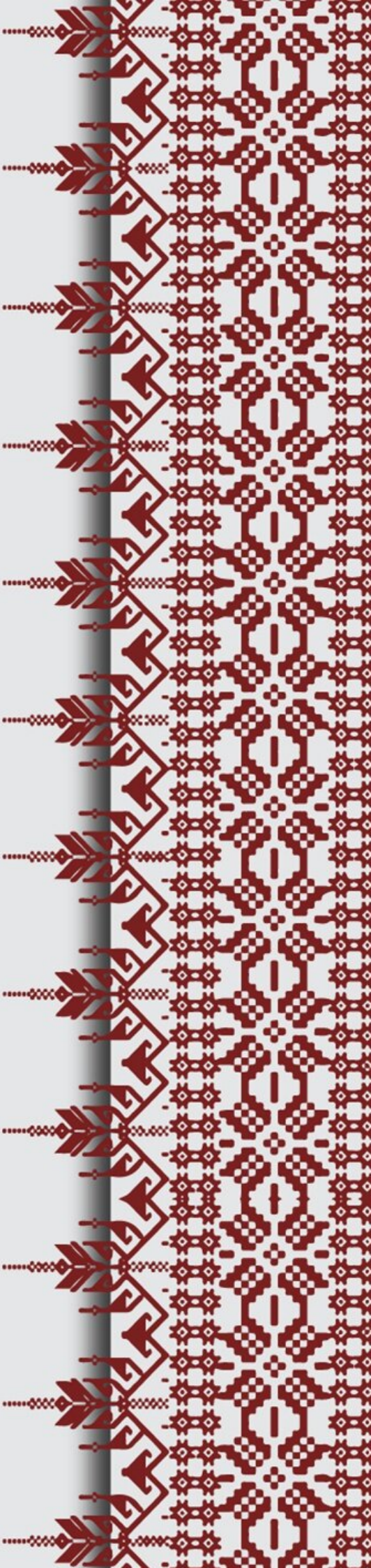
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HOW URBAN PARK CPTED INFLUENCES REVISIT INTENTION THROUGH PLACE ATTACHMENT WITH SOCIOECONOMIC STATUS AS A MODERATOR

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Abstract

Urban parks offer spaces for daily leisure and psychological recovery. However, safety concerns can reduce users' willingness to revisit. This study draws on crime prevention through environmental design (CPTED) and environmental psychology. It examines how CPTED shapes revisit intention in urban parks. It also tests place attachment as a mediator and socioeconomic status (SES) as a moderator. The data were collected from 361 users of Baitashan Park in Lanzhou, China. The data were analysed using partial least squares structural equation modelling. The results show that CPTED has a significant positive effect on place attachment. CPTED also has a significant positive effect on revisit intention. Place attachment partially mediates the link between CPTED and revisit intention. This pattern suggests that safety-oriented design encourages repeat use by building emotional bonds with the park. SES further strengthens the effects of CPTED on both place attachment and revisit intention. However, SES does not change the association between place attachment and revisit intention. Overall, the findings highlight an emotional pathway through which CPTED supports sustained park use. They also stress the need for socially inclusive safety design in urban parks.

***Keywords**:* Urban Park, Crime Prevention through Environmental Design, Place Attachment, Revisit Intention, Socioeconomic Status

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INTRODUCTION

In the field of environmental design, the value of urban parks has long been recognised. As an integral part of users' daily lives, urban parks not only provide physical space for leisure but also play a pivotal role in alleviating environmental stress and promoting physical and mental restoration (Bai et al., 2025). Despite these advantages, existing research indicates that parks, as open public spaces, are naturally exposed to potential crime risks while offering accessibility (Spencer & Schnell, 2025). This safety hazard directly threatens park vitality: even with high-quality natural landscapes and facilities, users' psychological defence mechanisms will be triggered when perceiving insecurity. This not only inhibits use frequency but also significantly undermines their future revisit intention (Wang et al., 2022). Therefore, for planners, the core challenge extends beyond merely beautifying the landscape and providing services. It lies in actively mitigating criminal opportunities through environmental design to rebuild user trust and sustain long-term revisit behaviour. Addressing this issue is a critical priority at the intersection of urban planning and environmental psychology. Furthermore, safe cities are crucial to the success of community development, urban development, and nation building (Shamsuddin & Azim Hussin, 2013).

Specifically, from an environmental psychology perspective, Nursyamsiah & Setiawan (2023) argue that rational spatial layout and clear accessibility serve not only as functional indicators but also create an atmosphere of defensible space, thereby fostering a sense of belonging and deepening users' place attachment. Research consistently shows that higher levels of belonging and place attachment positively predict users' revisit intention (Isa et al., 2020). However, it is crucial to note that perception is not uniform. Due to diverse backgrounds, groups of different socioeconomic status (SES) often exhibit significant disparities in interpreting environmental risk signals, influenced by their living environments, prior safety experiences, and resource accessibility (Evans & Kantrowitz, 2002). In other words, users from different SES strata may perceive the utility of the same CPTED strategy differently. Consequently, this study aims to examine the relationship between Crime Prevention Through Environmental Design (CPTED) and revisit intention in urban parks, incorporating SES as a moderating variable. The findings will offer critical insights for the renewal and refined governance of urban parks, particularly in formulating targeted CPTED strategies and socially inclusive design schemes.

LITERATURE REVIEW

CPTED and Revisit Intention

CPTED is no longer confined to crime control but is increasingly recognised as a marker of environmental quality that can enhance the appeal of public open

spaces and promote favourable behavioural responses (Mak & Jim, 2022). The dimensions emphasised by CPTED, such as natural surveillance, territoriality, access control, and image management, help reduce concealed spaces and enhance a sense of order, thereby enhancing users' perceived safety and reducing fears of crime (Mehta & Gopalakrishnan, 2024). Chen and Hedayati Marzbali (2024) found that implementing higher levels of environmental maintenance and optimisation in urban parks through CPTED not only improves perceived safety but also increases visit frequency and length of stay. In addition, CPTED can enhance users' perceived satisfaction with urban parks by improving and optimising environmental quality, thereby strengthening user loyalty (Hou, Hedayati Marzbali, & Abdullah, 2025). In sum, a higher level of CPTED is expected to encourage individuals to develop more positive usage behaviours.

Relevant research in environmental psychology shows that place attachment is an important psychological link between the physical environment and individual behaviour (Jayakody et al., 2024; Xu et al., 2022). High environmental quality, safe atmosphere, and positive landscape image can enhance users' emotional identity and sense of belonging. When users perceive the physical environment as safer and more orderly, they are more likely to develop trust and closeness toward the setting, which deepens place attachment and translates into more stable, loyal behaviour (Wu et al., 2024). Moreover, although optimised urban park design can effectively enhance satisfaction, it is primarily through place attachment that users' revisit intention is strengthened (Çevik, 2020). Therefore, this study proposes the following hypothesis:

H1: CPTED has a positive effect on urban park users' place attachment.
H2: CPTED has a positive effect on urban park users' revisit intention.
H3: Place attachment has a positive effect on urban park users' revisit intention.
H4: Place attachment mediates the relationship between CPTED and revisit intention.

SES and Parks

Users with different SES exhibit clear stratification in the accessibility and frequency of use of urban parks (Huang et al., 2022). High-SES individuals generally live in areas with better public services and economic conditions, and thus have easier access to parks with higher landscape quality and more comprehensive safety management (Mohamed et al., 2025). In contrast, low-SES residential environments are more likely to face problems such as inadequate facilities, crowding, and lower perceived safety, where potential environmental risks and uncivil behaviours are also more prevalent (Baum et al., 1999). These SES differences not only influence revisit intention and length of stay but also

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shape users' perceived safety and environmental quality. Based on this, the following hypothesis are proposed:

H5: Associations between study variables differ by SES.

Figure 1 presents the proposed model based on the hypothesis, which examines the relationships among CPTED, place attachment, and revisit intention while accounting for differences in SES.

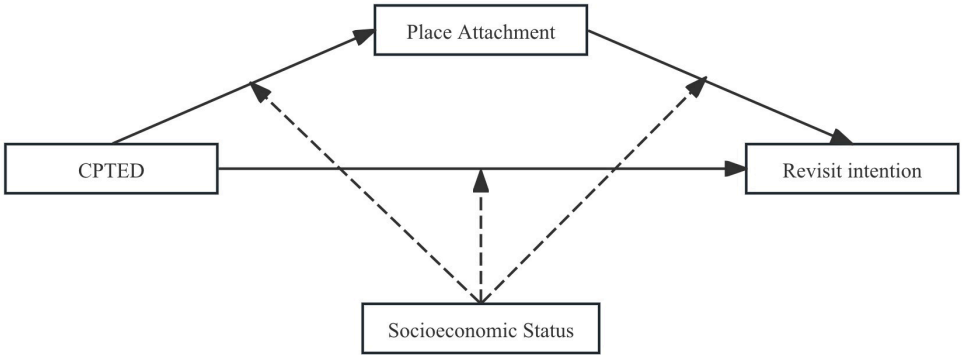


Figure 1: Research model
Source: Authors (2026)

RESEARCH METHODOLOGY

Study Site

This study selected Baitashan Park in Chengguan District, Lanzhou, China, as the study site, and park users as the survey participants. Chengguan District is the most populous area in Lanzhou, with high population density, commercial function agglomeration, and dense transportation hubs (Jiang et al., 2022). As a result, it accommodates a diverse and highly mobile population, and the socioeconomic context around the park is relatively complex. In this context, Baitashan Park can typically reflect the characteristics of perceived safety, place attachment, and revisit intention, thereby providing strong representativeness.

Questionnaire Design

This study developed a questionnaire based on previous studies, comprising two parts. The first part collected information of the participants, including gender, age, education level, occupation, and monthly income. SES was operationalised as a latent construct measured by three items: education level, occupation and monthly income (Smith et al., 2017). The second part measured the study variables based on conceptual frameworks (**Table 1**). CPTED was assessed using 17 items from Hou, Hedayati Marzbali, & Abdullah (2025), covering four

dimensions: surveillance, territoriality, access control, and image management. Place attachment was measured with seven items across two dimensions developed by Chen et al. (2026). Revisit intention was measured following Zhan et al. (2024). All items were rated on a five-point Likert scale ranging from "strongly disagree (1)" to "strongly agree (5)".

Table 1: Constructs and measurement items

Variable	Item code	Item
CPTED (1=strongly disagree, 5=strongly agree)		
Surveillance	S1	Security devices and lighting equipment are properly installed for safety in this park.
	S2	Security guard service in this park is acceptable.
	S3	Security Administration in this park is acceptable.
	S4	There is no obstacle on the boarders and entrances of this park, which do not interrupt the view.
	S5	Crowds can reduce potential infringement in this park
Territoriality	T1	The spatial boundary is clear and well-defined in this park.
	T2	Users can distinguish various functional areas by different topographical designs in this park.
	T3	Fences or plantings can clearly define and delineates between private, semi-private and public spaces in this park.
	T4	Plants cannot obscure users' views.
Access Control	AC1	Design of the entrance space is appropriate and clearly identified.
	AC2	The road connectivity design are appropriate and well.
	AC3	Design and layout of parks signage play an important role.
	AC4	Accesses to this park is clear and easily identifiable.
Image and Maintenance	IM1	Inside of the park are clean and well maintained.
	IM2	Park facilities (such as benches, dustbins, and signage) are well-maintained.
	IM3	Lighting system works well especially in the nighttime.
	IM4	There is no malicious graffiti phenomenon.
Place Attachment (1=strongly disagree, 5=strongly agree)		
Place Identity	PI1	I have a lot of fond memories of the park.
	PI2	I miss the park when I am away for a long time.
	PI3	The park reminds me of some of my loved ones (parents, children, friends, etc.).
	PI4	This park has a special meaning to me.
Place Dependence	PD1	I prefer to visit the park because I believe it offers a good, clean, safe, and relaxing environment.
	PD2	I am more satisfied with the activities in this park than in other parks.
	PD3	This park is the most suitable place for me to relax.

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Revisit Intention (1=strongly disagree, 5=strongly agree)		
	RI1	I have a strong desire to revisit this park next time.
	RI2	I will revisit this park in the near future.
	RI3	I will make this my first choice for my next visit to the park.

Source: Authors (2026)

Procedure

This study used convenience sampling to recruit target participants who were aged 18 years or above and had previously visited Baitashan Park. The questionnaire was distributed online through Wenjuanxing from February to April 2024 (https://www.wjx.cn/). Before completing the questionnaire, respondents were informed of the purpose of the study, the voluntary nature of participation and the confidentiality of their responses. Only those who read and agreed to this information were allowed to proceed with the questionnaire. To improve data quality, the questionnaire included two attention test items, each with a single correct answer. Questionnaires that failed either attention test item or contained incomplete responses were excluded from the analysis. A total of 429 questionnaires were collected through the online survey. After data screening, 361 valid questionnaires were retained for subsequent analysis, giving a valid completion rate of 84.15%. The data were stored on a password-protected computer and were accessible only to the researchers involved in this study. A post-hoc power analysis was conducted using G*Power 3.1. With the significance level set at $\alpha=0.05$ and an effect size of 0.15, the achieved statistical power was 0.89. This result indicates that the final sample size (n=361) is sufficient to meet the analytical requirements of this study.

RESULTS

Descriptive Statistics

Among the 361 respondents, 176 were male (48.8%), and 185 were female (51.2%), with a mean age of 40 years. Occupations included unemployed (28, 7.8%), manual workers (80, 22.2%), sales/service and general workers (123, 34.1%), self-employed (98, 27.0%), and professionals/officials (32, 8.9%). Education levels were secondary or below (18, 5.0%), high school (53, 14.7%), junior college (94, 26.0%), undergraduate (152, 42.1%), and master's degree or above (44, 12.2%). Monthly income was < 4,500 CNY (30, 8.3%), 4,500–5,999 (58, 16.1%), 6,000–7,999 (76, 21.0%), 8,000–9,999 (143, 39.6%), and ≥10,000 (54, 15.0%).

Measurement Model Evaluation

Table 2 reports the reliability and convergent validity of the constructs, while **Figure 2** presents the measurement model results. All Cronbach's alpha and

composite reliability values exceeded 0.70, and all AVE values were above 0.50, indicating acceptable internal consistency and convergent validity. Discriminant validity was examined using the Fornell–Larcker criterion and HTMT. As shown in **Table 3**, the square root of AVE for each construct on the diagonal was higher than the corresponding inter-construct correlations. **Table 4** further shows that all HTMT values were below 0.85, providing additional support for discriminant validity. Collinearity was also checked using VIF values, which ranged from 1.000 to 2.826 and were below the recommended threshold of 3.3. Overall, these results indicate that the measurement model had adequate reliability, validity and collinearity diagnostics for further structural model analysis (Hair et al., 2019).

Table 2: Reliability and convergent validity results

Variable	Dimension	α (≥ 0.7)	CR (≥ 0.7)	AVE (≥ 0.5)
CPTED		0.955	0.959	0.58
	Surveillance	0.91	0.933	0.736
	Territoriality	0.897	0.928	0.764
	Access Control	0.883	0.919	0.741
	Image Management	0.892	0.925	0.755
Place Attachment		0.906	0.926	0.64
	Place Identity	0.874	0.922	0.798
	Place Dependence	0.887	0.922	0.747
Revisit Intention		0.87	0.921	0.794
SES		0.708	0.821	0.609

Source: Authors (2026)

Table 3: Fornell-Larcker criterion

Variable	AC	IM	S	T	PD	PI	RI	SES
AC	**0.861**							
IM	0.707	**0.869**						
S	0.668	0.699	**0.858**					
T	0.742	0.682	0.711	**0.874**				
PD	0.36	0.382	0.365	0.36	**0.864**			
PI	0.413	0.388	0.393	0.403	0.661	**0.893**		
RI	0.372	0.354	0.343	0.405	0.284	0.34	**0.891**	
SES	0.13	0.153	0.112	0.171	0.164	0.169	0.098	**0.78**

Source: Authors (2026)

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Table 4: HTMT results

Variable	AC	IM	S	T	PD	PI	RI	SES
AC								
IM	0.796							
S	0.745	0.775						
T	0.834	0.763	0.786					
PD	0.406	0.43	0.406	0.404				
PI	0.47	0.44	0.441	0.456	0.75			
RI	0.424	0.402	0.386	0.458	0.323	0.389		
SES	0.159	0.173	0.127	0.213	0.178	0.189	0.109	

Source: Authors (2026)

Table 5 indicates that the model has moderate predictive power. The R^2 values indicate the explanatory power of the structural model for the endogenous constructs. Specifically, the model explained 24.7% of the variance in place attachment and 24.2% of the variance in revisit intention, suggesting a moderate level of explanatory power. All Q^2 values are greater than 0, indicating that the model had acceptable predictive relevance for place attachment and revisit intention. In addition, the model fit of 0.405 suggests a statistically meaningful model with satisfactory goodness of fit (GoF) (Hair et al., 2019).

Table 5: Coefficient of determination and predictive relevance and GoF

Variable	R^2	Q^2	AVE	GoF
CPTED	–	–	0.58	
PA	0.247	0.233	0.64	$\sqrt{(\bar{R}^2 \times \overline{AVE})} = \sqrt{0.245 \times 0.671} = 0.405$
RI	0.242	0.209	0.794	

Source: Authors (2026)

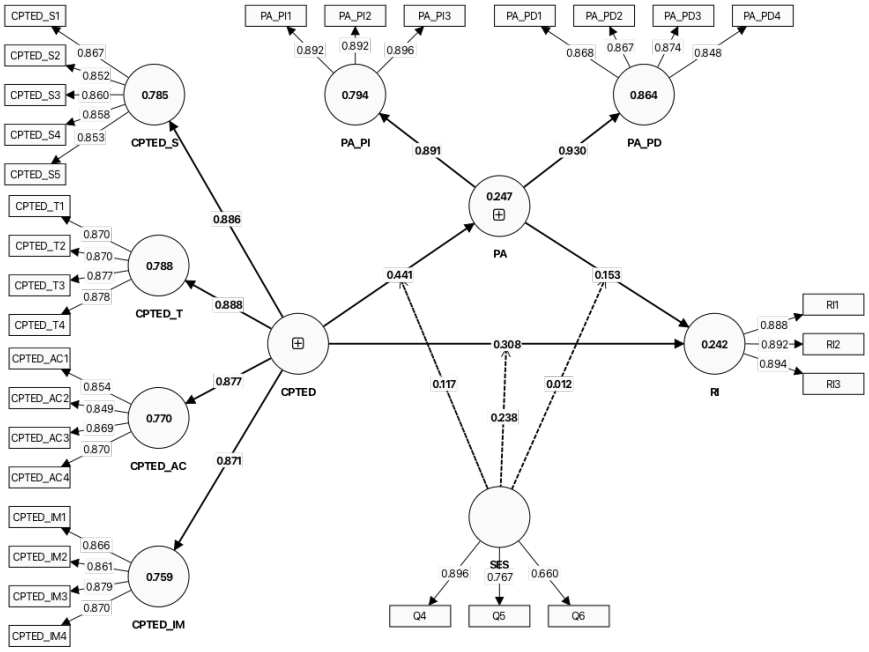


Figure 2: Measurement model path coefficients.
Source: Authors (2026)

Structural Model Evaluation

The significance of the direct, mediating, and moderating effects was tested using bootstrapping with 5,000 subsamples, bias-corrected 95% confidence intervals, and a two-tailed significance test at the 5% level (**Figure 3**). Effects were considered significant when the confidence interval did not include 0. **Table 6** shows the direct relationships between the main variables. CPTED has a strong positive effect on place attachment ($\beta = 0.441$, 95% CI [0.346, 0.526], T = 9.698, $p < 0.001$). When users perceive better surveillance, clearer boundaries, easier access and better maintenance, they also report stronger emotional bonds with the park. CPTED also has a positive direct effect on revisit intention ($\beta = 0.308$, 95% CI [0.200, 0.418], T = 5.595, $p < 0.001$), which means that a safer and more orderly environment makes users more willing to come back. In addition, place attachment is positively related to revisit intention ($\beta = 0.153$, 95% CI [0.046, 0.260], T = 2.791, $p < 0.01$). Users who feel attached to the park are more likely to choose it again for future visits.

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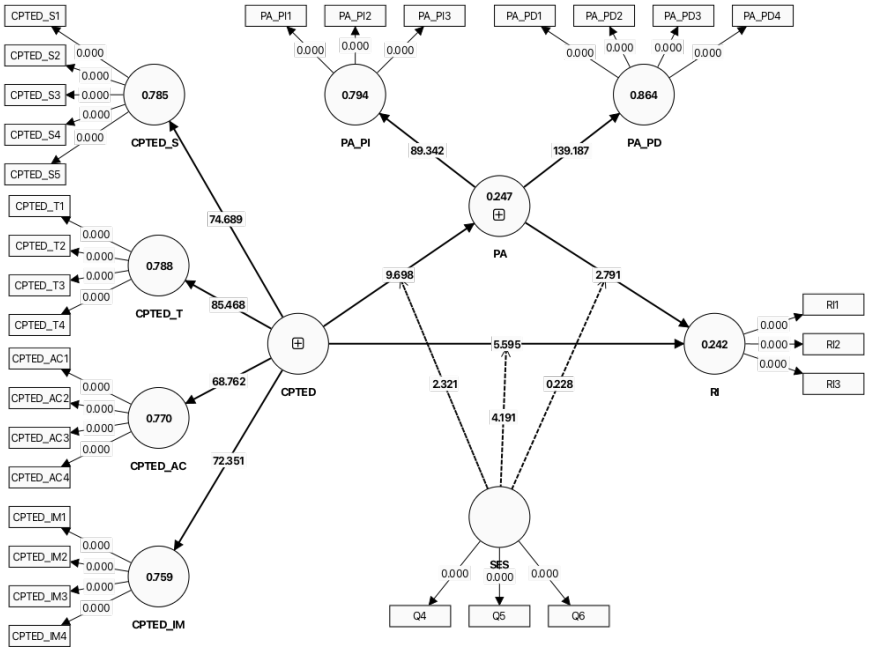


Figure 3: Bootstrapping results for the structural model.
Source: Authors (2026)

Table 6: Results of Hypothesis (direct effects)

Hs	Relationship	β	T value	f^2	95% CI	p	Decision
H1	CPTED→PA	0.441	9.698	0.246	[0.346, 0.526]	0.000 ***	Support
H2	CPTED→RI	0.308	5.595	0.095	[0.200, 0.418]	0.000 ***	Support
H3	PA→RI	0.153	2.791	0.023	[0.046, 0.260]	0.005 **	Support

*Note:***p<0.001, **p<0.01.* *Source: Authors (2026)*

Table 7 presents the mediating relationships in the model. Place attachment emerges as a significant mediator between CPTED and revisit intention (β = 0.068, 95% CI [0.021, 0.119], T = 2.723, $p < 0.01$). When users perceive higher levels of CPTED, they feel more emotionally attached to the park, and this attachment in turn increases their intention to revisit. This finding suggests that CPTED operates not only through a direct behavioural route but also through an emotional pathway that converts safer design into more stable repeat-use intentions.

Table 7: Results of Hypothesis (indirect effect)

Hs	Relationship	*β*	95% CI	T value	*p*	Decision
H4	CPTED→PA→RI	0.068	[0.021, 0.119]	2.723	0.006**	Support

*Note:**p<0.01.* *Source: Authors (2026)*

SES was further included in the structural model as a moderating variable. Specifically, interaction terms between SES and the relevant predictors were created to examine whether SES changed the strength of the relationships between CPTED, place attachment and revisit intention. **Table 8** reports the moderating role of SES. SES moderates the relationship between CPTED and place attachment (β = 0.117, 95% CI [0.019, 0.216], T = 2.321, p = 0.020) and the relationship between CPTED and revisit intention (β = 0.238, 95% CI [0.126, 0.342], T = 4.191, p < 0.001). Since both confidence intervals exclude 0, these moderating effects are significant. By contrast, SES does not moderate the relationship between place attachment and revisit intention (β = 0.012, 95% CI [-0.088, 0.123], T = 0.228, p = 0.820), as the confidence interval includes 0.

