Framework

## RESEARCH METHODOLOGY

This study adopted a quantitative approach to analyse the features of FWAs integrated in Kuala Lumpur bank physical offices, with a focus on the employees' perception experiences as well as their expectations. Quantitative approaches are appropriate when numerical data are required to statistically examine patterns, relationships, and variations among variables (Creswell & Plano Clark, 2023; Robinson, 2007). In this study, the quantitative design enables systematic assessment of how workplace features influence employees' experiences within

banking environments. This study focused on bank employees working in commercial bank headquarters located in Kuala Lumpur City Centre, where workplace environments increasingly incorporate FWA supportive features. The target population consists of employees from middle management, back-end support, and frontline operations departments who work in FWAs supportive settings like quiet pods, hot-desking areas, collaborative hubs, and wellness-integrated workspaces. According to the Association of Banks in Malaysia (2025), there are 24 commercial banks with their headquarters situated in Kuala Lumpur city centre, and there are 271 commercial bank branches operating throughout the Federal Territory of Kuala Lumpur as of 2025. Due to the absence of publicly available employee headcount information among commercial bank headquarters in Kuala Lumpur City Centre, the sample size was determined based on the research objectives, statistical requirements, and accessibility of respondents. Sekaran and Bougie (2009) emphasised that sample size determination should consider the purpose of the study, research design, and practical feasibility of obtaining responses. As a complete sampling frame of employees across the commercial bank headquarters was not publicly available, and access to internal employee databases was restricted by confidentiality requirements within banking organisations (Saunders et al., 2023), individual random selection of employees was not feasible. Therefore, respondents were recruited through the researcher's professional banking network and screened according to predefined inclusion criteria. The inclusion criteria required respondents to be employees of commercial banks headquartered in Kuala Lumpur City Centre and to work in office environments incorporating FWAs related workplace features. Primary data were collected through a structured questionnaire, which enables the systematic collection of standardised quantitative information from the sample for statistical evaluation of employees' expectation, perceptions and relationships among variables (Saunders et al., 2023). The questionnaire was distributed digitally through Google Forms using the researcher's professional banking network. Contacts within eligible banks were requested to circulate the survey to employees meeting the inclusion criteria. A stratified non-probability sampling approach was adopted to obtain representation across the relevant bank employee groups, including middle management, back-end support, and frontline operations departments. Because complete employee lists were not accessible, individual random selection of respondents could not be undertaken. The research was conducted with strict confidentiality, and participation was completely voluntary. The collected data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive analysis was conducted using frequencies, percentages, mean scores, and standard deviations to summarise respondent characteristics and evaluate the perceived satisfaction, and expectations towards FWAs features. Each item was


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measured using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), with higher mean scores indicating stronger agreement or satisfaction. Gap analysis was subsequently performed by comparing the mean scores of employees' perceived satisfaction and expectations for each FWAs feature to identify areas where current workplace provision falls short of employee expectations. Larger gap values indicate greater discrepancies and highlight priority areas for workplace improvement. Pearson correlation analysis was applied to determine the strength and direction of relationships between FWAs features and employee perceived satisfaction.

## ANALYSIS AND DISCUSSION

A total of 285 questionnaires were distributed to employees working in commercial banks within Kuala Lumpur City Centre. Of these, 250 completed questionnaires were returned and deemed valid for subsequent statistical analysis.

The internal consistency of the six (6) FWAs feature constructs was assessed using Cronbach's alpha coefficients. The Cronbach's alpha values ranged from 0.832 to 0.913 across the six constructs, exceeding the recommended threshold of 0.60 (Sekaran, 2003). These findings indicate acceptable to good internal consistency across all FWAs feature constructs, supporting their use in subsequent statistical analyses.

**Table 1:** Reliability of FWAs Feature Constructs

| No | Variable | Number of Items | Cronbach's α |
|---|---|---|---|
| **1** | Remote Work Support | 2 | 0.889 |
| **2** | Flexible Workstations | 2 | 0.857 |
| **3** | Collaboration Zones | 1 | 0.913 |
| **4** | Privacy & Focus Areas | 1 | 0.832 |
| **5** | Wellness Spaces | 2 | 0.893 |
| **6** | Smart Tools & Technology Support | 2 | 0.893 |

The respondents were predominantly female (61.6%), with most aged 30–39 years (48.0%), followed by 20–29 years (24.8%). Managers or assistant managers constituted the largest occupational group (30.4%), while clerical/administrative support (23.6%) and non-managerial officers/executives (23.2%) represented comparable proportions. The sample was almost equally distributed between local (50.4%) and foreign banks (49.6%). Most respondents had worked in their current organisation for more than six years (35.6%) or four to six years (32.8%), indicating substantial organisational experience. Additionally, 68.0% of respondents reported working in bank-owned office buildings, while 32.0% were employed in leased office premises. The

demographic profile indicates that the sample comprised employees from diverse organisational roles and banking institutions, providing a representative basis for subsequent analyses (Table 2).

**Table 2:** Respondent Profile

| Demographic Information | Frequency (N = 250) | Percentage (%) |
|---|---|---|
| 1. Gender | | |
| Male | 86 | 34.4 |
| Female | 154 | 61.6 |
| Prefer not to say | 10 | 4.0 |
| 2. Age Group | | |
| 20 - 29 | 62 | 24.8 |
| 30 - 39 | 120 | 48.0 |
| 40 - 49 | 52 | 20.8 |
| 50 and above | 16 | 6.4 |
| 3. Job Role | | |
| Teller / Counter Staff | 23 | 9.2 |
| Clerical / Administrative Support | 59 | 23.6 |
| Officer / Executive (Non-Managerial) | 58 | 23.2 |
| Manager / Assistant Manager | 76 | 30.4 |
| Department Head / Senior Leadership | 22 | 8.8 |
| Other | 12 | 4.8 |
| 4. Type of Bank | | |
| Local | 126 | 50.4 |
| Foreign | 124 | 49.6 |
| 5. Years in Current Organization | | |
| Less than 1 year | 24 | 9.6 |
| 1–3 years | 55 | 22.0 |
| 4–6 years | 82 | 32.8 |
| More than 6 years | 89 | 35.6 |
| 6. Office Ownership | | |
| Owns | 170 | 68.0 |
| Leases | 80 | 32.0 |

### *Gap Analysis of FWAs Office Design Features*

Table 3 compares employees' perceived satisfaction with the current provision of FWAs features against their expectations. Overall, respondents reported only moderate satisfaction with the existing workplace provision (mean = 3.24–3.36), whereas expectations for all FWAs features were consistently high (mean = 4.04–4.08), indicating that existing office environments have yet to fully support employees' evolving workplace needs.


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**Table 3:** Gap Analysis of Employees' Perceived Satisfaction and Expectations towards FWAs Features

| FWAs Features | Perceived Satisfaction Mean | Expectation Mean | Gap (E−S) | Rank |
|---|---|---|---|---|
| Remote Work Support | | | | |
| Remote work areas to support private work activities | 3.37 | 4.05 | 0.68 | 7 |
| Phone booths or enclosed pods to support short-duration virtual meetings and online communication | 3.35 | 4.02 | 0.67 | 8 |
| Overall Mean | **3.36** | **4.04** | **0.68** | 6 |
| Flexible Workstations | | | | |
| Hot-desking areas are available with ergonomic and comfortable setups | 3.32 | 4.00 | 0.68 | 7 |
| Shared workplace equipped with reliable booking or reservation system | 3.26 | 4.08 | 0.82 | 4 |
| Overall Mean | **3.29** | **4.04** | **0.75** | **4** |
| Collaboration Zones | | | | |
| Designated collaboration spaces to support group interactions and teamwork | 3.25 | 4.09 | 0.84 | 2 |
| Overall Mean | **3.25** | **4.09** | **0.84** | **1** |
| Privacy & Focus Areas | | | | |
| Individual work areas to support focused and independent work activities | 3.22 | 4.05 | 0.83 | 3 |
| Overall Mean | **3.22** | **4.05** | **0.83** | **2** |
| Wellness Spaces | | | | |
| Dedicated wellness spaces to support employee relaxation and recovery during working hours | 3.28 | 4.04 | 0.76 | 6 |
| Wellness areas are functional, comfortable, and conveniently located | 3.26 | 4.11 | 0.85 | 1 |
| Overall Mean | **3.27** | **4.07** | **0.80** | **3** |
| Smart Tools & Technology Support | | | | |
| Smart workplace tools and digital solutions to support flexible working practices | 3.38 | 4.04 | 0.66 | 9 |
| Technology-enabled workplace facilities support hybrid working and virtual collaboration | 3.34 | 4.13 | 0.79 | 5 |
| Overall Mean | **3.36** | **4.08** | **0.72** | 5 |

At the construct level, Collaboration Zones recorded the largest expectation–experience gap (Gap = 0.84), followed by Privacy & Focus Areas (Gap = 0.83), Wellness Spaces (Gap = 0.80), Flexible Workstations (Gap = 0.75), Smart Tools & Technology Support (Gap = 0.72), and Remote Work Support (Gap = 0.68). These findings indicate that collaborative work environments, dedicated focus spaces, and employee wellbeing facilities warrant greater attention in future workplace planning to better support flexible working practices in banking offices. The substantial gaps observed for these features indicate that existing office environments have not fully adapted to the evolving spatial requirements of hybrid work. Previous studies have similarly reported that flexible workplaces should provide a balanced combination of collaborative areas and quiet spaces to accommodate both teamwork and individual concentration, thereby enhancing employee productivity and workplace satisfaction (Babapour Chafi & Rolfö, 2019; Seddigh et al., 2015). Furthermore, workplace environments that integrate wellbeing facilities and employee-centred design have been shown to improve comfort, engagement, and overall user experience while supporting organisational performance (Appel-Meulenbroek & Danivska, 2021). Given the collaborative and knowledge-intensive nature of banking operations, these findings suggest that future office planning should prioritise multifunctional workspaces that simultaneously support interaction, focused work, and employee wellbeing to better align workplace provision with employees' expectations.

At the item level, the largest gaps were associated with the availability of wellness spaces that are functional, comfortable, and conveniently located (Gap = 0.85) and designated collaboration spaces (Gap = 0.84), followed by individual work areas to support focused and independent work activities (Gap = 0.83) and reliable workstation booking systems (Gap = 0.82). Conversely, relatively smaller gaps were observed for the provision of smart workplace tools (Gap = 0.66) and phone booths for virtual meetings (Gap = 0.67), suggesting that these features are comparatively better aligned with employees' expectations.

Overall, the gap analysis indicates that while banking organisations have begun incorporating FWAs supportive workplace features, substantial improvements are required to create office environments that effectively support collaboration, focused work, employee wellbeing, and flexible workspace management.

### *Relationship between FWAs Features and Employee Perceived Satisfaction*

Pearson correlation analysis was conducted to examine the relationship between the six FWAs features and employee perceived satisfaction. As presented in Table 4, all six FWAs main features were positively and significantly correlated


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with employee perceived satisfaction ($p < 0.05$), thereby supporting $H_{11}$ and lead to rejection of $H_{01}$.

**$H_{01}$:** There is no significant relationship between FWAs features and employee perceived satisfaction.
**$H_{11}$:** There is a significant relationship between FWAs features and employee perceived satisfaction.

**Table 4:** Pearson Correlation between FWAs Features and Employee Perceived Satisfaction (n=250)

| FWAs Features | Satisfaction with FWAs Features | |
|---|---|---|
| | Correlation Coefficient, r | Significance Value, p |
| Remote Work Support | 0.792* | 0.000 |
| Flexible Workstations | 0.818* | 0.000 |
| Collaboration Zones | 0.781* | 0.000 |
| Privacy & Focus Areas | 0.788* | 0.000 |
| Wellness Spaces | 0.786* | 0.000 |
| Smart Tools & Technology Support | 0.800* | 0.000 |

*Correlation is significant at the 0.05 level (2-tailed).

Among the six FWAs features, Flexible Workstations demonstrated the strongest positive relationship with employee perceived satisfaction (r = 0.818), followed by Smart Tools and Technology Support (r = 0.800), Remote Work Support (r = 0.792), Privacy and Focus Areas (r = 0.788), Wellness Spaces (r = 0.786), and Collaboration Zones (r = 0.781). The correlation coefficients indicate strong positive associations, suggesting that improvements in the provision of FWAs workplace features are associated with higher levels of employee satisfaction.

The findings highlight the importance of workplace flexibility in shaping employees' experiences within contemporary banking offices. In particular, the strong relationship between flexible workstations and employee perceived satisfaction suggests that adaptable work settings, supported by ergonomic furniture and efficient workspace reservation systems, play a critical role in accommodating diverse work activities. Similarly, the positive association between smart workplace technologies and employee perceived satisfaction reflects the increasing reliance on digital infrastructure to facilitate hybrid working, virtual collaboration, and seamless workplace interactions. These findings are consistent with previous studies, which emphasise that flexible workplaces should provide an appropriate balance between collaborative environments, individual focus spaces, and technology-enabled work settings to

enhance employee satisfaction and workplace performance (Berber et al., 2022; Seddigh et al., 2015).

Overall, the results demonstrate that the successful integration of FWAs features contributes positively to employees' workplace experiences. The consistently strong correlations across all six dimensions indicate that banking organisations should adopt a holistic workplace strategy that integrates flexible workstations, collaborative environments, privacy and focus areas, wellness facilities, remote work support, and smart workplace technologies to better meet employees' evolving expectations and support flexible working practices.

***Multiple Linear Regression: FWAs Features Predicting Employee Satisfaction***

Multiple linear regression analysis was conducted to further examine the extent to which the individual FWAs feature predict employee satisfaction. Six spatial features were entered into the regression model: remote work support, flexible workstations, collaboration zones, privacy and focus areas, wellness spaces, and smart tools and technology support. The results are presented in Table 5.

**Table 5:** Multiple Linear Regression Analysis of Individual FWAs Features Predicting Employee Satisfaction

| FWAs features | B | SE | β | *t* | *p* |
|---|---|---|---|---|---|
| **Constant** | 0.343 | 0.116 | — | — | — |
| **Remote Work Support** | 0.168 | 0.071 | 0.172 | 2.383 | 0.018* |
| **Flexible Workstations** | 0.205 | 0.078 | 0.222 | 2.644 | 0.009* |
| **Collaboration Zones** | 0.080 | 0.064 | 0.092 | 1.243 | 0.215 |
| **Privacy and Focus Areas** | 0.181 | 0.071 | 0.193 | 2.558 | 0.011* |
| **Wellness Spaces** | 0.014 | 0.082 | 0.015 | 0.173 | 0.863 |
| **Smart Tools and Technology Support** | 0.202 | 0.061 | 0.232 | 3.332 | 0.001* |
| **$R^2$** | 0.739 | | | | |
| **F** | 114.706 | | | | |
| **Significant** | 0.000 | | | | |

Significance level: 0.05 (2-tailed)
Dependent Variable: Employee Satisfaction

The regression model was statistically significant, $F(6, 243) = 114.706$, $p = 0.000 < 0.050$, and explained 73.9% of the variance in employee satisfaction ($R^2 = 0.739$). Examination of the individual predictors showed that four FWAs features significantly and positively predicted employee satisfaction. Remote Work Support was a significant predictor ($B = 0.168$, $\beta = 0.172$, $t = 2.383$, $p = 0.018$), as was Flexible Workstations ($B = 0.205$, $\beta = 0.222$, $t = 2.644$, $p = 0.009$). Privacy and Focus Areas also significantly predicted employee satisfaction ($B = 0.181$, $\beta = 0.193$, $t = 2.558$, $p = 0.011$), while Smart Tools and Technology Support showed a significant positive relationship ($B = 0.202$, $\beta = 0.232$, $t = 3.332$, $p = 0.001$).


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In contrast, Collaboration Zones (B = 0.080, β = 0.092, t = 1.243, p = 0.215) and Wellness Spaces (B = 0.014, β = 0.015, t = 0.173, p = 0.863) were not significant predictors of employee satisfaction. Based on the standardized coefficients, Smart Tools and Technology Support had the largest relative contribution to the prediction of employee satisfaction (β = 0.232), followed by Flexible Workstations (β = 0.222), Privacy and Focus Areas (β = 0.193), and Remote Work Support (β = 0.172). Overall, four of the six individual spatial features emerged as significant positive predictors of employee satisfaction, while Collaboration Zones and Wellness Spaces were not significant predictors.

## CONCLUSION

This study examined the integration of FWAs features within commercial bank offices in Kuala Lumpur City Centre and their influence on employee satisfaction. The findings indicate that although FWAs features are moderately available, employees consistently reported higher expectations than their current workplace experiences across all six spatial dimensions. Gap analysis revealed that the largest discrepancies were associated with collaboration zones, privacy and focus areas, wellness spaces, flexible workstations, and smart workplace technologies, highlighting these as priority areas for future workplace improvement. Pearson correlation analysis further demonstrated that all FWAs features were positively and significantly associated with employee satisfaction, indicating that employees' perceptions of these workplace features were generally related to higher satisfaction. The multiple linear regression analysis provided further insight into the unique predictive contribution of each FWAs feature. Four features which include Smart Tools and Technology Support, Flexible Workstations, Privacy and Focus Areas, and Remote Work Support were significant positive predictors of employee satisfaction, whereas Collaboration Zones and Wellness Spaces were not significant predictors when all six features were considered simultaneously.

The findings suggest that successful implementation of FWAs extends beyond providing digital technologies and remote working capabilities. While technology-enabled infrastructure and remote work support are important, attention should also be given to flexible workstations and spaces that support privacy and focused work. The non-significant regression results for collaboration zones and wellness spaces should not be interpreted as indicating that these features are unimportant; rather, their unique predictive effects were not statistically significant after accounting for the other FWAs features in the model. Equal attention should be given to creating balanced workplace environments that integrate collaborative spaces, focused work areas, flexible workstations, wellness facilities, and technology-enabled infrastructure to support evolving hybrid work practices. Importantly, physical workplace design

should be aligned with organisational FWAs policies to ensure that the spaces, technologies, and work arrangements provided are mutually supportive. For office designers, this highlights the need to translate FWAs requirements into adaptable spatial configurations that accommodate different work modes. Facilities managers can support this alignment through ongoing assessment of space utilisation, workplace performance and employee needs, enabling workplace provisions to be adjusted as FWAs practices evolve. HR departments can contribute by aligning FWAs policies with workplace requirements and employee needs, while banking organisations can integrate workplace planning, technology investment, and FWAs policies into a coordinated approach to support employee satisfaction and effective hybrid working.

These implications suggest that FWAs implementation should be approached as an integrated organisational and workplace strategy rather than solely as a policy or physical workplace intervention. These findings provide practical guidance for workplace planners, facilities managers, HR departments and banking organisations seeking to develop more flexible and employee-centred office environments. More broadly, the study contributes to the growing body of workplace design literature by providing empirical evidence on the relationship between FWAs features and employee satisfaction, as well as identifying the features that demonstrate significant unique predictive effects in the Malaysian banking sector while offering a foundation for future research on flexible workplace planning.

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# INFLUENCE OF MIHRAB GEOMETRY ON ACOUSTIC PERFORMANCE IN MALAYSIAN MOSQUES USING COMPUTER SIMULATION

**Asrul Sani Abdul Razak[1], Zufar Adzahan[2], Liyana Hasnan[1], Mohd Zamri Jusoh[3], Nazli Bin Che Din[1*]**

[1]*Department of Architecture, Faculty of Built Environment,*
UNIVERSITI MALAYA, KUALA LUMPUR
[2]*Kajang Home of Acoustics and Noise Sdn Bhd,*
KHAN ACOUSTICS, KAJANG, SELANGOR
[3]*Faculty of Electrical Engineering,*
UNIVERSITI TEKNOLOGI MARA TERENGGANU

## Abstract

Acoustic quality is essential in mosque architecture as it influences speech intelligibility and worshippers' auditory experience. Although the mihrab is a prominent architectural element, its contribution to the overall acoustic performance of mosques remains insufficiently understood. This study evaluates the influence of mihrab geometry on the acoustic performance of six Malaysian mosques using ODEON room acoustic simulation. Three acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), were analysed to compare different mihrab configurations. The findings reveal that variations in mihrab geometry have only a limited effect on acoustic performance, whereas prayer hall volume, ceiling configuration, and surface materials exert greater influence on speech intelligibility and sound distribution. The study highlights the importance of considering holistic architectural design strategies in mosque planning while preserving traditional mihrab forms. These findings provide practical guidance for architects, planners, and conservation practitioners in designing and conserving acoustically effective mosque environments.

***Keywords***: Mosque Architecture; Architectural Acoustics; Mihrab Geometry

* Corresponding author. Email: nazlichedin@um.edu.my

## INTRODUCTION

Mosques have long served as the spiritual, cultural, and social centres of Muslim communities, providing spaces for congregational prayers, religious education, and community activities (Baydoun et al., 2025). Beyond their religious significance, mosque buildings represent complex architectural environments where spatial configuration, construction materials, and geometric forms collectively influence environmental performance, including thermal comfort, lighting, ventilation, and acoustics. Among these attributes, acoustic quality is particularly important because the primary functions of a mosque rely on the clear transmission of speech during daily prayers, Friday sermons (khutbah), religious lectures, and Qur'anic recitation (Abdou, 2003). Consequently, achieving good speech intelligibility while maintaining an appropriate reverberant environment has become a fundamental consideration in mosque design.

The acoustic environment of a mosque differs substantially from that of other public buildings due to its unique architectural characteristics and functional requirements. Unlike theatres or concert halls that are primarily designed for musical performances, mosques are intended to optimise speech intelligibility while simultaneously preserving an appropriate degree of reverberation that enhances the spiritual experience associated with Qur'anic recitation. Achieving this balance presents a significant architectural challenge, particularly in contemporary mosques where increasing prayer hall dimensions, higher ceiling volumes, large domes, and the extensive use of hard reflective materials frequently produce excessive reverberation and uneven sound distribution (Din et al., 2013; Syazana et al., 2021; Din & Anuar, 2019). Consequently, acoustic performance has become an increasingly important consideration in mosque design, particularly as architects seek to reconcile aesthetic expression with functional requirements.

Architectural acoustics has become an integral component of building performance evaluation because it directly affects occupant comfort, communication effectiveness, and the overall quality of indoor environments. Previous studies (Setiyowati et al., 2026: Nazli et al., 2017) have demonstrated that room geometry, enclosure volume, ceiling configuration, surface materials, and interior architectural elements significantly influence acoustic behaviour within enclosed spaces. In religious buildings, these factors determine how sound waves propagate, reflect, and decay throughout the prayer hall, thereby affecting important acoustic parameters for evaluating speech clarity and acoustic quality within worship spaces.