Table 8: Results of Hypothesis (moderation effect)

Hs	Relationship	*β*	95% CI	T value	*p*	Decision
H5	SES*CPTED→PA	0.117	[0.019, 0.216]	2.321	0.02*	Support
	SES*CPTED→RI	0.238	[0.126, 0.342]	4.191	0.000***	Support
	SES*PA→RI	0.012	[-0.088, 0.123]	0.228	0.82	Not support

*Note:***p<0.001, *p<0.05* *Source: Authors (2026)*

DISCUSSION

Key Findings

The significant positive effects of CPTED on place attachment and revisit intention show that safety oriented design in urban parks is not only a technical tool to reduce crime risk, but also an important source of positive experience (Çevik, 2020). Natural surveillance, clear territoriality, access control, and image management create a setting that feels orderly, clean, and predictable, which helps users build trust in the park over time (Hou, Hedayati Marzbali, & Abdullah, 2025). This result shows that CPTED measures can directly enhance emotional bonds with the park and revisit intention.

A notable finding is that place attachment mediates the link between CPTED and revisit intention, suggesting that safety design works through an emotional route (Ling et al., 2024). Prior research has often focused on perceived safety or satisfaction as the main bridge to loyalty (Plunkett et al., 2019). Our results indicate that what matters in parks is also a sense of belonging and identity built through repeated safe and pleasant experiences. CPTED creates conditions

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that support daily activities, social interaction and positive memories (Cozens & Stoks, 2025; Lee et al., 2016). Over time, these experiences accumulate into attachment to the park, which in turn encourages users to choose the same park again when planning future visits.

Evidently, the moderation results indicate that SES strengthens the positive effects of CPTED on both place attachment and revisit intention, with high SES users more likely to read safety and order cues as signs of a high-quality park and convert them into emotional bonds and repeat use (Hou, Hedayati Marzbali, Maghsoodi Tilaki, et al., 2025). For low SES users, the same CPTED improvements bring smaller gains, which is consistent with studies showing that environmental upgrades are often unequally experienced across social groups (Lee et al., 2023). SES does not change the link between place attachment and revisit intention, suggesting that once attachment is formed, its impact on revisit intention is broadly similar for all users. Park designers and managers should therefore integrate CPTED with targeted efforts to improve visibility, accessibility and inclusiveness, particularly for low SES users, so that future upgrades in Baitashan Park and similar urban parks in Lanzhou translate into safer, fairer and more sustained use.

Implications and Future Research

Based on the findings, CPTED should be interpreted as more than crime prevention. It can be framed as a long-term spatial strategy that supports safe and sustainable park use. Park designers should embed CPTED into layout decisions, such as clear sightlines, legible paths, well-defined zones, and reduced hidden corners. They should also combine CPTED with inclusive design, especially for low-SES users, by improving accessibility, wayfinding, and everyday comfort. Meanwhile, park managers should treat CPTED as routine governance. They can maintain lighting, trim vegetation to protect visibility, manage circulation with clear signage, and respond quickly to damage or disorder. The SES moderation suggests that safety is experienced differently across social groups, so updates should prioritise vulnerable areas and ensure that low-SES users gain real and shared benefits.

This study has several limitations. Firstly, the cross-sectional design means that the relationships among CPTED, place attachment and revisit intention should be understood as associations at a specific point in time, rather than as causal or temporal effects. Future research could use longitudinal or repeated-measure designs to examine how users' attachment to parks develops through repeated visits and safety-related experiences. Secondly, the study focused only on Baitashan Park in Lanzhou. Although this site provides a useful case for examining CPTED, place attachment and revisit intention, the findings may not be directly generalisable to parks with different spatial layouts,

management practices or neighbourhood contexts. Future studies could compare multiple parks across different urban settings to test whether the proposed relationships remain consistent.

CONCLUSION

This study examined how CPTED influences urban park users' intention to revisit in the specific context of Baitashan Park in the Chengguan District of Lanzhou. Using survey data from park users, the analysis shows that CPTED has positive effects on both place attachment and revisit intention in this setting. Place attachment partly explains how safety oriented design in Baitashan Park is translated into repeated use. The findings also indicate that SES changes the strength of the effects of CPTED on place attachment and revisit intention, while the association between place attachment and revisit intention remains stable.

These results suggest that in parks such as Baitashan, which serve mixed socioeconomic groups and experience intensive daily use, CPTED should be regarded as both a crime prevention tool and a long term investment in user engagement. For Lanzhou and similar Chinese cities, priority should be given to inclusive CPTED measures that are visible, accessible and easy to understand, particularly for lower SES users, so that safety improvements support safe and equitable park use over time.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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STAYING OR LEAVING FLOOD-PRONE AREAS (FPAs)? COMMUNITIES' DECISION-MAKING AND ADAPTATION PATHWAYS IN THE MAHAKAM CASCADE LAKES (MCL), INDONESIA

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Abstract

The decision to move or stay in FPAs is crucial and impacts livelihood sustainability (LS). This study investigates household decisions to stay or relocate in flood-prone communities around the MCL in Indonesia and analyzes how these choices shape adaptation strategies. Drawing on qualitative data from in-depth interviews with residents of Pela Village (PV) (original settlement) and Sangkuliman Village (SV) (relocation site), the study reveals that the interplay of flood risk perception (FRP), place attachment (PA), and livelihood security (LSc) influences decisions. Communities remaining in PV have normalized flooding and are investing in structural adaptations, such as elevating house foundations to sustain their livelihoods and social ties. Conversely, relocated communities prioritize flood safety but face new challenges related to livelihood access and economic burden. Both groups exhibited active adaptive capacities and a willingness to bear adaptation costs, highlighting adaptation as a continuous process rather than a one-time response. The findings emphasize that relocation should be integrated within a holistic framework that balances risk reduction with economic and sociocultural sustainability, supported by community participation to enhance resilience in flood-prone settlements.

Keywords: Relocation, Place attachment, adaptation strategies, community decision-making, livelihood sustainability, socio-ecological resilience.

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INTRODUCTION

The increasing frequency and intensity of flooding worldwide pose unique challenges to the sustainability of settlements in flood-prone areas (FPAs). Various areas near river networks, including Jakarta (Gunandar et al., 2024), Onitsha (Chinedu et al., 2024), and Bangkok (Marks & Elinoff, 2020), face high flood risks and require flood mitigation strategies to increase settlement resilience. These improvements can be achieved through the spatial planning of FPAs, including settlement relocation, to reduce flood risk (Yang et al., 2022). However, relocation often faces political and social resistance from communities (Rahman et al., 2025). Therefore, a community-based approach that involves local stakeholders from planning to implementation stages is required (Auliagisni et al., 2022).

In the context of MCL, flood-prone areas experience extreme water fluctuations that impact livelihoods, transportation, and social activities (BWS Kalimantan IV, 2019). From 1987 to 1990, the Kutai Kartanegara Regency government implemented a three-phase relocation program from Pela Village (PV) to Sangkuliman Village (SV). However, the program only partially relocated the population, as some residents remained in PV, while others moved to SV.

Although relocation is widely discussed as a flood mitigation strategy, previous studies have generally examined relocation and decisions to stay separately. Consequently, limited attention has been paid to how households that stay and those that move adapt to the same socioecological context. This study addresses this gap by investigating household decisions to stay or move in flood-prone communities around the MCL and examining how these decisions shape adaptation strategies. These findings provide empirical support for more responsive spatial planning and relocation policies, particularly for government stakeholders involved in settlement planning and disaster-risk reduction.

LITERATURE REVIEW

The relocation process aims to reduce flood risk and consider its socio-economic impact on affected communities (Tasnia & Growe, 2025). The decision to move or stay is influenced by various factors, including socio-economic conditions, cultural ties and risk perception (Thompson, 2017). Economic factors are crucial in determining whether people decide to stay or move, with negative prospects influencing decisions more than positive ones (Czaika, 2015). Cultural ties are also highly influential in shaping a sense of home and purpose (Thompson, 2017). Furthermore, perceptions of various risks, particularly long-term environmental disasters, are positively associated with migration decisions (Koubi et al., 2016). Meanwhile, communities that choose to remain in flood-prone areas typically develop coping strategies to deal with flooding and strengthen their solidarity

(Auliagisni et al., 2022). Communities that decide to relocate must adapt to the environment at the relocation site, build social networks, and face economic challenges (Twerefou et al., 2024). However, the existing literature tends to differentiate between relocation and remaining in FPAs, and few studies have simultaneously compared these two decisions. This limitation creates a gap in understanding resilience in dynamic socioecological contexts, as the interactive dynamics between those who relocate and those who remain are often overlooked in the literature. Therefore, a comparative perspective is crucial for uncovering the diverse adaptation strategies and conditional factors that shape resilience in socioecological systems.

RESEARCH METHODOLOGY

Study Area

The research locations were PV and SV, both in the Kota Bangun District, Kutai Kartanegara Regency, East Kalimantan Province, Indonesia (**Figure 1**). These two villages are located around the outlet of the MCL. The MCL is a lake system that experiences frequent and often extreme annual flooding (BWS Kalimantan IV, 2019), directly impacting PV. This relocation site is not far from the initial settlement of PV, approximately 2 km away, and is separated by the outlet of Lake Semayang-Melintang, locally known as the Pela River. Despite their spatial proximity, these two areas exhibit significantly different flood exposures owing to elevation disparities; for instance, PV has minimal dry land as its elevation is close to 0 m above sea level (BWS Kalimantan IV, 2019). This spatial proximity allows for a comparison between the communities that moved and those that remained in PV, which share similar socioecological characteristics but experience different levels of flood exposure.

Data Collection Procedures

Data were collected from September to November 2024 through in-depth, semi-structured interviews. The village head initially recommended key informants with direct experience of the PV–SV relocation process (1987–1990). Snowball sampling was used to identify additional participants representing diverse experiences and perspectives. A total of 12 informants were interviewed, comprising six residents who moved to SV and six who remained in PV. All informants were male, aged between 55 and 70 years, reflecting the generation directly involved in or witnessing the relocation process. The informants included village heads (SV1 and PV1), a former resettlement coordinator (SV2), a traditional leader (PV2), and community members (SV3-6 and PV3-6), most of whom relied on fisheries-related livelihoods. Informants were selected based on their direct experience with relocation decisions, long-term residence in the study area, and ability to provide detailed information regarding their flood

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experiences, adaptation practices, and relocation outcomes. Data collection continued until thematic saturation was reached, as indicated by the absence of substantial new themes or explanations in subsequent interviews.

Interviews were conducted in Banjar, audio-recorded with participants' consent, supplemented with field notes, and transcribed verbatim. Coding and thematic analyses were conducted using the original transcripts to preserve the contextual meaning. The quotations presented in this article were subsequently translated into English and checked against the original recordings to ensure accuracy. Data validity was strengthened through source triangulation using relocation documents, member checking with selected informants, and researcher discussions to assess the consistency of coding and interpretation. This study received ethical exemption approval from the Research Ethics Committee of Malang State University (No. 26.07.6/UN32.14.2.8/LT/2024). Before participation, all informants were informed of the study's purpose, confidentiality measures, and their right to withdraw at any time, and verbal consent was obtained before each interview.

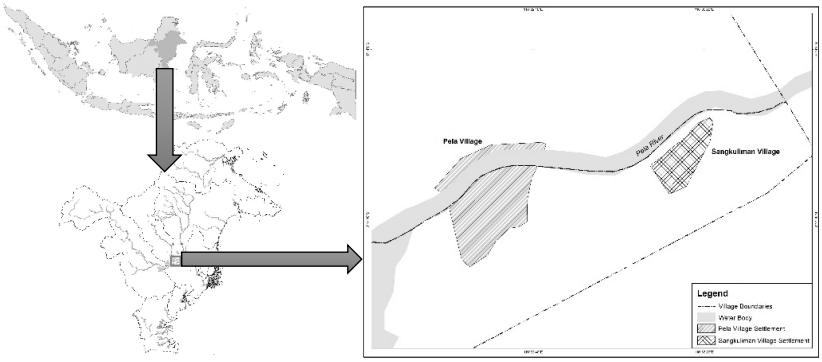


Figure 1: Research conducted in PV and SV, Kota Bangun District, Kutai Kartanegara Regency, East Kalimantan Province, Indonesia.

Data Analysis

Data analysis was conducted using a thematic analysis approach. After transcription, the transcripts were read repeatedly to gain familiarity with the data and identify meaningful patterns. Initial codes were generated from the participants' narratives regarding flood experiences, relocation decisions, place attachment, livelihood considerations, and adaptation practices. Related codes were then grouped into broader categories and further synthesized into themes explaining why households chose to remain in PV or moved to SV. A thematic matrix was used to compare similarities and differences between the two groups and to identify relationships between flood risk perceptions, place attachment, livelihood security, adaptation costs, and relocation decisions (**Table 1**).

To enhance analytical rigor, coding decisions and theme development were reviewed through discussions among the research team. This process helped refine categories, merge overlapping codes, and ensure that themes were grounded in the data rather than the researchers' assumptions. Member checking was also conducted with selected informants to validate the interpretations and confirm their alignment with the informants' experiences.

Table 1: Analytical Matrix of Factors Influencing Household Decisions

Example Initial Codes	Category	Final Theme	Interpretation	Stay in PV	Relocate to SV
Floods are routine; floods can be managed	Flood experience and risk evaluation	Flood Risk Perception	Risk is shaped by experience and adaptive capacity	Floods are perceived as manageable through experience and adaptation.	Floods are perceived as increasingly intolerable and disruptive.
Family history; inherited house; emotional ties	Emotional and symbolic attachment to place	Place Attachment	Attachment creates resistance to relocation	Strong emotional attachment, family history, and previous investments.	Relatively weaker attachment and greater willingness to pursue new opportunities.
Fish cages near home; access to fishing grounds	Dependence on livelihood resources	Livelihood Security	Livelihood dependence influences residential decisions	High due to proximity to fishing grounds and productive assets.	More uncertain due to greater distance from fisheries and additional operational costs.
House elevation; asset protection; transportation costs	Costs of adaptation and livelihood maintenance	Adaptation Cost	Different adaptation costs shape decision pathways	Costs associated with housing elevation and asset protection.	Costs associated with transportation, livelihood adjustments, and asset relocation.
Stay despite flood exposure; move for safety	Evaluation of risks and benefits	Decision Outcome	Decisions result from balancing risks and benefits	Remain in flood-prone areas.	Relocate to less flood-exposed areas.

RESULT

Factors Influencing the Decision to Move or Stay

Interviews revealed that decisions to stay or relocate were shaped by the interplay among FRP, PA, and LSc. Together, these factors influenced household decision-making in the MCL. The factors influencing these decisions are as follows:

FRP Factor

Experience with recurring floods shapes perceptions. According to all informants who chose to live in PV, flooding is a normal occurrence and part of life, described not as a threat requiring relocation but as an annual phenomenon that can be managed through adaptation. As one informant, PV5 stated: *"Flooding is common here. It's the same pattern every year, and we already know how to deal*

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with it." This perception refers not only to flood intensity but also to its impact on daily activities. Informants considered conditions safe as long as floodwaters did not enter their homes, even if roads were submerged, allowing daily activities to proceed normally. As PV1 stated: *"If the water is only under the house, it is still considered safe. As long as the floor isn't flooded, activities at home can still take place."* These results suggest that flood risk is assessed primarily through its impacts on daily activities and mobility rather than through hazard characteristics alone.

Although flooding is often perceived as a routine occurrence, changes in flood patterns, particularly increases in inundation height and duration, shape residents' tolerance limits. Informants who chose to relocate emphasized the impact of prolonged flooding on their physical and mental health, which prompted them to relocate. Informant PV3 described an extreme flood event that triggered this shift in perception: *"In the past, floods receded quickly, but there was a change in flood patterns in 1980, when the first major flood I experienced lasted for about two months. This made us unbearable because it was physically and mentally exhausting."* Collective memories of extreme flooding serve as a benchmark for determining whether flooding remains within normal limits or exceeds a community's adaptive capacity.

FRP is also shaped by adaptive capacity, particularly the ability to modify and protect homes from flooding. Communities with capital tend to feel more secure and can manage the impacts of flooding. These structural adaptations help provide a sense of security and reinforce the decision to remain in MCL FPAs. Conversely, communities with limited financial resources and unable to raise their homes tend to perceive the flood threat as beyond their control, making relocation the most reasonable option. Overall, these findings suggest that FRP is dynamic and is influenced by repeated interactions with flooding.

Attachment to Old Houses and Past Investments

Attachment to their old homes and past investments is one factor influencing people's decisions to remain in PV. A house is not only seen as a place to live but also as the result of hard work, capital, and memories of life experiences that are difficult to replace. Most informants who chose to stay stated that their houses were built in stages until they were comfortable living there. This implies a high economic and symbolic value of houses.

Beyond their physical value, old houses have emotional and historical significance for families. Several informants stated that the houses were inherited from their parents and passed down to them, where they raised their children. This attachment was deeply personal, as PV1 described: *"an inheritance from my parents, and this is where we grew up, and my children were born here. It feels hard to leave everything behind."* This illustrates that attachment to place was

rooted not only in physical ownership but also in family history, intergenerational continuity, and personal identity.

Attachment to old homes was also reinforced by the perception of inequality in their value relative to those at the relocation site. Several informants felt that relocation assistance was disproportionate to the value of their old homes, both in terms of land size, relocation costs, and location. This created feelings of loss and injustice for those who chose to move, as they perceived relocation as a 'loss' due to the small size of the land and inadequate assistance.

In contrast, those who chose to relocate had relatively weaker attachment, especially among informants who did not own homes. Relocation provided them with the opportunity to acquire their own homes and land despite the new environment. This is conveyed by SV2, who said: *"At that time, we didn't have our own house, so moving to SV was actually our opportunity to own one."* However, some informants who moved still felt a sense of loss for their old homes, particularly because of forced demolitions. This loss was both material and symbolic. According to informant SV3: *"We had no choice but to demolish our old house because of orders from the village government. It was actually sad, because we had to dismantle the results of years of work and rebuild it on a smaller scale in SV."* This suggests that relocation was perceived not only as a physical move but also as the loss of long-standing emotional and material investments. This sense of loss extended beyond the house's physical structure, reflecting the disruption of long-standing emotional and social connections to place. These results highlight that attachment to old houses and past investments plays an important role in discouraging relocation to safer areas. The house's inherent economic and symbolic value led some people to choose to stay rather than move, despite the risk of flooding in the area.

Security and Ease of Access to Livelihoods

LSc is a key determinant influencing people's decision to remain in or move out of FPAs in the MCL. For those who remain in PV, proximity to their homes, rivers, and lakes is crucial, as it facilitates monitoring and protection of productive assets, such as boats, boat engines, and fish cages. Informants who stayed underscored how proximity to water sources directly enabled LSc and reduced the operational costs. Informant PV4 emphasized this: *"Here, we keep our boats and engines (the engines are never removed and stored at home when not in use) and our fish cages in front of the house. This makes our assets safer because we can easily monitor them at any time."* This indicates that proximity to water resources supports both asset security and the continuity of fisheries-based livelihoods. Access to water is another key factor. Although flooding disrupted land transportation, water transportation remained normal and supported local livelihoods. As Informant PV2 explained: *"Even though there*

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was flooding, we could still carry out normal activities because every household has a boat for social and economic activities (fishing).” Thus, flood risk is not a barrier to livelihood continuity as long as water access is secure.

In contrast, residents who relocated to SV faced new challenges related to asset security and livelihood sustainability. Although their homes are safe from flooding, not all have direct access to waterways, making fishing and cage fish farming difficult for some. As SV5 explained: *“Our house is relatively safe from flooding, but access to the Pela River (waterway) is quite far. Furthermore, every time we leave our boat at the dock, we take the engine home to prevent it from being lost.”* This illustrates how relocation reduced flood exposure but increased the effort required to maintain livelihoods and productive assets. Similar concerns have arisen regarding fish cages, many of which are located far from homes. Therefore, residents build floating houses in groups so that they can take turns guarding them or hire someone to do so.

These findings underscore that flood safety alone does not determine relocation decisions. Access to water and the protection of productive assets are the determining factors of household LS. Furthermore, relocation does not always guarantee economic sustainability, especially in communities that depend on aquatic resources for their livelihoods. Thus, in the context of MCL, LSc is a crucial factor to consider in relocation planning and community-adaptation strategies.

Adaptation as an Alternative and Sustainability of Relocation

Households employed various strategies to respond to flood risks and adjust to changing environmental conditions. The findings indicate that both those who remain in FPAs and those who relocate adapt to maintaining their livelihoods. For those who stay, adaptation is gradual and structurally sustainable. The most prominent adaptation was raising the foundation pillars of stilt houses, which all informants viewed as a long-term solution to flooding. Tribal chief PV (PV2) explained the historical experience that drove this strategy: *“Previously, the foundation pillars of houses in this village were generally low, so regular floods would have submerged them. Now we have raised the foundation pillars of our houses by more than five meters, making them safer from the impact of flooding.”* However, when flooding is extreme and the raised foundations of stilt houses still sink, all informants stated that they implement temporary adaptation by building stilts inside their homes. This strategy allows people with PV to remain in their homes without being evacuated. This is explained by PV3: *“When this house (which has been elevated) is still submerged, we usually just build a platform inside the house, without needing to evacuate. Because in the past, when floodwaters submerged our house (before the foundation was raised), even almost reaching the roof, we remained in our house on a platform.”*

Additional measures have also been implemented by the PV government level by raising the elevation of the wooden road connecting stilt houses to public facilities so that daily activities can continue during mild floods. During extreme floods, community mobility relies solely on household boats. This aligns with PV6's statement: *"When extreme flooding occurs, activities at home are limited to the house on stilts, while outdoor activities are usually carried out by boat. So, even when the floodwaters are high, our lives are not significantly disrupted."* Raising a house's foundation pillars is a long-term investment, whereas building a platform inside a house is a short-term and less expensive option. This combination is considered more rational by the community, which chooses to stay rather than demolish their homes and move to a new location in the SV.

This contrasts with the community that relocated to the SV. They adapted to reduced access to water resources and changing livelihood patterns. These adjustments focused on maintaining access to livelihoods and asset security rather than protection from flood hazards. All informants stressed the need to rebuild their livelihoods, secure boat mooring locations, and develop security systems to protect the cages located far from their homes. This aligns with SV5 statement: *"Because most of the fish cages here are far from our homes, we formed a cage fish farming group and built a floating house near our cages to serve as a rotating guard post."* Adaptation also included more demanding routine changes, such as hauling boat engines back and forth to their homes and longer travel times to the lake. These conditions slightly increased labor and operational costs; however, they were a step towards maintaining the economic sustainability of the communities that chose to relocate.

Communities that remained in FPAs adapted primarily to reduce flood impacts, whereas those that relocated adapted to changes in access to water resources and livelihood activities. While the forms of adaptation differed between the two groups, both continued to adjust their practices in response to the challenges associated with their living environments.

Willingness to Pay (WtP) for Adaptation

These results demonstrate a strong willingness among households remaining in FPAs to invest in structural adaptation. All the informants (who decided to stay) stated that the cost of raising their house foundations and building temporary stilts was a crucial investment for maintaining their livelihoods. This was emphasized by PV2: *"If we don't pay to raise our house foundations, we will have difficulty living here because the floodwaters have been rising recently."*

Several informants emphasized that they would rather finance the cost of raising their house foundations, which ranges from IDR 100 million to IDR 300 million, than move to SV, which is slightly further away from water sources, because of concerns about losing their livelihoods. Informant PV4 expressed this

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sentiment: *"The cost of raising a house is indeed expensive, ranging from IDR 100 million to IDR 300 million, depending on the size of the house. However, it's still better than moving and starting from scratch."* This statement indicates that adaptation spending is viewed as a long-term investment to secure livelihoods, rather than a short-term response to flooding. The adaptations undertaken by the community are considered to provide direct benefits, particularly a sense of security from flooding and the sustainability of community socioeconomic activities. This was emphasized by PV1: *"Now when floods come, we don't have to panic anymore, because our houses are safe from floodwaters, and we can still carry out our activities as usual."* However, all informants acknowledged that this adaptation, which involved raising the foundations of their houses, was gradually implemented because of financial constraints.

In contrast, relocated households faced a different set of adaptation costs, primarily because of the greater distance to water resources. Additional expenses included transportation to the lake and the purchase of land for fish cages. As SV3 explained: *"Our house is now safe from flooding, but the cost of fuel to the lake has increased because the distance is somewhat greater. Furthermore, if we want to install fish cages, we have to buy land first; we can't just install them in front of our houses as we did in PV."* This account illustrates that adaptation costs did not disappear after relocation but instead shifted toward maintaining access to productive resources and sustaining livelihood activities in the new settlement. This financial burden persists because cage fish farming is their primary source of income. Informant SV4 emphasized this: *"We have no choice but to buy land to install the cages. Otherwise, we can't cultivate fish."* This land acquisition adaptation was carried out in stages, for example, by starting with small-scale cultivation or collectively purchasing land, as most of the informants did.

Overall, both communities that decided to stay or relocate demonstrated a WtP for adaptation but with different orientations. Those who stayed focused on flood risk reduction, whereas those who relocated focused on sustainable livelihoods. This WtP reflects not only economic capacity but also residents' evaluations of security, livelihood sustainability, and the relative benefits of different adaptation options.

DISCUSSION

The decision to move or remain in FPAs arises from interactions among FRP, PA, and LSc, highlighting the complexity of relocation outcomes. This finding is consistent with evidence from Ghana (Babanawo et al., 2022) and Pakistan (Ullah et al., 2025), where relocation did not necessarily reduce overall vulnerability, particularly when livelihood considerations were insufficiently integrated into planning.

This normalization of flood risk aligns with risk perception theory, which posits that repeated exposure to hazards without catastrophic consequences can shift the perception of risk from an extraordinary threat to an environmental condition considered normal (Rana et al., 2020). Rather than responding to flood hazards through avoidance or relocation, residents in PV instead incorporate flooding into their daily decision-making and adaptation practices. Similar patterns also occur in Ghana (Twerefou et al., 2024) and Central Vietnam (Duijndam et al., 2023), where prolonged exposure contributes to greater tolerance to flood risk. However, in contrast to these cases, PV residents actively invested in structural adaptations, such as raising house foundations and modifying living spaces. This shows that risk normalization does not mean a passive attitude but can be carried out simultaneously with ongoing adaptation efforts.

For households that relocated to SV, extreme and prolonged flooding was perceived as exceeding their adaptive capacity, triggering a shift in risk perception. Floods are no longer seen as something that can be overcome, but rather as a threat to welfare and daily life. These findings suggest that risk tolerance is not only shaped by repeated exposure but also by significant events that redefine acceptable levels of risk (Rana et al., 2020).

The contrasting experiences of informants in PV and SV indicate that PA goes beyond emotional ties. In PV, houses serve as both family heirlooms and productive assets, reinforcing residents' decisions to remain despite flooding. In contrast, some relocated households had weaker attachments due to limited prior ownership and investment. This finding suggests that attachment to residence becomes a significant barrier to relocation when reinforced by economic investment and livelihood dependence (Scannell & Gifford, 2017). Similar patterns have been observed in Chilean Patagonia (Wiegel et al., 2021) and the Pamir Mountains (Blondin, 2021), where resistance to relocation was driven by PA.

This contrasts with those who chose to relocate, particularly young households, whose ties to their homes in PV were more tenuous because of their minimal investment in previous residences. These individuals, a transitional group (newly establishing households and attempting to move out of their parents' homes), tended to have weak PA and were more open to relocation. Their decision to relocate was also supported by their lack of homes and limited asset ownership. Therefore, when these dimensions are weak or even absent, their attachment is weaker than that of communities with long-standing roots in the area (Thompson, 2017). In addition to ties to their homes or existing settlements, their decisions were influenced by security factors and easy access to their livelihoods.

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These findings underscore the central role of LSc in household decision-making. For fishers, proximity to water is a prerequisite for their continued livelihood and a means of protecting their assets (O'Mara et al., 2025). In this context, flooding is viewed not as a disruption but as an environmental rhythm that they cope with through daily adaptation.

For households that relocated to SV, reduced flood exposure is accompanied by new livelihood challenges. Greater distances to water resources increase transportation costs and require additional expenditures to maintain fisheries-based livelihoods, including the acquisition of waterways for cage fish farming. These findings support the interpretation of relocation as a form of risk transfer, whereby while flood exposure decreases, economic, social, and cultural vulnerabilities increase (Liu et al., 2024; Yokoyama et al., 2023). In the MCL, this transfer is reflected in increased livelihood costs, burdens of asset adjustment, and challenges in maintaining access to productive resources. A similar pattern has been observed in Kigali, Rwanda, where relocation reduced environmental risks but introduced new constraints on livelihoods and transportation (Nikuze et al., 2019).

Adaptation focuses on reducing flood risk for communities that decide to remain in FPAs. This strategy reflects the community's adaptive capacity, drawing on its experience and knowledge of floods. A similar situation is experienced by the people of Lagos, Nigeria, where those who have lived in FPAs for a long time tend to develop everyday adaptations based on repeated experiences and existing resources (Fayombo, 2024). One adaptation implemented by the PV community to cope with long-term flooding is raising the foundations of their houses, a practice similar to that of the Datian community in Zhejiang Province, China, where they raised their floors and implemented flood-proofing measures to mitigate flooding (Lai et al., 2023).

Adaptation was equally important for relocated households, although it focused on maintaining access to water resources and sustaining fisheries-based livelihoods. The findings demonstrate that relocation alters the ways households secure and sustain their livelihoods. This risk transfer often presents new challenges to livelihoods, social and cultural sustainability, potentially leading to maladaptation from disruptions to social networks, financial access to land and markets, and reduced mental health (Yokoyama et al., 2023).

Therefore, relocation policies must extend beyond hazard reduction to encompass livelihood sustainability, community participation, and long-term post-relocation support. Relocation planning should ensure continued access to productive resources, particularly for communities dependent on fisheries and water-based livelihoods, while also supporting locally developed adaptation measures for households that remain in FPAs. These findings highlight the importance of participatory planning processes that actively involve affected

communities in relocation and adaptation decisions to ensure that risk-reduction strategies align with local needs, capacities, and livelihood priorities.

All communities, whether they remained or relocated, were willing to allocate funds individually to reduce flood risk and survive in their new locations. This willingness reflects the efforts to maintain assets and livelihoods for sustainable development. Therefore, the desire to finance this adaptation demonstrates the community's priorities and strategies for preserving sustainability in their respective areas (Cabannes, 2021). This adaptation is a continuous negotiation process between risks, costs, and LSc for those who relocated and those who remained in the FPAs of the MCL.

Conceptually, this study refines existing theoretical perspectives by integrating FRP, PA, LSc, adaptation costs and WtP into a coherent framework for understanding decision-making in FPAs. The findings suggest that relocation should not be viewed solely as a mechanism for reducing flood exposure but rather as a process that can transform physical risk into economic and livelihood vulnerability. Consequently, relocation policies should be designed more holistically by integrating risk reduction, livelihood restoration, sociocultural sustainability, participatory planning, and long-term post-relocation support to enhance community resilience and sustainability.

CONCLUSION

This study demonstrates that decisions to remain in or relocate from FPAs emerge from the dynamic interaction among FRP, PA, and LSc. Households remaining in PV responded to recurring floods through structural adaptation and continued investment in existing livelihoods, whereas relocated households achieved greater flood safety but faced new challenges related to access to livelihoods and economic sustainability. Despite these differences, both groups demonstrated active adaptive capacities and a willingness to invest in adaptation. Rather than viewing relocation as a final solution to vulnerability, these findings emphasize that relocation represents a reconfiguration of risk and adaptation within a new socioecological context. Effective relocation policies should move beyond hazard-centred planning by integrating LS, sociocultural considerations, and meaningful community participation. Because adaptation to recurrent flooding is an ongoing process, governance frameworks should support flexible and long-term interventions that strengthen resilience rather than relying solely on one-off resettlement programs.

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INTRA-URBAN DISTANCE VARIATIONS IN PERCEIVED 20-MINUTE NEIGHBOURHOOD FEATURES: A KRUSKAL-WALLIS ANALYSIS WITHIN AN 800m WALKABLE CATCHMENT IN BAYAN BARU, PENANG, MALAYSIA

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Abstract

The 20-Minute Neighbourhood (20MN) has emerged as a prominent urban planning framework aimed at promoting accessibility, sustainability and local living. However, its application often assumes a uniform walking threshold, potentially overlooking variations in mobility needs, environmental perceptions, and demographic characteristics. This study examines how perceived neighbourhood performance varies across age groups and distance bands within an 800 m walkable catchment in a compact urban context. Using questionnaire data and non-parametric statistical analysis, the study evaluates six 20MN domains: safe, accessible and connected mobility; local economy and daily needs; essential services and community destinations; climate resilience and environmental comfort; high-quality public realm and open spaces; and housing diversity and affordability. Kruskal–Wallis tests identify significant differences in perceived neighbourhood features across distance bands, while age-group comparisons show limited variation across the six domains. The findings indicate that spatial proximity plays a stronger role than age in shaping perceived 20MN performance within the study area, although demographic characteristics remain relevant for inclusive neighbourhood planning. This study contributes to context-sensitive 20MN planning by highlighting the importance of considering intra-neighbourhood spatial variations when evaluating accessibility and neighbourhood quality in compact tropical urban environments.

Keywords: 20-minute neighbourhood, Walkability, Age Factors, Intra-Urban Distance, Perceived Accessibility, Kruskal-Wallis Analysis

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INTRODUCTION

Urban planning in dense cities faces ongoing challenges in promoting sustainable mobility, social equity, and liveability, particularly where private vehicle use dominates and pedestrian environments are compromised. The 20-Minute Neighbourhood (20MN) concept has emerged as a key framework to address these issues, advocating that residents access essential services such as food, education, healthcare, employment, and recreation within a 20-minute walk or cycle (Thornton et al., 2022; Chau et al., 2022). Despite its growing adoption, the operationalisation of the 20MN often relies on fixed spatial thresholds, commonly represented by an 800 m walking radius, which may overlook variations in residents' perceived accessibility and neighbourhood experiences. This assumption has been increasingly questioned, particularly in relation to demographic diversity and differences in how residents experience the urban environment. Age is an important consideration within neighbourhood accessibility research, as residents across different life stages may have different mobility patterns, activity requirements, and perceptions of environmental quality (Loo et al., 2017; Kim & Ulfarsson, 2022). Furthermore, spatial separation from neighbourhood facilities may influence residents' perceptions of accessibility and engagement with local environments, even where amenities fall within a formal walking threshold (Calafiore et al., 2022; Littlejohn et al., 2024). Bayan Baru, Penang, represents a suitable tropical urban context for examining these issues due to its compact urban form, diverse neighbourhood characteristics, and varying residential relationships with local facilities. This study examines whether perceived 20MN performance varies across different distance bands and age groups within an 800 m catchment. Rather than assuming that a fixed radius represents a uniform neighbourhood experience, this research investigates how spatial and demographic characteristics relate to residents' perceptions of accessibility and neighbourhood quality. By examining intra-urban variations in perceived 20MN features, this study contributes empirical evidence towards more context-sensitive approaches to applying the 20MN framework in compact tropical urban environments.

LITERATURE REVIEW

The 20-Minute Neighbourhood and Urban Accessibility

The concept of the 20-Minute Neighbourhood (20MN) builds on foundational neighbourhood planning theories that emphasise proximity, pedestrian orientation, and local self-sufficiency (Thornton et al., 2022; Chau et al., 2022). Contemporary applications extend beyond physical proximity to incorporate social, economic, and environmental dimensions, with recent research demonstrating positive relationships between local accessibility, health

outcomes, active mobility, and social engagement (Littlejohn et al., 2024; Iqbal, 2025). However, the operationalisation of 20MN through a fixed walking threshold, commonly represented by an 800 m radius, has been increasingly questioned due to distance decay effects, whereby residents' accessibility perceptions and interaction with neighbourhood amenities may vary according to spatial distance and across different population groups (Handley et al., 2023; Calafiore et al., 2022). Empirical studies further highlight that physical proximity does not necessarily translate into perceived accessibility or effective use of neighbourhood environments, as factors such as perceived safety, pedestrian infrastructure quality, environmental comfort, and neighbourhood conditions influence walking behaviour and local engagement (Roosli et al., 2024; Ewing & Handy, 2009; Forsyth et al., 2017; Roslan et al., 2025). Therefore, understanding how residents perceive neighbourhood features across different distances is essential for evaluating the effectiveness of the 20MN framework.

Age, Walkability and Distance Sensitivity

Age represents an important demographic consideration in understanding perceptions of walking accessibility, environmental comfort, and interaction with urban environments. Previous studies indicate that older adults may experience greater sensitivity to environmental barriers, including longer walking distances, inadequate pedestrian infrastructure, and uncomfortable outdoor conditions, which may influence perceived accessibility and neighbourhood participation (Lönn et al., 2025; Sánchez-González, 2025). In particular, climatic conditions such as heat exposure and humidity may affect outdoor comfort and walking experiences, especially in tropical urban environments where thermal conditions can influence residents' engagement with outdoor spaces (Núñez-Rodríguez et al., 2025; Fastl, 2024). However, the influence of environmental conditions and distance sensitivity is not limited exclusively to older adults, as residents across different age groups may perceive neighbourhood features differently according to their mobility needs, daily activities, and environmental preferences. Consequently, age remains an important consideration when examining variations in perceived neighbourhood suitability within the 20MN framework. In tropical cities, microclimatic interventions, including shaded pedestrian routes, green infrastructure, and urban cooling strategies, may contribute to improving outdoor comfort and supporting walkability for diverse population groups (Tan, 2025; Xiong et al., 2025). Recent urban studies advocate for age-inclusive planning approaches that move beyond universal distance thresholds by recognising variations in residents' abilities and perceptions (Loukaitou-Sideris et al., 2020). Nevertheless, age-related differences remain insufficiently explored in empirical evaluations of the 20MN framework (González, 2025).

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RESEARCH METHODOLOGY

Perceived 20-Minute Neighbourhood Features Across Distance Bands and Age Groups

This research focuses on urban areas of Bayan Baru, Penang, a dense tropical urban setting characterised by compact urban morphology. The study examines residents' perceptions within a nominal 800 m 20-Minute Neighbourhood (20MN) catchment, which was subdivided into three micro-scale distance bands (Table 1) and three age categories (Table 2) to investigate variations in perceived neighbourhood performance.

Table 1. Distance Band Classification within the 800 m 20-Minute Neighbourhood Catchment

Distance Band		Description
0-300m	Immediate neighbourhood	Closest proximity to local facilities and services
300-600m	Intermediate zone	Moderate walking distance within the 20MN catchment
600-800m	Outer neighbourhood edge	Outer limit of the defined 20MN catchment

Source: Author's data (2025)

The 800 m catchment was disaggregated into three distance bands to examine whether perceptions of 20MN features vary according to intra-neighbourhood spatial conditions. This approach recognises that walking experiences and perceived accessibility may differ across short-distance variations rather than assuming a uniform walking threshold throughout the entire catchment.

Table 2. Definition of Age Groups Used in the Study

Code	Age Group	Description
1	Young Adults (18-35 years)	Different activity patterns and mobility preferences
2	Middle-Aged Adults (36-55 years)	Diverse daily routines and neighbourhood requirements
3	Older Adults (56 years and above)	Potentially differences in accessibility perceptions and neighbourhood experience

Source: Author's data (2025)

Respondents were classified into three age groups to examine whether perceptions of 20MN features vary across different demographic categories. This categorisation enables comparative analysis of variations in neighbourhood perceptions across different life stages, while acknowledging that residents may experience and evaluate neighbourhood environments differently based on their

individual circumstances and needs. After data screening, 280 valid responses were retained for statistical analysis.

Table 3. Distribution of Respondents by Distance and Age Group

Distance Band	Young Adults	Middle-Aged Adults	Older Adults	Total
0-300m	21	26	31	78
300-600m	28	34	30	92
600-800m	34	35	41	110
Total	83	95	102	280

Source: Author's data (2025)

Six key themes of the 20MN framework were investigated: i) safe, accessible and connected mobility; ii) local economy and daily needs; iii) essential services and community destinations; iv) climate resilience and environmental comfort; v) high-quality public realm and open spaces; and vi) housing diversity and affordability. While the study focuses on subjective perceptions, the findings provide insights into micro-scale neighbourhood planning considerations related to spatial accessibility and demographic variations. Figure 1 illustrates the study area and distance bands.



Figure 1: Research Area (Radius 300m, 600m and 800m)
Source: Author's fieldwork (2025)

Non-parametric methods such as the Kruskal–Wallis H test are widely recommended for analysing differences across ordinal perception data and

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categorical groups, as they do not require assumptions of normality and are suitable for survey responses measured on Likert-type scales (Eiselen, 2023; Rustin & Arifin, 2026). The Kruskal–Wallis H test is particularly appropriate for comparing three or more independent groups, allowing for robust detection of statistically significant differences in perceptions across categories such as distance bands and age groups (Eiselen, 2023; Karsokiene et al., 2025). By integrating both spatial distance and demographic characteristic in the analysis of 20MN perceptions using this method, the study provides a nuanced understanding of perceived accessibility and neighbourhood experiences among different resident groups.

A quantitative survey was conducted among 280 urban residents of Bayan Baru capturing resident's perceived quality across six 20MN domains using a five-point Likert-scale. Residential locations were classified according to distance bands within the 0–800 m catchment (Table 1), while respondents were categorised into three age groups (Table 2). The Kruskal–Wallis H test was applied to identify whether statistically significant differences existed across both distance bands and age groups, with $p < 0.05$ indicating statistical significance.

ANALYSIS AND RESULTS

The analysis examined variations in perceived 20-Minute Neighbourhood (20MN) features across different age groups and distance bands to examine whether residents' perceptions of neighbourhood performance differed across distance bands and age groups. Descriptive statistics were first used to examine differences in mean perceived scores, followed by the Kruskal–Wallis H test to determine whether observed variations were statistically significant.

Perceived 20MN Features across Age Groups

The analysis of perceived 20MN features across age groups shows relatively small variations in mean scores across the six domains (Table 4). Differences between young adults, middle-aged adults, and older adults were observed, however, no consistent pattern indicates that any particular age group reported systematically higher or lower perceptions across all domains.

Older adults recorded slightly higher mean scores for local economy and daily needs (Mean = 4.4608) and housing diversity and affordability (Mean = 3.9338), while young adults reported marginally higher perceptions for safe, accessible and connected mobility (Mean = 2.4418) and high-quality public realm (Mean = 3.6657). Middle-aged adults recorded comparable perceptions across several domains. These descriptive variations indicate modest differences in mean perceptions across age groups; however, the magnitude of these differences is relatively small.

Table 4: Mean Perceived Scores of 20-Minute Neighbourhood Features across Age Groups

Domain	Age Group	Mean	N
Theme 1: Safe, Accessible and Connected Mobility	Young Adults	2.4418	83
	Middle-Aged Adults	2.1268	95
	Older Adults	2.3524	102
	Total	**2.3534**	**280**
Theme 2: Local Economy and Daily Needs	Young Adults	4.3494	83
	Middle-Aged Adults	4.3158	95
	Older Adults	4.4608	102
	Total	**4.3786**	**280**
Theme 3: Essential Services and Community Destinations	Young Adults	3.6566	83
	Middle-Aged Adults	3.6737	95
	Older Adults	3.6373	102
	Total	**3.6554**	**280**
Theme 4: Climate Resilience and Environmental Comfort	Young Adults	3.5582	83
	Middle-Aged Adults	3.4421	95
	Older Adults	3.5000	102
	Total	**3.4976**	**280**
Theme 5: High-Quality Public Realm and Open Spaces	Young Adults	3.6657	83
	Middle-Aged Adults	3.6158	95
	Older Adults	3.6103	102
	Total	**3.6286**	**280**
Theme 6: Housing Diversity and Affordability	Young Adults	3.8404	83
	Middle-Aged Adults	3.8579	95
	Older Adults	3.9338	102
	Total	**3.8804**	**280**

Source: Author's data (2025)

Perceived 20MN Features across Distance Bands

The descriptive analysis by distance bands demonstrates greater variation compared with age groups (Table 5). The 0–300 m zone recorded the highest perceived score for safe, accessible and connected mobility (Mean = 2.7479), suggesting that proximity contributes to perceptions of accessibility. Meanwhile, the 300–600 m zone recorded the highest mean scores for local economy and daily needs (Mean = 4.6576), essential services and community destinations (Mean = 3.9429), and high-quality public realm (Mean = 3.7527).

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The 600–800 m zone generally recorded lower perceptions for selected domains, particularly essential services and community destinations, although the spatial pattern varied across the six domains particularly essential services and community destinations (Mean = 3.5227) and high-quality public realm (Mean = 3.7068). However, the results do not indicate a uniform linear decline across all domains, suggesting that different neighbourhood characteristics may influence perceptions at different spatial ranges.

Table 5: Mean Perceived Scores of 20-Minute Neighbourhood Features across Distance Band

Domain	Distance Band (m)	Mean	N
Theme 1	0–300	2.7479	78
	300–600	2.1268	92
	600–800	2.3524	110
	Total	**2.3534**	**280**
Theme 2	0–300	4.0641	78
	300–600	4.6576	92
	600–800	4.3682	110
	Total	**4.3786**	**280**
Theme 3	0–300	3.5032	78
	300–600	3.9429	92
	600–800	3.5227	110
	Total	**3.6554**	**280**
Theme 4	0–300	3.5299	78
	300–600	3.4746	92
	600–800	3.4939	110
	Total	**3.4976**	**280**
Theme 5	0–300	3.3718	78
	300–600	3.7527	92
	600–800	3.7068	110
	Total	**3.6286**	**280**
Theme 6	0–300	3.8686	78
	300–600	3.9130	92
	600–800	3.8614	110
	Total	**3.8804**	**280**

Source: Author's data (2025)

Kruskal–Wallis Test Results

The Kruskal–Wallis H test was conducted to examine whether perceived 20MN features differed significantly across distance bands and age groups (Table 6). The test was considered appropriate due to the ordinal nature of the Likert-scale responses and the non-normal distribution of perception data.

The results demonstrate that distance significantly influenced perceptions across several 20MN domains. Significant differences were identified for safe, accessible and connected mobility ($H = 9.667$, $p = 0.008$), local economy and daily needs ($H = 31.438$, $p < 0.001$), essential services and community destinations ($H = 51.784$, $p < 0.001$), and high-quality public realm ($H = 37.496$, $p < 0.001$). Among these domains, essential services and community destinations recorded the strongest effect size ($\varepsilon^2 = 0.179$) indicating that perceptions of essential services and community destinations vary more strongly across distance bands than the other domains examined.

The observed pattern across distance bands indicates that perceptions of 20MN features vary within the 800 m catchment, although the direction of these differences differs by domain. For example, local economy and daily needs and essential services and community destinations recorded the highest mean perceptions within the 300–600 m zone, suggesting that the spatial distribution of amenities and neighbourhood functions may influence residents' perceptions beyond simple physical proximity.

In contrast, age-based comparisons did not demonstrate statistically significant differences across any of the six 20MN domains ($p > 0.05$). Although descriptive variations were observed among age groups, the effect sizes were negligible to small, indicating that age alone did not represent a significant determinant of perceived neighbourhood performance within the study area.

Table 6: Kruskal–Wallis Test Results and Effect Sizes for 20MN Domains

Domain	Factors	H	df	p-value	ε^2	Effect	Observed Pattern/ Interpretation
Theme 1	Distance	9.667	2	0.008	0.028	Small	Higher perceived accessibility was observed in the 0–300 m zone compared with the 600–800 m zone
	Age	0.768	2	0.681	0.003	Negligible	No statistically significant differences

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Domain	Factors	H	df	p-value	ε^2	Effect	Observed Pattern/ Interpretation
							across age groups
Theme 2	Distance	31.438	2	<0.001	0.106	Medium	Highest mean perception was observed in the 300–600 m zone, with significant differences among distance groups
	Age	0.753	2	0.686	0.003	Negligible	No statistically significant differences across age groups
Theme 3	Distance	51.784	2	<0.001	0.179	Large	Highest mean perception was observed in the 300–600 m zone, while the 600–800 m zone recorded lower perceptions.
	Age	0.739	2	0.691	0.003	Negligible	No statistically significant differences across age groups
Theme 4	Distance	1.305	2	0.521	0.000	None	No meaningful differences across distance bands
	Age	0.491	2	0.782	0.001	Negligible	No statistically significant differences across age groups

Domain	Factors	H	df	p-value	ε^2	Effect	Observed Pattern/ Interpretation
Theme 5	Distance	37.496	2	<0.001	0.128	Medium	Higher perceptions were observed in the 300–600 m zone, with lower perceptions in the outer distance band.
	Age	0.890	2	0.641	0.003	Negligible	No statistically significant differences across age groups
Theme 6	Distance	1.518	2	0.468	0.000	None	No clear spatial pattern across distance bands
	Age	3.893	2	0.143	0.007	Negligible	No statistically significant differences across age groups

Notes:
i. H = Kruskal-wallis test statistic
ii. df = degrees of freedom
iii. $p < 0.05$ = considered statistically significant
iv. ε^2 = epsilon squared effect size

Source: Author's data (2025)

Overall, the findings indicate that intra-urban distance is a more influential factor than age in shaping perceived 20MN features within the 800 m catchment of Bayan Baru. While age remains an important consideration in inclusive neighbourhood planning, the statistical findings indicate that spatial accessibility and the distribution of neighbourhood functions are more strongly associated with residents' perceptions of 20MN performance than age within the study area.