Among the architectural elements within a mosque, the mihrab occupies a unique functional and symbolic position. Located on the qiblah wall, it indicates the direction of prayer while serving as the location from which the imam leads congregational worship (Whelan, 1986). In Malaysian mosques,


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mihrab designs vary considerably in terms of geometry, depth, curvature, and decorative treatment, reflecting differences in architectural styles and historical development (Rosniza, 2011). Traditionally, the concave form of the mihrab has been associated with favourable acoustic characteristics, as it is believed to enhance the projection of the imam's voice towards the congregation (Khidir, 1998; Ahmad et al., 2013; Hossameldien & Alshan, 2019). Nevertheless, empirical evidence regarding the extent of its contribution to the overall acoustic performance of mosque prayer halls remains limited.

Recent advances in computer-based acoustic simulation have enabled researchers to evaluate architectural acoustic performance under controlled conditions before construction or renovation (Abd Jalil et al., 2019). Despite increasing interest in mosque acoustics, most previous studies have examined the combined influence of room volume, ceiling configuration, dome geometry, and material properties, while comparatively few have isolated the effect of mihrab geometry under consistent architectural conditions (Nazli et al., 2017). Consequently, architects and conservation practitioners continue to have limited evidence on whether modifications to mihrab geometry significantly improve speech intelligibility or overall acoustic performance.

Therefore, this study investigates the influence of different mihrab geometries on the acoustic performance of six representative Malaysian mosques using computer simulation. The evaluation is based on three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT). The findings provide evidence-based insights into the acoustic role of mihrab geometry and support architects, planners, and conservation practitioners in balancing architectural authenticity with acoustic performance in the design and conservation of mosque prayer halls.

## LITERATURE REVIEW

### Mosque Architecture and Acoustic Performance

Mosques are among the most significant public buildings in Islamic societies, serving not only as places of worship but also as centres for education, social interaction, and community development (Rasdi & Tajuddin, 2007; Yusoff, 2026; Baydoun et al., 2025). Their architectural form has evolved across different regions in response to climatic, local traditions, technological advances, and cultural influences. Despite these regional variations, the principal function of the mosque remains unchanged: to provide an environment that facilitates congregational and effective communication between the imam and worshippers. Consequently, architectural design must satisfy both symbolic and functional requirements, including the provision of an acoustically comfortable environment.

Daily prayers, Friday sermons (khutbah), Qur'anic recitation, and religious lectures depend on the accurate transmission of spoken words throughout the prayer hall. Poor acoustic conditions may reduce speech clarity, diminish listener concentration, and affect worshippers' overall experience (Kusno et. al 2025). Therefore, acoustic performance should be considered an integral component of mosque design rather than a secondary engineering consideration. Architectural elements such as prayer hall dimensions, ceiling height, dome geometry, structural configuration, and material selection collectively influence sound propagation within mosque interiors. Large-enclosed volumes and highly reflective finishes, which are common in many contemporary mosques, often increase reverberation time and reduce speech intelligibility unless appropriate acoustic design strategies are incorporated. These observations demonstrate that architectural form and acoustic performance are closely interrelated and should be evaluated as complementary aspects of building design

**Architectural Acoustics in Mosque Design**

Architectural acoustics examines the interaction between sound and the built environment, emphasising how spatial configuration, enclosure geometry, and surface materials influence acoustic performance. In mosque architecture, acoustic quality is essential because speech intelligibility directly affects prayers, Qur'anic recitation, and religious sermons. Therefore, successful mosque design requires a balance between architectural aesthetics and functional acoustic performance. Three objective parameters are widely used to evaluate mosque acoustics: Sound Pressure Level (SPL), which measures sound distribution; Speech Transmission Index (STI), which assesses speech intelligibility; and Reverberation Time (RT), which indicates the persistence of sound after the source has ceased. Together, these parameters provide a comprehensive assessment of acoustic performance and are widely employed in both field measurements and computer-based acoustic simulations.

Previous studies (Nazli et al., 2017; Abdou, 2003; Eldien, 2024) have consistently shown that room volume, ceiling configuration, dome geometry, and surface finishes exert substantial influence on these acoustic indicators. Excessively long reverberation times may produce overlapping reflections that reduce speech clarity, whereas insufficient reverberation may diminish the perceived richness of Qur'anic recitation. Therefore, the challenge in mosque design is to achieve an appropriate balance between clarity and reverberance that supports both verbal communication and religious recitation


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### The Mihrab as an Architectural and Acoustic Element

The mihrab is one of the most recognisable architectural features in mosque design. Located on the qiblah wall, it identifies the direction of Makkah and provides the position from which the imam leads congregational prayers. Although its symbolic and religious significance has been extensively documented, its functional contribution to acoustic performance remains less clearly understood. Traditionally, many mosque builders have believed that the concave geometry of the mihrab assists in reflecting or projecting the imam's voice into the prayer hall. This assumption has influenced mosque architecture across different Islamic civilizations, resulting in diverse mihrab forms ranging from shallow recesses to deep semi-circular niches. Malaysian mosques similarly exhibit considerable diversity in mihrab geometry, reflecting differences in historical period, architectural style, and construction technology.

Numerous studies on mosque acoustics have primarily focused on the influence of prayer hall volume, ceiling configuration, dome geometry, building materials, and electroacoustic systems on overall acoustic performance. Comparatively, limited research has investigated the isolated influence of mihrab geometry under comparable architectural conditions. Recent advances in computer-based acoustic simulation, particularly using ODEON (Naylor & Rindel, 1992), have enabled reliable prediction of key acoustic parameters, including Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT). However, existing studies have largely adopted an engineering perspective, with limited emphasis on the implications of mihrab geometry for architectural design and heritage conservation. Therefore, this study addresses this research gap by evaluating the influence of different mihrab geometries on the acoustic performance of Malaysian mosques through computer simulation to support evidence-based mosque design and conservation.

## RESEARCH METHODOLOGY

The first stage of this study involved the identification and selection of representative mosques in Malaysia for acoustic simulation. From the inventory of 56 mosques documented by Ahmad et al. (2013), six mosques were purposively selected as representative case studies for controlled computer-based acoustic simulation rather than as a statistically representative sample of all Malaysian mosques. The selection was guided by architectural diversity and the availability of sufficiently detailed architectural information for three-dimensional reconstruction. This selection enabled controlled comparison of alternative mihrab geometries across different architectural contexts while maintaining the modelling requirements necessary for reliable acoustic simulation and aimed to ensure that the chosen case studies reflected variations

in architectural characteristics that could potentially influence acoustic performance.

Several selection criteria were established to ensure the suitability of the case studies. These included roof typology, construction period (ranging from the 1800s to the 1900s), mihrab geometry, spatial configuration, and the availability of complete architectural drawings for three-dimensional modelling. In addition, mosque layout, prayer hall geometry, and other architectural features were considered to ensure that the selected mosques represented the evolution of Malaysian mosque architecture while providing sufficient variation for comparative analysis. The selected mosques encompass different architectural styles and historical periods, thereby allowing the influence of mihrab geometry on acoustic performance to be evaluated across diverse architectural contexts. The availability of accurate architectural drawings further enabled the development of reliable three-dimensional digital models for acoustic simulation.

**Mosque Description**

Table 1 summarises the principal physical and architectural characteristics of the six selected mosques used as case studies in this research. The information includes the year of construction, prayer hall volume, architectural style, and geographical location of each mosque. These characteristics were selected because they are recognised as important factors influencing the acoustic behaviour of enclosed worship spaces.

The six mosques, located across the western region of Peninsular Malaysia, represent a broad spectrum of Malaysian mosque architecture, encompassing both traditional and modern architectural styles constructed between the nineteenth and twentieth centuries. Their inclusion enables a comparative assessment of acoustic performance across different architectural periods and design typologies. Selected prayer halls exhibit considerable variation in spatial volume, ranging from approximately 617 $m^3$ in smaller mosques to more than 2,500 $m^3$ in larger prayer halls. This variation provides an appropriate basis for investigating the influence of mihrab geometry while accounting for differences in room size and spatial configuration. The diversity of architectural characteristics among the selected mosques enhances the robustness of the comparative analysis and allows the findings to be interpreted within a broader architectural context.


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**Table 1:** Main physical characteristics of mosques adopted in the study

| No | Mosque Name | Code | Volume ($m^3$) | Construction Year | Architectural Style |
|---|---|---|---|---|---|
| **Pyramidal Roof Type** | | | | | |
| 1 | Masjid Kg Bukit Belimbing | P1 | 617 | 1800s | Vernacular/ Traditional |
| 2 | Masjid Jamek Kg Sungai Gulang-Gulang | P2 | 1109 | 1898 | Vernacular/ Traditional |
| 3 | Masjid Dato Dagang | P3 | 777 | 1876 | Sino Eclectic |
| **Dome Roof Type** | | | | | |
| 4 | Masjid Sultan Suleiman | D1 | 1844 | 1932 | Neo-Colonial |
| 5 | Masjid Jamek Kuala Lumpur | D2 | 2971 | 1909 | Neo-Colonial |
| 6 | Masjid Sultan Alaeddin | D3 | 1030 | 1898 | Neo-Colonial |

**Table 2:** Basic information of simulation settings fixed in ODEON

| | | | |
|---|---|---|---|
| **No. of sound source** | **:** | 1 (set at 1.5 m high) setting at *imam* position | |
| **Sound source type** | **:** | a) OMNI.S08 (0 gain) for RT<br>b) BOSE BB93_NORMAL_NATURAL_S08 (Mihrab direction) Total power: 68.4 dB(A) for STI and SPL | |
| **No. of multi point source** | **:** | Grid Points (all set at 1.5 m high) | |
| | | Pyramid | Dome |
| | | P1: 156 | D1: 254 |
| | | P2: 295 | D2: 493 |
| | | P3: 122 | D3: 158 |
| **Impulse response length** | **:** | between 1660 ms to 6020 ms | |
| **Temperature input** | **:** | 24ºC | |
| **Background noise** | **:** | NC-35 | |
| **Scattering coefficient** | **:** | 0.05 | |

## Three-Dimensional Model Development and Acoustic Simulation

The three-dimensional (3D) models used for acoustic simulation were adapted from architectural models developed by undergraduate students as part of the Digital Architecture (DA) course. In this course, students reconstructed selected Malaysian mosques into detailed digital models based on existing two-dimensional (2D) architectural drawings. A total of six mosque models were selected and categorised into two principal architectural typologies based on their roof forms, namely pyramidal-type and dome-type mosques. Each category comprised three representative mosque models, enabling a comparative investigation of different architectural forms commonly found in Malaysian

mosque architecture. This classification facilitated the evaluation of whether roof typology, together with mihrab geometry, influences the acoustic behaviour of mosque prayer halls.

The present study focused exclusively on the main prayer hall of each mosque, as this space accommodates congregational prayers and contains the mihrab, which serves as the location from which the imam leads prayers and delivers sermons. Since the objective of the study was to investigate the influence of mihrab geometry on acoustic performance, other ancillary spaces such as corridors, ablution areas, offices, and circulation spaces were excluded from the simulation models.

A limitation of the study concerns the origin of the three-dimensional models, which were initially developed by undergraduate students based on available two-dimensional architectural drawings and subsequently refined for acoustic simulation. Although the principal spatial geometry was retained, insignificant architectural details, decorative elements, and non-essential surfaces were simplified or omitted to improve computational efficiency while maintaining the essential geometry of the prayer halls (Abd Jalil et al., 2019). Nevertheless, uncertainties may remain in the representation of complex architectural details, dimensions, surface conditions, and material properties, and these may influence the absolute acoustic values predicted by the simulations. Therefore, the results are interpreted primarily as comparative evidence of the relative influence of mihrab geometry rather than as exact representations of the measured acoustic performance of the existing mosques.

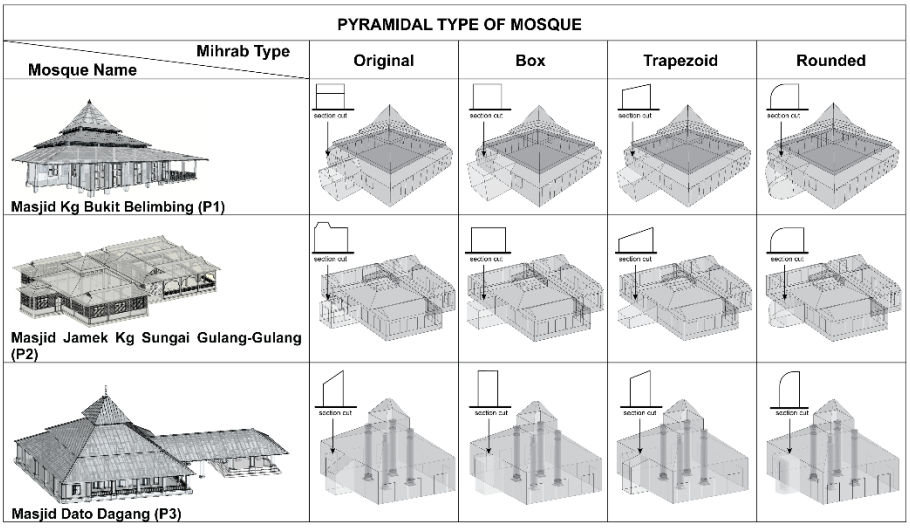



**Figure 1**: Type of mihrab for pyramidal type of mosque


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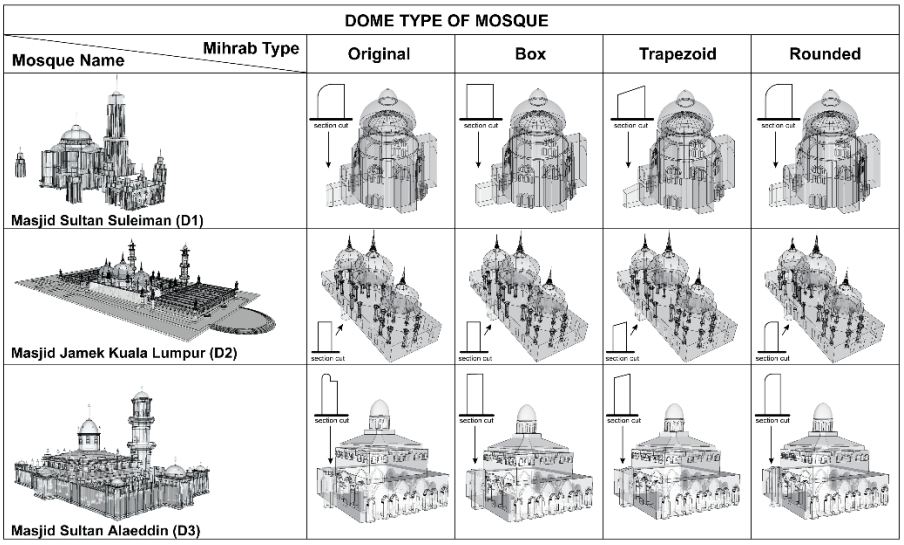



**Figure 2**: Type of mihrab for dome type of mosque

Following model preparation, three prototype mihrab geometries representing commonly observed architectural forms in Malaysian mosques were digitally constructed and substituted into each prayer hall model. This approach enabled the acoustic influence of different mihrab configurations to be evaluated under identical architectural and environmental conditions while minimising the effects of other variables. The mihrab types of the representative mosques were identified with reference to the typological classification presented by Rosniza (2011), which served as the baseline for developing the simulation configurations. In this study, the semi-circular concaved mihrab type was represented by the rounded prototype. The recessed room on the qibla wall type was represented by two simplified geometric configurations according to the ceiling condition: box, representing a flat ceiling, and trapezoid, representing an inclined ceiling. These three configurations were therefore derived from the observed mihrab characteristics of the selected Malaysian mosques and translated into simplified geometric prototypes for controlled acoustic simulation. However, these configurations were not intended to constitute an exhaustive classification of Malaysian mihrab typologies, but rather to provide representative geometric prototypes derived from documented Malaysian mosque examples for the purpose of controlled comparative simulation.

All digital models were developed using SketchUp Pro® before being exported into ODEON Room Acoustic Software (Version 16) for acoustic simulation. Appropriate acoustic properties were assigned to all room surfaces based on their material characteristics. Material assignment represented one of

the most critical stages of the modelling process because the actual acoustic properties of existing mosque finishes were not always available. Consequently, sound absorption was selected from the ODEON material library and supplemented by published acoustic databases where necessary to ensure realistic representation of interior finishes as presented in Appendix A.

The sound source was positioned at the imam's standing location within the mihrab to replicate actual worship conditions. Receiver points were distributed throughout the main prayer hall according to its spatial configuration to evaluate sound propagation and speech intelligibility across the occupied prayer area. This arrangement enabled the comparison of three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), which collectively describe sound distribution, speech clarity, and reverberation characteristics within the prayer hall. Prior to the final simulations, a preliminary estimation of RT was performed to determine an appropriate impulse response length for each model. The selected impulse response length was configured to exceed two-thirds of the estimated reverberation time to ensure reliable acoustic calculations. The simulation settings and scattering coefficients adopted for each prayer hall are summarised in Table 2. In addition, the background noise level was standardised at 44 dBA (NC-35) based on average field measurements obtained from previous investigations (Nazli et al., 2017) to represent typical indoor acoustic conditions during congregational prayers. The completed digital models of the six mosque prayer halls together with the three prototype mihrab configurations are illustrated in Figures 1 and 2.

It should be noted that direct field validation of the simulation models was not undertaken because measured RT data for the six selected mosques were not available. The objective of the simulation was therefore comparative rather than predictive, focusing on the relative effect of alternative mihrab geometries on the overall reverberation characteristics of each prayer hall. To maintain comparability, the hall geometry, material assumptions, sound-source position, receiver distribution, and other simulation parameters were kept consistent when the three mihrab configurations were introduced. Consequently, the resulting RT differences were interpreted as the relative acoustic contribution of mihrab geometry under controlled simulation conditions. The absorption and scattering coefficients were assigned using the ODEON material library and published acoustic references where specific measured properties of existing finishes were unavailable. This limitation is acknowledged, as uncertainty in material acoustic properties may affect the absolute RT values predicted by the models.


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## ANALYSIS AND DISCUSSION

### Sound Pressure Level (SPL) Distribution

Figure 3 illustrates the average A-weighted Sound Pressure Level (SPL) distribution with increasing source-to-receiver distance for the original and prototype mihrab configurations in both pyramidal- and dome-type mosques. Overall, all simulated prayer halls exhibited a similar attenuation pattern, whereby the SPL gradually decreased as the distance from the sound source increased. This trend is consistent with the expected reduction in sound energy as it propagates through enclosed spaces.

Among the pyramidal-type mosques, the SPL distributions generally followed comparable trends for all mihrab configurations. However, a noticeable deviation was observed in Mosque P2 (Figure 3b), where the original mihrab produced a maximum SPL difference of approximately 3 dB(A) compared with the three prototype geometries. Despite this localised variation, the overall sound attenuation pattern remained consistent across the different mihrab configurations. Similarly, the dome-type mosques (Figures 3c–3e) demonstrated comparable SPL distributions regardless of mihrab geometry. The maximum differences recorded among the dome-type models were generally less than 1.5 dB(A), indicating only minor variations in sound pressure distribution.

Overall, the simulation results suggest that changes in mihrab geometry produce relatively small variations in SPL distribution across both pyramidal- and dome-type mosques. Although isolated differences of up to 3 dB(A) were observed in individual cases, the overall sound pressure patterns remained largely unaffected by the different mihrab configurations.

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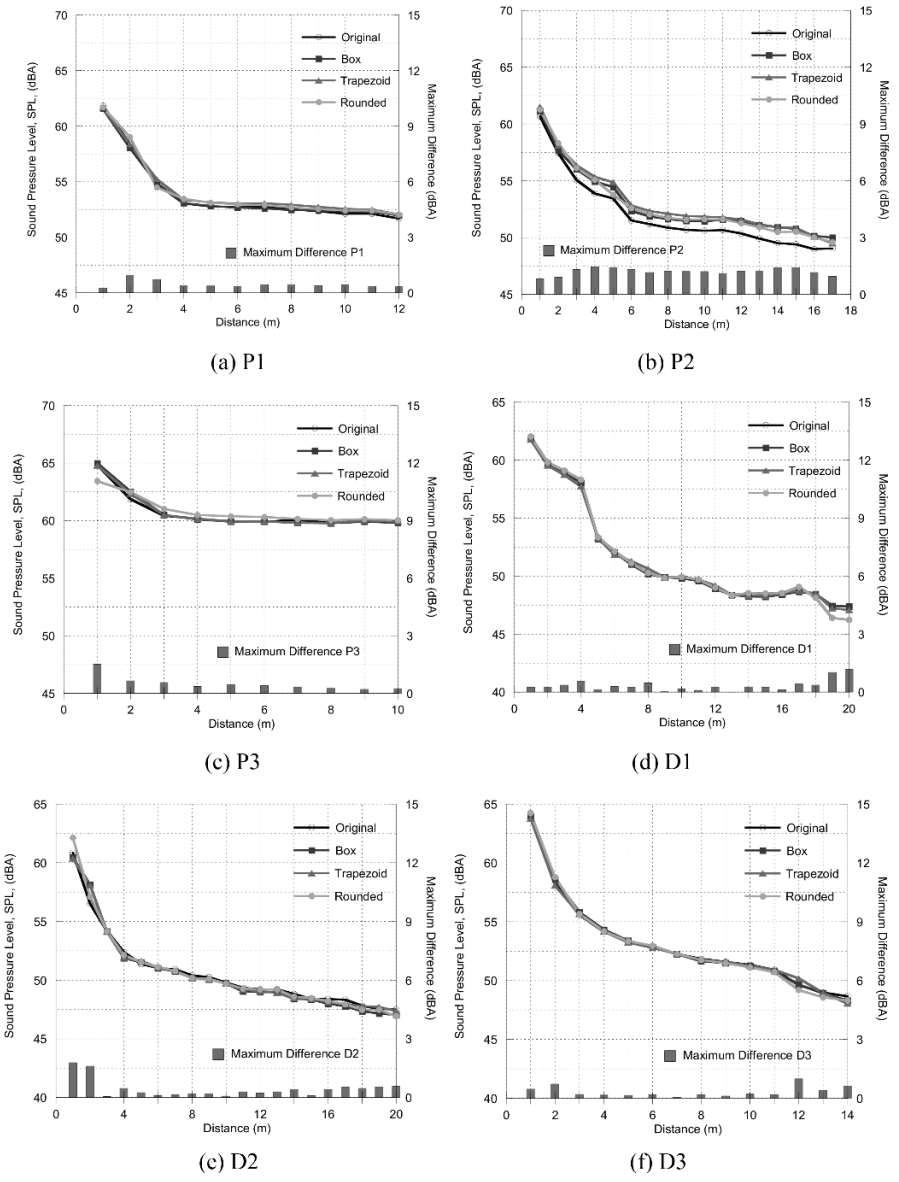
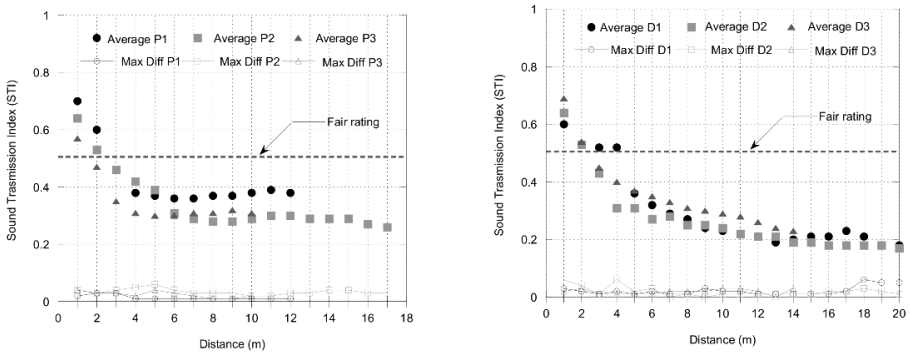



**Figure 3**: Comparison of sound pressure level (SPL) and maximum differences (MD) between each type of mihrab. Pyramidal Type (a) P1 (b) P2 (c) P3; Dome Type (d) D1, (e) D2 and (f) D3


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*(a) Pyramidal Type* *(b) Dome Type*

**Figure 4**: Comparison of average sound transmission index (STI) and maximum differences (MD) between all main prayer halls; (a) piramidal type and (b) dome type

**Sound Transmission Index (STI) vs Distance**

Speech intelligibility is one of the most important acoustic performance criteria in mosque design, as it directly affects the clarity of prayers, Qur'anic recitation, and sermons. To facilitate a concise comparison among the different mihrab configurations, the STI values obtained from the simulations were averaged for each mosque, while the maximum differences between the original and prototype mihrab geometries were calculated to evaluate their acoustic influence.