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DISCUSSION

The findings of this study demonstrate that the operationalisation of the 20-Minute Neighbourhood (20MN) as a uniform 800 m walking threshold requires consideration of intra-neighbourhood spatial variations. Although the 800 m radius provides a useful planning reference, the results indicate that residents do not experience neighbourhood accessibility uniformly across space. The significant differences identified across distance bands in several 20MN domains suggest that perceived neighbourhood performance is influenced by the spatial distribution of facilities, services, and environmental characteristics within the walking catchment.

The observed variations across distance bands are consistent with the concept of distance sensitivity, whereby residents' perceptions of accessibility and neighbourhood functionality may be influenced by spatial separation from local facilities and services (Handy et al., 2002; Leslie et al., 2010). Residents within the 0–300 m zone recorded higher perceptions for safe, accessible, and connected mobility, indicating that closer proximity contributes positively to perceived accessibility. However, the findings also demonstrate that the relationship between distance and perceived neighbourhood quality is not entirely linear. For example, local economy and daily needs, essential services and community destinations, and high-quality public realm recorded higher mean perceptions within the 300–600 m zone. This suggests that factors such as amenity concentration, activity intensity, and neighbourhood function may influence perceived accessibility beyond physical distance alone.

The significant differences observed in local economic vitality and service-related domains further highlight the importance of spatial arrangement within the 20MN framework. While proximity remains an important consideration, the presence and distribution of neighbourhood activities influence how residents perceive the functionality and attractiveness of local environments. This aligns with Jacobs' (1961) perspective that urban vitality is shaped not only by the existence of amenities but also by their concentration, diversity, and potential to encourage everyday interaction. Therefore, planning strategies should consider balanced distribution of services and local activity nodes to support consistent neighbourhood experiences across different spatial zones.

Climate-related considerations remain relevant in tropical urban environments, although the present study did not identify statistically significant differences for the climate resilience domain across distance bands or age groups. Previous research highlights that thermal conditions, shading, and environmental comfort can influence outdoor activity and walking experiences, particularly in warm climate contexts (Yin et al., 2018). Therefore, climate-responsive interventions, including shaded pedestrian routes, street trees, and green infrastructure, remain important strategies for improving outdoor comfort and supporting walkability.

In addition, built environment characteristics that encourage walking and active mobility continue to represent important considerations in neighbourhood planning (Ewing & Cervero, 2010). Although age was included as an important demographic factor in this study, the statistical results indicate that age-group differences were not significant across the six 20MN domains. While descriptive variations were observed among young adults, middle-aged adults, and older adults, these differences were relatively small and did not demonstrate a consistent pattern of disadvantage among any particular age group. This suggests that, within the Bayan Baru context, spatial characteristics and neighbourhood conditions may have a stronger influence on perceived 20MN performance than age alone.

Nevertheless, age remains an important consideration in inclusive neighbourhood planning. Previous studies have highlighted that residents at different life stages may experience and evaluate neighbourhood environments differently due to variations in mobility needs, daily activities, and environmental preferences (Loukaitou-Sideris et al., 2020). Therefore, while this study does not identify significant age-based differences, incorporating demographic diversity remains essential to ensure that 20MN planning. Overall, the findings suggest that the 20MN should not be interpreted solely as a fixed spatial radius, but rather as a dynamic neighbourhood experience influenced by distance, amenity distribution, and environmental conditions. Results highlight that spatial accessibility represents a key determinant of perceived neighbourhood performance within the 800 m catchment of Bayan Baru, while demographic characteristics should continue to inform inclusive planning approaches. This perspective supports a more context-sensitive application of the 20MN framework, particularly in dense tropical urban environments where walking experiences are influenced by physical and experiential factors.

CONCLUSION

The findings of this study offer important implications for the operationalisation of the 20MN concept within Malaysia's planning framework, particularly in relation to the PLANMalaysia planning guidelines and the aspirations outlined in the Twelfth Malaysia Plan, which emphasise liveability, inclusivity, and low-carbon urban development. The present findings demonstrate that defining the 20MN as a uniform 800 m radius may overlook experiential and demographic realities. The significant differences identified across distance bands indicate that physical proximity alone does not necessarily translate into consistent perceptions of accessibility, neighbourhood services, and overall neighbourhood quality. Therefore, the application of 20MN principles should consider intra-neighbourhood spatial variations rather than relying solely on fixed distance-based benchmarks.

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The study further aligns with Malaysia's sustainable mobility and healthy city aspirations by highlighting climate comfort as a decisive factor in tropical urban contexts. Existing guidelines encourage pedestrian infrastructure and green elements; however, the results underscore the necessity of embedding microclimatic design, including shaded pedestrian routes, street trees, green infrastructure, and well-designed pedestrian facilities as core neighbourhood infrastructure rather than aesthetic enhancements. Integrating these elements into local plans and development control standards would strengthen policy implementation and ensure that walkability remains functional across age diverse population groups.

From a stakeholder perspective, local authorities, developers, and community planners can utilise these findings to refine neighbourhood design strategies. Rather than concentrating amenities at a single centre within an 800 m buffer, planners could introduce decentralised micro-nodes and evenly distributed service clusters to sustain perceived economic vitality across distance bands. The findings suggest the potential value of distributed service nodes and balanced activity locations to maintain neighbourhood functionality across different distance zones. Inclusive design considerations, such as barrier-free pedestrian facilities, safe crossings, and resting areas, should continue to be incorporated to support residents with diverse mobility needs. Community stakeholders may also leverage these insights to advocate for equitable infrastructure improvements that reflect lived realities rather than theoretical standards.

This study contributes to the growing body of 20MN research by examining perceived neighbourhood performance within a dense tropical Southeast Asian context, an area that remains less represented compared with Global North case studies. By demonstrating that perceived accessibility varies across intra-neighbourhood distances, the study extends understanding beyond conventional spatial thresholds and highlights the experiential dimension of the 20MN framework. Conceptually, the findings support viewing the 20MN not only as a fixed geographical radius but also as a dynamic socio-spatial construct shaped by perceived accessibility across different intra-neighbourhood distances within the broader neighbourhood environment.

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ANALYSIS OF THE LEVEL OF USER AWARENESS OF SAFETY IN USING PUBLIC BUS TRANSPORTATION IN BATAM CITY

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Abstract

Safety awareness among public transport users is a critical component of traffic safety and sustainable urban mobility, yet empirical evidence focusing on passenger-centred behaviour remains limited in developing city contexts. This study examines the level of safety awareness among city bus passengers, identifies factors associated with different awareness levels, and proposes planning-oriented recommendations to enhance public transport safety. A mixed-methods approach was employed, combining a questionnaire survey, exploratory factor analysis (EFA), ordinal logistic regression, and in-depth interviews. The descriptive results indicate that most passengers demonstrate a moderate level of safety awareness, suggesting that basic safety knowledge exists but has not been fully internalised into consistent behaviour across all stages of the journey. The EFA confirms that safety awareness is a multidimensional construct consisting of three domains: boarding safety awareness, on-board safety behaviour, and alighting safety practices. Ordinal logistic regression analysis reveals that demographic characteristics, particularly age and gender, are significant predictors of safety awareness levels, with older passengers and female users more likely to exhibit higher awareness. In contrast, experience of safety incidents, exposure to safety information, and frequency of bus use do not show statistically significant effects, although their positive coefficient directions indicate a supportive role. Qualitative findings further suggest that inexperienced users tend to exhibit riskier behaviours and that learning through experience and information requires structured reinforcement. Overall, the findings highlight that passenger safety awareness is shaped by an interaction between individual characteristics, learning processes, and institutional context. This study contributes to traffic safety research by applying ordinal modelling to passenger safety awareness and provides evidence-based implications for safer public bus systems in medium-sized cities.

Keywords: Transportation safety, Passenger behaviour, Safety awareness, City bus transportation, Mobility planning

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INTRODUCTION

Urban bus transportation systems play a strategic role in supporting sustainable mobility, social inclusion, and cities' decarbonisation efforts in developing countries. Various reviews show that buses are the backbone of daily mobility for low- and middle-income groups with limited access to private vehicles, including in Batam City, where buses are the primary mode for routine trips (Sogbe et al., 2025; Sugito et al., 2024). In addition to providing basic accessibility, bus systems also contribute to road safety by shifting users from high-risk modes, such as motorcycles, to safer public transportation (Ibrahim et al., 2023).

Nevertheless, safety concerns are still a significant obstacle in the use of public transportation. Various studies have concluded that perceptions of safety have a considerable influence on the choice of transportation modes and the sustainability of bus service use, along with traditional factors such as service reliability and comfort (Chau et al., 2024; Sugito et al., 2024). In the Southeast Asian region, this issue is increasingly relevant as national efforts to reduce accidents through the Malaysia Road Safety Plan 2022 - 2030 emphasise the importance of a culture of public safety, including for public transportation users. Related findings point to the need for effective communication strategies and safety campaigns that are adaptive to user characteristics (Sinnappan et al., 2023).

Globally, research on safety in public transportation is also developing by highlighting aspects of safety perception in vulnerable groups, bus stop design, passenger density, and exposure to risks and antisocial behaviours (Mchunu et al., 2025; Soltani et al., 2025). However, empirical evidence on the level of safety awareness among bus passengers is limited, especially in the urban context of Southeast Asia. Most studies focus more on technical risk analysis or aggregate accident data rather than the cognitive dimensions and behaviour of passengers as users of transportation systems (Sethulakshmi, 2023; Sethulakshmi & Mohan, 2024). In fact, findings in traffic safety studies show that safety awareness is an important predictor of safe behaviour, compliance with procedures, and changes in patterns of action in transportation use (Mbagha, 2023; Wang et al., 2020).

Based on these gaps, this study aims to analyse the level of safety awareness of city bus passengers and identify the main factors that affect them in the context of medium-sized cities in Indonesia. Specifically, this study: (1) measured the level of safety awareness at the boarding stage, during the trip, and when getting off the bus; (2) Analyse the relationship between sociodemographic characteristics, travel patterns, safety experiences, and information exposure to the level of awareness; and (3) formulate policy recommendations that can be integrated in the planning and management of city bus services. The academic contribution of this research lies in operationalising safety awareness as a multi-indicator construct for bus passengers, providing empirical evidence from the Southeast Asian context, and translating the findings into actionable planning

recommendations to strengthen the safety culture in the public transportation system.

LITERATURE REVIEW

Quality of Service, Safety, and Behaviour of Public Transportation Users

Studies on public transportation services in developing countries show that safety is a key component in the perception of service quality, along with aspects of comfort, reliability, accessibility, and safety (Sogbe et al., 2025). In the urban context, perceptions of safety directly affect the sustainability of public transportation use and the accessibility of daily activities, so that safety is no longer seen as an additional issue but as a determinant of travel behaviour (Chau et al., 2024). Developments in cutting-edge research show a shift from an engineering-based safety approach to an understanding of user behaviour. Ibrahim et al., (2023) emphasised that safety should be positioned as a core element in mobility management policies and fashion transition strategies. Similar studies show that the quality of perceived safety of corridors, bus stops, and on-board experiences influences users' decisions to choose buses over private vehicles (Soltani et al., 2025). In the city bus system, the passenger safety experience is formed from a series of trips ranging from access to the bus stop, the condition of the waiting room, to the experience on the bus, such as the driver's driving style, passenger density, and the technical condition of the vehicle. Weaknesses in these areas not only increase the risk of incidents but also lower perceptions of safety, potentially reducing long-term bus use in the long term (Sethulakshmi, 2023; Sethulakshmi & Mohan, 2024).

Safety Awareness as a Determinant of Safe Behaviour Practices

Safety awareness is defined as an individual's ability to understand and anticipate risks and choose safe behaviours in a specific context. In the study of transportation behaviour, safety awareness is seen as a prerequisite for the formation of safe behaviour, in line with behavioural theory that emphasises the role of knowledge, attitudes, and perceptions of control in influencing safety practices (Mbagha, 2023). Empirical findings in public transportation show that the level of safety awareness is a strong predictor of compliance with safety procedures, including when boarding and disembarking the bus, using handrails, and avoiding risky behaviours during travel (Henezi & Winkler, 2023). Evidence from other road user groups also reinforces this finding that increased awareness can reduce risky behaviours even when infrastructure is not yet optimal (Asah Nasrudin et al., 2023). Recent studies highlight the mediating role of safety awareness in the relationship between safety attitudes and safe behaviours. Rahman (2024) shows that awareness functions as a mechanism for forming effective safety behaviours, so that educational interventions can

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increase the level of compliance and vigilance of passengers (Rahman, 2024). Although the study focused on drivers, the exact psychological mechanisms could potentially apply to bus passengers, given their contribution to safety during the trip.

Determinants of Safety Perception and Awareness

Recent research identified several factors that affect the perception of public transportation safety, including sociodemographic characteristics, travel patterns, bus stop design, and exposure to safety information. A study by Sethulakshmi and Mithun (2023) found that age, gender, frequency of trips, and bus stop conditions have a significant effect on the perception of bus users' safety. Contextual factors such as lighting, passenger density, surveillance, and officer presence also play an important role in shaping users' perceptions of risk and safety (Soltani et al., 2025). The context of vulnerable groups, particularly women and students, shows an additional dimension of safety related to harassment and fear of crime. The study of Mchunu et al. (2025) concluded that the lack of physical protection and weak safety facilities are the main obstacles for women in using public transportation. Research in Malaysia has shown that improvements in bus stop design and security measures, including lighting and surveillance, can enhance the perceived safety of vulnerable users, particularly women (Adilah Shamsul Harumain et al., 2024). In addition, information digitisation also plays a role in increasing safety awareness. Husnina et al. (2022) show that transportation applications with real-time information and travel navigation features can improve the understanding and perception of passenger safety (Husnina et al., 2022). The information indicates that the safety experience is influenced not only by the physical aspects but also by the information the user receives before and during the journey.

Research Gap and Conceptual Framework

A review of the literature indicates three main gaps. First, although the perception of safety in public transportation has been extensively researched, studies on safety awareness as a multidimensional construct in the context of city buses are still limited (Sethulakshmi, 2023). Second, there is a lack of empirical evidence from Southeast Asian cities regarding variations in safety awareness based on user characteristics, travel patterns, and exposure to safety campaigns (Adilah Shamsul Harumain et al., 2024; Husnina et al., 2022). Third, findings on the role of safety awareness in shaping safe behaviour have not been fully applied in the context of planning and designing public transportation services, especially to support sustainable mode switching (Rahman, 2024). In response to these gaps, this study developed a conceptual framework that explains that safety awareness is influenced by: (1) sociodemographic factors (age, gender, education, and

income); (2) travel behaviour (frequency and purpose of travel); (3) previous safety experience; (4) exposure of safety information; and (5) service context (passenger density, driver behaviour, and bus stop/bus conditions). Safety awareness is then predicted to influence passenger safety practices and contribute to the sustainability of city bus use in the long term. This framework is the basis for the preparation of survey instruments and analytical approaches used in the research.

RESEARCH METHODOLOGY

This study was conducted on the city bus transportation system in Batam, Indonesia, where structured route-based services have been implemented. Over the past decade, Batam has experienced significant growth in motor vehicle ownership and congestion, prompting local authorities to modernise bus services as part of a sustainable mobility strategy. This situation reflects broader conditions in many Southeast Asian cities, where motorcycles remain dominant and public transport safety particularly for buses frequently becomes a concern in public discourse. A mixed-methods approach with an explanatory sequential design was employed. Quantitative analysis was first conducted to measure passenger safety awareness, followed by qualitative analysis to explore the underlying reasons and contextual factors. The quantitative phase used a cross-sectional survey conducted through on-board intercepts, with a target of 350 respondents based on multivariate analysis requirements (Sogbe et al., 2025).

For the qualitative phase, semi-structured interviews were conducted with five key informants, including regular passengers, women, students, elderly users, drivers, and operators, to deepen the interpretation of survey findings. A combination of purposive and convenience sampling was applied. Purposive sampling ensured that respondents met inclusion criteria (aged ≥18 years and using the bus at least twice per month), while convenience sampling was used due to the dynamic nature of the passenger population. To enhance representativeness, quota-based sampling was applied based on routes, days (weekdays and weekends), and travel times (peak and off-peak), consistent with previous public transport studies (Husnina et al., 2022; Sethulakshmi & Mohan, 2024).

The research instrument comprised four components: sociodemographic characteristics, travel patterns, safety exposure and experience, and a Safety Awareness Scale covering boarding, on-board behaviour, and alighting. All items were measured using a five-point Likert scale. Instrument development was based on prior studies of public transport safety behaviour (Asah Nasrudin et al., 2023; Mbagha, 2023). For the qualitative component, interview guidelines focused on safety experiences, risk perception, and service improvement expectations. Data collection was conducted by trained

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enumerators through face-to-face interviews on operating buses. All participants provided informed consent. Qualitative interviews were recorded (with permission) and transcribed for analysis. Data analysis followed the mixed-methods sequence. Quantitative analysis included data cleaning, reliability testing (Cronbach's Alpha), and exploratory factor analysis using KMO and Bartlett's tests. A composite index of safety awareness was then developed and categorised into low, moderate, and high levels. Ordinal logistic regression was applied to identify influencing factors, including interaction effects (e.g., gender and incident experience). Qualitative data were analysed using thematic analysis to identify patterns and to support the quantitative findings.



Figure 1: Conceptual Model

ANALYSIS AND DISCUSSION

Respondent Profiles and Descriptive Statistics

A total of 350 respondents participated in the survey. Table X summarises their sociodemographic characteristics and travel-related attributes. The sample is predominantly female (66.6%), compared to 33.4% male respondents, suggesting a higher reliance on public bus services among women in the study area. In terms of age, the sample is heavily concentrated in the 41-60 age group (79.2%), followed by those aged 26-40 years (16.0%) and 18-25 years (4.6%), while respondents over 60 represent only a marginal proportion (0.3%). This distribution indicates that bus usage is largely associated with middle-aged, economically active individuals who depend on public transport for daily activities.

Regarding service frequency, respondents are relatively evenly distributed: 36.3% are high-frequency users (more than five trips per week), 33.4% medium-frequency (three to five trips), and 30.3% low-frequency users (two trips or fewer). This suggests that a substantial proportion of respondents regularly use bus services, reinforcing the importance of safety awareness in routine travel.

In terms of safety experience, only 14.3% of respondents reported having experienced or witnessed a safety incident, while the majority (85.7%) had no such experience. However, exposure to safety information remains limited, with 46.0% reporting low exposure, 29.4% medium exposure, and only

24.6% high exposure. Overall, the findings indicate that although bus services are widely used by regular and economically active passengers, the dissemination of safety information remains insufficient. This highlights the need for more systematic and targeted safety communication strategies to improve safety awareness among users.

Instrument Reliability Analysis

The reliability analysis indicates that all dimensions of the Safety Awareness Scale demonstrate acceptable internal consistency, with Cronbach's Alpha values exceeding the recommended threshold of 0.70. The "Access and Boarding" dimension achieved an Alpha of 0.736, followed by "On-board Safety Practices" (0.708) and "Alighting and Exits" (0.725), indicating consistent measurement across all stages of the bus travel process. Overall, the full scale, comprising 18 items, yielded a Cronbach's Alpha of 0.731, confirming satisfactory internal consistency. These results support the reliability of the instrument for assessing passenger safety awareness and its suitability for further statistical analysis.

Exploratory Factor Analysis (EFA)

The factor feasibility test indicates that the data are suitable for exploratory factor analysis. The Kaiser-Meyer-Olkin (KMO) value of 0.774 reflects good sampling adequacy, while Bartlett's test of sphericity is significant ($\chi^2 = 1154.8$, $p < 0.001$), confirming sufficient correlations among variables. The exploratory factor analysis (EFA) identifies three underlying factors of safety awareness, with items retained based on factor loadings greater than 0.30. The first factor, On-board Safety Behaviour, comprises seven items and explains 14.63% of the variance. The second factor, Access and Boarding Safety Awareness, includes six items and accounts for 14.59%, while the third factor, Alighting Safety Practices, consists of five items and explains 13.63% of the variance. Collectively, these three factors explain 42.86% of the total variance, indicating a meaningful structure of passenger safety awareness. Given the behavioural and perceptual nature of the construct, this level of explained variance is considered acceptable and consistent with previous transport behaviour studies.

Preparation of the Safety Awareness Index (SAI)

The Safety Awareness Index (SAI) was constructed using factor scores and classified into three categories (tertiles). The results indicate that safety awareness is predominantly low to moderate, with 34.6% of respondents in the low category, 58.0% in the moderate category, and only 7.4% in the high category. This distribution suggests that, although a proportion of users demonstrate adequate safety awareness, a substantial share remains at lower levels, requiring attention. Overall, the findings highlight the need for more

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targeted safety education and intervention strategies to improve passenger safety awareness.

Ordinal Logistic Regression Results

The ordinal logistic regression analysis identifies age and gender as the only significant predictors of safety awareness among bus passengers, while travel behaviour, incident experience, and exposure to safety information are not statistically significant. Age shows a positive association with safety awareness ($\beta = 0.033$, $p = 0.013$), indicating that older passengers are more likely to exhibit higher awareness, likely due to accumulated experience and increased risk perception. Gender is also significant, with male passengers less likely to demonstrate higher safety awareness than females ($\beta = -0.661$, $p = 0.006$), supporting evidence that women tend to adopt more safety-oriented behaviours in public transport contexts. In contrast, frequency of bus use has no significant effect ($\beta = -0.010$, $p = 0.942$), suggesting that habitual use alone does not enhance safety awareness. Similarly, experience of safety incidents is not significant ($\beta = 0.217$, $p = 0.493$), indicating that experiential exposure without reinforcement may not lead to sustained awareness. Although exposure to safety information shows a positive relationship ($\beta = 0.437$, $p = 0.118$), the effect is not statistically significant, implying that existing communication strategies may be insufficient to influence behaviour. Overall, these findings suggest that safety awareness is more strongly shaped by demographic characteristics than by routine behaviour, prior experience, or passive information exposure, highlighting the need for targeted and behaviourally informed safety interventions.

The ordinal logistic regression results indicate that safety awareness among bus users is primarily influenced by demographic characteristics rather than by experiential or informational factors. Although experience of safety incidents and exposure to safety information are not statistically significant predictors, the positive direction of their coefficients suggests a complementary role in shaping safety awareness. Experience may act as a contextual corrective stimulus that prompts risk reassessment, while safety information may function as a preventive cognitive mechanism by providing anticipatory safety cues, albeit with limited effectiveness when delivered passively. Overall, experiential learning and informational exposure appear to support, rather than determine, safety awareness, operating alongside more stable demographic factors such as age and gender. This relationship can be conceptualised as a partial learning loop, in which experience and information provide situational reinforcement but require structured intervention to translate into higher safety awareness levels, as illustrated in Figure 2.