Figure 4(a) and Figure 4(b) present the average STI values for the pyramidal- and dome-type mosques, respectively, as a function of the distance from the sound source. Overall, all simulated prayer halls exhibited a similar trend, whereby the STI gradually decreased with increasing source-to-receiver distance. This reduction indicates the expected deterioration in speech intelligibility as sound propagates further from the imam's position.

Among the six case study mosques, D1 consistently achieved the highest speech intelligibility, maintaining a 'Fair' or better STI rating over a larger portion of the prayer hall. In contrast, the remaining mosques exhibited STI values below the 'Fair' classification when the receiver distance exceeded approximately 2.0 m from the sound source.

Despite these variations among the individual mosque models, the maximum differences in STI between the original and prototype mihrab geometries were consistently less than 0.10. This finding indicates that modifications to mihrab geometry produced only marginal changes in speech intelligibility, regardless of roof typology or prayer hall volume.

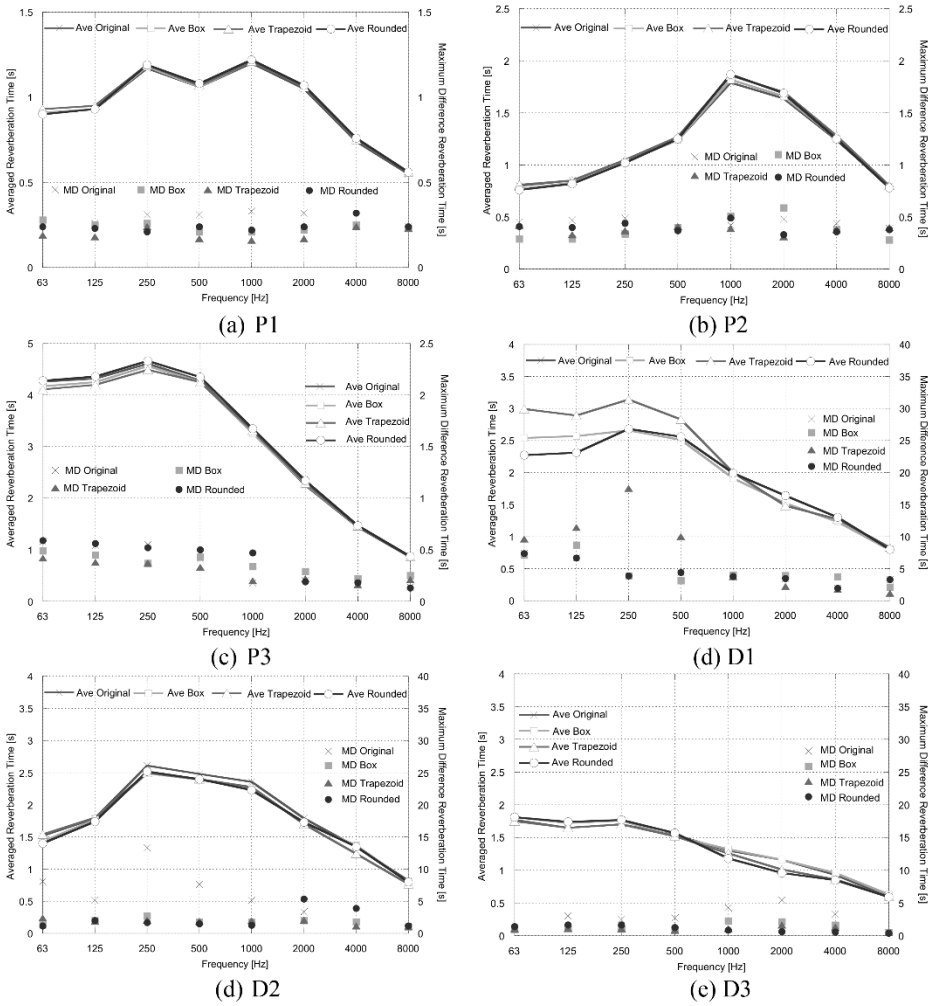



**Figure 5**: Comparison of averaged reverberation time (RT) between all types of mihrab. Pyramidal type (a) P1, (b) P2 and (c) P3; Dome type (d) D1, (e) D2 and (f) D3

## Reverberation Time (RT)

Reverberation Time (RT) was evaluated to examine the acoustic response of the main prayer halls and to determine whether variations in mihrab geometry influence sound decay characteristics. Although reverberation is primarily governed by room volume, spatial geometry, and the acoustic properties of interior surfaces, RT was included in this study to evaluate the relative contribution of mihrab geometry under comparable simulation conditions.


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The simulated $RT_{500Hz}$ values for the pyramidal-type mosques ranged from 1.06 s to 4.35 s, whereas the dome-type mosques recorded values between 1.52 s and 2.83 s. The RT values obtained at multiple receiver locations within each prayer hall were spatially averaged, and the maximum differences between the original and prototype mihrab geometries were calculated for comparative analysis, as presented in Figure 5. For the pyramidal-type mosques, Mosque P3 exhibited the highest average $RT_{500Hz}$ of approximately 4.0 s, reflecting its relatively large-enclosed volume and architectural configuration. Nevertheless, the spatially averaged RT values showed only minor variations among the different mihrab geometries across the analysed frequency range. The maximum differences were consistently below 0.6 s, indicating that changes in mihrab geometry had a negligible influence on the reverberation characteristics of the prayer halls.

A different trend was observed for the dome-type mosques. Slight discrepancies in the average RT values were identified, particularly for Mosque D1, where greater variations occurred at frequencies of 1,000 Hz and below. These differences may be associated with variations in room volume, dome configuration, and interior surface materials rather than the geometry of the mihrab itself. The simulated RT values fall within ranges reported in previous studies (Nazli et. al., 2017) of unoccupied Malaysian mosques of comparable size. These comparisons provide contextual reference for interpreting the simulated results; however, they do not constitute direct validation of the present models.

Overall, the results indicate that although reverberation characteristics vary among the selected mosques due to their architectural differences, modifications to mihrab geometry produced only marginal changes in RT. These findings suggest that reverberation performance is influenced more substantially by the overall spatial characteristics of the prayer hall than by the geometric configuration of the mihrab.

## CONCLUSION

This study investigated the influence of mihrab geometry on the acoustic performance of six representative Malaysian mosques using ODEON room acoustic simulation. Three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), were analysed to evaluate the acoustic response of different mihrab configurations under comparable architectural conditions. The findings indicate that mihrab geometry contributes to the acoustic behaviour of mosque prayer halls; however, its influence is dependent on the overall architectural context. While certain mihrab configurations may improve local sound reflection and speech intelligibility, particularly at shorter source-to-receiver distances and in

smaller prayer halls, their overall effect is moderated by broader architectural characteristics, including prayer hall volume, roof configuration, ceiling geometry, and surface material properties.

The findings provide practical implications for mosque design, conservation, and acoustic assessment. For architects, mihrab geometry should be considered as a complementary component of an integrated acoustic strategy, alongside prayer-hall volume, ceiling or dome configuration, room proportions, and surface materials, which have broader effects on sound propagation and reverberation. For conservation practitioners, the relatively limited acoustic influence of mihrab geometry suggests that traditional forms may generally be retained to preserve the historical and architectural character of mosques, while acoustic improvements can focus on appropriate spatial and material interventions. For acoustic consultants, assessment should consider the overall prayer-hall sound field rather than the mihrab as an isolated element, supported by computer simulation and, where possible, field measurements to inform design and conservation decisions. Future studies should combine computer simulation, field measurements, and user perception to develop comprehensive acoustic design guidelines for contemporary and heritage mosques.

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APPENDIX A

Sound Absorption Coefficient Applied in This Study

| Mosque | Architectural Element | Sound Absorption Coefficient Frequencies. (Hz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **63** | **125** | **250** | **500** | **1000** | **2000** | **4000** | **8000** |
| Masjid Kampung Belimbing (P1) | Ceiling | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.10 | 0.11 | 0.11 |
| | Door | 0.14 | 0.14 | 0.10 | 0.06 | 0.08 | 0.10 | 0.10 | 0.10 |
| | Floor | 0.09 | 0.09 | 0.08 | 0.21 | 0.26 | 0.27 | 0.37 | 0.37 |
| | Wall | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.1 | 0.11 | 0.11 |
| | Window | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.10 | 0.11 | 0.11 |
| | Louvre | 0.42 | 0.42 | 0.38 | 0.34 | 0.27 | 0.28 | 0.29 | 0.29 |
| Masjid Jamek Kg. Sungai Gulang-Gulang (P2) | Ceiling | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.10 | 0.11 | 0.11 |
| | Door | 0.14 | 0.14 | 0.10 | 0.06 | 0.08 | 0.10 | 0.10 | 0.10 |
| | Floor | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 |
| | Lower Wall | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Ventilation | 0.42 | 0.42 | 0.38 | 0.34 | 0.27 | 0.28 | 0.29 | 0.29 |
| | Wall | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.10 | 0.11 | 0.11 |
| | Window | 0.68 | 0.68 | 0.63 | 0.59 | 0.56 | 0.54 | 0.52 | 0.52 |
| Masjid Dato Dagang (P3) | Ceiling | 0.05 | 0.05 | 0.05 | 0.05 | 0.08 | 0.14 | 0.20 | 0.20 |
| | Column | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Door | 0.14 | 0.14 | 0.10 | 0.06 | 0.08 | 0.10 | 0.10 | 0.10 |
| | Floor | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 |
| | Wall | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Masjid Sultan Sulaiman (D1) | Floor | 0.02 | 0.02 | 0.06 | 0.14 | 0.37 | 0.60 | 0.65 | 0.65 |
| | Opening | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Inner Roof | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Glass/Window | 0.35 | 0.35 | 0.35 | 0.18 | 0.12 | 0.07 | 0.04 | 0.04 |
| | Wall | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| Masjid Jamek Kuala Lumpur (D2) | Window Dome | 0.35 | 0.35 | 0.25 | 0.18 | 0.12 | 0.07 | 0.04 | 0.04 |
| | Column | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Floor | 0.02 | 0.02 | 0.06 | 0.14 | 0.37 | 0.60 | 0.65 | 0.65 |
| | Roof Structure | 0.40 | 0.30 | 0.25 | 0.20 | 0.10 | 0.10 | 0.15 | 0.15 |
| | Door | 0.14 | 0.14 | 0.10 | 0.06 | 0.08 | 0.10 | 0.10 | 0.10 |
| | Wall | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Window | 0.35 | 0.28 | 0.25 | 0.17 | 0.12 | 0.07 | 0.04 | 0.04 |
| Masjid Sukltan Alaeddin (D3) | Ceiling | 0.28 | 0.28 | 0.22 | 0.17 | 0.09 | 0.10 | 0.11 | 0.11 |
| | Floor | 0.02 | 0.02 | 0.06 | 0.14 | 0.37 | 0.60 | 0.65 | 0.65 |
| | Louvre | 0.64 | 0.64 | 0.61 | 0.59 | 0.55 | 0.55 | 0.56 | 0.56 |
| | Opening | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Inner Roof | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| | Wall | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |

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# PROBLEMS AND OPPORTUNITIES IN ADOPTING SMART AND PARTICIPATORY SYSTEM ON FLOOD RISK REDUCTION: CASE STUDY OF SURABAYA FLOOD RISK MANAGEMENT

**Adjie Pamungkas[1*], Muhammad Ifaldy Amrila Zulkarnain[2], Muhammad Rafli Al Ghiffari Ferani[3]**

[1,2,3]*Urban and Regional Planning Department,*
INSTITUT TEKNOLOGI SEPULUH NOPEMBER

## Abstract

Smart system and participatory process become buzz words in disaster risk management highlighting the importance of those concepts in reducing the impact of disasters effectively. Surabaya, like other cities, put a lot of effort to implement them in their administrative process especially in flood risk management. Apparently, the integration between smart system and participatory process in flood risk management need further improvements. 10 problems typologies have been formulated based on the discussion within 12 key stakeholders from government, private sectors, media, academia and community groups. Based on MICMAC analysis, the problems are structured resulting the improvement of policy direction became the key driver problem that can influent to all others problem. The policy direction becomes the umbrella to establish a proper smart and participatory system in flood risk management. 6 others are relay variables that can change other problem partially. Those relay variables are more on the technical problem on how the system applied such as data availability and human resource capacity. While excluded variables are perceived as latent social enablers. Those variables are significant once the system has been established. Without solving the excluded variables, the value of smart-participative management can be jeopardized.

***Keywords***: Flood, Flood Risk Management, Smart City, Participatory

[1] Corresponding author. Email: adjie@its.ac.id

## INTRODUCTION

Urban flooding is a complex socio-technical risk shaped by interacting technological, institutional, and social factors. Although cities deploy smart technologies like IoT and AI, these systems often evolve fragmentally without integrated governance (Kaluarachchi, 2020). Additionally, citizen participation frequently lacks genuine co-production, whereas AI tools require transparent, inclusive decision-making (Mupfumira et al., 2024). Surabaya presents a context-specific case study to examine how technological and participatory gaps constrain local flood resilience, offering an analytical approach for comparative urban studies. Surabaya's rapid urbanization escalates its vulnerability to tidal and pluvial flooding (Pamungkas et al., 2019; Anggraini et al., 2024). In 2022, severe flooding disrupted over 10,000 residents across 118 locations (Ginanjar, 2022; Wardana, 2024). Currently, local disaster governance remains reactive rather than proactive (Pamungkas et al., 2019). Despite adopting "smart city" measures, implementation falters due to fragmented, early-stage, and opaque technological systems (Ifaldy et al., 2025). Furthermore, community involvement remains predominantly consultative rather than co-decisional (Ifaldy et al., 2025; Wessel et al., 2021). This paper identifies crucial leverage points for policy interventions, aiming to align technological deployment with citizen preparedness for genuinely smart, participative flood risk governance.

## LITERATURE REVIEW

To integrate the concepts of smart city and participatory approaches into flood risk management, 8 indicators and 28 key variables were formulated in this study. These indicators and variables also serve as the basis for developing the interview protocol, which is designed to assess the implementation of participatory smart city practices in flood disaster management in Surabaya.

**Table 1.** Research Indicators and Variables

| Indicators | Code | Variables | Source |
|---|---|---|---|
| Digital Technology Utilization (IoT) | A.1.1 | Sensor Network Utilization | (Anbarasan et al., 2020; Ibrahim & Mishra, 2021; Josipovic & Viergutz, 2023; Munawar et al., 2021; Sood et al., 2018; Jaafar et al., 2024) |
| | A.2.1 | Big Data Analytics | |
| | A.3.1 | Digital Twin Implementation | |
| | A.4.1 | Remote Sensing | |
| | A.5.1 | Artificial Intelligence (AI) | |
| | A.6.1 | Applications & Websites | |
| Real-Time Monitoring Effectiveness | B.1.1 | Hydrological Information | (Fairuz et al., 2020; Jan et al., 2022; Jang & Jung, 2023; Kim et al., 2022; Şensoy et al., 2018) |
| | B.2.1 | Water Storage Automation | |


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| Indicators | Code | Variables | Source |
|---|---|---|---|
| Early Warning Effectiveness | C.1.1 | Warning Outreach | (Hammood et al., 2020; Hasan & Islam, 2024; Kuller et al., 2021; Perera et al., 2019; Rana et al., 2021; Afida et al., 2016) |
| | C.2.1 | Warning Accuracy | |
| | C.3.1 | Quality of Information Content | |
| | C.4.1 | Community Response Capability | |
| Disaster Prediction Capability | D.1.1 | Data Input Completeness | (Cha & Lee, 2021; Hossain Anni et al., 2020; Ma et al., 2021; Starzec & Kordana-Obuch, 2024; Xing et al., 2021) |
| | D.2.1 | Predictive Modeling Quality | |
| | D.3.1 | Drainage Infrastructure | |
| Resource Accessibility | E.1.1 | Emergency Apps | (Cools et al., 2023; Das et al., 2024; Henriksen et al., 2018; Jiang et al., 2024; McCallum et al., 2016) |
| | E.2.1 | Disaster Education | |
| | E.3.1 | Disaster Facilitator | |
| | E.4.1 | Shelter/Evacuation Facilities | |
| | E.5.1 | Medical Facilities | |
| Inter-Agency Collaboration | F.1.1 | Governance & Planning | (Cools et al., 2023; Puzyreva et al., 2022; Thaler & Levin-Keitel, 2016; Watkins & Collins, 2024) |
| | F.2.1 | Planning Vision & Mission with Collaborative Solution | |
| | F.3.1 | Bottom-Up Planning | |
| | F.4.1 | Proactive Policies | |
| Community Awareness | G.1.1 | Community Flood Risk Awareness | (Huang et al., 2020); Gunandar et al., 2024; Modul KRB Banjir BNPB (Flood risk model from BNPB Modul) |
| | G.2.1 | Flood Disaster Mitigation Actions | |
| Active Community Engagement | H.1.1 | Infrastructure Maintenance | (Begg et al., 2018; Hendra & Kismartini, 2018; Rewah, 2022) |
| | H.2.1 | Decision Making | |

*Source: Author, 2026*

## RESEARCH METHODOLOGY

This study utilizes a mixed-method, sequential exploratory design to investigate urban flood management for Surabaya City context (Fetters et al., 2013). Data were gathered via in-depth interviews with purposively selected stakeholders directly involved in Surabaya's flood mitigation efforts (Agustina et al., 2024; Challies et al., 2016). To capture comprehensive technical, institutional, and operational perspectives, the respondents were categorized using the pentahelix model. Consequently, the sample encompasses key representatives from

government, private enterprise, local communities, academia, and media networks (Agustina et al., 2024; Challies et al., 2016; Riama et al., 2021).

**Table 2.** Stakeholder Profile

| Stakeholders | Respondents |
|---|---|
| Local Communities | Neighborhood Unit Head; Community Unit Head; Prominent Figure |
| Government | Surabaya City Water Resources and Highways Officer; Head of Mulyorejo District; Head of Keputih Subdistrict |
| Academia | Head of Research Center for Disaster Mitigation and Climate Change; Smart City Expert |
| Private Enterprise | Pakuwon City Officer; Grand Pakuwon Officer |
| Media Networks | JTV (local television station); Memorandum (local newspaper) |

*Source: Author, 2026*

The analytical procedure integrates quantitative content analysis with MICMAC structural analysis (Ahmad et al., 2019; Pathania & Tanwar, 2024). Interview transcripts were systematically coded in NVivo by two independent coders using a deductive-inductive strategy to identify thematic factor salience across technological, institutional, and social dimensions (Allsop et al., 2022). To ensure empirical rigor, coding underwent stringent inter-coder reliability testing via Cohen's Kappa and Gwet's AC1 coefficients. Coding discrepancies were resolved through joint re-evaluations and arbitration by the lead author until 100% agreement was achieved. High inter-coder agreement confirmed the reliability of the identified problem sets. Subsequently, MICMAC analysis mapped the systemic relationships of these factors based on relative driving power and dependence. Stakeholders evaluated pairwise relationships using a 5-point scale (0 to 4) to construct the Direct Influence Matrix (MDI). Iterative matrix multiplications validated the Indirect Influence Matrix (MII), establishing final driving and dependence scores to categorize factors into four MICMAC quadrants (Ifaldy et al., 2025).

## ANALYSIS AND DISCUSSION

The statistical evaluation demonstrates that all research variables exhibit high-level reliability, with Cohen's Kappa coefficients ($C\kappa$) ranging from 0.70 to 0.98 and Gwet's AC1 values consistently reaching near-perfect levels. A mean agreement rate of 99% and frequency (F) further validates the objectivity and methodological rigor maintained during the classification of stakeholder interview data into thematic variables.


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**Table 3.** Content Analysis Result Summary.

| Problem Typologies | Actual Problems | Related Variables |
|---|---|---|
| [P1] Policy direction and planning priority (F = 34) | Policy framework lacks focus on big data optimization (F:4) (Cκ:0,88); High procurement costs leading to budgetary constraints (F:5) (Cκ:0,81); No development plan; reliance on social media (WA groups) (F:3) (Cκ:0,91); Lack of strategic focus on AI for flood mitigation (F:3) (Cκ: 0,91); Budget priorities not aligned with integrated app development (F:1) (Cκ: 0,96); Siloed/partial smart city development priorities (F:2) (Cκ: 0,92); Budget and policy constraints regarding predictive technology (F:3) (Cκ: 0,88); Sustainability at risk due to shifting budget priorities (F:2) (Cκ: 0,92); Technical agency priorities hinder "bottom-up" planning (F:4) (Cκ: 0,85); Bottom-up proposals clash with formal agency KPIs (F:7) (Cκ: 0,73). | Big Data Analytic; Digital Twin Implementation; Remote Sensing; Artificial Intelligence (AI); Applications & Websites; Data Input Completeness; Predictive Modeling Quality; Planning Vision & Mission with Collaborative Solution; Bottom-Up Planning; Decision Making. |
| [P2] Technological facilities and system adequacy (F = 32) | Automated operations remain reliant on manual field personnel (F:8) (Cκ:0,80); Absence of specialized technology for predictive data processing (F:2) (Cκ:0,92); Insufficient technological facilities for virtual city modeling (F:1) (Cκ:0,96); Minimal technological infrastructure to support AI implementation (F:5) (Cκ:0,81); Pumps and sluice gates lack full automation (require operators) (F:9) (Cκ:0,96); Absence of physical warning infrastructure (e.g., sirens) in residential areas (F:1) (Cκ:0,96); Limited technological facilities to ensure information accuracy (F:1) (Cκ:0,96); Insufficient automated monitoring in flood-prone zones (F:1) (Cκ:0,96); Absence of technology for automated sedimentation tracking (F:4) (Cκ:0,85). | Sensor Network Utilization; Big Data Analytics; Digital Twin Implementation; Artificial Intelligence (AI); Water Storage Automation; Warning Outreach; Warning Accuracy; Data Input Completeness; Drainage Infrastructure. |
| [P3] Data availability and | Data siloed across departments without centralized integration (F:3) (Cκ:0,92); Incomplete data variables and low accuracy for modeling (F:7) (Cκ:0,91); Available data | Big Data Analytics; Digital Twin Implementation; |

| Problem Typologies | Actual Problems | Related Variables |
|---|---|---|
| completeness (freq = 16) | variables lack the complexity required for AI (F:2) (C**κ**:0,92); Severe lack of hydrological variables for predictive modeling (F:3) (C**κ**:0,90); Lack of clear technical data regarding drainage sediment conditions (F:1) (C**κ**:0,96). | Artificial Intelligence (AI); Data Input Completeness; Drainage Infrastructure. |
| [P4] System integration level (freq = 27) | Institutional silos hindering cross-agency sensor integration (F:1) (Cκ:0,96); Deficient inter-agency collaboration due to fragmented data systems (F:3) (C**κ**:0,95); Public fatigue due to fragmented, agency-specific applications (F:1) (Cκ:0,96); Information not connected through a unified system (F:1) (Cκ:0,91); Poor data recording due to non-integrated cross-agency sensors (F:1) (Cκ:0,96); Lack of data processing systems for disaster forecasting (F:3) (Cκ:0,91); Fragmented data across agencies hindering model accuracy (F:6) (Cκ:0,80); Tertiary channels disconnected from main drainage systems (F:1) (Cκ:0,96); Integrated system unavailable due to pending development (F:2) (Cκ:0,92); Absence of integrated systems for medical service coordination (F:7) (Cκ:0,91); Inter-departmental silos and overlapping system functions (F:1) (Cκ:0,96). | Sensor Network Utilization; Big Data Analytics; Applications & Websites; Hydrological Information; Warning Accuracy; Data Input Completeness; Predictive Modeling Quality; Drainage Infrastructure; Emergency Apps; Medical Facilities; Governance & Planning. |
| [P5] Information and reporting mechanisms (freq = 13) | Monitoring and reporting heavily reliant on manual WhatsApp groups (F:5) (Cκ:0,85); Information flow delayed by intermediaries in WhatsApp groups (F:1) (Cκ:0,96); Inundation info dissemination relies solely on WhatsApp messages (F:2) (Cκ:0,98); Manual monitoring/reporting via WhatsApp groups (F:1) (Cκ:0,96); Reporting remains limited to social media (WhatsApp) (F:4) (Cκ:0,88). | Applications & Websites; Hydrological Information; Warning Outreach; Predictive Modeling Quality; Emergency Apps. |
| [P6] Human resource capacity and quality (freq = 17) | Human resources capacity unfamiliar with large-scale data management technologies (F:3) (Cκ:0,95); Scarcity of experts proficient in digital twin management (F:6) (Cκ:0,87); Human resources unpreparedness regarding unfamiliar | Big Data Analytics; Digital Twin Implementation; Artificial |


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| Problem Typologies | Actual Problems | Related Variables |
|---|---|---|
| | AI-based technologies (F:7) (Cκ:0,81); Limited human resources capacity in predictive data management (F:1) (Cκ:0,96). | Intelligence (AI); Data Input Completeness. |
| [P7] Limited community participation in decision-making (freq = 15) | Community proposals ignored due to rigid agency priorities (F:4) (Cκ:0,85); Participation limited to issue identification, not decision-making (F:2) (Cκ:0,92); Public involvement lacks authority in the decision-making process (F:9) (Cκ:0,70). | Planning Vision & Mission with Collaborative Solution; Bottom-Up Planning; Decision Making. |
| [P8] Manual field monitoring (freq = 3) | Water level monitoring is still performed manually in the field (F:3) (Cκ:0,91). | Data Input Completeness |
| [P9] Limitations of training activities (freq = 6) | Irregular training; limited to neighborhood officials (F:6) (Cκ:0,84). | Disaster Education |
| [P10] Social conflicts (freq = 5) | Public complaints regarding nighttime pump operational noise (F:4) (Cκ:0,91); Unilateral drain closures causing local conflicts and flooding (F:1) (Cκ:0,99) | Water Storage Automation; Infrastructure Maintenance. |

*Source: Author, 2026*

Findings reveal a critical misalignment between Surabaya's smart city ambitions and its empirical reality. Flood management remains highly path-dependent on fragmented policy directions and inadequate planning priorities (P1). This political volatility discourages investment and limits public participation to symbolic, top-down gestures. Furthermore, technological facilities and system adequacy (P2) lack sufficient automation for critical infrastructure. Consequently, this reliance on traditional, manual interventions exacerbates urban flood risks by delaying operational responses (Abd-Elaty et al., 2025). System integration levels (P4) present another major barrier due to isolated sectoral data. This fragmentation relies heavily on informal reporting mechanisms (P5), particularly WhatsApp, which causes communication bottlenecks (Khan et al., 2023; Yang et al., 2025). Additionally, limited data availability and completeness (P3) hinder the development of accurate predictive

models. These data deficits are worsened by persistent manual field monitoring (P8) that lacks automated sensor support. Non-technical impediments also significantly restrict the success of smart flood management systems. Specifically, human resource capacity (P6) struggles to adapt to advanced digital technologies like digital twins. This deficiency is compounded by irregular, localized training activities (P9) that lack long-term sustainability. Socially, community participation (P7) remains marginalized and is typically limited to simply reporting grievances. This exclusionary approach inevitably triggers social conflicts (P10) regarding uncoordinated and unilateral technical interventions.

Surabaya's smart flood management is operationally complex but remains heavily governed by centralized policy direction. The MICMAC mapping (**Table 4**) reveals an asymmetric structure anchored in policy coherence rather than distributed learning. Specifically, policy direction and planning priority (P1) emerges as the dominant first-order driver in the upper-left quadrant. These strategic variable dictates resource distribution, technological adoption, and inter-agency coordination across the entire governance chain. As observed in similar contexts, such policy coherence functions as the essential "governance spine" for smart urban performance (Choi & Song, 2022).

Surrounding this governance nucleus is a dense cluster of highly interdependent relay variables forming the operational core. Variables involving technological adequacy, data completeness, and system integration create a feedback-driven architecture where isolated deficiencies quickly destabilize the entire system. This configuration represents a relay-dominant subsystem that is functionally sophisticated but structurally fragmented and weakly synchronized (Godet, 2000). Furthermore, the complete absence of purely dependent variables indicates an interactive, non-linear network rather than a strict hierarchy. Such feedback-rich configurations are characteristic of adaptive governance systems that constantly balance top-down control with cross-sectoral responsiveness (Meadowcroft, 2011).

Conversely, community participation, training, and social conflicts currently reside in the excluded quadrant with merely peripheral systemic influence. However, these participatory and institutional learning factors hold latent potential to significantly enhance governance legitimacy and long-term effectiveness (Nordbeck et al., 2022; Hedelin, 2017). To bridge this gap, real-time IoT and digital application data must be integrated into community forums via citizen science mechanisms. Transforming digital systems from purely top-down monitoring tools into bottom-up feedback channels allows citizen-generated data to directly influence policy directions and budget allocations (P1, P7), enabling genuine co-decision-making (Mupfumira et al., 2024; Wessel et


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al., 2021). Ultimately, this mapping delineates a three-tier hierarchy comprising a strategic governance core, an operational relay cluster, and a peripheral social substrate. This pronounced vertical asymmetry demonstrates that Surabaya is still transitioning from technocratic management toward a truly adaptive model. Achieving genuinely participatory smart flood management requires horizontally activating these social variables to complement the existing vertical coordination.

**Table 4.** Asymmetric Structure of Surabaya Flood Risk Management

| Quadrant | Code | Obstacles & Problems | Driving Power | Dependence |
|---|---|---|---|---|
| **I** (Key Drivers) | P1 | Policy direction and planning priority | 4,85 | 2,10 |
| **II** Relay Variables | P2 | Technological facilities and system adequacy | 4,45 | 4,60 |
| | P3 | Data availability and completeness | 4,35 | 4,70 |
| | P4 | System integration level | 4,25 | 4,50 |
| | P5 | Information and reporting mechanisms | 4,10 | 4,40 |
| | P6 | Human resource capacity and quality | 3,95 | 4,25 |
| | P8 | Manual field monitoring | 3,90 | 4,00 |
| **III** Depending Variables | - | - | - | - |
| **IV** Excluded Variables | P7 | Limited community participation in decision-making | 2,30 | 2,20 |
| | P9 | Limitations of training activities | 2,15 | 2,05 |
| | P10 | Social conflicts | 2,00 | 2,10 |

*Source: Author, 2026*

To address existing operational gaps, a strategic roadmap is structured across smart city and participatory dimensions. This framework couples technological integration with collaborative decision-making mechanisms to achieve an adaptive flood risk management system.

**Table 5.** Strategic Roadmap for Smart Participatory Flood Risk Reduction

| Dimension | Baseline Gaps & Obstacles | Strategic Action & Target |
|---|---|---|
| **Smart City** | Fragmented agency apps, data silos, WA-based manual reporting, and low infrastructure automation. | Integrate digital platforms & automate infrastructure to establish a unified, real-time, and adaptive flood management system *(Target: Integrated System)* |
| **Participatory** | Consultation-only involvement, infrequent training, low HR capacity, and unmitigated social conflicts. | Institutionalize co-decision-making & citizen literacy to build an inclusive, community-driven mitigation framework (Target: Inclusive Governance). |

## CONCLUSION

Surabaya's smart flood risk management exhibits a critical structural imbalance, operating as a semi-closed, top-down system where social variables are weakly institutionalized despite strong policy drivers. MICMAC analysis indicates that policy direction is the primary systemic leverage point, dictating operational relay variables such as technological facilities, data completeness, system integration, and human resource capacities. Currently, public participation remains an excluded variable, largely consultative and peripheral to formal decision-making. This dynamic creates a governance framework that is technologically complex yet socially fragile, exposing a persistent gap between administrative capability and genuine citizen engagement.

To overcome these barriers, flood risk management must transition from a technology-driven approach to a learning-based, adaptive governance model. This shift demands strategic policy frameworks linking digital systems and inter-agency interoperability with inclusive participatory mandates. Institutionalizing co-production mechanisms and accessible digital platforms will activate latent social enablers and leverage community-based knowledge. Aligning these technological and social dimensions within a unified policy framework is crucial to transforming fragmented smart city initiatives into an inclusive, sustainable resilience system.

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# ENHANCING URBAN RESILIENCE THROUGH SOCIAL VALUE: THE EMOTIONAL ATTACHMENT OF COMMUNITIES TO TUNJUNGAN'S HISTORIC BUILDINGS

**Bambang Soemardiono[1*], Khusnul Hanifati[2], Fardilla Rizqiyah[3], Purwanita Setijanti[4], Shafira Zulfa Audina[5], Izzah Desta Bastian Ramadhani[6]**

[1,2,3,4,5,6] *Department of Architecture,*
INSTITUT TEKNOLOGI SEPULUH NOPEMBER SURABAYA

## Abstract

The idea of community attachment towards a particular place can be viewed from the perspective of social values. In this case, it plays an important role for heritage conservation and urban resilience. Tunjungan, a city center area in Surabaya, Indonesia, has been categorized as a conservation area containing many significant historical buildings such as Siola, Majapahit Hotel, Locaahands Cafe, and Tanjung Anom Corridor. These buildings have not only been categorized as having historical, architectural, and artistic significance but also contain a high social value which stands for a tie to the people in the area and identity of the city. This study aims at understanding how social value operates within the framework of urban resilience, and more specifically in the context of the impacts of globalization and urban pressure. To better understand stakeholders' emotional connections to specific buildings, this study employed a qualitative intersubjective approach through spatial walkthroughs, focus group discussions (FGDs), and in-depth interviews. Johnston's framework was applied to map community emotional attachment and identify social value characteristics along Jalan Tunjungan. The findings indicate that buildings with strong historical narratives and ties to personal and collective experiences generate higher emotional attachment. Collective memory, routine activities, spatial experiences, and adaptive building functions collectively shape social values in this historic corridor, reinforcing community engagement and attachment. The study concludes that integrating social value into conservation and management strategies is essential for preserving the unique character and resilience of historic areas like Tunjungan, ensuring their sustainability for future generations.

***Keywords***: Social value, Urban Resilience, Conservation, Historic Building, Tunjungan

[1] Corresponding author. Email: bamsoem16@gmail.com

## INTRODUCTION

The development of cities will inevitably face obstacles from social change, economic pressures, and changes in urban space. Numerous phenomena such as pandemics, natural disasters, and terrorism, constitute constant threats to the sustainability of the urban environment (Glaeser, 2021). The idea of urban resilience, which aims to protect urban areas without compromising their intrinsic values, developed out of these challenges. Ribeiro (2019) defined urban resilience as the city's ability to withstand and absorb shocks, minimize the impacts of disturbances, adapt to changing conditions, and proactively transform structures that constrain present or future adaptive capacity. This study further categorizes five dimensions that support urban resilience which are the natural, economic, social, physical, and institutional dimensions. To achieve urban resilience, cultural heritage areas constitute a crucial factor due to its role as a key driver of citizen engagement grounded in the idea of the common good, as well as their contribution to social, environmental, economic, and governance innovation (Fabbricatti, et al, 2020).

According to Indonesian regulation as stipulated in Law No. 11 of 2010, a cultural heritage area is defined as a site or location that contains cultural heritage objects. Heritage areas are an essential component of the urban structure, yet they are vulnerable because they have to sustain the historical values that have been deeply rooted in the area while also adapting to the dynamics of an ever-changing urban context. According to the Burra Charter in Soemardiono et al. (2025) heritage areas as places with cultural significance are characterized by aesthetic, historic, scientific and social values. However, economic, physical, and regulatory reasons continue to dominate approaches to the concept of urban resilience in heritage context, ignoring social aspects, especially social value. The lack of attention to social values in an area can weaken its role as a meaningful living space for the community and reduce its capacity to support the city's social resilience.

Social value is an essential concept that may be applied to comprehend the link between communities and heritage areas. Johnston (2023) defines social value as a strong bond that is developed through social, cultural, and spiritual factors between a place and its community. This attribute has to do with an area's capacity to uphold cultural customs that have been passed down through the generations and retain the collective memory of its people (Ramadhani et al., 2026). Furthermore, the concept of social value emphasizes the importance of an area as a marker of a community's identity and as an emotional attachment formed through the daily use of a certain location. Both tangible components, like buildings and the activities that take place within them, and intangible components, like knowledge, customs, traditions, and cultural obligations, can contribute to the formation of this social value. In order to preserve the

sustainability of the relationship between the area and the community that has been established, community involvement becomes a crucial component of the concept of social value in the management of a heritage area, which involves hearing directly how the area is needed and what it means to them.

The concept of social value has been developed in various studies. Johnston (1992) outlines ten criteria for places that contain social value, including collective/shared value, public places, experience-based, only known by those who value the place, provide community grounding, sense of ownership of the place as our heritage, culturally sensitive, contemporary, emotional attachment, and sense of personal loss if the place is damaged. Social value and historical value have a strong relationship despite their different characteristics. This strong relationship can arise alongside changes in meaning that are collectively constructed by the local community. In line with this, Torrieri et al. (2021) emphasizes social value through a people-based approach and community mapping as a means to encourage community involvement in heritage area planning. Jones (2017) also emphasizes that social value encompasses the meaning of heritage areas for communities that are fluid and formed through social practices, including people's sense of identity, belonging, and place, as well as forms of memory and spiritual association. Meanwhile, Rossitti et al. (2025) identifies various domains of knowledge in the study of social value, including official heritage doctrine, conservation debate, economic evaluation, cultural heritage economy, and critical heritage studies, which then give rise to nine attributes of social value, which are aesthetic, educational, historical, memory, reference, safety, and cultural.

According to this approach, historic corridors can be viewed as social resilience laboratories where memory, activity, and urban identity can interact in a dynamic way. As one of Indonesia’s metropolitan cities, historical corridors in the center of Surabaya, such as Jalan Tunjungan, are surrounded by intensive urban development, especially the cultural industry infrastructure (Nugroho et al., 2026). This condition is consistent with the characteristics of metropolitan areas, which are commonly associated with tremendous spatial growth driven by economic pressures and global economic competition (Dadashpoor, et al,., 2023). The government-led revitalization program has restored the vitality of Jalan Tunjungan, a corridor designated as a cultural heritage area in 1998. The high level of visitor euphoria has activated public spaces and transformed Tunjungan into a heritage tourism destination with diverse multisensory experiences (Bayu Sutjipto & Subiyantoro, 2023; Mahendra et al., 2026). However, its location in the city center renders it vulnerable to changes that are not aligned with conservation principles. Based on historical significance as one of Surabaya's heritage areas and its function as a public place, commercial corridor, and symbol of urban identity, the Jalan Tunjungan corridor was selected as a case study.


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Previous studies that integrated heritage conservation and urban resilience conducted through various approaches such as physical (Harbiankova et al., 2023; Teklemariam, 2024), economic (Naheed & Shooshtarian, 2022; Noaime & Alnaim, 2025) and tourism (Kalla & Metaxas, 2024; Moser et al., 2024). Moreover, Fabbricatti's (2020) study has examined human involvement and community engagement in the management of heritage conservation toward urban resilience; however, the exploration of social values remains limited. Thus, this study uses the Jalan Tunjungan case study to investigate how social values contribute to urban social resilience in a heritage context. Employing qualitative methods, this study will identify buildings along Jalan Tunjungan with emotional attachment using street pictures and explore people's perception on how Johnston's (2023) framework is perceived in socially valued places in Tunjungan.

## METHODOLOGY

A qualitative methodology with an intersubjective framework was conducted in this research to investigate its socio-cultural dimensions (Groat & Wang, 2013). In order to obtain a comprehensive interpretation, Jalan Tunjungan was chosen as a single study case. Located in the city center of Surabaya, Indonesia (see Figure 1), Jalan Tunjungan is a 700-meter-long road corridor that has been designated a cultural heritage site since 1998 due to its historical role and value (Surabaya City Government, 1998). Jalan Tunjungan has experienced fluctuating vitality from the Dutch colonial period to the present. After declining in the early 2000s due to the growth of superblock malls, the corridor was revitalized by the end of 2021. These changes make Jalan Tunjungan a relevant case for examining urban resilience.

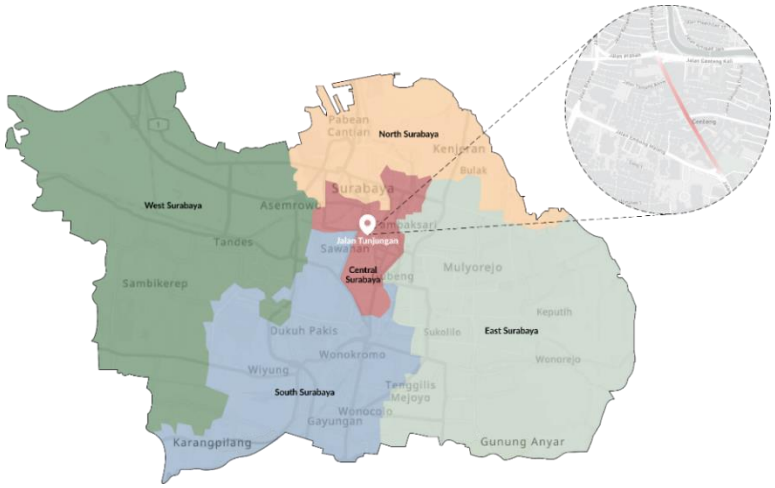



**Figure 1**: Jalan Tunjungan location
*Source: Researcher, 2026*

This study employed several data collection tactics, such as walkthrough and in-depth interviews, which were integrated into a Focus Group Discussion (FGD). The FGD was attended by twelve participants selected through purposive sampling to ensure adequate representation of stakeholders in Jalan Tunjungan (see Table 1). As a heritage tourism area, the economic interests, local community, and street users must be taken into account by experts, academics, and the government. The representation of these various interests was designed to enhance diverse perspectives and information.

**Table 1**. Participants' profile

| Participant | Code | Professional Background |
|---|---|---|
| Participant 1 | P1 | Business Owner |
| Participant 2 | P2 | Urban Expert |
| Participant 3 | P3 | Academician |
| Participant 4 | P4 | Urban Expert |
| Participant 5 | P5 | Urban Expert |
| Participant 6 | P6 | Community Member |
| Participant 7 | P7 | Government Employee |
| Participant 8 | P8 | Street User, Urban Expert |
| Participant 9 | P9 | Government Employee |
| Participant 10 | P10 | Architect |
| Participant 11 | P11 | Business Owner, Journalist |
| Participant 12 | P12 | Street User |

*Source: Researcher, 2026*

A modified spatial walkthrough that uses architectural drawing as a mediating tool was conducted (Chafi & Cobaleda-Cordero, 2022). During this phase, the research team prepared a street picture that captured all of the building facades along Jalan Tunjungan in a single straight line. The participants then asked to put stickers on the buildings with which they had an emotional attachment. There were three stickers of different colors representing level of


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attachment scores: red for buildings with high emotional attachment (3 points), blue for moderate emotional attachment (2 points), and yellow for low emotional attachment (1 points). Buildings that did not receive stickers were buildings with no emotional attachment at all. The mean values obtained for each building then classified (see Table 2.). Thus, the classifications were displayed on color-coded street picture graphics.