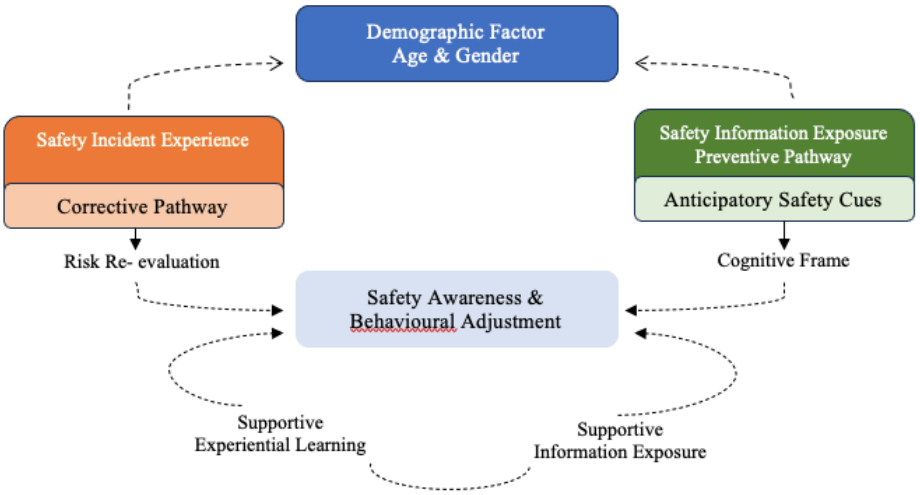


Figure 2. The Learning Loop

Model Analysis

The adequacy of the ordinal logistic regression model was assessed using model fit statistics, pseudo R-square measures, and the proportional odds assumption. The Model Fitting Information shows that the final model significantly improves upon the intercept-only model, with a reduction in −2 Log Likelihood from 442.997 to 423.644 ($\chi^2 = 19.353$, df = 6, p = 0.004), indicating that the predictors jointly contribute to explaining variations in safety awareness levels. The pseudo R-square values suggest modest explanatory power, with Nagelkerke $R^2 = 0.068$, Cox and Snell $R^2 = 0.054$, and McFadden $R^2 = 0.035$. This is consistent with behavioural transport studies, where outcomes are influenced by multiple unobserved factors. The Test of Parallel Lines is non-significant ($\chi^2 = 8.688$, df = 6, p = 0.192), confirming that the proportional odds assumption is satisfied. Overall, the results indicate that the model is statistically valid, appropriately specified, and suitable for analysing factors associated with safety awareness levels among bus passengers.

Results of Qualitative Analysis

The qualitative findings indicate that user experience and behaviour play a crucial role in shaping safety awareness among bus passengers. A key theme is the limited awareness among new users, who tend to overlook safety practices, such as rushing during boarding and alighting. Awareness typically increases after individuals experience or witness safety incidents, leading to more cautious behaviour. The analysis also highlights the limited availability of safety information, including signage and audio announcements, which hinders the

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internalisation of safe practices. In addition, driver behaviour influences passengers' safety perceptions, as aggressive or high-speed driving creates discomfort and anxiety. Furthermore, the findings suggest that a strong safety culture has not yet been established among users. This is reflected in behaviours such as not queuing, standing near doors before the bus stops, and using mobile phones without maintaining stability. Overall, these qualitative insights support the quantitative findings, indicating that experience, information exposure, and operational conditions are key factors influencing safety awareness among bus passengers.

DISCUSSION

The findings indicate that most bus passengers fall within the moderate level of safety awareness, suggesting that basic safety knowledge exists but has not yet been fully internalised into consistent behaviour across all stages of travel. This reflects a knowledge–behaviour gap, where awareness remains largely cognitive rather than habitual. Similar patterns have been reported in previous transport safety studies, where users possess safety knowledge but do not consistently translate it into practice (Febryana & Fitria, 2024; Mbagha, 2023; Wang et al., 2020). In public transport settings, this gap may be explained by dynamic travel conditions such as crowding and time pressure which can override safety intentions. From a theoretical perspective, this finding aligns with the Theory of Planned Behaviour (TPB), which suggests that behaviour is shaped not only by knowledge but also by attitudes, social norms, and perceived behavioural control (Ajzen, 1991). In this context, safety awareness represents a cognitive foundation that requires environmental reinforcement to translate into behaviour. Consistent with prior studies, contextual factors such as infrastructure, passenger density, and driver behaviour play a critical role in shaping safety practices (Sethulakshmi & Mohan, 2024; Soltani et al., 2025). The regression results further show that demographic factors, particularly age and gender, are the most significant predictors of safety awareness. Older passengers tend to exhibit higher awareness, likely due to accumulated experience and greater risk sensitivity. This finding is consistent with previous research indicating that older individuals adopt more cautious travel behaviour (Sethulakshmi & Mohan, 2024). Similarly, female passengers demonstrate higher safety awareness than males, supporting evidence that women are generally more risk-averse and attentive in public transport environments (Mchunu et al., 2025; Soltani et al., 2025).

In contrast, experiential and informational factors do not significantly influence safety awareness, although their effects are positive. This suggests that experience and exposure alone are insufficient to generate sustained behavioural change. From the perspective of Risk Perception Theory, direct exposure to risk may trigger temporary caution but does not necessarily lead to long-term

awareness without reinforcement. Similar findings have been reported in previous studies, where passive safety information fails to produce measurable behavioural change unless supported by active engagement (Sinnappan et al., 2023; Wang et al., 2020). The qualitative findings provide further insight into this mechanism. New or inexperienced users tend to exhibit riskier behaviours, such as rushing during boarding or neglecting handrails, reflecting limited familiarity with safety norms. Awareness often increases after direct or observed incidents; however, this learning process remains inconsistent. Additionally, limited safety communication such as inadequate signage and audio announcements restricts the internalisation of safe practices. Driver behaviour also plays a significant role, as aggressive or high-speed driving increases passenger anxiety and influences safety perception. These findings indicate that safety awareness is shaped by the interaction between individual experience and operational conditions.

Overall, the results highlight that safety awareness is not solely an individual attribute but a social and system-dependent phenomenon. Consistent with existing literature, passenger safety is influenced by the interaction between individual behaviour, operational management, and infrastructure design (Chau et al., 2024; Ibrahim et al., 2023). Safety culture, therefore, emerges from the alignment of these elements rather than from individual learning alone. Supporting this perspective, research in Malaysia demonstrates that improvements in public transport infrastructure including bus stop design, system modernisation, and service integration can significantly enhance perceived safety, particularly among vulnerable users (Dayini et al., 2025; Sugito et al., 2025). From an academic perspective, this study contributes to the literature in three key ways. First, it conceptualises safety awareness as a multidimensional construct across the stages of bus travel (boarding, on-board, and alighting), providing a behaviourally grounded measurement framework. Second, it applies ordinal logistic regression, enabling a more nuanced analysis of awareness levels compared to conventional linear approaches. Third, it integrates quantitative and qualitative evidence to explain the mechanisms underlying safety awareness formation, particularly in a Southeast Asian urban context where such studies remain limited. These contributions shift the analytical focus from general safety perception towards a more behaviour-oriented understanding of passenger safety awareness.

From a practical perspective, the findings emphasise the importance of system-level interventions. Improving safety awareness requires more than individual experience; it depends on structured and behaviourally informed strategies, including clear signage, regular audio announcements, and driver training in safety communication. The integration of digital platforms may further enhance engagement, particularly among younger users. Without consistent institutional support, safety awareness is likely to remain fragmented and

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situational, limiting its development into a shared safety culture. Overall, this study provides an evidence-based foundation for designing targeted interventions to improve passenger safety in urban public transport systems.

CONCLUSION

This study examined the level of safety awareness among city bus passengers, identified its key determinants, and explored its implications for improving public transport safety in an urban context. The findings reveal that passenger safety awareness predominantly falls within the moderate category, indicating that while basic safety knowledge is present, it has not yet been fully internalised into consistent behavioural practices across all stages of the journey. This highlights the existence of a knowledge–behaviour gap in public transport use. The study confirms that safety awareness is a multidimensional construct comprising boarding, on-board, and alighting stages, reflecting the sequential nature of bus travel. The results further demonstrate that demographic characteristics, particularly age and gender, are the most significant predictors of safety awareness, while experiential and informational factors play a supportive rather than decisive role. These findings suggest that safety awareness is shaped not only by individual learning processes but also by relatively stable personal characteristics and broader environmental conditions. By integrating quantitative and qualitative analyses, this study provides a more comprehensive understanding of how safety awareness develops in real-world travel contexts. The findings emphasise that experiential learning and exposure to safety information alone are insufficient to ensure consistent safe behaviour without structured reinforcement and supportive system conditions. From a theoretical perspective, this study contributes to the literature by positioning safety awareness as a behaviourally grounded construct that links cognitive understanding with actual travel practices. Methodologically, the use of ordinal logistic regression combined with qualitative insights offers a nuanced approach to analysing variations in awareness levels among passengers. In practical terms, the findings underscore the importance of system-level interventions in enhancing passenger safety. Improving safety awareness requires not only individual adaptation but also the strengthening of infrastructure, operational practices, and safety communication strategies within the public transport system. Overall, this study highlights that passenger safety awareness is a product of the interaction between individual characteristics, learning processes, and institutional environments. Strengthening this interaction is essential for fostering a sustainable safety culture and supporting the development of safer and more inclusive public transport systems in rapidly growing urban areas.

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Recommendations and Future Research Directions

Based on the findings, several strategic recommendations can be proposed. First, transport operators and local authorities should prioritise targeted and behaviour-oriented safety communication. Safety information should move beyond passive dissemination and be embedded within daily travel contexts through clear signage, standardised audio announcements, and integration into digital mobility platforms. Second, operational safety practices should be strengthened to support behavioural internalisation. This includes enhanced driver training focused on defensive driving and safety communication, as well as stricter enforcement of boarding and alighting procedures. The presence of operational staff at high-demand locations may further improve compliance, particularly among new users. Third, the development of a collective safety culture should be treated as a long-term institutional priority. Public campaigns promoting behavioural norms such as orderly queuing, waiting for a complete stop before boarding, and using handrails can help translate individual awareness into shared practices. Given the influence of demographic factors, interventions should also be tailored to different user groups rather than adopting uniform approaches.

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SUSTAINABLE CONSERVATION OF THE SILOKEK GEOPARK AREA TO BECOME A LEAD TOURISM DESTINATION IN WEST SUMATERA, INDONESIA

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Abstract

Geoparks play an important role in integrating geological conservation with sustainable tourism development. However, many geopark studies remain largely descriptive and provide limited analytical insights into governance and spatial planning implications. This study examines sustainable conservation practices in the Silokek Geopark, West Sumatra, Indonesia, focusing on the interaction between geodiversity conservation, community participation, and institutional governance within a spatial planning context. A qualitative approach was employed through in-depth interviews, field observations, and document analysis. Data were analyzed using the sustainable geopark management framework proposed by Xu and Wu, which emphasizes environmental conservation, community participation, and governance structures. The findings show that conservation practices in the Silokek Geopark are supported by strong community involvement through local institutions. However, governance arrangements remain largely operational and have not been fully integrated into formal spatial planning frameworks. This situation limits the strategic role of conservation in guiding sustainable tourism development and regulating spatial use. This study contributes to the planning literature by demonstrating that effective geopark conservation requires not only environmental protection but also the integration of community-based conservation into spatial planning instruments and governance systems. The findings provide policy insights for strengthening sustainable geopark management in developing regions.

Keywords: Geopark, sustainable conservation, community participation, spatial planning, governance

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INTRODUCTION

Indonesia possesses remarkable geological diversity, providing a strong foundation for geopark development that integrates geo-conservation, geo-education, and sustainable tourism (Ansori et al., 2022; Bhinekawati et al., 2020; Mallinis et al., 2023; Mucivuna et al., 2022; Reinhart et al., 2023). Geoparks are increasingly recognised as planning instruments that balance environmental conservation with regional economic development by protecting geological heritage while promoting community-based tourism. Within this context, sustainable geopark management requires not only the conservation of geological resources but also effective governance, stakeholder collaboration, and spatial planning to ensure that tourism development does not exceed environmental carrying capacity (Crofts, 2019; Gordon et al., 2021; Ríos et al., 2020).

One of Indonesia's geoparks with significant geological potential is the Silokek Geopark (SG) in Sijunjung Regency, West Sumatra. The geopark contains karst landscapes, caves, waterfalls, rivers, and diverse geological formations that support geotourism development (Febrianto et al., 2022; Bhinekawati et al., 2020). Nevertheless, the area faces substantial environmental challenges. Illegal gold mining within production and protected forest areas has accelerated land degradation, increased river sedimentation, and threatened ecological sustainability (Sijunjung Regency Government, 2019). These environmental pressures may reduce both the conservation value of geosites and the long-term attractiveness of the geopark as a tourism destination.

Sustainable geopark management depends on collaborative governance involving governments, local communities, customary institutions, and tourism stakeholders (Irwandi et al., 2024; Ari Sulistyo et al., 2023). In the Silokek Geopark, collaboration is implemented through the Geopark Management Agency, Forest Village Community Institutions (LMDH), Tourism Awareness Groups (Pokdarwis), and local communities. Their respective roles include environmental conservation, tourism management, visitor services, and community-based enterprises, contributing to local economic development while strengthening conservation efforts (Sumarmi & Untari, 2022; Hazar et al., 2024).

Although previous studies have examined geodiversity, geotourism, and community participation in geoparks, limited attention has been given to how sustainable conservation is implemented through the integration of environmental conservation, community participation, governance, and spatial planning within a single geopark management system. Furthermore, few studies have analysed how local conservation practices are supported by planning instruments and institutional arrangements to maintain environmental sustainability while promoting tourism development. This gap is particularly evident in Indonesian geoparks, where conservation and tourism frequently develop at different rates.

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Therefore, this study aims to analyse sustainable conservation practices in the Silokek Geopark using the Sustainable Geopark Management Framework proposed by Xu and Wu (2022). Specifically, the study examines how environmental conservation, community participation, and governance interact to support sustainable tourism development. The findings are expected to contribute to sustainable geopark planning by providing empirical evidence on the integration of conservation strategies, stakeholder collaboration, and spatial planning within an Indonesian geopark.

LITERATURE REVIEW

Sustainable Environmental Conservation and Management

Geoparks are recognized as a regional development approach that integrates geological conservation, environmental education, and sustainable tourism to promote local economic development. Within the planning perspective, geoparks function not only as areas of high geological value but also as spatial entities requiring integrated governance, stakeholder collaboration, and adaptive spatial planning to balance conservation objectives with regional development (Xu & Wu, 2022; Gordon et al., 2021; Mucivuna et al., 2022; Reinhart et al., 2023). Consequently, sustainable environmental conservation extends beyond protecting geological resources to include participatory governance, spatial planning, and community involvement. Previous studies indicate that conservation initiatives are more effective when governments, local communities, and other stakeholders collaborate to maintain environmental quality while supporting sustainable regional development (Crofts, 2019; Gordon et al., 2021; Ríos et al., 2020).

Geological Diversity (Geodiversity)

Geodiversity refers to the diversity of geological features, including rocks, minerals, fossils, landforms, geomorphological processes, and geological structures that shape the Earth's landscapes (Mallinis et al., 2023; Mucivuna et al., 2022). Beyond its scientific significance, geodiversity provides the foundation for geopark development by supporting conservation, environmental education, and geotourism (Ansori et al., 2022; Bhinekawati et al., 2020). Within spatial planning, geodiversity also serves as a basis for conservation zoning, land-use planning, development control, and environmental risk mitigation. Integrating geodiversity into spatial planning is therefore essential to ensure that tourism development remains consistent with the environmental carrying capacity of geopark areas.

Geopark Management Bodies and Stakeholder Collaboration

Effective governance is a key determinant of sustainable geopark management because geoparks function simultaneously as conservation areas, educational sites, and tourism destinations (Reinhart et al., 2023). The Sustainable Geopark Management Framework proposed by Xu and Wu (2022) identifies governance, environmental conservation, and community participation as three interrelated dimensions supporting sustainable geopark management. Governance emphasizes institutional coordination, stakeholder collaboration, and policy implementation to ensure that conservation and tourism development are managed in an integrated manner. Previous studies indicate that well-structured geopark management institutions strengthen institutional capacity, facilitate stakeholder collaboration, and support sustainable management practices by coordinating governments, local communities, customary institutions, tourism organizations, and other stakeholders (Irwandi et al., 2024).

In the Silokek Geopark (SG), the establishment of the Geopark Management Agency in 2023 marked an important step toward strengthening institutional governance. The agency is responsible for planning, coordinating, implementing, and monitoring geopark development and conservation programs. Through collaboration with the Sijunjung Regency Government, Forest Village Community Institutions (LMDH), Tourism Awareness Groups (*Pokdarwis*), customary institutions, and local communities, the management body supports community participation while promoting environmental conservation and sustainable tourism development. This collaborative approach strengthens institutional coordination and contributes to the long-term sustainability of the Silokek Geopark (Sumarmi et al., 2022; Xu & Wu, 2022).

Based on the preceding literature, this study adopts the Sustainable Geopark Management Framework proposed by Xu and Wu (2022) as the analytical lens for examining sustainable conservation practices in the Silokek Geopark. The framework integrates three interrelated dimensions-environmental conservation, community participation, and governance-which provide the basis for analysing empirical findings presented in the subsequent sections.

METHODOLOGY

This study employed a qualitative case study to examine sustainable conservation practices in the Silokek Geopark (SG), Sijunjung Regency, West Sumatra, Indonesia. The study adopted the Sustainable Geopark Management Framework proposed by Xu and Wu (2022), which comprises three analytical dimensions: environmental conservation, community participation, and governance. These dimensions guided the research design, data collection, coding, and interpretation of the findings. The overall research framework is presented in Figure 2, while the analytical indicators are summarized in Table 2.

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The research was conducted in the Silokek Geopark, Sijunjung Regency, West Sumatra, a national geopark characterized by significant geological, biological, and cultural diversity.

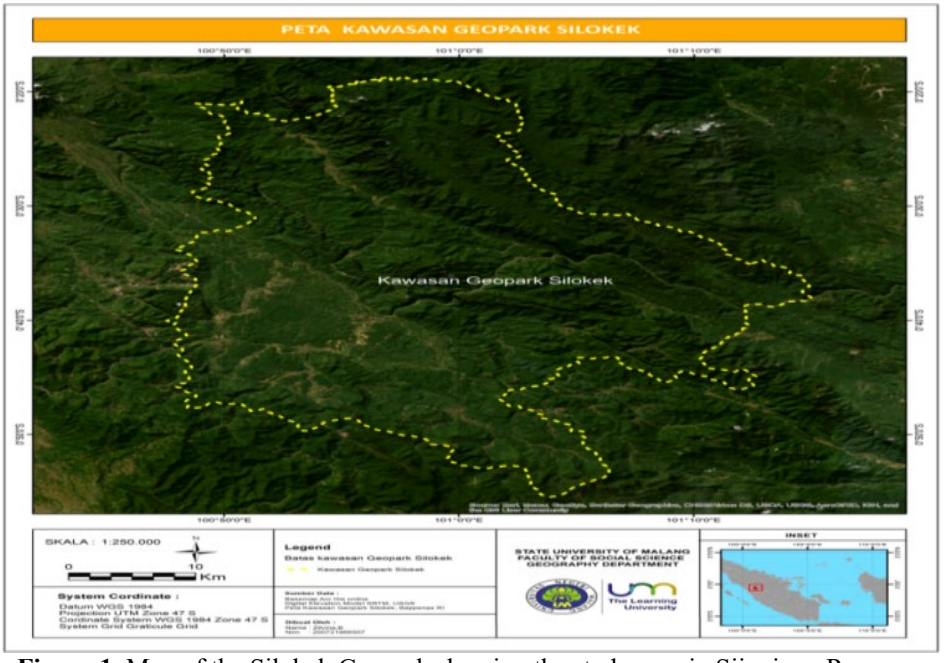


Figure 1. Map of the Silokek Geopark showing the study area in Sijunjung Regency, West Sumatra Province, Indonesia.
(Source: Author, 2023)

Purposive sampling was used to select informants directly involved in the management and conservation of the Silokek Geopark. The selected participants included the Executive Chair of the Silokek Geopark Management Authority, tourism awareness groups (Pokdarwis), Nagari government representatives, and local community members involved in geopark management and tourism activities. This approach enabled the study to capture diverse perspectives on conservation practices and geotourism development. Details of the informants are presented in Table 1.

Table 1. List of Informants and Data Collection Methods

Informant	Role	Data Collection Methods
|1	Geopark Management	In-depth Interview
|2	Local Government	Interview and Observation
|3	Tourism awareness Group Aia Angek	Interview and Observation
|4	Tourism awareness GroupTimbulun	Interview and Observation
|5	Tourism awareness GroupLubuk Tarok	Interview and Observation
|6	Tourism awareness GroupBatu Manjulur	Interview and Observation
|7	Tourism awareness Group Sumpur Kudus	Interview and Observation
|8	Tourism awareness GroupKampung Adat Sijunjung	Interview and Observation

Primary data were collected between **August and December 2023** through semi-structured interviews, non-participant observations, and document analysis. Eight key informants were selected using purposive sampling based on their direct involvement and strategic roles in the management and conservation of the Silokek Geopark. The participants consisted of the Executive Chair of the Silokek Geopark Management Authority, one representative from the local government, and six representatives of Tourism Awareness Groups (Pokdarwis) from different geosites within the geopark.

Semi-structured interviews were conducted using an interview guide developed from the sustainable geopark management framework proposed by Xu and Wu (2022)**,** which focuses on three analytical dimensions: environmental conservation, community participation, and governance. Each interview lasted approximately 30–90 minutes, was conducted face-to-face, and was audio-recorded with the participants' consent before being transcribed for analysis.

Non-participant observations were carried out during field visits to several geosites in the Silokek Geopark. The observations focused on the condition of geological heritage sites, tourism infrastructure, conservation practices, community participation, and environmental issues, including indications of illegal mining activities and river degradation. Observation data were used to verify and complement information obtained from interviews.

Document analysis was undertaken to strengthen the empirical findings. The documents reviewed included the **S**ilokek Geopark Masterplan (2019)**,** the Decree on the Establishment of the Silokek Geopark Management Authority**,** Nagari regulations concerning community-based conservation (Rimbo Larangan and Lubuk Larangan)**,** tourism development reports, and relevant

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planning and policy documents issued by the Sijunjung Regency Government. The combination of interviews, observations, and document analysis enabled methodological triangulation and enhanced the credibility of the research findings.

The collected data were analysed using Framework Analysis based on the Sustainable Geopark Management Framework proposed by Xu and Wu (2022). The analysis consisted of five stages: (1) familiarisation with interview transcripts, field notes, and documentary evidence; (2) development of an analytical framework based on environmental conservation, community participation, and governance; (3) coding and indexing qualitative data into thematic categories; (4) charting the coded data into analytical matrices; and (5) interpreting the findings by comparing empirical evidence with the analytical framework. The coding process followed the analytical dimensions presented in Table 2, while the overall research procedure is illustrated in Figure 2.

Data validity was ensured through source and method triangulation by comparing information obtained from interviews, observations, and documentary sources. In addition, cross-validation among informants was conducted to ensure data consistency and credibility. This approach was intended to enhance the reliability of the research findings and to strengthen the validity of the analytical interpretations.

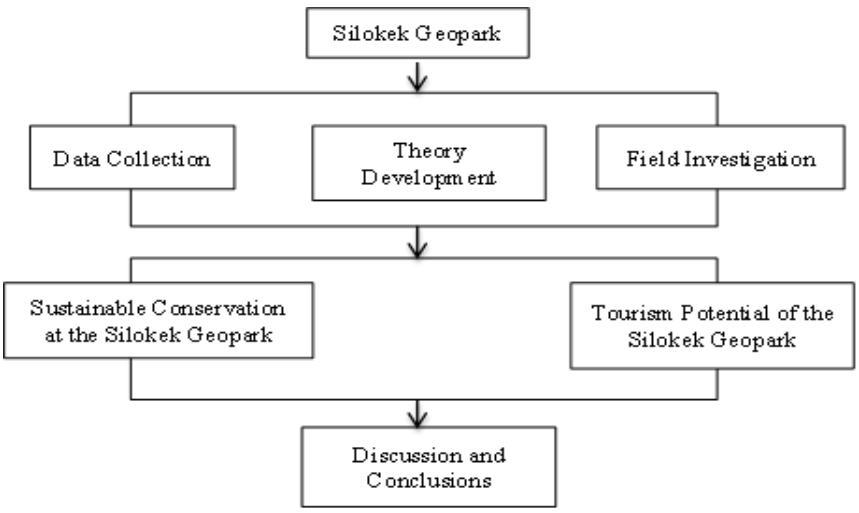


Figure 2: Research Framework and Framework Analysis Process (Adapted from Xu & Wu, 2022).