**Table 2**. Building scoring

| Score | Classification | Color Code |
|---|---|---|
| 0.00 - 0.67 | High Emotional Attachment Building | Red |
| 0.68 - 1.34 | Moderate Emotional Attachment Building | Blue |
| 1.35 - 2.00 | LowEmotional Attachment Building | Yellow |

*Source: Researcher, 2026*

Furthermore, an in-depth interview using open-ended questions were conducted to explore participants' thoughts, emotions, and narrative understanding (Chand, 2025). Six of the twelve participants were selected based on their expertise for further exploration of their perceptions of social value on Jalan Tunjungan. The data obtained was processed using thematic analysis with coding to identify patterns and main themes (Creswell, 2013). Combined with representative visuals, the results are presented in a descriptive-narrative approach to explain the role of social value in urban resilience within the heritage corridor.

## RESULT AND DISCUSSION

In this section, the results and discussions were addressed in two subsections that sequentially identify the level of attachment to the buildings on Jalan Tunjungan and the exploration of participants' perceptions about building characteristics with social value. Hence, the discussion focuses on the role of social value as the basis for the resilience of historic areas.

### Level of Attachment in Jalan Tunjungan Buildings

The street picture depicting the level of emotional attachment to the buildings on Jalan Tunjungan is divided into four segments. Segment 1 spans from the Siola to the Tiger Ergonomic Chair Office which is next to the Genteng intersection (see the distribution graphic in Figure 2). From twelve buildings along the segment, Siola became the building with the highest level of emotional attachment (M=2.00), followed by Gading Murni Bookstore (M=0.75) within the

moderate attachment category. As one of the historic buildings that serves as a landmark along the Tunjungan, 8 out of 12 participants chose Siola as the building with which they felt the strongest emotional connection in the corridor. Other buildings such as Tunjungan Electronic Center, Platinum Hotel, and Optik Seiss, categorized as low attachment buildings with overall mean score below 0.67.



**Figure 2**: Street picture of Tunjungan Street, Segment 1
*Source: Researcher, 2026*

The second segment spans from Locaahands to the Excelso and Sentral Tunjungan complexes at the end of Jalan Tunjungan (see the distribution graphic in Figure 3). Two iconic buildings are categorized as the high emotional attachment buildings, which are Locaahands (M=1.75) and Majapahit Hotel (M=1.42). Furthermore, Varna Hotel (M=0.75), MAJ Restaurant (M=0.75), and Indigo Restaurant (M=0.83) were selected by participants as buildings with moderate emotional attachment category. Nine other buildings in this segment are categorized as low emotional attachment buildings.



**Figure 3**: Street picture of Tunjungan Street, Segment 2
*Source: Researcher, 2026*

Segment 3 is located on the western side of Tunjungan Street, which stretches from the Press Monument to the 7-Stars Restaurant (see the distribution graphic in Figure 4). Of the 21 buildings in this segment, only Rabo Bank fits into the moderate emotional attachment category (M=0.75). Other buildings such as Pasar Tunjungan, Klub Breakfast, Gelateria, and Indomaret Point were categorized as low emotional attachment buildings with overall mean values below 0.67. This segment features many types of shophouses that have been reused with different functions.


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**Figure 4**: Street picture of Tunjungan Street, Segment 3
*Source: Researcher, 2026*

The fourth segment spans from Toko Kopi Padma to the former unoccupied Louvre building at the end of the street (see the distribution graphic in Figure 5). Toko Kopi Padma (M=0.83) and Ludic (M=0.75), where both repurpose old buildings as cafes were selected by participants as buildings with moderate emotional attachment. Tanjung Anom Corridor, however, was categorized into the high emotional attachment buildings (M=1.58), with 7 out of 12 participants selecting it. Nineteen other buildings, such as Bank BCA, Wizzmie, and Taman Gantung, categorized into the low emotional attachment buildings (M=<0.67).



**Figure 5**: Street picture of Tunjungan Street, Segment 4
*Source: Researcher, 2026*

Emotional attachment is one of the criteria for places with social value in Johnston's (1992) preliminary research. Emphasized by Johnston's latest research (2023), attachment in socially valued places is a strong connection feeling that gives meaning to people's lives. The emotional attachment experienced by people to a specific place can further develop a place attachment (Inalhan et al., 2021).

Based on street pictures and emotional attachment mapping, buildings marked in red with high emotional attachment, such as Siola and Majapahit Hotel, are officially designated as cultural heritage buildings. These buildings have strong historical narratives related to Surabaya residents' battle to defend their independence, which are well known to the community. Furthermore, buildings marked in blue with moderate emotional attachment, such as Varna Hotel and Toko Kopi Padma (former: Tjantik Shoe House), are old but lack a strong historical narrative, while buildings marked in yellow with low emotional attachment are buildings with little-known identities. This finding indicates a

connection between participants' emotional attachment and three other aspects of Johnston's (1992) place criteria, which are collective-shared value, community grounding, and sense of heritage ownership.

Furthermore, the connection above puts emotional attachment as a contributing aspect to the urban resilience of Jalan Tunjungan. The presence of high emotional attachment buildings functioning as a social safeguard that strengthens the area's capacity to withstand and recover from disruptive pressures such as commercial redevelopment. These findings are consistent with Tilaki's (2025) research, which considers emotional attachment as the community's foundation to maintain their collective identity, encourage active participation, and develop coping mechanisms in time of disruptions. However, this resilience-building capacity is not evenly distributed. Buildings with low emotional attachment and less-recognized historical identities are less likely to attract protective attention, making them more vulnerable to loss without eliciting collective concern.

**Social Value Characteristics of Tunjungan Street Buildings**

Following nearly two decades of commercial decline, the revitalization program implemented on Jalan Tunjungan in 2021 marked a renewed phase of activity along the historic corridor. Through in-depth interviews with six participants representing the roles of business owners, academicians, urban observers, journalists, residents, and street users, the social value characteristics of Tunjungan Road were further explored based on Johnston's (1992). Table 3 provides Creswell's (2013) thematic analysis process including participants' statements, codes, categories, and themes.

**Table 3**. Thematic analysis process of in-depth interviews

| Participant | Representative Statement | Code | Category | Theme |
|---|---|---|---|---|
| P3 | "There are more young people walking around now... It's more colorful than before." | Revitalization increases attractiveness | Perception & Experience | Experience-based |
| P4 | "Starting from taking photos, creating content, pre-wedding... a gathering center, socializing for the people of Surabaya." | Multifunctional public space | | |
| P4 | "It gives a dirty impression, sometimes friends who stop by there leave their drinking cups lying around." | Dirty/incidental impressions interfere with the experience | | |


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| Participant | Representative Statement | Code | Category | Theme |
|---|---|---|---|---|
| P4 | "The future of Tunjungan, as is but good. That's life, huh." | Hope to maintain the character of the area | | |
| P4 | "It's very easy... so it's not totally close." | Easy access from various circles | Accessibility | |
| P1 | "The only obstacle is that parking is a bit difficult." | Parking problems | | |
| P3 | "Public transportation is still not available... the transportation that used to be available is now only available at a few locations." | Public transportation is underdeveloped | | |
| P1 | "If it could be maximized like Malioboro, the road would really be reduced." | Vehicular access - vehicle space dominance | | |
| P4 | "My childhood ended there... That is my memory." | Personal memory / childhood nostalgia | Emotional Connection | Emotional Attachment & Identity |
| P2 | "The most memorable was at the Majapahit Hotel because there was a history of the flag tearing." | Historical/ heritage value of the building | Heritage & Identity Value | |
| P5 | "We have references from our experiences of working there... we have an imagination about the building." | The social value of collective experience & imagination | | |
| P1 | "Even though there is a change in function, its social value is still maintained." | Changes in function do not eliminate social value | | |
| P1 | "It depends on the value of the building itself... how we can increase the value of the building." | Building value = adapted utility | | |
| P4 | "It's sad, but on the one hand I have to understand because those buildings are privately owned." | Loss of building = loss of social marker | | |
| P4 | "Enforcement of regulations regarding the protection of cultural heritage buildings... is very weak." | Weak protection of cultural heritage buildings | | |

| Participant | Representative Statement | Code | Category | Theme |
|---|---|---|---|---|
| P5 | "For example, if I go to the Siola office, I don't have to take care of my ID card... but I just want to play." | Open access of buildings to the public is important | | |
| P1 | "Not yet for residents. Because interaction between residents... that's not yet." | There is still not enough space for local residents to interact | Social Interaction | Social Life in Public Space (Social Interaction) |
| P5 | "The image must be ready with money for food, drink... the community is different from the one gathered." | Visitor segmentation based on economy | | |
| P4 | "There are several sections that provide space for MSMEs to display their products." | Space for MSMEs/local business actors is available | | |
| P3 | "There's still a lack of things like public toilets or something, places for people to sit." | Lack of free public facilities (seating, toilets) | | |
| P1 | "There are a lot of chairs in front of the restaurant. There's a lot of overlap between the restaurants." | Conflict over sidewalk use by restaurants/ street vendors | Public Space Amenities | Public Space & Facilities (Public Space Amenities) |
| P3 | "Not enough. Because it's cleaned in the morning, but there's nothing in the afternoon." | Cleanliness is not consistent | | |
| P2 | "What makes it less neat is the abandoned building." | Abandoned buildings reduce visual neatness | | |
| P1 | "Does a building have to be visible from the street?... we can enjoy the proportions of the building when we are walking." | Vegetation vs. building visibility trade-off | | |
| P5 | "It's not free, like for example, if you go to Bungkul, you can just hang out in the main area." | Facilities improvement - less spacious space compared to city parks | | |
| P1 | "Yeah, most likely to the cafe... straight to the destination." | Main activities: hanging out/ culinary at cafes | User Activity | |


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| Participant | Representative Statement | Code | Category | Theme |
|---|---|---|---|---|
| P6 | "Pick up and drop off my grandchildren at the high school complex." | Non-tourist routine activities (personal/ family needs) | | |
| P6 | "Collaboration between Traditional and Colonial buildings." | Collaboration of traditional & colonial buildings | Design & Planning | |
| P1 | "It's safe, because Jalan Tunjungan is already segmented." | Feel safe because the area is segmented/ known | Safety & Comfort | Safety & Comfort |
| P2 | "It's safe, but if it's crowded it could be unsafe." | Be wary of crowds/ unknown people | | |
| P4 | "The needs of people with disabilities are still lacking... the height of the sidewalks, oh my, are not up to standard." | Facilities for the disabled are still minimal | | |
| P1 | "Its function is still a friction between those who hope for the slow lane and those who hope for the fast lane." | Fast lane vs slow lane conflict | | |
| P5 | "At least people are sure that this is being monitored by security." | The need for visible security/ regulating officers | | |
| P3 | "Income has had a huge impact from the past to the present... the impact is good." | Positive impact on business income | Economic Value | Economic & Governance Values |
| P3 | "If local economic growth is still lacking, yes." | Local economic benefits are still limited | | |
| P4 | "Sometimes such activities are just a formality." | Public participation is often just a formality | Governance & Participation | |
| P4 | "Still don't feel attached to Tunjungan." | The residents of the surrounding villages do not feel they have any ownership. | | |
| P5 | "This value must be applied in other areas." | Tunjungan as a replicable model | | |

| Participant | Representative Statement | Code | Category | Theme |
|---|---|---|---|---|
| P6 | "Maintain order and order in pedestrian and highway areas." | Participation is interpreted as maintaining order | | |

*Source: Researcher, 2026*

In order to explore a comprehensive understanding of the social values' natures identified during the initial coding phase, these findings were further analyzed using Johnston's (1992) ten criteria for social value. Table 4 shows the mapping between the codes obtained from the initial coding and Johnston's criteria. Frequencies are displayed to identify patterns and preferences of each participant.

**Table 4.** Coding matrix according Johnston's criteria

| Social value's criteria | Codes | Category | Frequency |
|---|---|---|---|
| Collective or shared value | The social value of collective experience & imagination | Social Value of Buildings | 2 |
| | Multifunctional public space | Perception & Experience | 3 |
| Public places | Easy access from various circles | Accessibility & Connectivity | 1 |
| | Multifunctional public space | Perception & Experience | 3 |
| Experience-based | Revitalization increases attractiveness | Perception & Experience | 4 |
| | Multifunctional public space | | 3 |
| | Dirty/incidental impressions interfere with the experience | | 1 |
| | Hope to maintain the character of the area | | 1 |


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| Social value's criteria | Codes | Category | Frequency |
|---|---|---|---|
| Only known by those who value the place | Feeling safe because the area is segmented/known (insider knowledge) | Safety & Comfort | 2 |
| Provide community grounding | Non-tourist routine activities (personal/family needs) | User Activities & Facilities | 1 |
| Sense of ownership place as our heritage | The residents of the surrounding villages do not yet feel they own it (in contrast to the symbol of the city's struggle) | Community Engagement & Participation | 1 |
| Culturally sensitive | Historical/heritage value of buildings related to national events | Social Value of Buildings | 3 |
| Contemporary | Building value = adapted utility | Social Value of Buildings | 1 |
| | Changes in function do not eliminate social value | | 2 |
| Emotional attachment | Emotional attachment/childhood nostalgia | Social Value of Buildings | 2 |
| Sense of personal loss if place damaged | Loss of building = loss of social marker | Social Value of Buildings | 2 |

*Source: Researcher, 2026*

The initial themes in Table 3 were identified and aligned with Johnston's (1992) criteria (see Table 4). The experience-based aspect emerged as the criterion with the highest perceived frequency among participants. Among the other three codes, the revitalization process turns out to become the point of attraction to the participants, followed by multifunctional public spaces. Collective or shared value criteria ranked second in frequency, as the presence of buildings along Jalan Tunjungan is linked to the nation's history and personal experience from the past. These two criteria are reflected in the buildings that are

categorized as high emotional attachment in the previous subsection, such as Siola and the Majapahit Hotel, which played key roles in the Battle of Surabaya.

From the coding matrix in Table 4, the multifunctional public space' code is consistently mentioned in three different criteria contexts and refers to the presence of the Siola building. As the building with the highest mean value (M=2.00), Siola simultaneously embodies collective value, public places, and experience-based elements on Jalan Tunjungan. At the corridor scale, the use of Jalan Tunjungan as a public space is supported by various facilities, including street furniture, shading trees, and pedestrian ways. Nevertheless, participants expressed the expectation that the public space could be further enhanced to foster broader social interactions between visitors and local residents, without the necessity of engaging with commercial tenants along Jalan Tunjungan.

The next frequent criteria are contemporary and culturally sensitive. The contemporary criterion is closely linked to the revitalization programs implemented by the government, where the adaptive reuse approach to historic buildings has generated numerous tourist attractions. It further draws crowds, aesthetic photography spots, and informal hangout activities which leads to the new function without eliminating the social values. While the culturally sensitive criterion related to the building's national history, the key buildings such as Siola and Majapahit Hotel once again referred.

Emotional attachment emerged at the same frequency as sense of personal loss and only known by those who value the place criteria. Three of them are closely associated with personal memories and buildings that hold particular significance for the participants. Tanjung Anom, one of the high emotional attachment objects, is associated with childhood memories that continue to resonate with participants to this day. As stakeholders with an interest in Jalan Tunjungan, the participants are well aware of the value of each building, whether related to architectural styles, abandoned buildings, or the street value. Although not as well-known as Siola and the Majapahit Hotel, the building currently occupied by Locaahands is categorized into a high emotional attachment building due to its significant architectural value. In the context of a sense of personal loss, negative emotions, such as sadness and reluctance, emerged when participants were asked to express their feelings should the buildings along Jalan Tunjungan be lost or destroyed in the future.

This condition leads to a desire to preserve these buildings in accordance with conservation principles, which forms part of the aspect of sense of ownership of the place as our heritage. Participants also anticipate that the appropriate authorities will pay greater attention to maintaining these buildings, especially since some of them are currently abandoned. These abandoned structures could harm the corridor's attractiveness if nothing is done. To conclude, the need for non-tourist activities along Jalan Tunjungan is also present for the


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locals to provide a community grounding. Recognizing and appreciating social value in the context of heritage corridors promotes community involvement in conservation planning, execution, and assessment. Participation fosters a sense of accountability, unity, and preservation sustainability (Liang et al., 2022). Considering the interests and opinions of both locals and tourists, social values help in striking a balance between tourism marketing and heritage preservation (Parga-Dans et al., 2020).

This pattern shows that the frequency of a code's occurrence is not always directly proportional to the level of a building's attachment value. Siola and Hotel Majapahit represent collective social values that are often explicitly articulated by various participants, whereas Locaahands and Tanjung Anom represent social values that are more personal, hidden, and deeply understood only by specific groups with a direct history tied to those places. This combination enriches our understanding of how Johnston's (1992) criteria manifest differently in the context of a multidimensional urban heritage public area such as Jalan Tunjungan. Additionally, incorporating social values into the management of heritage corridors increases community attachment to and ownership of the area, which eventually promotes urban vitality (Audina & Nugroho, 2026). Heritage corridors serve as both cultural assets and adaptable locations that may sustainably respond to social, economic, and tourism developments when heritage preservation is in line with local demands and social practices.

Social values play a key role in shaping urban resilience, especially in the context of heritage area preservation. Urban resilience depends not only on the quality of physical infrastructure, but also on the strength of social networks, collective memory, and the values that bind communities to their historic spaces. In order to prevent top-down preservation, social values in heritage areas promote community involvement in the conservation, functional adaptation, and space management procedures. Furthermore, social values support inclusive urban governance and social innovation, which help heritage sites adjust to the demands of urbanization, tourism, and economic development while preserving local identity and long-term sustainability (Feinberg et al., 2023).

## CONCLUSION

This study demonstrates that social value plays a critical role in strengthening urban resilience within historic corridors, as evidenced by the case of Jalan Tunjungan in Surabaya. The findings reveal that buildings with strong historical narratives, collective memory, and continuous everyday use generate higher levels of emotional attachment among community stakeholders. Social value in Tunjungan is mainly characterized by experience-based, public space, emotional attachment, value that is only known by those who valued the place and

contemporary aspect. It emerges as key dimensions that connect communities to heritage buildings, fostering a desire to protect and sustain them. These socially embedded meanings enhance the corridor's capacity to adapt to urban pressures while maintaining its cultural significance, thereby positioning social value as a foundational component of urban social resilience alongside physical and economic dimensions.

Building on these findings, four policy directions are recommended: adaptive reuse control that safeguards the legibility, public accessibility, and street-level presence of buildings rather than merely restricting functional change; public realm management treated as an instrument of conservation, given that attachment is largely produced on the sidewalk; community heritage mapping to record values known only to those who use the place, extended to residents of adjacent kampungs; and social-value-based conservation review embedded in existing assessment procedures, so that unlisted buildings and corridor-scale units with demonstrated attachment are also evaluated. Further studies could expand the scope by combining qualitative social value assessments with quantitative resilience indicators to provide a more comprehensive evaluation of heritage-led urban resilience. In addition, long-term monitoring of social value dynamics is needed to understand how emotional attachment evolves amid tourism growth, commercialization, and infrastructural change. By embedding social value within conservation policies, historic corridors such as Jalan Tunjungan can function not only as preserved cultural assets, but also as resilient, inclusive, and adaptive urban spaces for future generations.

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# GEOTECHNICAL RISK ASSESSMENT OF SUBSURFACE CAVITIES IN LIMESTONE FORMATIONS USING 2D ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT) FOR INFRASTRUCTURE DEVELOPMENT IN KAMPAR, PERAK DARUL RIDZUAN, MALAYSIA

**Audra Irlyssa Irwan[1], Noor Halizah Abdullah[2*], Saidatul Nadirah Amir[3]**

[1,2]*School of Housing, Building and Planning,*
UNIVERSITI SAINS MALAYSIA
[3]*Geophysics, AMT Geo Services, No. 33-1, Jalan 4/11A, Persiaran Bangi, Bandar Baru Bangi, 43650 Bangi, Selangor Darul Ehsan, Malaysia*

## Abstract

Subsurface cavities in limestone formations poses hazardous risks to infrastructure from sudden ground movement, subsidence, and structural failure. These cavities form mainly from natural dissolution of carbonate rocks. Traditional methods like borehole drilling are costly, limited in resolution, and require many boreholes to cover large areas. To address this, the utilisation of 2D Electrical Resistivity Tomography (ERT) as a non-invasive geophysical technique to investigate potential subsurface voids at a proposed site in Taman Bandar Baru, Mukim Kampar, Daerah Kampar, Perak Darul Ridzuan, Malaysia. Three survey profiles (L-1,L-2, L-3) were conducted using a dipole-dipole array, and data were analysed with RES2DInv software to produce subsurface resistivity profiles. Geological formations identified through resistivity ranges revealed weakly consolidated soils, weathered or fractured limestone bedrock, and water-filled cavities, all indicating potential instability. A risk matrix applied to each profile confirmed that zones with groundwater activity and voids pose a high collapse risk to surface layers. The study highlights the value of early ERT and geotechnical risk assessments for guiding mitigation strategies, recommending continuous monitoring, adapted designs, and best practices to reduce hazards.

***Keywords***: electrical resistivity, geotechnical risk assessment, limestone formations, RES2DInv, subsurface cavities

[2] Corresponding author. Email: nhalizah@usm.my

## INTRODUCTION

Subsurface cavities in limestone formations pose significant hazards to infrastructure development, particularly in karst environments where dissolution of carbonate rocks by acidic groundwater creates sinkholes, voids, and underground channels (Zhang et al., 2018; Zhao & Shen, 2022). Human activities such as uncontrolled construction and urban drainage further accelerate cavity formation, making early detection critical. Traditional detection methods such as borehole drilling are costly, time-consuming, and limited in spatial coverage (Hossain et al., 2018; Estrada-Medina et al., 2012).

Electrical Resistivity Tomography (ERT) offers a non-invasive and cost-effective alternative for subsurface mapping. The technique injects electrical current into the ground via source electrodes and measures the resulting voltage difference, producing apparent resistivity values that are then converted into real resistivity using inverse modelling (Vanella et al., 2022). This enables identification and description of subsurface voids, alerting engineers to potential threats such as ground collapse and groundwater intrusion. ERT is particularly effective in water-rich soils due to their higher conductivity, making it advantageous for locating water tables and monitoring moisture changes (Vanella et al., 2021; Innocenti et al., 2024). It has been widely applied in civil engineering, hydrological studies (Paz et al., 2020), and environmental assessments (Abdul Rahman et al., 2016).

The main objective of this study is to evaluate the geotechnical risks of subsurface cavities in limestone formations using 2D ERT for infrastructure development in Kampar, Perak. Specifically, the study aims to: (1) identify the location of subsurface cavities using 2D ERT, (2) classify cavity risks using a geotechnical risk assessment framework, and (3) evaluate the potential hazards posed by these cavities on infrastructure development.

## MATERIALS AND METHOD

This research was conducted in Taman Bandar Baru, Mukim Kampar, Daerah Kampar, Perak Darul Ridzuan, Malaysia. Figure 1 presents the location of the survey area. The mean elevation of the point above the mean sea level of the survey site is 205.00 m and located at approximate coordinates 4.323265 N and 101.146431 E.


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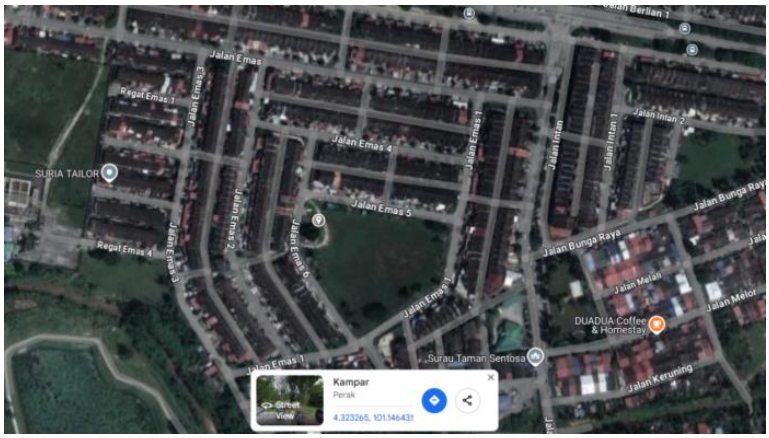



**Figure 1**. Location of the study area.

## Regional Geology

Figure 2 shows the ground beneath the survey site constitutes a thick underburden of limestone. Geologically, Kampar, in the state of Perak, Malaysia consists mainly of areas of limestone dating back to the Devonian age (Metcalfe, 2023).

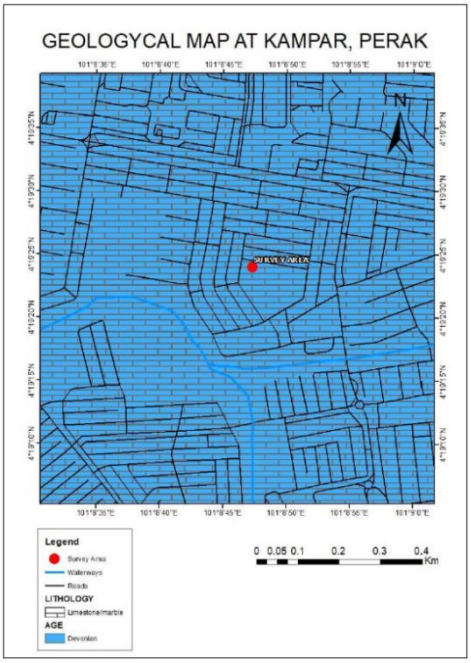



**Figure 2**. Geological map of Kampar, Perak Darul Ridzuan, Malaysia
(Department of Mineral and Geoscience Malaysia (JMG), 2013).

The Devonian limestone in Kampar is especially famous for its quality assemblage of fossils, both conodonts and various marine organisms, for paleo-environmental and evolutionary studies (Hassan, 2021). These limestones are very soluble. Hence, during long-term dissolution with acidic water, they can form characteristic karstic features such as sinkholes, caves, and underground rivers. This results from more prolonged exposure of limestone to acidic water, and the dissolution of the rock takes place more slowly in most natural environments examining over geologic time.

Geological studies has also shown the presence of the Kampar limestone overlain by alluvial materials composed of layer s of relatively younger sedimentary material. This stratigraphy has important implications for groundwater flow dynamics and ground stability, particularly in urban environment where the natural geology may be disturbed.

**Field measurement**

This study was conducted using the ASTM D6431-99 (2010) standard, Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation. The electrical resistivity measurements were made with the ABEM Terrameter LS2 equipment (Figure 3).

Two multicore cables were used in the measurement process, the method injects an electrical current into the ground with two current electrodes, C1 and C2, and then measures the resulting voltage difference at two potential electrodes, P1 and P2. Each cable contained electrodes spaced 2.50 m apart. This results in a 100.00 m total length of the measurement line, with a maximum depth of about 25.00 m.


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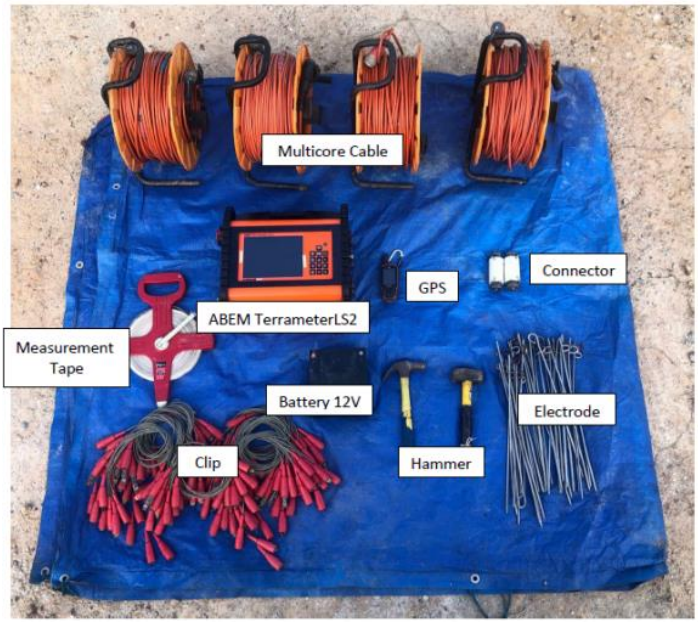



**Figure 3**. 2D Electrical Resistivity Tomography (ERT) equipment.

## Equipment and Electrode Configuration

The measurements of resistivity imaging were made with an ABEM Terrameter LS2, the electrode array was arranged in the dipole-dipole (DD) configuration. This configuration has a much deeper extent of coverage and generally gives superior data quality, especially when targeting subsurface features at moderate to greater depths. As shown in Figure 4, the dipole-dipole (DD) method is well recognised for the possibility to provide resistivity variation within a broad depth range and deliver actual data even when the geological structure of the site is difficult. It is very effective when greater depth penetration is needed since, for deeper layers, higher sensitivity of the change in resistivity appears, and it is indispensable for the full subsurface mapping. The technique optimises the performance of the dipole-dipole (DD) tool in providing high resolution resistivity images.

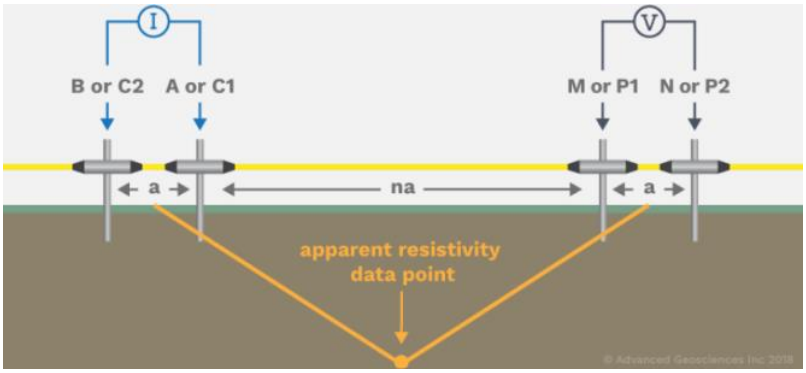



**Figure 4**. The arrangement of dipole-dipole (DD) array.

## Methods of Data Analysis

The on-site data are initially converted into .DAT file format using S4Kwin, a software interface for ABEM Terrameter LS2 that digitises field manual measurements for further processing tasks. This data conversion is then analysed using RES2DInv software to facilitate inversion data-processing, converting field obtained apparent resistivity to produce 2D ERT output models comprising of in-depth visualisation of subsurface anomalies. Inversion data are computed based on standard and modified algorithm, such as least-squares inversion.

The generated surface and cross-section resistivity model visualises areas of subsurface interest that are prominent with other geology of the study area. Detailed visualised resistivity output profiles on subsurface condition in specific coordinates are extracted and redrawn in CorelDRAW to improve the graphical quality of the sectioned resistivity data plots.

The first approach in geotechnical risk assessment employs qualitative methodologies, which rely on expert judgement, experience, and the categorisation of hazards to determine risk levels and propose mitigation strategies. The second approach involves quantitative risk assessment, employing mathematical modelling, probabilistic analysis, and numerical evaluations to calculate risk indices, prioritise hazards, and inform decision-making.

These approaches, whether used individually or combined, collectively aim to safeguard safety, optimise competitiveness, and ensure the prosperity of geotechnical engineering projects by systematically identifying, assessing, and managing uncertainties throughout geotechnical design and construction stages. Modern advanced data-processing and modelling tools, when integrated with structured methodologies for risk assessment in geotechnical engineering, facilitate a proactive and systematic approach for the successful management of evolving hazards and their consequences.


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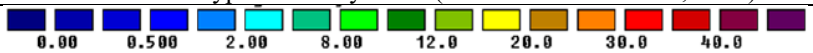
**Softwares**

The most commonly used inversion program for processing 2D ERT data is RES2DInv, which transforms apparent resistivities into a subsurface resistivity model that can be interpreted in terms of geological structure and features.

**Resistivity Value**

Resistivity values in the field typically range from 1.00 Ωm to 3,000.00 Ωm, and are classified by material type as summarised in Table 1 to guide interpretation of subsurface geological conditions.

**Table 1**.Rock type resistivity value (Keller & Frishcknecht, 1996).

|  | |
|---|---|
| < 100.00 Ωm | Geological formation that has a high conductivity value (Clay/Silt/Phylite)/Void |
| 20.00 Ωm – 150.00 Ωm | Geological formation that contained with groundwater |
| 100.00 Ωm – 1000.00 Ωm | Other geological formation / Weathered material |
| > 1000.00 Ωm | Dry sand/Compacted material/Rock (Granite/ Conglomerate/ Sandstone) |

**Geotechnical Risk Assessment**

Geotechnical risk assessment in this study integrates both qualitative and quantitative approaches, combining expert judgement with systematic identification of geological and hydrogeological hazard criteria as outlined in Table 2. It is crucial for the safety of civil engineering projects which it addresses uncertainties in subsurface soil and rock conditions using advanced methods involving geology, hydrogeology, etc. Futhermore, it also supports the identification and mitigation of geohazards by optimising the design compliance with standards to ensure the long-term sustainability and performance of structures such as foundations, retaining walls, and reinforced soil systems.

Table 2 revealed that geological factors such as the physical and structural properties of soil and rock were important in the risk of ground instability of the subsidence, collapse, and sinkhole. Groundwater, including its depth and fluctuations, was able to dissolve soluble rock, enable the formation of voids, reduce or remove support to overburden strata, and facilitate the possibility of collapse.

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**Table 2**: Resistivity value and conductivity of some rocks, soil, and groundwater.

| | Criteria | Risk Level | | | |
|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** |
| **Geology** | Depth to bedrock (m) | >15 | 10 - 15 | 5 - 10 | <5 |
| | Soil Raveling Potential | CH | NH/CL | SC/SM/ML | SP/SW |
| | Soil Desiccation Potential | SP/SW | SC/SM/ML | MH/CL | CH |
| | Potential for Boulders | - | No cap rock | Cap rock | - |
| | Fracturing of top 5m of Rock | Unfractured | Slightly Fractured | Moderate Fractured | Highly Fractured |
| | Voids and Fissures in Soil | - | No | - | Yes |
| | Depth of Void (m) | >15 | 10 - 15 | 5 - 10 | <5 |
| | Proximity of Voids (m) | >30 | 15 - 30 | 3 - 15 | <3 |
| | History of Sinkholes, within 30 m | - | - | - | Yes |
| | Bedrock Orientation | Horizontal | Slight dip | Moderate dip | Steep dip |
| **Groundwater** | Depth to Groundwater (m) | >15 | 10 - 15 | 5 - 10 | <5 |
| | Groundwater Pumping History | Never | Stopped | Deep | Shallow |
| | Groundwater Flow in Voids | >30 | 15 - 30 | 3 - 15 | <3 |

## ANALYSIS AND DISCUSSION

### Results

Based on Figure 5 shows the layout and configuration of the geophysical investigation in Taman Bandar Baru, Mukim Kampar, Daerah Kampar, Perak Darul Ridzuan, Malaysia. The ERT measurements were conducted using an ABEM Terrameter LS 2. The geophysical survey involved three parallel survey lines, labelled as L-1, L-2, and L-3, each extending 100.00 m in length. A total of five electrodes were installed in succession along each line at a uniform 25.00 m interval, starting at 0.00 m and ending at 100.00 m. The electrode array was arranged in the dipole-dipole (DD) configuration, it provides a greater depth of coverage, extending to depths of up to 25.00 m. Each electrode was positioned on a pre-marked to facilitate an exact spacing and alignment. A GPS unit was placed directly at the electrode location during electrode installation, and the corresponding geospatial coordinates were recorded in real-time.


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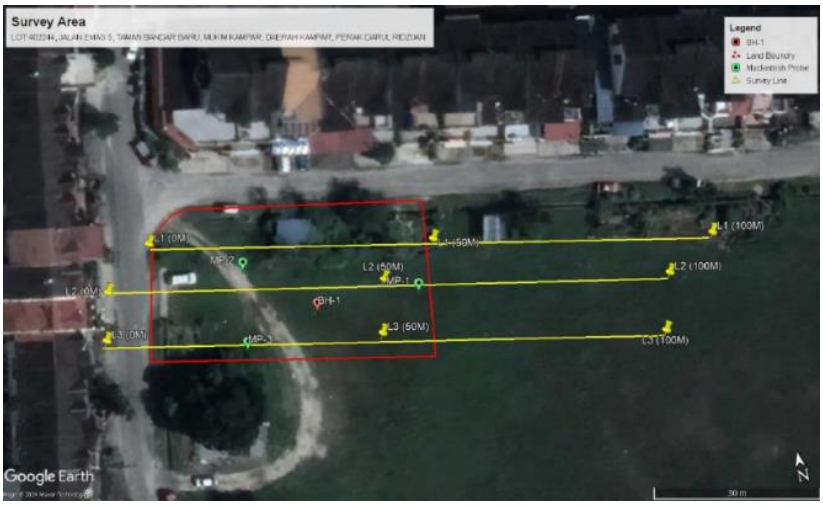
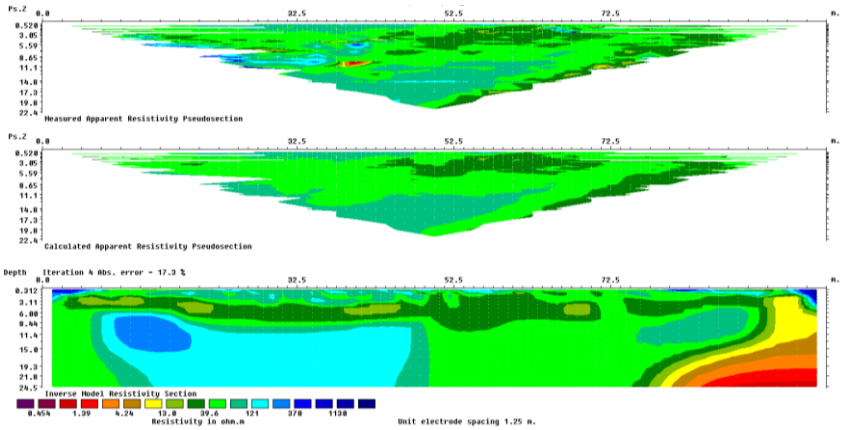



**Figure 5**. Layout of ERT survey lines location

## Apparent Resistivity Pseudosection

The apparent resistivity pseudosection of survey lines, as shown in Figure 6 represents the raw field measurements of resistivity values obtained from the dipole–dipole electrode configuration. The colour distribution reflects variations in apparent resistivity with depth and horizontal distance along the survey line. Higher resistivity zones (warmer colours) may indicate compact or dry materials, such as limestone or gravel layers, while lower resistivity zones (cooler colours) are typically associated with clay-rich soils, water-saturated layers, or potential voids.

(a)



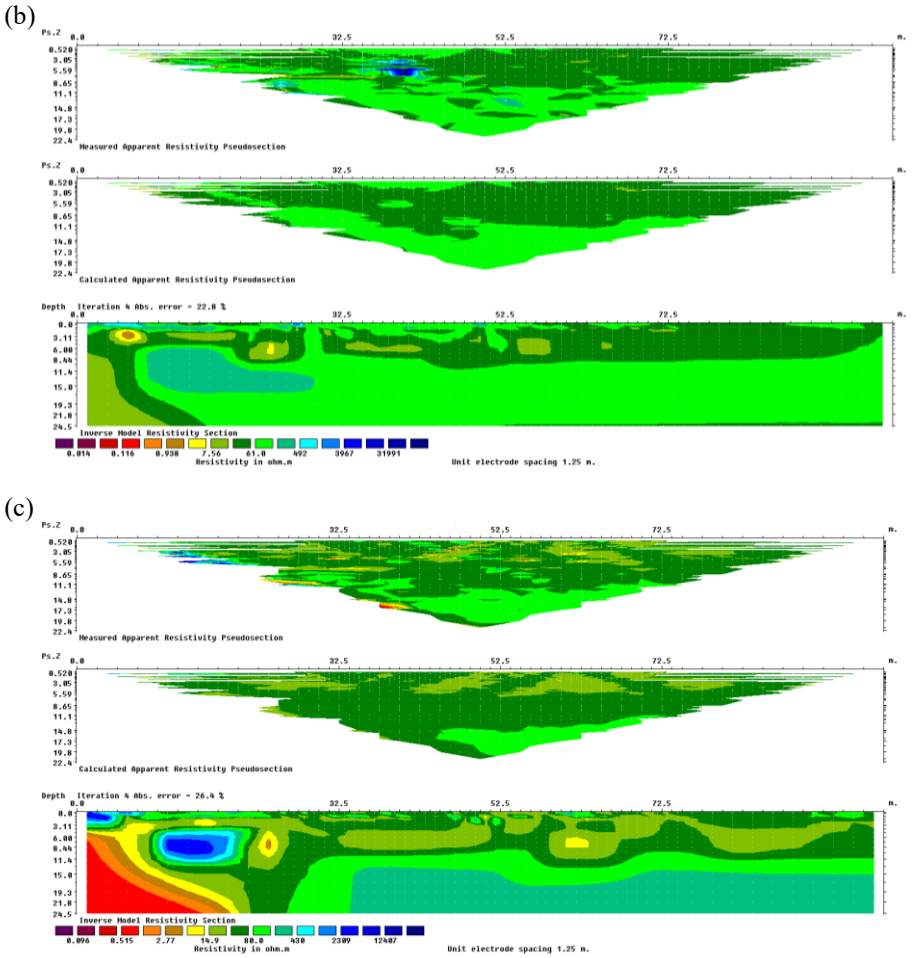



**Figure 6**. Apparent resistivity pseudosection of survey line (a) L-1, (b) L-2 and (c) L3.

## Root-Mean-Square (RMS) Error

The inversion of all three survey lines produced RMS errors predominantly below 20%, confirming the reliability of the subsurface resistivity models generated using RES2DInv.

## 2D Electrical Resistivity Tomography (ERT) Imaging Profile

The interpreted geology of the profile is presented on Figure 7(a) with annotations of major hazards like possible cavities and stratigraphic boundaries. The inversion of all three survey lines was performed using RES2DInv. The inversion parameters were kept consistent for all survey lines to ensure comparable results.


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The inversion process was carried out for seven iterations, with each iteration progressively improving the model fit between the measured and calculated apparent resistivity data. The final inversion models were selected after the seventh iteration, which provided the optimised subsurface resistivity imaging profiles. This imaging profile is almost identical to a similar one from an adjacent and parallel line surveyed 9.00 m away, thereby implying subsurface continuity of geology and confirmation of observed patterns.

The profile shows that the area is subsurface condition is dominantly layered structured and underlain by loose alluvial deposit consist of-layered sandy soil composed of sandy-silt top soil, silty-clay sub soil and partly large boulder within its overburden. The sandy silt deposit has intermediate resistivity values of between 50.00 and 150.00 Ωm and is identified as partly saturated with fine sediments. The sandy silt constituted the upper 1.00 m thickness of its overburden of the sounding curve and is typical of material of normally unconsolidated regolith indicative of materials with fine sediment and excess surface water infiltration.

Underlying this overburden is a water-bearing silty clay of 7.00 m thickness with resistivity values between 0.00 and 50.00 Ωm. Materials such as these have very low resistivity typical of water saturated, poorly drained clayey lithologies. Silty clays are fine particles that permit high capillary saturation of the upper soil horizon typical of poor drainage. Underneath these materials next to the bedrock is a thin layer weathered sand sometimes with gravel that has high resistivity values ranging from 120.00 to 200.00 Ωm. These materials are very dried and characterised as well-drained material. These channels form a transition zone between normally porous poorly consolidated alluvial fill with underlying lithified material.

The lower part of the profile shows weathered, fractured limestone bedrock with a resistivity values of 300.00 Ωm to 1000.00 Ωm depending on the degree of fracturing and amount of groundwater present. However, undulating features are observed in the limestone at the depth of approximately 7.00 m along a horizontal distance between 58.00 m and 66.00 m: these features have been interpreted as infilled cavities- possibly karst features filled with sandy, silts and clay particles. Also, the feature seen at a depth of approximately 25.00 m between 42.00 m and 54.00 m along the survey line is interpreted as a zone of fractured limestone having very low resistivity interpreted as a possibly a large cavity or an area of high moisture accumulation.