Table 2. Analytical Framework Applied in the Study

Analytical Dimension (Xu & Wu, 2022)	Indicators	Data Sources	Empirical Evidence
Environmental Conservation	Protection of geosites, forest conservation, river conservation, environmental sustainability	Interviews, field observations, document analysis	Community-based conservation practices, including *Rimbo Larangan*, *Lubuk Larangan*, and the *Pohon Asuh* program, contribute to protecting geological and ecological resources.
Community Participation	Community involvement in conservation, tourism management, and environmental awareness	Interviews, field observations	Local communities actively participate through Tourism Awareness Groups (Pokdarwis), environmental monitoring, and tourism-related economic activities.
Governance	Stakeholder collaboration, institutional coordination, policy implementation	Interviews, document analysis	The Silokek Geopark Management Agency, local government, and Nagari institutions collaborate in managing conservation and tourism, although coordination among stakeholders still requires improvement.
Spatial Planning Implications	Integration of conservation into spatial planning, land-use control, and tourism zoning	Document analysis, interviews	Conservation objectives have not yet been fully integrated into spatial planning instruments, indicating the need to strengthen zoning regulations, visitor management, and sustainable tourism planning.

Table 2 operationalizes the Sustainable Geopark Management Framework proposed by Xu and Wu (2022). The analytical dimensions guided the coding and interpretation of empirical findings obtained from interviews, observations, and document analysis.

RESULTS AND DISCUSSION

The Silokek Geopark (SG) in Sijunjung Regency, West Sumatra, possesses significant geological diversity that forms the foundation for conservation, education, and sustainable tourism development. The geopark contains karst landscapes, granite formations, river systems, and other geological features that provide important environmental, scientific, and tourism values.

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A. Geological Diversity (Geodiversity) of the Silokek Geopark

The geological diversity of the Silokek Geopark is the result of long-term regional tectonic dynamics on the island of Sumatra, characterized by the interaction between the subduction of the Indo-Australian Plate and the Eurasian Plate. These geological characteristics are also recognized by local tourism managers. As stated by one informant:

> *"Silokek has unique karst cliffs, caves and granite formations which make it an important geological heritage area that needs protection." (Informant 3 – Pokdarwis Aia Angek).*

Another informant also emphasized the importance of geological features along the Kuantan River:

> *"The geological formations along the Kuantan River attract visitors and researchers because they clearly expose rock structures and geomorphological processes." (Informant 4 – Pokdarwis Timbulun)*

These tectonic processes have produced metamorphic rocks, granite intrusions, karst landscapes, and river systems that provide significant scientific, educational, and tourism values while requiring integrated conservation and spatial planning.

From a regional planning perspective, the diverse and environmentally sensitive geological characteristics of the area necessitate adaptive spatial planning instruments that are grounded in environmental carrying capacity. However, field findings indicate that spatial planning and tourism development policies in the Silokek Geopark have not yet fully positioned geodiversity as a primary determinant in spatial decision-making. Geodiversity is more frequently treated as a tourism attraction rather than as a basis for regulating land use, zoning, and development intensity. As a result, conservation practices tend to operate at an operational level, lacking support from integrated long-term strategic planning.

The presence of the Kuantan Formation, granite intrusions, karst landscapes, and the Kuantan River demonstrates the high geological value of the geopark while also indicating its vulnerability to environmental degradation caused by land-use change and tourism pressure. These findings highlight the importance of integrating geodiversity into spatial planning and conservation policies.

Interviews with Informant 1 (Executive Chair of the Silokek Geopark Management Authority) indicate that although community-based conservation initiatives have been implemented through the Geopark Management Authority

and Tourism Awareness Groups (Pokdarwis), conservation objectives have not yet been fully integrated into statutory spatial planning. This situation reflects a governance gap between local conservation practices and formal planning systems, limiting the long-term sustainability of geodiversity conservation. Therefore, stronger integration of geodiversity into spatial planning instruments-including conservation zoning, land-use regulation, visitor carrying capacity management, and environmental protection-is essential to ensure that tourism development remains compatible with long-term conservation objectives.

B. Geotourism Potential of the Silokek Geopark

Karst morphology in the Silokek Geopark represents a major geotourism asset with significant scientific, educational, and economic value. The presence of caves, gorges, karst hills, and river landscapes forms a distinctive geological setting that supports sustainable geotourism development in Sijunjung Regency, West Sumatra. The spatial distribution of geosites across several *nagari* provides opportunities to diversify tourism destinations, reduce visitor concentration, and distribute economic benefits more equitably among local communities.

Field interviews indicate that improvements in accessibility have increased tourism activities within the geopark. As stated by one tourism manager:

> *"Since road access improved, tourist visits have increased. Visitors usually come for rafting, cave exploration and educational tourism activities."* (Informant 5 – Pokdarwis Lubuk Tarok)

Another informant emphasized the contribution of tourism events to geopark promotion:

> *"Tourism events such as marathons and outdoor activities help introduce the Silokek Geopark to a wider audience and support the local economy."* (Informant 6 – Pokdarwis Batu Manjulur)

The improvement of road networks and supporting tourism facilities has enhanced visitor accessibility, increased tourism activities, and strengthened the local tourism economy in the Silokek Geopark. These improvements have supported a variety of geotourism activities, including recreational tourism, educational tourism, rafting, cave exploration, and outdoor events involving schools, universities, and community organisations. Together, these activities demonstrate the geopark's potential to integrate environmental education with local economic development. However, increasing visitor numbers also place greater pressure on environmentally sensitive geosites, particularly karst

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ecosystems and river corridors. Therefore, tourism development should be supported by spatial planning instruments that regulate conservation zoning, visitor carrying capacity, and development intensity to ensure that environmental conservation remains the primary foundation of sustainable geopark management. Consistent with the Blue Economy approach, sustainable tourism should balance environmental protection, community welfare, and cultural preservation (Sumarmi et al., 2020), while collaborative governance and stakeholder participation are essential to maintaining environmental quality and generating long-term socio-economic benefits (Marlina et al., 2020; Yayun et al., 2025).

C. Community-Based Geopark Conservation

Community participation plays a central role in supporting sustainable conservation in the Silokek Geopark. Local communities actively contribute to environmental protection through customary institutions, conservation programmes, and tourism-related activities that strengthen both environmental sustainability and local livelihoods.

a. Rimbo Larangan (Protected Forest)

As explained by Informant 1: *"Geopark conservation efforts include the designation of Rimbo Larangan as a protected forest area covering approximately 4,500 hectares, established through Nagari Regulation No. 1 of 2002. This regulation prohibits logging activities and imposes social sanctions on violators. The primary objective of Rimbo Larangan is to function as a water catchment and storage area that supports community needs for agriculture and household use."*

The Rimbo Larangan system demonstrates how customary regulations function as an effective community-based mechanism for protecting forests and maintaining ecosystem services, particularly water resources.

b. Lubuk Larangan (Protected River)

Source 2 explained: *"Several geopark areas have implemented the Lubuk Larangan concept in certain rivers that are collectively agreed upon as no-fishing zones. Community members who violate these rules are subject to fines in accordance with agreements established in each region that applies Lubuk Larangan."*

Lubuk Larangan integrates customary rules with conservation objectives by protecting river ecosystems through community-based monitoring and social sanctions.

c. Foster Tree Program

Based on the explanation of Source 7: *"The Pohon Asuh Program is a forest conservation initiative developed to attract financial support from various stakeholders and is implemented at the Sumpur Kudus geosite."*

The Foster Tree Program represents an incentive-based conservation approach that encourages stakeholder participation while supporting forest restoration and community welfare.

d. Disaster-Resilient Nagari

In addition to traditional conservation practices, Source 2 explained: *"The community has also actively established Nagari Siaga Bencana (Disaster-Resilient Villages) as a strategic step to build resilience and self-reliance in facing natural disasters, particularly in the Silokek geosite area".* This explanation regarding *Nagari Siaga Bencana* is further reinforced by the statement of Source 1, the establishment of Disaster-Resilient Nagari reflects the community's capacity to integrate disaster risk reduction into geopark conservation through collaboration between local government, Pokdarwis, and community organizations.

Community-based conservation in the Silokek Geopark is reflected in several traditional management practices, including *Rimbo Larangan*, *Lubuk Larangan*, and the *Pohon Asuh* program. These initiatives demonstrate the integration of local wisdom and environmental conservation (Figure 3 and 4).



Figure 3 Rimbo Larangan



Figure 4 Lubuk Larangan

(Source: Silokek Geopark Daily Management Board 2023)

Community participation is also reflected in the tourism services provided by residents in the Silokek Geopark area. Local communities play an important role not only in maintaining environmental sustainability but also in supporting tourism activities by providing various facilities for visitors.

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> *"Local communities provide supporting facilities such as homestays, food stalls, ATV rentals, and camping equipment for tourists visiting the Silokek Geopark area." (Informant 8 – pokdarwis Kampung adat Sijunjung).*

Community participation plays a central role in supporting both environmental conservation and sustainable tourism development in the Silokek Geopark. Consistent with Ariffin et al. (2023), meaningful citizen engagement strengthens heritage conservation through active local stewardship and collaborative management. In the Silokek Geopark, local communities contribute to conservation through customary institutions such as *Rimbo Larangan*, *Lubuk Larangan*, and the *Pohon Asuh* programme, while simultaneously supporting the local economy by providing homestays, food stalls, ATV rentals, camping equipment, and other tourism services. These findings are also consistent with Bachri et al. (2023), who emphasise that sustainable tourism depends on collaboration among local communities, tourism managers, and other stakeholders. Although community participation has effectively supported conservation, these initiatives remain largely community-driven and have not yet been fully integrated into statutory spatial planning instruments.

The findings further demonstrate that geopark governance has been strengthened through collaboration among the Geopark Management Agency, the Sijunjung Regency Government, Nagari governments, Tourism Awareness Groups (*Pokdarwis*), and local communities. This collaborative arrangement reflects the importance of multi-level governance in coordinating conservation and tourism policies across different institutional levels, consistent with Devi et al. (2025). Although the Silokek Geopark Masterplan and the Decree establishing the Geopark Management Agency provide an institutional framework for management, policy integration remains limited. Consequently, key spatial planning instruments—including conservation zoning, buffer zones, visitor carrying capacity, land-use control, and sustainable tourism zoning—should be more comprehensively incorporated into regional spatial planning to ensure long-term environmental conservation and sustainable tourism development.

The findings indicate that the Silokek Geopark has strong potential to become a leading tourism destination in West Sumatra due to its outstanding geodiversity, active community participation, and collaborative governance. However, achieving this vision requires stronger integration of conservation objectives into statutory spatial planning through conservation zoning, visitor carrying capacity management, and coordinated multi-level governance. Such integration will ensure that tourism development enhances, rather than compromises, the long-term sustainability of the geopark.

CONCLUSION

This study examined sustainable conservation practices in the Silokek Geopark, Sijunjung Regency, West Sumatra, using the Sustainable Geopark Management Framework. The findings demonstrate that the geopark possesses significant geological, ecological, and cultural resources that provide a strong foundation for sustainable geotourism. Community-based conservation initiatives, including *Rimbo Larangan*, *Lubuk Larangan*, the *Pohon Asuh* programme, and Disaster-Resilient Nagari, have contributed substantially to protecting natural resources while supporting local livelihoods and tourism development.

The study also reveals that collaborative governance involving the Geopark Management Agency, the Sijunjung Regency Government, Nagari governments, Tourism Awareness Groups (*Pokdarwis*), and local communities has strengthened conservation efforts. However, conservation initiatives remain largely community-driven and have not yet been fully integrated into statutory spatial planning instruments. Stronger policy integration is therefore required through conservation zoning, land-use regulation, visitor carrying capacity management, and coordinated multi-level governance to ensure that tourism development does not compromise environmental sustainability.

This study contributes to the planning literature by demonstrating that sustainable geopark management depends not only on conserving geological heritage but also on integrating community-based conservation, collaborative governance, and spatial planning within a single management framework. The findings provide practical guidance for local governments in incorporating geopark conservation into regional spatial planning and tourism policies, thereby supporting balanced regional development while safeguarding geoheritage and ecosystem integrity.

This study is limited to a single case study of the Silokek Geopark. Future research should undertake comparative analyses of multiple geoparks in Indonesia or internationally to examine different governance models and planning approaches. Further studies may also evaluate the effectiveness of spatial planning instruments, conservation zoning, and visitor carrying capacity management in supporting the long-term sustainability of geoparks.

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PUBLIC TRANSPORTATION DEMAND TO TOURISM DESTINATIONS IN ACEH PROVINCE, INDONESIA

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Abstract

According to the 2020–2034 Aceh Besar Regency Tourism Development Plan, Lhoknga Beach Recreation Area is one of the province's leading tourism destinations. Coastal tourism destinations often exhibit high dependence on private vehicles, resulting in congestion, environmental degradation, and reduced accessibility. Therefore, the provision of public transportation is essential to facilitate tourist mobility between origins and destinations. This study aims to examine tourists' potential demand for public transportation and identify the key factors influencing their willingness to shift from private vehicles. A quantitative approach was adopted, with a questionnaire administered to 306 tourists visiting six beach destinations, and the data were analysed using factor analysis. The results reveal three principal factors influencing tourists' potential demand for public transportation: (1) traffic and cost-related factors, including congestion, fuel prices, parking limitations, and safety concerns; (2) service quality attributes, such as punctuality, comfort, cleanliness, accessibility, and information availability; and (3) tourists' perceptions of public transport, including flexibility, privacy, and perceived mobility constraints. These findings suggest that enhancing service quality and addressing congestion and travel cost issues can significantly increase tourists' acceptance of public transportation. This study contributes empirical evidence to support sustainable transport planning and policy development for tourism destinations in coastal areas.

Keywords: Public transportation; Tourism destination; Tourist Characteristics; Public Transportation Potential Demand; Coastal tourism

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INTRODUCTION

The tourism industry is a significant source of revenue for both national and world economies. Tourism, as a form of travel, is highly dependent on efficient transportation, which moves tourists from their point of departure to the destination (Rohini & Meenakshi, 2024; Rodrigue, 2016). Adequate transportation infrastructure and services enhance tourists' mobility and accessibility to tourist sites, thereby directly supporting tourism development (The Tourism Institute, 2025). Furthermore, transportation connectivity and accessibility play a key role in influencing tourism activities and destination economic growth (Sitorus & Sitorus, 2017). The quality of the tourist experience is also highly influenced by transportation services. Jie & Abu Talib (2024) emphasise that convenience, comfort, and safety in transportation significantly influence tourists' overall satisfaction.

According to the 2020–2034 Aceh Besar Regency Tourism Development Plan (RIPPARKAB), the Lhoknga Beach Recreation Tourism Strategic Area is one of the region's leading tourism destinations, consisting of six major beach attractions: Pantai Lampuk, Pulo Kapuk, Pantai Lhoknga, Pantai Momong, Pantai Babah Dua, and Pantai Babah Kuala Mon Ikeun. This area is strategically located near Banda Aceh City, the capital of Aceh Province, as the main gateway for both international and domestic tourists. As a Tourism Strategic Area, it must integrate four key tourism components, namely, attractions, accessibility, amenities, and ancillary services—as emphasised by Cooper et al (2005). Accessibility refers to the infrastructure and facilities required for visitors to reach a destination, including public transportation access; operational factors such as service frequency and route availability; and transportation hubs, such as airports, seaports, railway networks, and other supporting transport systems (Sunaryo, 2013).

Transportation plays a major role in generating carbon emissions in tourism activities, particularly in the movement of tourists to, from, and within destinations (Peeters & Dubois, 2010). Recent studies have shown that transportation is a significant source of carbon emissions in tourism, with transport-related travel being one of the largest contributors to tourism's overall environmental footprint (Yan & Phucharoen, 2024). Improving public transportation access, a key component of accessibility, has been shown to enhance access to tourism sites and promote sustainable tourism growth by reducing dependence on private vehicles (Naik et al., 2025). Furthermore, encouraging tourists to adopt sustainable travel options - such as public transport, walking, and cycling - can help reduce the carbon footprint associated with tourism transportation (Naik et al., 2025).

According to Government Regulation No. 50 of 2011 concerning the National Tourism Development Master Plan (2010–2025), the development of

transportation facilities aims to ensure tourist accessibility, mobility, and safety in reaching tourism destinations. Furthermore, the 2020–2034 Aceh Besar Regency Tourism Development Plan emphasises that one of the strategic approaches to tourism destination development is the provision of public transportation services through regulatory arrangements and collaboration among stakeholders from both government and private sectors. Therefore, the provision of efficient and reliable public transportation infrastructure is essential for achieving sustainable tourism development (Iamtrakul et al., 2025). Given this phenomenon, investigating tourists' characteristics and potential demand factors that influence the provision of public transportation is crucial.

LITERATURE REVIEW

Public Transportation

Public transport is defined as a shared passenger transport service operating on fixed routes and schedules, designed to carry large volumes of passengers efficiently and equitably (Vuchic, 2017). Saif et al. (2019) also stated that public transport is conceptualised as a shared mobility service that improves accessibility by offering high-capacity, cost-effective travel options for diverse user groups. Enhancing public transport services is essential for improving accessibility for diverse users, particularly low-income groups who are unable to use private vehicles (Othman & Ali, 2020), and for reducing social exclusion (Litman, 2025). It provides multiple benefits across environmental, economic, and social dimensions, including ensuring accessibility to activities and services, reducing traffic congestion, enhancing productivity, and lowering carbon emissions (Litman, 2013). Furthermore, it provides accessibility that can significantly affect daily outcomes and directly influences individuals' ability to reach jobs, services, and social activities (Saif et al., 2019). Encouraging a modal shift from private vehicles to public transportation is also considered essential for achieving sustainable mobility (Banister, 2008). It aligns with Sustainable Development Goal (SDG) 11, particularly Target 11.2, which emphasises providing access to safe, affordable, accessible, and sustainable transport systems for all, while improving road safety and expanding public transport, particularly for vulnerable groups.

In conclusion, public transport plays a critical role in creating accessible, equitable, and sustainable urban mobility systems. By enhancing access to essential activities, reducing congestion and emissions, and supporting social inclusion, strong public transport systems directly enhance the everyday quality of life (Litman, 2023). Strengthening the public transport system is a major solution for reducing dependence on private vehicles and improving urban mobility efficiency (Purwoko et al., 2022). Therefore, encouraging people to shift

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away from private vehicles is an essential step in achieving sustainable cities and inclusive transport systems.

Tourism Destinations

UNWTO (2019) defined a tourism destination as a physical space where visitors spend time. A tourism destination is an integrated system comprising 6A framework elements: attractions, accessibility, amenities, activities, available packages, and ancillary services (Buhalis, 2000). Accessibility is one of the six essential components of a tourism destination, emphasising its role in connecting tourists to attractions and services. The development and competitiveness of destinations depend on effective planning, including infrastructure, accessibility, and resilience (Rodrigues et al., 2025), as well as on the contributions of government and coordination among stakeholders to ensure high-quality experiences while maintaining environmental and socio-cultural sustainability (Dredge & Jenkins, 2007).

In conclusion, tourism destinations are multidimensional systems that integrate physical space, infrastructure, and services. Accessibility plays a vital role in connecting tourists to attractions and services and in shaping destination competitiveness and development outcomes. Therefore, integrated planning and stakeholder collaboration in the provision of public transportation are essential for strengthening destination performance while maintaining environmental and socio-cultural sustainability (Becken & Simmons, 2010).

Transportation and tourism

Various studies related to transportation and tourism have been conducted, and they have a strong relation. Prideaux (2000) further demonstrates that transport infrastructure and service provision significantly influence tourism flows, spatial development patterns, and destination competitiveness. Potential tourism destinations can’t be reached or developed without transportation infrastructure. The better the infrastructure, the more tourists are willing to visit, and vice versa. Law (2002) stated that the provision of public transportation in tourism development is often neglected. In fact, the tourism sector has increased steadily over the years and will likely continue to grow, as demand for travel is also expected to rise (Graham, Papatheodorou, & Forsyth, 2008). Therefore, to accommodate the increasing number of tourists and maintain sustainable mobility at destinations, it is important to shift to sustainable transport and to improve the efficiency of the transport system (Peeters & Dubois, 2010). Hall (1999), as cited in Madeno (2011), identified 4 transportation roles in tourism development. First, connect tourists’ origins to tourist destinations; provide access and mobilise tourists either within the destination's wider area or within the destination itself; and provide access surrounding the destination.

In transporting tourists to and from tourism destinations, transportation has a significant impact on carbon dioxide emissions (Peeters & Dubois, 2010). Among modes of transportation, private vehicles are the most effective means of reaching tourism destinations in developed countries (Hall, 2011). Indeed, it can increase air pollution and endanger the natural environment in tourism destinations. Therefore, to reduce such environmental problems, it will be necessary to reduce personal car use and encourage other, more environmentally sustainable modes of personal transport, such as walking, cycling, and, for longer distances, greater use of public transport (Graham-Rowe et al., 2011). Peeters & Dubois (2010) also stated that the most effective way to minimise air pollution and protect the natural environment is to switch to or increase the use of sustainable modes of transport, such as buses, trains, cycling, and walking.

Factors Influencing the Demand for Public Transport

Several factors influence the demand for public transport, including the quantity and quality of service, spatial factors, fares, and economic factors (Stover & McCormack, 2012). Spatial access, cost, information, physical access, and attitude are the factors that influence someone's ability and desire to use public transport (Daniels & Mulley, 2013). Environmental factors, attitudes, and service quality provided by public transport are determining factors in public transport use (Borhan et al., 2014). It aligns with Sugito et al. (2024), who argue that the quality of public transportation needs improvement by considering passengers' perceptions of service quality, safety, comfort, and accessibility. Environmental aspects and service quality positively affect public transportation users' attitudes.

According to Diab et al. (2017), factors that influence users' perceptions of public transport use include the provision of better-quality services. For new users, quality factors such as punctuality, travel time, and waiting time can affect their satisfaction more than other quality factors, such as seat comfort, air conditioning, and so on. Accessibility, travel purpose, travel time, convenience, service frequency, cost, and parking space availability are also influencing factors of public transport demand (Corpuz, 2007). In addition, Wang & Liu (2015) identified environmental factors, safety, travel distance and time, accessibility, availability, and service frequency as influencing factors in the use of public transport. According to Polat (2012), two factors influence the demand for public transport: structural and external factors. Structural factors include fare, service quality, travel time, travel distance, mode of transportation and travel destination. In contrast, external factors include dependence on public transport, social and economic factors, and policies and attitudes towards public transport.

Overall, the literature suggests that public transport demand is shaped by a combination of service-related, spatial, economic, and behavioural factors. However, it is important to distinguish between actual demand and potential

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demand in the context of this study. Actual demand refers to the observed usage of existing public transport services, whereas potential demand reflects the likelihood of individuals using public transportation if such services were available. Since no public transport system currently operates in the Lhoknga coastal tourism area, this study focuses on potential demand, which is assessed through tourists' willingness to shift from private vehicles and their perceptions of hypothetical public transport services. Therefore, the factors identified in this study should be interpreted as determinants of potential demand rather than indicators of actual public transport usage.

RESEARCH METHODOLOGY

Lhoknga District, Aceh Besar Regency, Aceh Province, Indonesia was selected as the study area due to its status as one of the key coastal tourism destinations identified in the 2020–2034 Aceh Besar Regency Tourism Development Plan (RIPPARKAB). The area comprises six major beach attractions, namely Lampuuk Beach, Pulo Kapuk Beach, Lhoknga Beach, Momong Beach, Babah Dua Beach, and Babah Kuala Mon Ikeun Beach. Despite its strong tourism potential and strategic location near Banda Aceh City as the main gateway for visitors, the area is currently not served by public transportation. This condition makes Lhoknga an appropriate case for analysing the potential demand for public transport in coastal tourism destinations.

A quantitative research design was employed to examine the factors influencing the potential demand for public transportation to tourism destinations. The study focused on measurable variables adapted from a validated instrument developed in previous research by Alotaibi (2017), consisting of 17 indicators related to transport demand and tourism behavior.

Data were collected using a structured questionnaire administered directly to tourists at selected beach destinations. A non-probability sampling technique, specifically accidental sampling, was applied due to the dynamic and unpredictable nature of tourist populations. This approach allowed the researchers to efficiently reach respondents who were present at the study sites and met the inclusion criteria, namely tourists who had visited at least one of the six selected beaches.

The field survey was carried out from 3 to 10 July 2021 across six coastal tourism sites in Lhoknga District, namely Lampuuk Beach, Pulo Kapuk Beach, Lhoknga Beach, Momong Beach, Babah Dua Beach, and Babah Kuala Mon Ikeun Beach. A total of 306 valid responses were obtained and used for analysis.