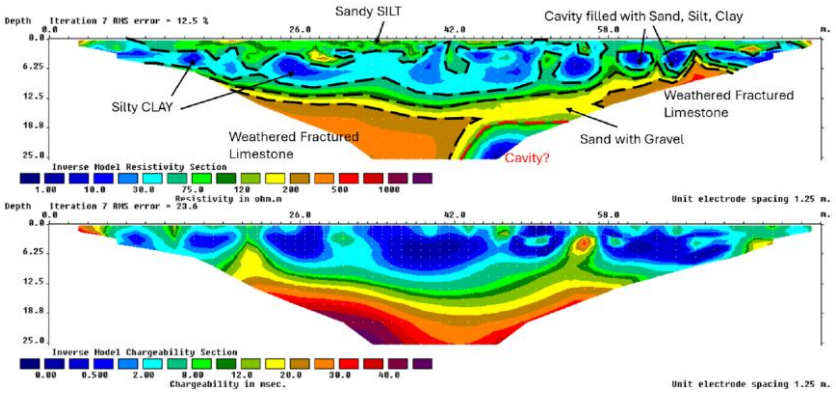
Figure 7(b) shows the line L-2 reveals major subsurface geologic features. This indicated a rather fairly uniform geologic stratification similar to that of line L-1. The top layer is sandy silt with resistivity values ranging from 50.00 Ωm to 150.00 Ωm and thickness of 5.00 m. It appears due to the existence of lots of silty fine to medium sand sized particles in a comparatively dry

environment. The underlying layer is silty clay with very low resistivity values ranging from 0.00 Ωm to 50.00 Ωm in thickness of 7.00 m. The low resistivity of this layer indicates its high moisture content which is characteristic of clayey deposits. These may present geotechnical problems with potential settlement problems.

The overlying transitional sand and gravel layer between 120.00 Ωm to 200.00 Ωm, resistivity values higher than those of the wet low permeability media below occurs as a thin layer. The base of the profile is characterised with high resistivity from 300.00 Ωm to 1000.00 Ωm, which is interpreted as weathered and fractured limestone. This is a common formation of limestone found in a karst environment; the degree of fracturing and wetness reflects the condition of the weathered limestone under a possible influence of drying or compacting. The nature of the anomaly indicates karst mechanics (filled cavity) at least within the first 25.00 m under ground level.

The resistivity distribution shown in Figure 7(c) outlines the main stratigraphic contacts consistent with L-1 and L-2, comprising a sandy silt top layer (50.00 – 150.00 Ωm, ~5.00 m thick), an underlying silty clay layer (0.00 – 50.00 Ωm, ~7.00 m thick), a thin transitional sand and gravel layer (120.00 – 200.00 Ωm), and weathered fractured limestone bedrock (300.00–1,000.00 Ωm). A distinct anomaly is detected between 30.00 m and 34.00 m at approximately 25.00 m depth, interpreted as a void infilled with sand, silt, and clay — consistent with karstic dissolution features observed in the other survey lines.

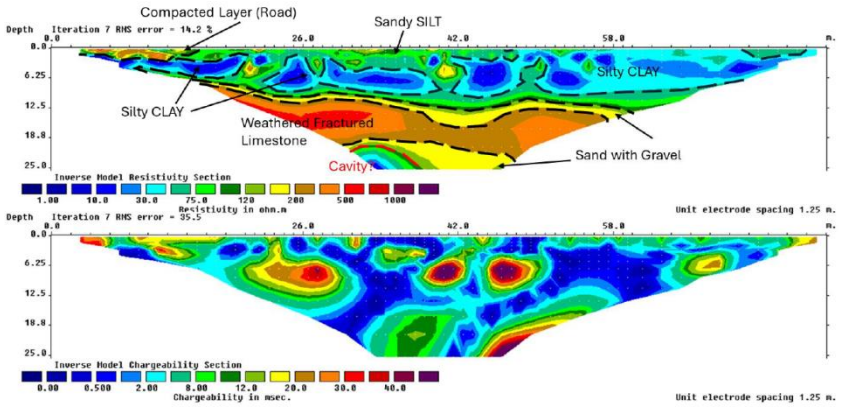
(a)





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(b)




(c)

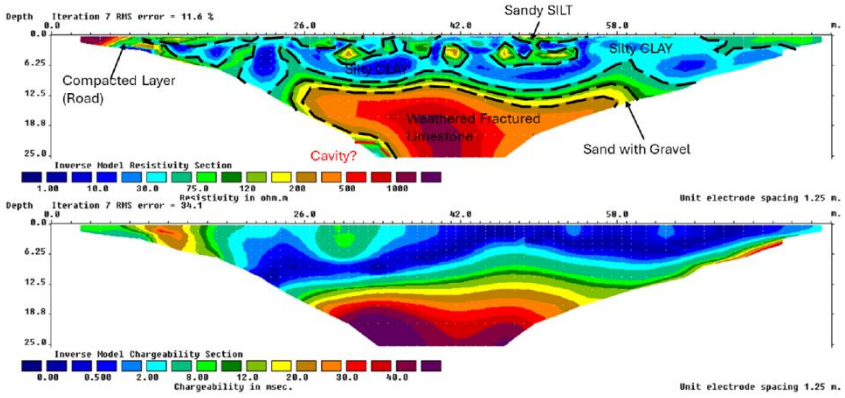



**Figure 7**. 2D ERT imaging profile section of survey line (a) L-1, (b) L-2 and (c) L-3.

## DISCUSSION

### Integrated Interpretation of Subsurface Stratigraphy

The 2D ERT imaging profiles as shown in Figure 8 extend to a maximum depth of approximately 25.00 m, and their interpretation is based on an integration of borehole logs, earlier research, and geological maps. All three survey lines (L-1, L-2, and L-3) run parallel to one another and are spaced roughly 9.00 m apart, producing broadly consistent resistivity responses that enable reliable correlation across the site. The resistivity results consistently identify four principal subsurface layers across all survey lines: sandy silt, silty clay, sand with gravel, and weathered fractured limestone.

Findings from the borehole summary based on Table 3 support the resistivity interpretation. The borehole data indicate that the site area is underlain by residual soils, up to about 14.50 m thick, consisting mainly of sandy silt and sand with Standard Penetration Test (SPT) values not exceeding N=5, pointing to very soft to loose ground conditions. At 14.50 m, limestone bedrock of the Kinta Limestone formation was encountered, overlain by the residual soils and alluvium. Between 16.50 m and 18.00 m, sandy gravelly material was recorded, interpreted as an infilled cavity within the limestone sequence. Below this, the limestone continues until about 23.00 m depth. Rock quality designation (RQD) results show that the recovered limestone cores are generally very weak and highly fractured, with an RQD of 0%, except for one core (C1) that showed a moderately fractured condition with an RQD of 25%. The integration of borehole and ERT data confirms the presence of two cavity types as shown in Table 3.

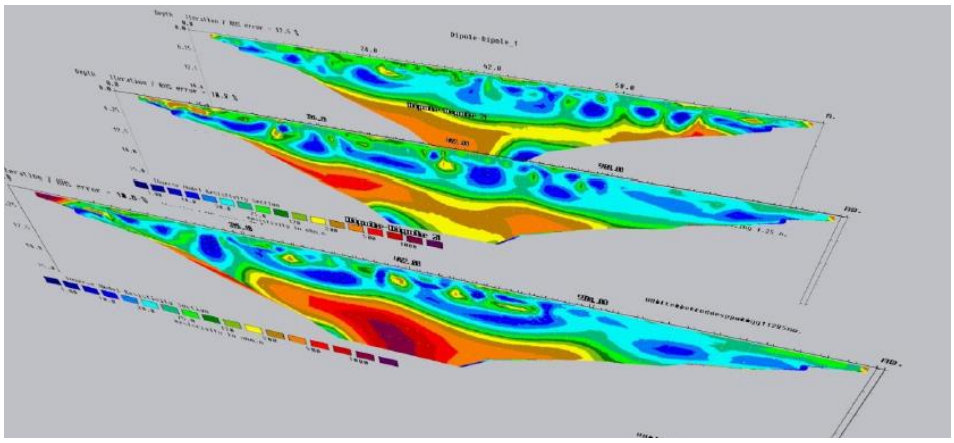


**Figure 8.** Fenced diagram of survey lines with views from south.

Table 3: Summary of Borehole Investigation Results.

| Depth (m) | Material | SPT (N-value) | Remarks |
|---|---|---|---|
| **0.00 – 14.50** | Sandy silt / residual soil | ≤ 5 | Very soft to loose |
| **14.50** | Limestone bedrock (Kinta Formation) | — | Bedrock encountered |
| **16.50 – 18.00** | Sandy gravelly material | — | Infilled cavity |
| **18.00 – 23.00** | Limestone | — | Continues to depth |

*RQD: Generally 0% (highly fractured); C1 core = 25% (moderately fractured)*


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**Geotechnical Risk Assessment**

Based on the comparative analysis of risk assessments across three survey lines (Table 4), varying levels of geotechnical and hydrogeological risks were observed. Survey line L-1, with a depth to bedrock of 10 m to 15 m, indicates moderate to high-risk conditions. The soil types present categorised as SC/SM/ML, exhibit moderate raveling and desiccation potential. The existence of a cavity filled with loose material signifies high risk due to possible voids and fissures, compounded by fractured limestone contributing to instability. Groundwater is likely shallow between 10 m to 15 m with risk factors contributing to an overall risk score of 5 (very high).

Survey line L-2 displays even more severe conditions with a shallower depth to bedrock of less than 10 m, resulting in a high risk rating. Similar soil types are present, alongside a visible void at depth and evidence of fractured limestone supports a very high risk of collapse or sinkhole development. The depth of voids ranges between 10 m to 15 m with proximity less than 15 m heightening the risk score to 5 (very high), although the absence of boulders and sinkhole history mitigates some risk factors.

In contrast, survey line L-3 shows the least severe conditions with a depth to bedrock of around 15 m classified as low to moderate risk. The voids here, though present, are isolated, leading to a moderate likelihood status. Groundwater depth is somewhat deeper from 10 m to 15 m, maintaining a moderate risk rating but overall structural integrity appears better thanks to a well-defined compacted surface layer.

It is clear that geotechnical hazards associated with the presence of voids and fissures in the soil material at the site is significant, with all three lines experiencing high geotechnical risks. Voids are relatively shallow in survey line L-2 and L-3 with each of them being found close to the surface material. This relatively shallow depth of voids increases the probability of the ground surface experiencing a collapse due to the presence of voids.

Groundwater from anthropogenic means from pumping is prone to very little influence on the groundwater level given the difference in pumping height and deepest groundwater level of >100 m (water needing to travel to greater depth reduces flow rate into subsurface rock) and potential groundwater flow within voids can be characterised to be moderate, which is adequate for the expansion of voids and or facilitating the collapse of inadequately filled void spaces.

Based on the results of each respective risk assessment model developed for each survey profiles in the study, it can be concluded that L-1 and L-2 are more susceptible to risks of void formation because of their shallower bedrocks and shallower voids, with L-3 having comparatively better score results in terms of sinkhole formation.

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**Table 4**: Comparison of risk level of survey lines.

| | Criteria | Risk Level | | |
|---|---|---|---|---|
| | | **L -1** | **L -2** | **L -3** |
| **Geology** | Depth to bedrock (m) | 2 | 3 | 2 |
| | Soil Raveling Potential | 3 | 3 | 3 |
| | Soil Desiccation Potential | 2 | 2 | 2 |
| | Potential for Boulders | 1 | 1 | 1 |
| | Fracturing of top 5m of Rock | 1 | 2 | 1 |
| | Voids and Fissures in Soil | 4 | 4 | 4 |
| | Depth of Void (m) | 2 | 1 | 1 |
| | Proximity of Voids (m) | 1 | 1 | 1 |
| | History of Sinkholes, within 30 m | 1 | 1 | 1 |
| | Bedrock Orientation | 3 | 3 | 3 |
| **Groundwater** | Depth to Groundwater (m) | 2 | 3 | 2 |
| | Groundwater Pumping History | 1 | 1 | 1 |
| | Groundwater Flow in Voids | 2 | 2 | 2 |

**Implications for Commercial Building Development and Mitigation Measures**

The risk assessment indicates that the site presents significant geotechnical and hydrogeological risks, particularly along survey lines L-1 and L-2, where increase the potential for ground instability and sinkhole formation. These conditions are particularly critical for commercial buildings because ground movement may cause differential settlement and structural damage. The 2D ERT and borehole results can be used to determine appropriate mitigation measures which may include pressure grouting or cementitious filling of cavities and ground improvement. Moreover, an effective groundwater monitoring and drainage system should be implemented to control changes in groundwater conditions and minimise erosion of subsurface cavities. Construction activities such as excavation, dewatering, and heavy loading should be carefully controlled especially in high-risk areas. Furthermore, the continuous monitoring using inclinometers or piezometers should be considered during construction and throughout the building's service life.

## CONCLUSION

The first objective was successfully addressed through the interpretation of resistivity profiles across three survey lines. Line L-1 revealed a distinct anomaly between 58 to 66 metres at approximately 7 metres depth, characterised by moderate resistivity values (300 Ωm – 1000 Ωm), indicative of fractured limestone and voids potentially filled with sand, silt, and clay. L-2 showed a deeper cavity between 30 to 37 m at about 25 m depth within the high-resistivity limestone, which could represent a significant karstic cavity. Meanwhile, for L-3 also detected a cavity between 30 to 34 m at a depth of 25 m with similar resistivity characteristics.


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The second objective was to classify the geotechnical risk associated with these cavities as inferred by the ERT data. L-1 is classed as very high risk as the shallow voids, fractured bedrock and groundwater involvement all contribute to instability. Furthermore, L-2 is classed as very high risk due to the shallow bedrock, cavity volume and hydrogeological activity, which collectively enhance the probability of ground failure. While line L-3 exhibits similar geological characteristics, due to the relatively deep voids and well compacted surface, it is considered to be of high risk.

Engineering solutions such as pressure grouting and deep foundations are recommended for L-1 and L-2, while continued monitoring is advised for L-3.

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# ANALYSIS ON SOCIAL WELL-BEING INDICATORS: A CASE STUDY OF KETENGAH DISTRICT IN MALAYSIA

**Muhammad Khairulhamizan Md Nazir[1], Noor Suzilawati Rabe[2], Mariana Mohamed Osman[3]**

[1,2,3]*Kulliyyah of Architecture and Environmental Design,*
UNIVERSITI ISLAM ANTARABANGSA MALAYSIA

## Abstract

Social well-being is a multidimensional construct reflecting the quality of life experienced by individuals and families across economic, housing, educational, health, safety and community dimensions. Although Malaysia has formulated the Family Well-Being Index (FWBI) to track these dimensions on the national level, limited research has examined on how the framework can be localized in the semi-rural settings. This paper uses the FWBI domains to examine the social well-being within the Central Terengganu Development Authority (KETENGAH) region, a predominantly semi-rural development region. Data were collected through a household survey supplemented by focus group discussions and interviews. To investigate the relationship between socio-economic characteristics and well-being scores, the mixed-methods methodology was used: descriptive statistics (the profiling of respondents), Relative Importance Index (RII) to compare satisfaction across indicators and correlation analysis to assess the relationship. The findings identified lower satisfaction in several economic and infrastructural areas, particularly income adequacy, environmental services, transportation, and digital connectivity. Spearman's rho analysis further identified statistically significant but generally weak-to-moderate associations between selected socioeconomic characteristics and well-being indicators. The findings demonstrate that national well-being frameworks should be adjusted to local settings and offer policy-relevant implications to enhance social well-being in semi-rural Malaysia.

***Keywords***: Family Well-Being Index, Social Well-Being, Semi-Rural, KETENGAH

[2] Corresponding author. Email: suzilawati@iium.edu.my

## INTRODUCTION

Social well-being has become an important development concern beyond economic growth. It is a multidimensional concept encompassing financial security, housing, health, education, safety, and community relationships (Diener et al., 2018; Noor et al., 2014). In Malaysia, the Family Well-Being Index (FWBI) provides national benchmarks for these dimensions, but national-level findings may not fully reflect the distinct socioeconomic conditions of semi-rural communities (Ahmad & Noor, 2021).

The Central Terengganu Development Authority (KETENGAH) area represents such a context, where households face challenges related to infrastructure access, rising living costs, and limited employment diversification (Omar et al., 2020; Razak, 2019). However, local applications of the FWBI remain limited, restricting the development of context-specific interventions.

This study therefore applies the FWBI framework in KETENGAH using a mixed-methods approach comprising descriptive statistics, the Relative Importance Index (RII), correlation analysis, and focus group discussions. It aims to assess social well-being across multiple domains, identify the socioeconomic indicators associated with well-being outcomes, and propose policy recommendations for semi-rural communities.

From a regional planning perspective, the localisation of the FWBI provides a decision-support mechanism for identifying spatial and socioeconomic disparities that may be obscured by national averages. In KETENGAH, well-being indicators related to household economy, housing, accessibility, digital connectivity, environmental services, health and safety can inform the prioritisation of infrastructure investment, service provision and community development programmes. This is particularly relevant to KETENGAH's role as a regional development authority responsible for coordinating socioeconomic and physical development across dispersed semi-rural settlements. Consequently, a locally adapted FWBI can support programme targeting, resource allocation and the monitoring of development outcomes at the regional level.

## LITERATURE REVIEW

Social well-being is a multidimensional concept encompassing economic security, education, housing, health, safety, and social cohesion (Keyes, 1998; Noor et al., 2014). In Malaysia, the Family Well-Being Index (FWBI) provides national benchmarks for monitoring these dimensions. However, national findings may conceal regional disparities, particularly in rural and semi-rural communities (Omar et al., 2020).

Research shows that well-being is context dependent. Financial security does not always translate into greater subjective well-being, while housing

quality, infrastructure, sanitation, and clean water access significantly influence household satisfaction (Ahmad & Noor, 2021; Omar et al., 2020; Razak, 2019; Stiglitz et al., 2018). Well-being frameworks should therefore be adapted to local social, cultural, and infrastructural conditions (Diener et al., 2018; Helliwell et al., 2020).

Research applying the FWBI at the subnational level remains limited, especially in semi-rural areas such as KETENGAH. This study addresses the gap by combining quantitative and qualitative methods to identify the socioeconomic factors most closely associated with local well-being.

### *Definition of Social Well-Being*

Social well-being refers to the quality of life experienced by individuals, families, and communities. It extends beyond material prosperity to include financial security, health, housing, education, safety, social inclusion, and spirituality (Keyes, 1998; Noor et al., 2014). It comprises objective conditions, such as income and access to essential services, and subjective assessments of life satisfaction (Diener et al., 2018; Stiglitz et al., 2018).

In Malaysia, family well-being is closely associated with broader social well-being because families are fundamental to social stability and national development (Noor et al., 2014; Razak, 2019). Strengthening family well-being therefore contributes to more inclusive development and improved quality of life.

### *Definition of Family Well-Being Index*

The Family Well-Being Index (FWBI) is a multidimensional measure used to assess the quality of life of Malaysian families. Its domains include the economy, housing, health, education, family relationships, safety, community participation, and spirituality (Ahmad & Noor, 2021; Noor et al., 2014).

By combining respondents' satisfaction ratings with socioeconomic and service-access indicators, the FWBI provides a culturally relevant assessment of family well-being (Razak, 2019; Stiglitz et al., 2018). It also enables policymakers, researchers, and development planners to monitor changes over time, evaluate progress, and formulate targeted interventions.

### *Importance of Family Well-Being Index*

The Family Well-Being Index (FWBI) provides a national benchmark for monitoring well-being, identifying emerging concerns, evaluating programmes, and establishing development priorities (Ahmad & Noor, 2021; Department of Statistics Malaysia [DOSM], 2011, 2011, 2011). It also supports national agendas by informing policies related to financial security, healthcare, education, and infrastructure (Economic Planning Unit, 2019).


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Localising the FWBI in KETENGAH helps reveal rural and semi-rural disparities that national averages may conceal, including challenges in sanitation, housing, water supply, and economic opportunities (Omar et al., 2020). Its inclusion of spirituality and family cohesion also makes it culturally relevant to Malaysia and supports evidence-based policymaking (Helliwell et al., 2020; Noor et al., 2014; Razak, 2019).

## RESEARCH METHODOLOGY

This study employed a mixed-methods design to assess family well-being within the Central Terengganu Development Authority (KETENGAH) region. The Malaysian Family Well-Being Index (FWBI) developed by the National Population and Family Development Board (LPPKN) was used as the conceptual reference. Rather than applying the national instrument without modification, the indicators were contextualised to reflect the socioeconomic characteristics, settlement patterns, infrastructure accessibility and service-delivery conditions of KETENGAH. The localised questionnaire therefore incorporated household economy and work balance, housing and neighbourhood conditions, technology and communication, family relationships and financial adequacy, education, social involvement, spiritual practices and family values, transportation and logistics, family safety, and family health.

To operationalise the adapted Family Well-Being Index (FWBI) within the KETENGAH context, the questionnaire was structured around a series of localised well-being dimensions and indicators. These indicators were derived from the broader Malaysian FWBI framework and contextualised to reflect the socioeconomic conditions, service accessibility, infrastructure characteristics, and community dynamics of the KETENGAH region. The selected indicators were subsequently measured through respondents' satisfaction ratings and analysed to identify relative strengths, weaknesses, and priority areas for intervention. Table 1 summarises the localised dimensions and indicators incorporated into the questionnaire.

**Table 1:** Localised FWBI dimensions and indicators used in the KETENGAH survey

| Localised dimension | Indicators |
|---|---|
| Household economy & work balance | Satisfaction with career opportunities, workload, wage adequacy, and income relative to living costs. |
| Housing & neighbourhood | Satisfaction with electricity supply, living environment, internet availability, waste management, and 3R practices. |
| Technology & communication | Satisfaction with internet access, internet speed, and telecommunication costs. |
| Family well-being | Satisfaction with family relationships, family safety, and financial adequacy. |

| Localised dimension | Indicators |
|---|---|
| Education | Satisfaction with education quality, institutional safety, access, affordability, and education system effectiveness. |
| Social involvement | Satisfaction with neighbourhood relations, social activities, and arts and cultural participation. |
| Spiritual practices & family values | Satisfaction with personal spiritual practices, religious tolerance, and community religious participation. |
| Transportation & logistics | Satisfaction with road accessibility, signboards, road quality, public transport, and e-hailing services. |
| Family safety | Satisfaction with residential safety, street lighting, and police/fire services. |
| Family health | Satisfaction with clean water, environmental cleanliness, and healthcare facilities. |

Respondents rated the satisfaction items using a four-point Likert scale: 1 = Very Dissatisfied, 2 = Dissatisfied, 3 = Satisfied and 4 = Very Satisfied. The scale was subsequently transformed into Relative Importance Index (RII) values to facilitate comparison across indicators.

The Relative Importance Index was calculated as

$$RII = \frac{\sum(W \times n)}{A \times N}$$

where W is the assigned weight, n is the response frequency, A is the maximum weight (4), and N is the total number of respondents (400). RII values range from 0 to 1, with higher values indicating greater relative satisfaction. The RII was used descriptively and does not imply statistical significance or causality.