The respondents were predominantly young domestic tourists, with female respondents forming the majority of the sample. Most participants were residents of Banda Aceh and Aceh Besar, primarily students and young working

adults, who generally accessed the destinations using private vehicles. This demographic profile reflects the dominant visitor characteristics of the study area and provides a relevant basis for assessing potential demand for public transportation services.

Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS). Factor analysis was employed to identify the underlying dimensions influencing tourists' potential demand for public transportation. Prior to factor extraction, the suitability of the data was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. The KMO test evaluates the adequacy of the sample for factor analysis, while Bartlett's test determines whether the correlation matrix is appropriate for structure detection and factor extraction. The map of the study area is presented in Figure 1.

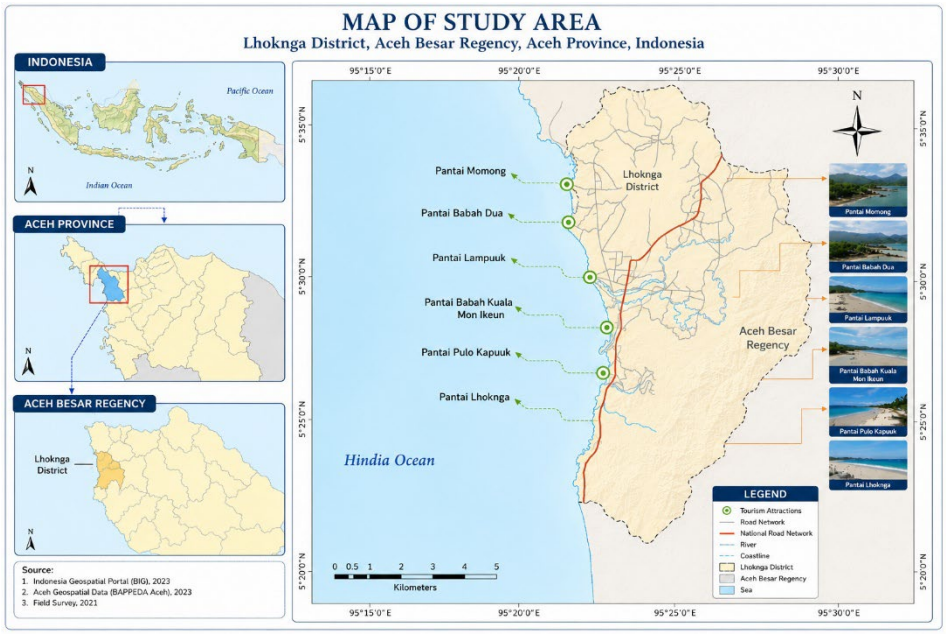


Figure 1: Research Location
Source: Author's elaboration using ArcGIS based on Google Maps, with photographs from Google

ANALYSIS AND DISCUSSION

This section presents the results of the data analysis and findings on the factors influencing the potential demand for public transportation to beach tourism destinations. Factor analysis was applied to systematically identify and prioritise demand-related factors for the formulation of a customised public transport system.

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Potential Demand

a. KMO and Barlett's Test

The Kaiser-Meyer-Olkin measure assesses the adequacy of the sample, based on the sample size. The recommended value of the KMO is above 0.5. In this research, the KMO value is 0.900, which is above the recommended value (0.5) (Table 1). This indicates that the data are valid and sufficient for further analysis. In addition, Bartlett's test of Sphericity is used to test if "x" samples are from populations with equal variances. The recommended value is less than 0.05. Bartlett's test of sphericity for the study yields a p-value of 0.000; therefore, the null hypothesis is not accepted.

Table 1. KMO MSA Test

Kaiser-Mayer-Olkin Measure of Sampling Adequacy		.900
Bartlett's Test of Sphericity	Approx. Chi-Square	2634.460
	Df	136
	Sig.	.000

Note: KMO Measure of Sampling Adequacy .900.
Bartlett's test of sphericity (p<.001)

b. Anti-image correlation

Anti-image correlation is used to determine which variables are appropriate for retention in the study by examining the MSA value. The recommended MSA value exceeds 0.5. If the value is less than 0.5, the variable should be omitted from the research. Based on the SPSS result, the MSA values of all the variables are more than 0.5 (Table 2). This means that all variables can be used in this research.

Table 2. Anti-image correlation Test

Indicator	Anti-Image Correlation
If public transport is provided, I will encourage and recommend my family to use public transport	.946[a]
I will use public transport if the stop location is accessible and efficient	.931[a]
I will use public transport to avoid congestion when visiting the beach tourism destinations.	.930[a]
I will use public transport if there is a special discount on the ticket	.928[a]
I am willing to use public transport instead of using my car	928[a]
Public transport is a solution for women, the elder and children when visiting beach tourism destinations.	.927[a]
I agree that public transport is provided to access the beach tourism destinations	.925[a]
If the price of fuel is increased, I will consider using public transport	.910[a]
Limited parking and high entry fees at beach tourist destinations will encourage me to use public transport.	.910[a]

Indicator	Anti-Image Correlation
My decision to switch to public transport depends on its safety and security	.898[a]
I always worry about traffic accidents when I travel, so I am willing to use public transport because it will be safer than driving a car	.882[a]
I prefer high-quality public transport, such as comfortable seats, air conditioning, and cleanliness.	.868[a]
Punctuality on the public transport system is very important for me	.867[a]
Clear and efficient passenger information on the public transport system is very important	.852[a]
I prefer driving instead of mixing with others when I am travelling	.671[a]
I have a negative impression of public transport.	.582[a]
If I use public transport, I have limited access to the destinations.	.580[a]

Source: Author's calculation
Note: MSA (Measure of Sampling Adequacy) > 0.5
All the variables are adapted from Alotaibi (2017)

c. Total Variance Explained

Total Variance Explained shows the total variance explained by the factors obtained from the eigenvalue. The eigenvalue must be > 1. The analysis identifies 3 newly formed factors from 17 variables (Table 3).

Table 3. Total Variance Explained

Component	Total	% of Variance	Cumulative %
1	7.119	41,829	41.829
2	1.758	10,342	52.221
3	1.362	8,012	60,232

Source: Author's calculation

d. Rotated Component Matrix

The rotated component matrix helps identify which component corresponds to which factor. Although there are 17 factors, they can be grouped into 3 broader factors. Table 4 presents the categorised factors as defined in SPSS.

Table 4. Rotated Component Matrix

Component Matrix	Loading factor		
	1	2	3
I agree that public transport is provided to access the beach tourism destinations	.553		
I am willing to use public transport instead of using my car	.737		
I always worry about traffic accidents when I travel, so I am willing to use public transport because it will be safer than driving a car	**.812**		
I will use public transport to avoid congestion when visiting the beach tourism destinations.	.738		

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Component Matrix	Loading factor		
	1	2	3
I will use public transport if the stop location is accessible and efficient		.706	
Punctuality on the public transport system is very important for me		**.798**	
I prefer high-quality public transport, such as comfortable seats, air conditioning, and cleanliness.		**.734**	
Clear and efficient passenger information on the public transport system is very important		**.836**	
I will use public transport if there is a special discount on the ticket	.653		
If the price of fuel is increased, I will consider using public transport	.**802**		
Limited parking and high entry fees at beach tourist destinations will encourage me to use public transport.	**.777**		
If I use public transport, I have limited access to the destinations.			**.670**
I prefer driving instead of mixing with others when I am travelling			**.733**
My decision to switch to public transport depends on its safety and security	.614		
Public transport is a solution for women, the elder and children when visiting beach tourism destinations.	.569		
If public transport is provided, I will encourage and recommend my family to use public transport	.680		
I have a negative impression of public transport.			**.704**

Source: Author's calculation
Note: All the variables are adapted from Alotaibi (2017)

Based on the analysis, three principal factors were identified as influencing the potential demand for public transportation to beach tourism destinations in Lhoknga District (Table 3). These factors consist of multiple indicators derived from the rotated component matrix (Table 4).

1. Traffic Costs and Problems

The first factor is identified as the most significant determinant influencing the use of public transportation, explaining 41.829% of the total variance and comprising ten indicators with varying factor loadings. The indicator with the highest loading factor (0.812) is related to concerns about traffic accidents, indicating that respondents are more willing to use public transportation because it is perceived as safer than driving private vehicles. These finding highlights that travel safety is a critical consideration in shaping tourists' mode choice. This result is consistent with the findings of Beirão & Cabral (2007), who identified safety, along with travel time, as a primary determinant of public transport use.

The second-highest loading factor (0.802) corresponds to the indicator concerning fuel price increases. This suggests that rising fuel costs can significantly influence tourists' willingness to shift from private vehicles to public transportation. This finding supports the argument presented by Department for Transport (2015), which states that economic factors, such as fuel prices and road-related expenses, play an important role in determining public transport demand.

The third-highest loading factor (0.777) is associated with parking-related constraints, including limited parking availability, entry fees, and high parking charges at tourism destinations. This indicates that parking restrictions and costs can act as a push factor encouraging the use of public transportation. This result is in line with the study by Ison & Wall (2002), which found that parking management policies, particularly the implementation of parking fees, can effectively promote a shift from private vehicle use to public transport.

Based on these indicators, it can be concluded that traffic-related issues and economic considerations are the dominant factors influencing the potential demand for public transportation. Therefore, this factor is appropriately classified as "Traffic Costs and Problems", reflecting the combined influence of safety concerns, fuel costs, and parking constraints on tourists' travel behaviour.

2. Service Quality of Public Transport

The second factor consists of four indicators and explains 10.342 of the total variance. The indicator with the highest loading factor (0.836) relates to the importance of clear and efficient passenger information, followed by other indicators such as punctuality, comfort, cleanliness, and accessibility of public transport services. These findings indicate that service quality attributes play a crucial role in influencing tourists' willingness to use public transportation.

This result is consistent with the findings of Polat (2012), who emphasised that service quality elements—such as reliability, waiting time, comfort, and service frequency—significantly affect user satisfaction and public transport demand. Similarly, Diab et al. (2017) found that operational attributes, particularly punctuality and travel time, are key determinants in shaping users' acceptance of public transportation, especially among potential users.

Furthermore, the importance of accessibility and information provision identified in this study aligns with the findings of Daniels & Mulley (2013), who highlighted that spatial accessibility and the availability of clear information significantly influence public transport usage. These findings suggest that improving service reliability, accessibility, and passenger information systems is essential to enhance the attractiveness of public transport for tourists.

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Based on these indicators, this factor is appropriately labelled as "Service Quality of Public Transport", reflecting the importance of operational performance and user-oriented service attributes in influencing travel behaviour.

3. Tourists' Perceptions of Public Transport

The third factor comprises three indicators and explains 8.012% of the total variance. The indicator with the highest loading factor (0.733) reflects a preference for using private vehicles rather than sharing space with others when travelling. Other indicators include negative perceptions of public transport and concerns about limited accessibility when using public transportation. These findings indicate that subjective perceptions and personal preferences significantly influence tourists' mode choice decisions.

This result is consistent with the study by Cullinane & Cullinane (2003), which found that individuals tend to prefer private vehicles due to greater privacy, comfort, and personal control. Public transportation, in contrast, is often perceived as less flexible and less convenient.

In addition, the perception of limited accessibility identified in this study supports the findings of Caisarina & Mat (2010), who argue that private vehicles offer greater flexibility and allow users to access a wider range of destinations more efficiently. This limitation may reduce tourists' willingness to rely on public transport, particularly in tourism areas where destinations are spatially dispersed.

Therefore, addressing negative perceptions and improving perceived flexibility are essential strategies to increase public transport demand. One possible approach is the integration of supporting local transport modes, such as feeder services, to enhance mobility within tourism destinations.

Based on these indicators, this factor is labelled as "Tourists' Perceptions of Public Transport", highlighting the importance of psychological and behavioural aspects in influencing transport choices.

However, unlike the first two factors, this factor reflects deeper behavioural and psychological barriers that cannot be addressed solely through infrastructure or pricing policies. Negative perceptions and habitual preferences for private vehicles may persist even when service quality improves. Encouraging a modal shift requires not only physical and operational improvements but also strategies aimed at changing user perceptions, such as awareness campaigns, service branding, and improving the overall travel experience (Graham-Rowe et al., 2011; Banister, 2008).

The identified factors indicate that future public transportation planning for coastal tourism destinations should integrate both service improvements and travel demand management strategies. Shuttle bus routes supported by feeder services, affordable fares, accessible bus stops, reliable schedules, real-time

passenger information, and park-and-ride facilities may contribute to increasing tourists' potential demand for public transportation. In addition, promotional campaigns highlighting the convenience and environmental benefits of public transport may improve tourists' perceptions and encourage a shift from private vehicles, thereby supporting more sustainable tourism mobility in the study area.

Despite these findings, several limitations should be acknowledged. This study was conducted only in six beach tourism destinations in Lhoknga District, used accidental sampling, and collected data within a one-week period. Therefore, the findings may be limited in terms of generalisability and may not fully capture seasonal variations in tourist behaviour. Future studies are recommended to expand the geographical scope, apply probability sampling techniques, and conduct longer observation periods to improve robustness.

CONCLUSION

This study identified three principal factors influencing tourists' potential demand for public transportation to coastal tourism destinations in Lhoknga District: traffic costs and problems, public transport service quality, and tourists' perceptions. Traffic-related and economic considerations were found to be the most influential factors. These findings provide useful insights for transport planners and local governments in developing sustainable public transportation strategies that encourage a shift from private vehicles to public transport in coastal tourism destinations.

ETHICAL CONSIDERATION

This study adhered to ethical research standards. All respondents participated voluntarily and were informed about the purpose of the study prior to data collection and the data were used solely for academic purposes.

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SATURATION DEVELOPMENT PATTERN OF BUILT-UP AREAS IN KUALA LUMPUR CITY CENTER

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Abstract

Kuala Lumpur, designated a city in 1972 and a Federal Territory in 1974, has undergone rapid urbanisation, significantly impacting its infrastructure and environmental systems. With a population exceeding 1.9 million by 2022 within 242.7 square kilometres, the city's land area has expanded to 2,584.11 hectares, reflecting intense development pressures and increased land densification. This study presents a comprehensive analysis of the spatio-temporal dynamics of urban development within the Kuala Lumpur City Centre (KLCC) between 2015 and 2023. The primary objective is to evaluate the intensity and saturation of development patterns within a one-kilometre radius of the Petronas Twin Towers and to investigate the correlation between these patterns and existing development control instruments. A mixed methodology is employed, integrating qualitative field observations with quantitative analysis of satellite imagery through advanced image processing and Geographic Information System (GIS) techniques. Situated within the context of the KLCP 2040's land use targets and the high-intensity zoning of the "City Centre" (plot ratio 4:1 to 10:1). The results indicate that built-up areas increased significantly between 2015 and 2023, with Bukit Bintang recording the highest saturation level. Development intensity was strongly associated with zoning regulations, plot ratio controls, and high-rise mixed-use developments within the KLCP2040 framework. The findings provide evidence to support sustainable development control and urban growth management within Kuala Lumpur City Centre.

Keywords: Built-up Area, Development Intensity, Saturated Development, Remote Sensing

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INTRODUCTION

Urbanisation in Malaysia is a multifaceted phenomenon, propelled by demographic factors such as natural population growth and net migration, alongside administrative mechanisms like the annexation and reclassification of rural territories (Cohen, 2004; Todd et al., 2019). This has resulted in a disproportionately rapid expansion of the urban populace, leading metropolitan centres to extend beyond their gazetted limits and exhibit increased development density (Grunsven & Benson, 2020). The area surrounding Kuala Lumpur City Centre (KLCC) exemplifies the challenges of this rapid expansion. Central urban zones are approaching a state of saturation, where infrastructural and land resources are fully utilised, compelling development to spill over into peripheral rural areas (Hasan & Nair, 2014; Tey & Lai, 2022). Monitoring this saturation growth is therefore essential for sustainable urban management. To regulate this expansion, authorities employ development control instruments such as zoning laws and density regulations (Boori et al., 2015; Yin & Abdullah, 2020). This study aims to quantify the development intensity that has shaped urban growth patterns in KLCC between 2015 and 2023. It will further analyse the influence of these control tools on the resulting saturation, offering critical insights into the efficacy of regulatory frameworks for sustainable urban expansion.

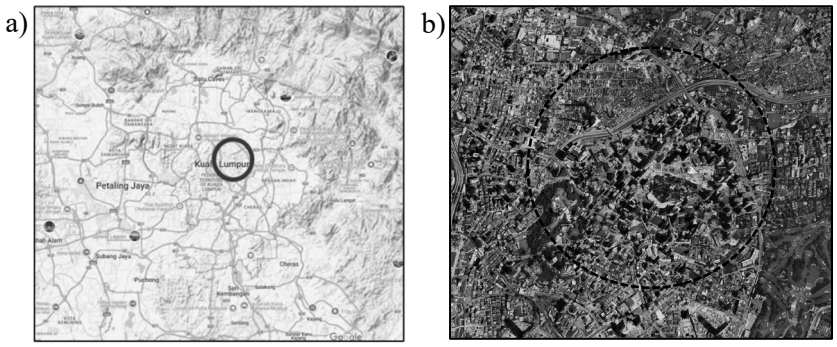


Figure 1: 1km Radius Study Area Kuala Lumpur City Center

Figure 1 shows the study area in this study, which is Kuala Lumpur City Centre. Map (a) shows the location of the study area, which is Kuala Lumpur, and (b) Kuala Lumpur City Centre. The land use (1 km radius) is from KLCC towards Kampung Baru, Bukit Bintang, Bukit Nanas, and Jalan Ampang. Additionally, it demonstrates how Kuala Lumpur's area controls the land use, with commercial as the major development. The total area of Kuala Lumpur City Centre is 247.1 acres in 2024. The red mark on each map indicates the exact pinpoint of the study area. On the eastern and northern edges of the radius lies Jalan Tun Razak, a major ring road facilitating north-south traffic and connecting

to highways leading out of the city. Jalan Kia Peng runs southward from KLCC Park, lined with luxury hotels like the Mandarin Oriental and leading toward the Pavilion shopping area in Bukit Bintang. To the southwest, Jalan Raja Chulan links KLCC to the Bukit Bintang district, passing by commercial offices and intersecting with Jalan Sultan Ismail near Menara KL Tower. Lastly, Jalan Yap Kwan Seng, located north of the Twin Towers, runs parallel to Jalan Ampang and provides access to quieter residential and commercial zones, while also connecting to Kampung Baru and Jalan Tun Razak. Together, these roads form a vital network within this bustling city centre.

PROBLEM STATEMENT

KLCC has led to significant urban issues, including overcrowding, land scarcity, and intense development pressure. The saturation of Kuala Lumpur City Centre (KLCC) is evident, showcasing how urban growth has intensified within this central area. One of the most significant signs of saturation is the high-density development within KLCC. This area is characterised by a concentration of commercial, residential, and leisure spaces, including iconic landmarks such as the Petronas Twin Towers and Merdeka 118. These skyscrapers represent the trend of vertical development, where the limited available land pushes the construction of taller buildings to maximise the use of space. As a result, KLCC's skyline has become defined by high-rise structures, with mixed-use developments that combine office, residential, and retail spaces. This vertical growth is a direct response to the constrained land availability in the area (Aktas et al., 2020; Botti, 2023). Another key factor contributing to the saturation of KLCC is the limited land availability. The scarcity of new land for horizontal expansion forces urban planners and developers to prioritise vertical growth. With no room for outward development, the only option for expanding the urban environment is to build upward. This leads to an increase in building coverage, with a higher portion of the land being developed for buildings. As urban density rises, there is a need to optimise every available space, which is often achieved by constructing taller buildings with larger floor spaces (Al-Kodmany, 2023; Yang & Luan, 2024). The scarcity of land is compounded by the presence of natural barriers and the already developed urban infrastructure that surrounds KLCC. The issue of building saturation in KLCC has become particularly relevant in the context of urban development intensity, where increasing floor space and building height are prioritised over the provision of adequate amenities and public spaces. This shift to vertical development is a clear indicator of saturation, as horizontal expansion becomes impractical due to physical, environmental, and regulatory limitations. The shortage of non-built-up areas, such as parks and recreational spaces, has become a pressing concern, with some areas even experiencing urban problems such as sinkholes due to overdevelopment (Hidayati et al., 2021).

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This directly examines how development control influences land use patterns and helps assess the correlation between development intensity and infrastructure demands. In analysing the relationship between development control and saturation patterns in the Kuala Lumpur City Centre (KLCC) 1 km radius, the complexity arises from the regulatory framework that includes zoning regulations, floor space index (FSI), height restrictions, and land use controls, which directly influence development intensity. Defining "saturation" is another challenge, as it can be understood in terms of building density, traffic congestion, or infrastructure limitations, and establishing clear thresholds for saturation that are both physical and functional is subjective and crucial to understanding when further development is no longer feasible, especially in the city centre (Wang et al., 2020; Dong et al., 2023). The area's preference for high-rise buildings, due to limited land availability, further complicates how development controls interact with the saturation pattern, as these controls influence building height, design, and usage (Yin & Abdullah, 2020; Yasin et al., 2022). These issues underscore the need for a nuanced approach to understanding how development control measures affect the intensity of development and the saturation patterns within KLCC.

LITERATURE REVIEW

In this study, urban saturation is operationally defined as the stage at which available land within the study area has been extensively utilised, resulting in limited opportunities for further horizontal expansion and increasing dependence on vertical intensification and redevelopment. Rather than relying on a single indicator, the level of saturation was evaluated using five measurable indicators of urban development intensity: (i) built-up area percentage, (ii) building density (buildings per acre), (iii) average plot ratio, (iv) average building height (storeys), and (v) floor space area. These indicators are widely recognised as reliable measures of development intensity, land-use efficiency, and urban compactness in planning and remote sensing studies (Yin & Abdullah, 2020; Razak & Yin, 2021; Wang et al., 2024; Yang & Luan, 2024). Instead of applying a universal numerical threshold, saturation levels were interpreted comparatively across the 2015–2023 study period based on temporal changes in these five indicators. As urban areas approach saturation, the emphasis of development shifts from horizontal expansion to optimising vertical land use, redeveloping underutilised spaces, and enhancing the efficiency of existing infrastructure. (Li, et al., 2022; Yeo, et al., 2022). Similarly, the percentage of non-saturated areas is derived by subtracting the saturated area from the total area and applying the same proportional formula. These calculations are repeated annually to analyse trends in land-use change over time. Non-saturated areas are urban zones that have not yet reached a high level of development and still have significant potential for

further urbanisation and growth. These areas are generally characterised by available land, which allows for horizontal expansion and the establishment of new infrastructure, residential, and commercial developments (Hu, et al., 2023; Angel, 2023). Unlike saturated areas, non-saturated zones typically experience lower building densities and may still have undeveloped or underdeveloped parcels of land that can be utilised to accommodate future growth. The potential for growth in these areas makes them more flexible in terms of urban development, as they have not yet reached the physical or regulatory constraints that define more saturated environments (Yang, et al., 2021; Wang, et al., 2024). In KLCC, several green spaces serve as non-saturated areas, offering natural vegetation and open spaces amidst urban development. The level of saturation in urban development refers to the stage at which further expansion, particularly horizontal growth, becomes increasingly difficult or unfeasible due to constraints such as limited land availability, infrastructure capacity, and regulatory limits (Wang et al., 2020; Ahani & Dadashpoor, 2021). At this stage, urban areas face significant challenges in accommodating growth without intensifying existing land use or altering the built environment. The level of saturation can vary depending on the stage of urban development, infrastructure capabilities, and the effectiveness of urban planning policies. In such saturated areas, development is primarily managed through regulatory tools such as plot ratios and building height restrictions. These controls are crucial for managing the available space while avoiding overcrowding or infrastructure overload. As the area reaches saturation, building height and density are increasingly restricted to maintain the integrity of the urban landscape and ensure the continued viability of the city's infrastructure (Razak & Yin, 2021; Kadhim et al., 2022).