Spearman's rho correlation was used to examine associations between selected respondent characteristics such as age, household income and household size and satisfaction with well-being indicators. A two-tailed significance level of $p < 0.05$ was used. The analysis was intended to identify statistical associations rather than causal effects.

The qualitative component comprised semi-structured interviews and focus group discussions with KETENGAH representatives, local residents, community leaders, agency officials and relevant service providers selected through convenience sampling. The discussions focused on household economic conditions, access to infrastructure and public services, community relationships, and key challenges affecting family well-being. Responses were analysed thematically to identify recurring issues and to contextualise the quantitative findings.


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Using stratified sampling with district-based allocation, 400 respondents were selected from Dungun (35%), Kemaman (35%), and Hulu Terengganu (30%), as shown in Table 2. Descriptive statistics were used to establish household profiles and well-being patterns, while the Relative Importance Index (RII) ranked the indicators according to respondents' priorities. The sample size was adequate for the study design, although the district allocation and demographic concentration limit population-wide generalisation.

**Table 2:** Distribution of total respondents based on districts

| District | No. of Target Respondent | Percentage (%) |
|---|---|---|
| Dungun | 140 | 35.0 |
| Kemaman | 140 | 35.0 |
| Hulu Terengganu | 120 | 30.0 |
| **Total** | **400** | **100.0** |

*Source: Author's Calculation*

## ANALYSIS AND DISCUSSION

This study included 400 respondents who represented households in the KETENGAH region. Table 3 shows the socio-demographic characteristics of the participants with gender, ethnicity, marital status, age, educational level, employment, and household income, as well as the length of residence in KETENGAH.

**Table 3** Detailed background on respondent's profile

| Variable | Category | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Male | 224 | 56.0 |
| | Female | 176 | 44.0 |
| Ethnicity | Malay | 390 | 97.5 |
| | Chinese | 0 | 0.0 |
| | Indian | 0 | 0.0 |
| | Others | 10 | 2.5 |
| Marital Status | Single | 47 | 11.8 |
| | Married | 297 | 74.3 |
| | Divorced/Widowed | 56 | 14.0 |
| Age | 15-24 years | 27 | 6.8 |
| | 25-34 years | 54 | 13.5 |
| | 35-44 years | 82 | 20.5 |
| | 45-55 years | 89 | 22.3 |
| | 55-64 years | 81 | 20.3 |
| | Above 64 years | 67 | 16.8 |
| Educational Attainment | No Certificate | 113 | 28.2 |
| | PMR or equivalent | 62 | 15.5 |
| | SPM or equivalent | 124 | 31.0 |

| Variable | Category | Frequency | Percentage (%) |
|---|---|---|---|
| | STPM or equivalent | 20 | 5.0 |
| | Certificate | 24 | 6.0 |
| | Diploma | 36 | 9.0 |
| | Bachelor's Degree | 14 | 3.5 |
| | Master/PhD | 7 | 1.8 |
| Employment Status | Employed | 273 | 68.3 |
| | Unemployed | 127 | 31.7 |
| Household Income | Less than RM2,000 | 235 | 58.8 |
| | RM2,000-RM2,999 | 83 | 20.8 |
| | RM3,000-RM3,999 | 48 | 12.0 |
| | RM4,000-RM4,999 | 19 | 4.8 |
| | RM5,000-RM5,999 | 5 | 1.3 |
| | RM6,000-RM6,999 | 2 | 0.5 |
| | RM7,000-RM7,999 | 3 | 0.8 |
| | RM9,000-9,999 | 1 | 0.3 |
| | More than RM10,000 | 4 | 1.0 |
| Duration of Stay in KETENGAH | 1-3 years | 5 | 1.3 |
| | 3-6 years | 12 | 3.0 |
| | 6-8 years | 6 | 1.5 |
| | 8-10 years | 10 | 2.5 |
| | 10-12 years | 11 | 2.8 |
| | 12-14 years | 3 | 0.8 |
| | More than 14 years | 353 | 88.3 |

*Source: Author's Calculation*

The sample was predominantly Malay (97.5%), married (74.3%), middle-aged, and long-established in KETENGAH, with 88.3% having lived in the region for more than 14 years. Most respondents were employed (68.3%), while household income was generally low, with 58.8% earning below RM2,000 per month. Educational attainment was relatively modest, with 31.0% completing SPM and 28.2% having no formal certificate. These characteristics provide important context for interpreting the findings, which primarily reflect the experiences of long-established Malay households and may underrepresent ethnic minorities, recent residents, and more mobile population groups.


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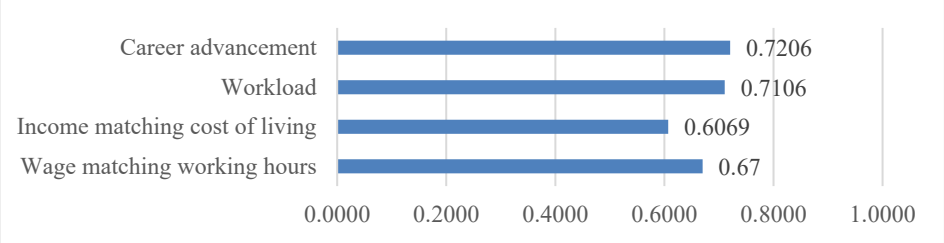



**Figure 1:** Results of the RII calculation for respondent's household economy and work balance in KETENGAH
*Source: Author's Calculation* (2024)

Figure 1 presents the RII results for household economy and work balance. According to the Relative Importance Index (RII) analysis, career advancement recorded the highest satisfaction-based RII within the household economy and work-balance dimension (RII = 0.7206), followed by workload (RII = 0.7106), wage compatibility with working hours (RII = 0.6700), and income adequacy relative to the cost of living (RII = 0.6069). The comparatively low rating for income adequacy indicates greater dissatisfaction with household purchasing capacity and suggests that cost-of-living pressures warrant policy attention.

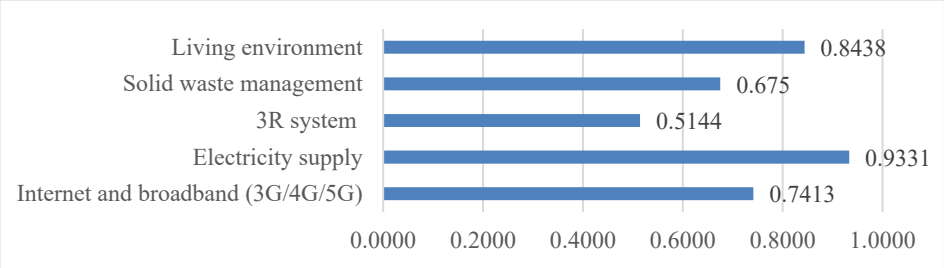



**Figure 2:** Results of the RII calculation for respondent's housing and neighbourhood in KETENGAH
*Source: Author's Calculation* (2024)

Figure 2 shows that electricity supply recorded the highest satisfaction-based RII (0.9331), followed by the living environment (0.8438) and internet and broadband availability (0.7413). Solid waste management (0.6750) and the 3R system (0.5144) received comparatively lower ratings.

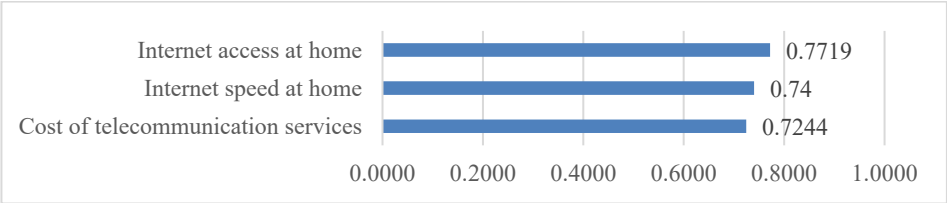



**Figure 3:** Results of the RII calculation for technology and communication in KETENGAH
*Source: Author's Calculation* (2024)

As can be seen in Figure 3 of the RII results, internet access at home recorded the highest RII (0.7719), followed by internet speed (0.7400) and telecommunication costs (0.7244). The relatively small differences suggest comparable levels of satisfaction across the three technology and communication indicators.

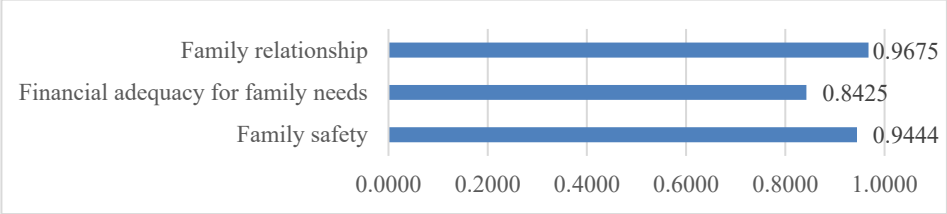



**Figure 4:** Results of the RII calculation for respondent's family well-being in KETENGAH
*Source: Author's Calculation* (2024)

In the sphere of family well-being, family relationships recorded the highest RII (0.9675), followed by family safety (0.9444) and financial adequacy for family needs (0.8425). The results indicate comparatively higher satisfaction with relational and safety aspects than with financial adequacy.

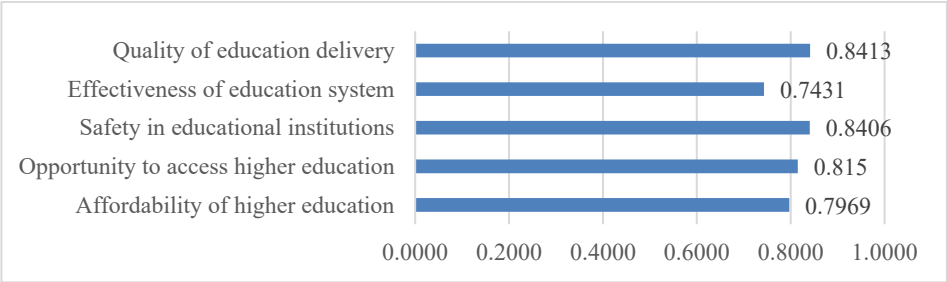



**Figure 5:** Results of the RII calculation for education in KETENGAH
*Source: Author's Calculation* (2024)


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Within the education dimension, quality of education delivery (RII = 0.8413) and safety in educational institutions (RII = 0.8406) received the highest satisfaction ratings. These were followed by access to higher education (0.8150), affordability of higher education (0.7969), and effectiveness of the education system (0.7431).

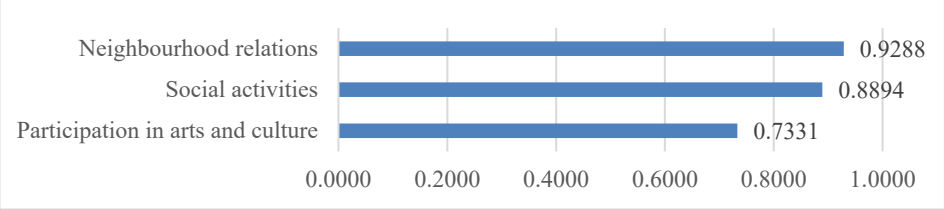



**Figure 6:** Results of the RII calculation for respondent's social involvement in KETENGAH
*Source: Author's Calculation* (2024)

With regards to social participation in Figure 6, neighbourhood relations recorded the highest RII (0.9288), followed by social activities (0.8894), while participation in arts and culture recorded a comparatively lower rating (0.7331). This pattern indicates stronger satisfaction with everyday neighbourhood and social interaction than with arts and cultural participation.

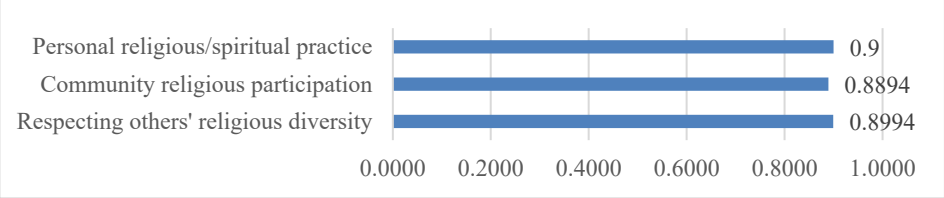



**Figure 7:** Results of the RII calculation for respondent's spiritual practices and family values in KETENGAH
*Source: Author's Calculation* (2024)

Figure 7 showed that the personal religious or spiritual practice recorded the highest RII (0.9000), followed closely by respect for religious diversity (0.8994) and community religious participation (0.8894). The closely grouped ratings indicate consistently high satisfaction across the spiritual and family-values indicators.

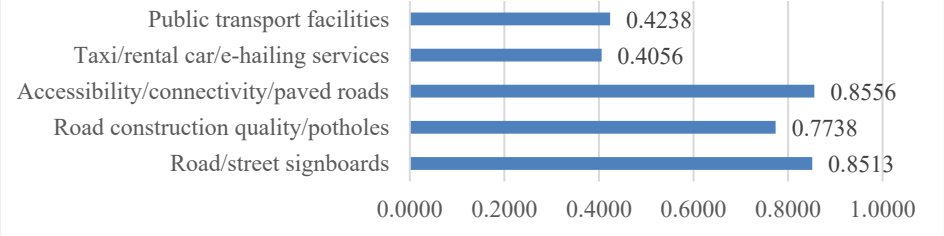



**Figure 8:** Results of the RII calculation for respondent's transportation and logistics in KETENGAH
*Source: Author's Calculation* (2024)

The situation was different in Figure 8 with transportation and logistics. Accessibility and paved roads (RII = 0.8556) and road or street signboards (RII = 0.8513) received relatively high ratings, followed by road quality (0.7738). In contrast, public transport (0.4238) and taxi or e-hailing services (0.4056) recorded the lowest satisfaction ratings.

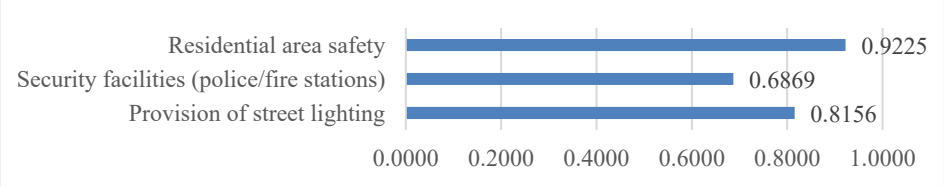



**Figure 9:** Results of the RII calculation for respondent's family safety in KETENGAH
*Source: Author's Calculation* (2024)

With respect to family safety in Figure 9, residential-area safety recorded the highest RII (0.9225), followed by street-lighting provision (0.8156). Police and fire services received a lower rating (0.6869), indicating comparatively lower satisfaction with institutional safety provision.

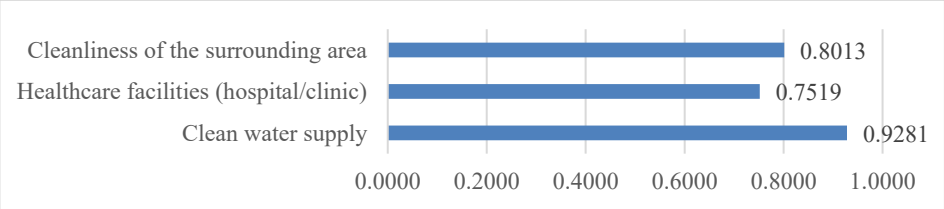



**Figure 10:** Results of the RII calculation for respondent's family health in KETENGAH
*Source: Author's Calculation* (2024)


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Basic infrastructure needs are further indicated in health-related indicators in Figure 10. Clean water supply recorded the highest RII (0.9281), followed by cleanliness of the surrounding area (0.8013) and healthcare facilities (0.7519). The results indicate comparatively higher satisfaction with basic environmental health conditions than with healthcare-facility provision.

Spearman's rho analysis indicated several statistically significant, although generally weak to moderate, associations between household characteristics and well-being indicators. Household income was negatively associated with satisfaction with the living environment ($\rho = -0.312$, $p < 0.001$), affordability of higher education ($\rho = -0.211$, $p < 0.001$), road construction quality ($\rho = -0.338$, $p < 0.001$), residential-area safety ($\rho = -0.158$, $p = 0.002$), and cleanliness of the surrounding area ($\rho = -0.401$, $p < 0.001$). Household size showed positive associations with family relationships ($\rho = 0.153$, $p = 0.002$), neighbourhood relations ($\rho = 0.198$, $p < 0.001$), and clean-water supply ($\rho = 0.166$, $p < 0.001$). Age was negatively associated with internet access at home ($\rho = -0.106$, $p = 0.034$) and access to healthcare facilities ($\rho = -0.167$, $p < 0.001$). These results indicate that selected dimensions of well-being vary systematically across household characteristics, but the observed correlations should not be interpreted as causal effects.

The Family Well-Being Index (FWBI) provides a holistic assessment of household well-being across social, economic, and environmental dimensions.

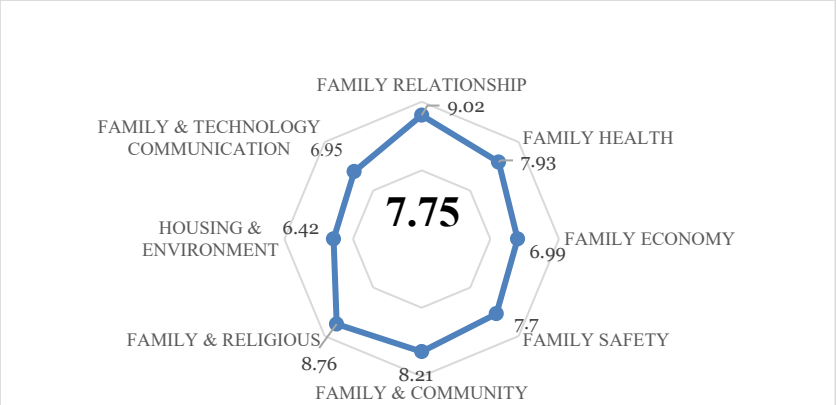



**Figure 11:** Results of the Family Well-Being Index in KETENGAH
*Source: Author's Calculation* (2024)

Family Relationships recorded the highest FWBI score (9.02), followed by Religious and Spiritual Practices (8.76) and Family and Community (8.21). Lower scores were recorded for Family Economy (6.99), Communication Technology (6.95), and Housing and Environment (6.42).

KETENGAH recorded an overall FWBI score of 7.75. Despite strong family, spiritual and community dimensions, comparatively weaker economic and infrastructural conditions remain (Ahmad & Noor, 2021).

## COMPARISON WITH MALAYSIA NATIONAL FAMILY WELL BEING INDEX

KETENGAH's FWBI scores were benchmarked against the Malaysian FWBI 2022 to identify relative strengths and weaknesses across domains, as shown in Table 4.

**Table 4:** Comparison of KETENGAH and Malaysia Family Well-Being Index Scores

| Domain | KETENGAH FWBI Score | Malaysia FWBI 2022 Score |
|---|---|---|
| Family Relationships | 9.02 | 8.44 |
| Family Health | 7.93 | 8.07 |
| Family Economy | 6.99 | 6.90 |
| Family Safety | 7.70 | 7.69 |
| Family & Community Involvement | 8.21 | 8.24 |
| Family, Religious Roles & Spiritual Practices | 8.76 | 8.37 |
| Housing & Environment | 6.42 | 7.55 |
| Family & Communication Technology | 6.95 | 8.18 |
| **Overall FWBI Score** | **7.75** | **7.93** |

*Source: Malaysian Family Well-Being Index 2022 and Author's Calculation*

KETENGAH's overall FWBI score of 7.75 was slightly lower than the 2022 national score of 7.93. However, KETENGAH performed better in Family Relationships (9.02 versus 8.44) and Religious Roles and Spiritual Practices (8.76 versus 8.37), reflecting strong family support, social trust, and spirituality (Noor et al., 2014).

In contrast, KETENGAH recorded lower scores for Housing and Environment (6.42 versus 7.55) and Communication Technology (6.95 versus 8.18), indicating weaknesses in housing, environmental services, and digital access (Omar et al., 2020). Family Economy scores were broadly comparable (6.99 in KETENGAH and 6.90 nationally), suggesting that economic pressure is not unique to the study area (Razak, 2019; Stiglitz et al., 2018). Overall, the findings support locally tailored interventions for semi-rural communities.


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## RECOMMENDATION

The FWBI findings for KETENGAH indicate the need for policies that address structural weaknesses while preserving strong family, spiritual, and neighbourhood relationships. Economic interventions should strengthen income security through skills training, employment diversification, income-generating opportunities, and targeted assistance for low-income households (Razak, 2019; Stiglitz et al., 2018).

Policies should also improve housing quality, waste management, affordable broadband access, road conditions, and public transportation (Omar et al., 2020). These measures would enhance access to employment, education, healthcare, and digital services. Meanwhile, community organisations and participatory programmes should continue to reinforce social cohesion and resilience (Helliwell et al., 2020; Noor et al., 2014). Overall, an integrated and locally adapted approach is required to improve family well-being in KETENGAH.

For regional planning practice, these findings suggest that KETENGAH should integrate selected FWBI indicators into programme design, infrastructure prioritisation and development monitoring. Lower-performing indicators, particularly public transport, environmental management, income adequacy and digital connectivity, can be used to identify areas requiring targeted intervention, while high-performing domains such as family relationships and community cohesion should be preserved through community-based programmes. Periodic household-based monitoring would allow KETENGAH and relevant state agencies to evaluate whether infrastructure and socioeconomic interventions result in measurable improvements in family well-being.

## CONCLUSION

This study applied the Family Well-Being Index (FWBI) and Relative Importance Index (RII) to assess family well-being in KETENGAH. Family relationships, religious values, neighbourhood cohesion, household safety, and clean water access emerged as key strengths. Lower performance was observed in income security, housing, waste management and transportation, alongside an overall FWBI score of 7.75.

The findings support targeted interventions involving skills development, income diversification, improved environmental and housing services, and affordable rural transportation. Future studies should use longitudinal and cross-regional data to strengthen locally responsive family well-being policies.

## ETHICS

The study followed standard research ethics procedures. Participants were informed of the study objectives and participated voluntarily. Confidentiality and anonymity were maintained, and the data were used solely for academic purposes.

## ACKNOWLEDGEMENT

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B-01-02, Jalan SS7/13B, Aman Seri, Kelana Jaya,
47301, Petaling Jaya, Selangor Darul Ehsan, MALAYSIA
Tel: +603 78770637 Fax: +603 78779636
Email: pmjournal@gmail.com or mip@mip.org.my
Website: www.planningmalaysia.org

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