METHODOLOGY

Figure 2 presents a comprehensive examination of the image processing flow chart utilised to assess urban development intensity and saturation patterns in Kuala Lumpur City Centre (KLCC), based on findings gathered during the site visit at the Malaysian Space Agency (MYSA). The initial phase involves systematic acquisition of high-resolution satellite images of KLCC, covering the years from 2015 to 2023. The comparison will be made between two years, such as 2015-2016 and 2017-2018, and will continue to show how the urban saturation evolved. Satellite images used in this study were obtained from Landsat 8 Operational Land Imager (OLI) and Sentinel-2 MSI. Landsat images have a spatial resolution of 30 m, whereas Sentinel-2 images have a spatial resolution of 10 m. Images acquired between 2015 and 2023 were downloaded from the USGS Earth Explorer. This foundational dataset forms the basis for subsequent analysis, allowing for an examination of changes in land use, the built environment, and overall urban dynamics. Once the satellite images have been acquired, the process

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undergoes a thorough preprocessing stage. This involves correcting atmospheric distortions, geometric inaccuracies, and sensor-related artefacts that may obscure the true representation of the urban landscape.

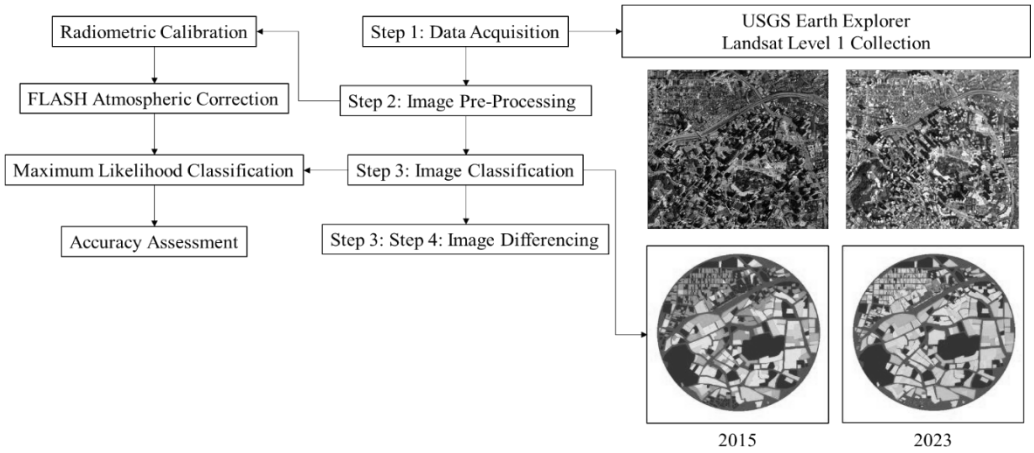


Figure 2: Image Processing of Landsat Image

After pre-processing, the satellite images were enhanced to improve image quality and feature visibility. The preprocessing procedures included radiometric, atmospheric, and geometric corrections, image mosaicking, and clipping to the study area. The enhanced images were then classified into residential, commercial, industrial, and green spaces using supervised and unsupervised classification methods based on spectral characteristics. Supervised classification employed training samples, while unsupervised classification grouped pixels according to spectral similarities. The classified images were subsequently refined through post-classification processing, including majority filtering, ancillary data integration, and class merging, to improve classification accuracy and produce reliable land use maps for analysing spatial distribution and land use changes in KLCC. The post-classification phase is essential for ensuring the reliability of the dataset as it mitigates errors that could undermine the analysis of urban development intensity and saturation. A supervised Maximum Likelihood Classification (MLC) approach was applied to classify built-up and non-built-up land uses in significant change within KLCC. This is accomplished through techniques such as image differencing, post-classification comparison, or change vector analysis. By analysing the transformations in land use and the built environment over the selected years, it becomes possible to pinpoint regions that have experienced notable development, such as new constructions, conversions, or the emergence of green spaces. Change detection is a critical tool

for understanding the dynamics of urban growth and its implications on the saturation of development in KLCC. The insights gained from the classified images and change detection processes are then subjected to comprehensive data analysis. This analysis aims to correlate the observed changes with various influencing factors, such as zoning regulations, infrastructure development, and demographic shifts. By exploring these relationships, it becomes possible to assess the intensity of urban development and identify patterns of saturation that may inform future urban planning initiatives. The analysis not only contributes to a deeper understanding of KLCC's development dynamics but also provides valuable data that can guide policymakers and planners in making informed decisions. The final phase of the image processing workflow involves visualising the analytical results through maps and graphical representations of urban growth, land use changes, and saturation patterns. Both raw satellite images and processed maps are compared to illustrate changes in development intensity over time. The processed images use colour coding to distinguish land use and density levels, where red represents high-density built-up areas, green indicates open or low-density areas, and yellow denotes transitional or medium-density zones. The comparison reveals an increase in high-density development and a reduction in green spaces, providing a clear understanding of urban expansion and the spatial evolution of KLCC. These visual outputs also support the assessment of development intensity and the impacts of development policies. Classification accuracy was evaluated using confusion matrix analysis. The overall classification accuracy exceeded 90%, with a Kappa coefficient above 0.85. While building formula used:

Building Density = Unit of Buildings / Land Area in Acre
Built-up Percentage = (Built-up Area / Total Area) ×100%

SIGNIFICANCE OF THE STUDY

This study focuses on identifying the key drivers of urban growth and assessing their impact on different subsystems across multiple scales, specifically in the context of KLCC’s geographic development. By using these insights, urban planners can anticipate where urban growth is most likely to occur, enabling better preparation for future development. The study provides a comprehensive approach to urban growth management, offering guidance on the identification of areas for expansion, the appropriate intensity of development, and the strategic allocation of land. The study contributes to the advancement of GIS-based remote sensing techniques for urban planning, providing a tool for evaluating the city’s growth potential. Additionally, the findings will help to refine policies related to intensity development in key areas in high-rise developments like Merdeka 118

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and Exchange 106, ensuring that they align with broader citywide development goals (Rosni et al., 2016; Yu & Fang, 2023).

ANALYSIS AND DISCUSSION

The importance of understanding these saturation dynamics in urban planning, particularly in areas like KLCC, which experience significant development pressures. As urban areas reach higher levels of saturation, there is a direct relationship between land value and the need for densification. Densification refers to the process of increasing the intensity of land use within a given area, typically through taller buildings, increased floor space, and more compact designs. In the context of KLCC, as available land becomes more valuable, developers seek to maximise their return on investment by constructing taller buildings with higher Gross Development Values (GDV) (Lehmann, 2016; Sime Darby, 2023). Part IV of Act 172 explains planning control and mentions several development control methods that approve development (through planning permission) that can result in changes in land use, building, and development intensity. Building alterations must also be approved by the city council, according to Section 19 (2) of Act 172. Many buildings have been altered to expand their height and floor space, resulting in a larger built-up area (Yin & Abdullah, 2020; Razak & Yin, 2021). However, non-saturated areas may also benefit from development incentives that encourage investment and expansion, often in the form of relaxed building regulations or infrastructure support to attract developers and businesses (MIDA, 2022). The development analysis based on the given statement involves a multi-faceted investigation of urban growth patterns and the influence of development control measures within a 1km radius of the Petronas Twin Towers in Kuala Lumpur City Centre. The analysis spans the period from 2015 to 2023 and aims to understand how the intensity of development impacts the evolution of the urban landscape.

Table 1: Comparison Saturated Development Intensity from 2015-2023

Land Use	**Average Storey Building (Level)**		**Average Plot Ratio (FSI)**		**Building Density (Unit/Acre)**		**Number of buildings (Unit)**		**Floor Space Area (acre)**		**Floor Space Area (acre)**	
Year	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Built-up	50	65	1:09	1:09	12.56	13.38	453	453	67.96	72.92	964.75	1004.36
Non-Built-up	-	-	-	-	-	-	-	-	14.62	9.46	-	-
Year	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Built-up	48	53	1:10	1:10	13.87	13.73	189	223	77.45	76.62	1108.75	1038.77
Non-Built-up	-	0	-	-	-	-	-	-	8.07	5.74	-	-
Year	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Built-up	7	8	1:08	1:08	21.19	19.35	336	386	77.86	92.92	111.35	141.87
Non-Built-up	0	0	-	-	-	-	-	-	4.43	8.53	-	-
Year	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Built-up	51	67	1:10	1:10	25.84	57.67	177	211	70.91	78.08	3407.83	3945.36
Non-Built-up	0	0	-	-	-	-	-	-	6.4	4.33	-	-
Year	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023

Land Use	Average Storey Building (Level)		Average Plot Ratio (FSI)		Building Density (Unit/Acre)		Number of buildings (Unit)		Floor Space Area (acre)		Floor Space Area (acre)	
Built-up	65	55	1:10	1:10	65.9	26.09	206	265	16.81	28.68	302.9	460.65
Non-Built-up	-	-	-	-	-	-	-	-	6.1	6.1	-	-
TOTAL							1361	1538	350.61	383.38	5895.58	6591.01

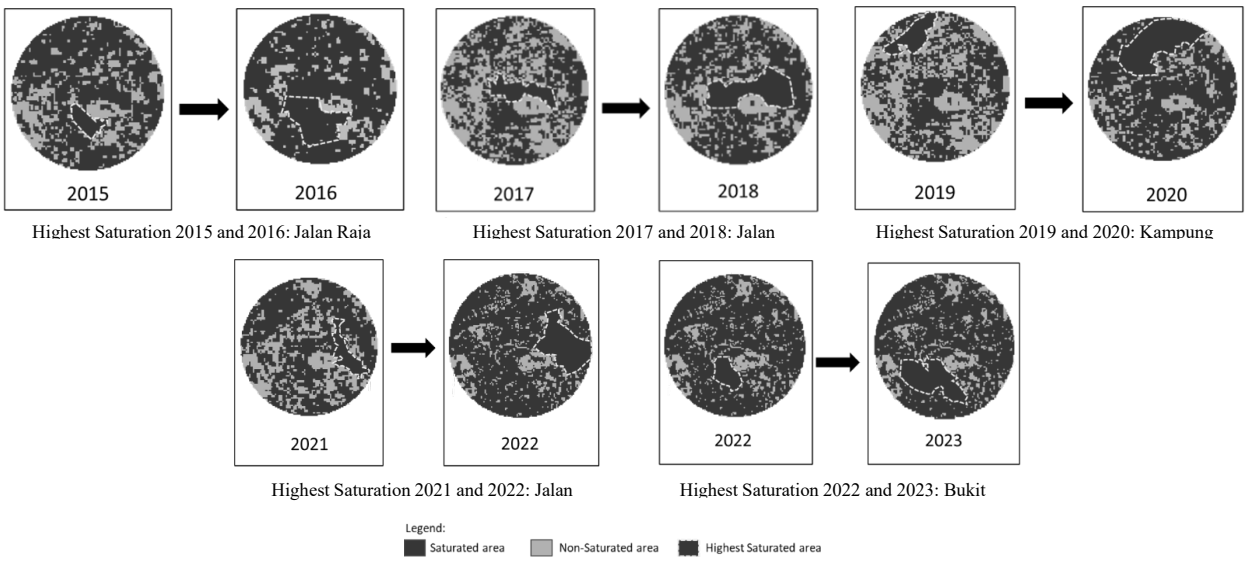


Figure 3: Highest Saturation Development Comparison From 2015-2023

Table 2: Comparison Observation Pattern to KLCP2040

Observed Pattern	KLCP2040
High building density	Allowed
Plot ratio increase	Consistent
Loss of green space	Needs mitigation

Analysis of Saturation Development Pattern in Built-up Area

The analysis of land use changes in Figure 3 and Table 1 between 2015 and 2016 indicates rapid urban intensification, particularly along Jalan Raja Chulan, driven by high-density developments and evolving land use policies. Residential and commercial sectors experienced the most significant growth, reflecting a strong shift toward vertical urbanisation. Residential development saw a sharp increase in average building height from 17 to 27 storeys, alongside an expansion in floor space area, largely due to major projects such as Banyan Tree Kuala Lumpur. Similarly, the commercial sector recorded increased building heights and a substantial rise in floor space area, supported by developments like Pavilion Kuala Lumpur's expansion and the renovation of Sungei Wang Plaza. In contrast, open space areas declined notably, highlighting increasing pressure on green

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spaces as urban development intensified. Infrastructure and utilities remained stable, suggesting reliance on existing systems, while institutional, industrial, and facility-related land uses showed slight reductions in floor space, indicating land reallocation or optimisation. Overall, the dramatic increase in total built-up area from 5.48 acres in 2015 to 27.55 acres in 2016 illustrates an aggressive phase of urbanisation. The yellow dashed line emphasises the strong relationship between expanding residential and commercial developments and urban saturation, often at the expense of open spaces.

Between 2017 and 2018, Jalan Ampang became the most saturated development corridor, reflecting rapid urban intensification driven by strategic planning and high-profile developments. Both residential and commercial sectors recorded substantial growth, with increases in building numbers, density, and vertical development. Major projects such as Eaton Residences, Four Seasons Place, Oxley Towers, and KL Trillion significantly contributed to the expansion of floor space and reinforced Jalan Ampang's role as a high-density urban corridor. The total built-up area rose sharply from 12.44 acres in 2017 to 41.33 acres in 2018. Although KLCP2040 encourages high-density mixed-use development within the city centre, the reduction in open spaces indicates increasing development pressure that may require stronger green infrastructure protection (Refer to Table 2). However, this intensification occurred at the expense of open spaces, which declined noticeably, raising sustainability concerns. Other land-use categories, including infrastructure, institutions, and industry, showed minimal change, suggesting reliance on existing facilities. Overall, Jalan Ampang's development saturation reflects efficient land use and strong policy support but highlights the need for a more balanced and sustainable approach to future urban development.

Between 2019 and 2020, Kampung Baru underwent significant development intensification driven by strategic redevelopment initiatives aimed at modernising the area while preserving its cultural identity. The residential sector experienced the most substantial growth, marked by an increase in building numbers and expansion of space and floor areas, primarily through horizontal development associated with affordable housing initiatives such as RUMAWIP. This reflects efforts to address urban housing demand while maintaining lower building densities. Commercial development recorded modest growth under strict planning controls, with projects like the Kampung Baru City Centre (KBCC) introducing new retail and office spaces. Notably, open spaces expanded during this period, indicating a planning emphasis on sustainability and green space preservation under the Kampung Baru Special Area Plan (RKK 2020). Infrastructure, institutional, and industrial sectors also showed measured growth, supported by improved connectivity and upgraded facilities, enabling Kampung Baru to accommodate increasing development pressures. Overall, the total built-

up area increased sharply from 10.01 acres in 2019 to 39.74 acres in 2020, highlighting the transformative impact of coordinated redevelopment projects. These trends demonstrate Kampung Baru's transition toward a modern urban district while maintaining a balanced and culturally sensitive approach to urban development.

Between 2021 and 2022, Jalan Binjai and Jalan Kia Peng experienced intensified urban saturation, driven by the completion of major high-density developments and continued construction despite the COVID-19 pandemic. Residential and commercial sectors showed notable growth, with increases in building numbers, density, and floor space, reflecting strong demand for central urban living and mixed-use environments. Landmark projects such as Merdeka 118, Star Residences, and Oxley Towers played a pivotal role in accelerating this saturation. Infrastructure and utility developments expanded to support growing residential and commercial activity, aided by improved connectivity through MRT infrastructure. Institutional and industrial sectors also increased in building numbers, although within smaller land areas, indicating a trend toward more compact and efficient land use. Conversely, open spaces declined as land was increasingly prioritised for built environments. Overall, the total built-up area increased from 77.31 acres in 2021 to 82.41 acres in 2022, marking a peak phase of urban saturation in these areas. Compared to earlier periods, this phase represents a final push toward high-density urbanisation in central Kuala Lumpur, demonstrating the resilience of urban development driven by strategic projects, infrastructure investments, and evolving market demands.

Between 2022 and 2023, Bukit Bintang experienced a significant intensification of urban saturation, marked by substantial increases in building numbers, floor space area, and land-use transformation. Both residential and commercial sectors recorded major expansion, with sharp growth in total floor space despite declining building densities, indicating a shift toward larger, lower-density or multi-use developments rather than compact high-density structures. Major projects such as The Exchange TRX, Pavilion Kuala Lumpur Extension, and KL118 played a central role in driving this transformation. Residential developments expanded considerably, reflecting increased demand for high-end and spacious urban housing, while commercial growth reinforced Bukit Bintang's role as a key business and retail hub. Open spaces remained constant, suggesting efforts to preserve existing green areas amid rapid development. Infrastructure and institutional sectors showed moderate growth, largely through more compact and space-efficient developments, while industrial activities continued to decline, reflecting land-use reallocation toward higher-value urban functions. The total built-up area increased dramatically from 302.9 acres in 2022 to 460.65 acres in 2023, marking the highest level of urban saturation observed in Bukit Bintang. This growth was facilitated by favourable planning regulations,

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development control policies, and large-scale flagship projects. Overall, 2023 represents the peak of urban intensification in Bukit Bintang, characterised by a clear transition toward large-scale, mixed-use developments and highly optimised land use in Kuala Lumpur's city centre.

CONCLUSION

Overall, the analysis of land use changes from 2015 to 2023 reveals a clear trajectory of progressive urban intensification across key areas in central Kuala Lumpur, driven by strategic planning policies, major flagship developments, and evolving market demands. The study period demonstrates a shift from early stages of vertical urbanisation in Jalan Raja Chulan (2015–2016), through rapid corridor-based saturation in Jalan Ampang (2017–2018), to more policy-guided and socially responsive redevelopment in Kampung Baru (2019–2020). From 2021 onwards, development trends in Jalan Binjai, Jalan Kia Peng, and Bukit Bintang indicate a peak phase of urban saturation characterised by large-scale, high-density, and mixed-use developments. Despite disruptions caused by the COVID-19 pandemic, construction activity remained resilient, supported by landmark projects such as Merdeka 118, Oxley Towers, Star Residences, The Exchange TRX and Pavilion Kuala Lumpur Extension. These developments significantly increased building density, floor space, and total built-up areas, reinforcing Kuala Lumpur's role as a compact and vertically orientated global city. Across all study areas, residential and commercial land uses consistently emerged as the dominant drivers of urban growth, often expanding at the expense of open spaces. While some areas, notably Kampung Baru, demonstrated efforts to preserve or enhance green spaces through targeted planning frameworks, the overall trend highlights the growing pressure on open land in highly urbanised zones. Future development should therefore prioritise a balanced approach that integrates high-density growth with environmental sustainability, social inclusivity, and long-term urban liveability. Future development within KLCC should prioritise redevelopment rather than further land consumption. Development control policies should strengthen green infrastructure protection, optimise plot ratio allocation according to infrastructure capacity, encourage transit-orientated development, and preserve strategically important open spaces. Periodic GIS-based monitoring should also be adopted to support evidence-based planning and sustainable urban growth management.

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ENVIRONMENTAL QUALITY OF TRANSITIONAL SPACES AND STUDENT BEHAVIOUR ON A UNIVERSITY CAMPUS

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Abstract

Transitional spaces (outdoor and semi-open areas) are increasingly used by university students for informal learning and social interaction; however, these spaces are often overlooked in campus planning, resulting in environmental conditions that may not support learning-related behaviours and user satisfaction. This study aims to evaluate the environmental qualities of campus transitional spaces and examine how these qualities relate to students' behaviours and satisfaction in a tropical university setting. A case study was conducted at the Universiti Sains Malaysia (USM) main campus using on-site observation and a questionnaire survey (n = 300). Environmental quality was assessed across six dimensions (colour, size, temperature, ventilation, acoustics, and lighting), while students' behaviours were measured through learning outcomes and interactions, together with satisfaction regarding environmental quality. Descriptive and inferential analyses show that temperature and lighting are the most problematic aspects across the study areas and are associated with students' behaviours and satisfaction. Higher temperatures, unstable thermal conditions, and insufficient lighting are linked to reduced learning outcomes and lower satisfaction in transitional spaces. These findings suggest that improving transitional spaces requires a system-level approach rather than isolated upgrades, and they support planning actions to integrate transitional spaces into campus public realm optimisation strategies for tropical university campuses.

Keywords: Campus master planning, Transitional spaces, Informal learning, Microclimate, Malaysia

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INTRODUCTION

Universities are increasingly expected to function as campus-scale learning ecosystems where students study, collaborate, and socialise between scheduled classes. Alongside student-centred and active learning approaches, learning activities have expanded beyond formal classrooms into a distributed "learning landscape" that includes libraries, breakout areas, outdoor settings, and circulation zones (DeFrain & Hong, 2020). Consequently, spaces historically treated as circulation or "in-between" areas are now frequently used for short-duration study, waiting, peer discussion, and spontaneous collaboration.

This shift raises an international planning issue: campuses must support learning-related behaviours and student experience across a network of formal, informal, and transitional settings, yet research and planning practice often remain centred on discrete indoor spaces. Transitional (in-between/interstitial) spaces—such as covered walkways, verandas, breezeways, corridors, entrance forecourts, semi-open terraces, and courtyard edges—operate at the boundary between movement and stay and form part of the campus public realm network that structures everyday mobility and encounter patterns (Wang et al., 2025). In the Malaysian higher-education context, Abdul Munir et al. (2018) reported that learning-space attributes are associated with students' satisfaction and perceived performance, while Yaman et al. (2018) highlighted the relevance of outdoor learning settings for contemporary learning approaches in universities. These perspectives indicate that transitional spaces should be assessed and improved as a connected system supporting learning and student experience, rather than treated as residual leftover areas.

The challenge is especially salient in tropical, hot–humid campuses where environmental conditions strongly influence whether semi-open and outdoor spaces can be occupied beyond brief periods. Transitional-space comfort requires context-specific responses in shade, ventilation pathways, and radiation exposure (Hou et al., 2024), and studies of campus pedestrian environments in tropical regions further suggest that microclimatic performance must be integrated with physical design attributes in circulation and public realm planning (Suwanmanee et al., 2024). Beyond microclimate, transitional spaces must also support adequate lighting, visibility, and acoustic conditions that enable both quiet individual use and small-group interaction.

Despite increasing recognition of informal learning spaces, transitional spaces remain less systematically studied as a campus planning issue in two ways: (i) many studies focus on discrete indoor settings rather than examining how formal, informal, and transitional spaces operate together as a coherent campus system; and (ii) empirical findings are not always translated into planning-oriented outputs that can inform campus master planning, spatial hierarchy, and prioritised investment decisions. Guided by Social Cognitive Theory (SCT),

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which conceptualises reciprocal relationships between environmental influences and behavioural outcomes (Bandura, 1989), this study evaluates transitional spaces within the USM main campus and examines how environmental quality relates to student behaviour and satisfaction. Using a zone-based case study design across three selected campus zones (School of Housing, Building and Planning; School of Arts; and the Main Hall and Library area), the research assesses six environmental dimensions (colour, size, temperature, ventilation, acoustics, and lighting) through on-site observation and a questionnaire survey (n = 300). The study identifies critical environmental deficiencies and translates the findings into actionable planning strategies to support system-level optimisation of transitional-space networks in tropical university contexts.

LITERATURE REVIEW

Theoretical Background: Social Cognitive Theory

This study is grounded in SCT, which explains behaviour through reciprocal interactions among environmental influences, individual factors, and behavioural outcomes (Bandura, 1989). SCT provides a lens for linking perceived environmental qualities of transitional spaces to students' behavioural use and satisfaction.

Informal Learning and Campus Learning-Space Ecosystems

Informal learning is commonly described as learning initiated and self-regulated by the learner, differing from structured learning in traditional classroom settings (Akkurt & Akbulut, 2025). In contemporary higher education, informal learning is increasingly linked to flexibility, short-duration study, peer exchange, and spontaneous collaboration occurring across semi-formal and informal settings. This has led scholars to frame the campus as a distributed learning-space ecosystem in which learning support depends on the availability, accessibility, and quality of multiple alternative spaces rather than any single facility (DeFrain & Hong, 2020; Peng et al., 2022). Within this perspective, learning environments should facilitate interaction, communication, and cooperation to complement formal teaching spaces (Salih et al., 2024).

Methodologically, informal learning research has used diverse approaches to capture both behaviours and perceptions. Studies have applied surveys, behavioural measures, and choice-based methods (Peng et al., 2022; Zhang et al., 2022), qualitative techniques such as behavioural logs, focus groups, and interviews (Mantooth, 2020; Wang, 2020), and mixed methods combining questionnaires with interviews to strengthen interpretation and context sensitivity (Peng et al., 2021; Wu et al., 2021). Across these approaches, a consistent planning implication is that learning-support spaces should be evaluated not only

by provision but also by how students perceive, choose, and use spaces during everyday academic routines.

Transitional Spaces as Learning-Support Settings Within the Campus

Transitional spaces are commonly discussed as in-between or interstitial settings that mediate movement and environmental change between indoor and outdoor conditions. Literature offers several ways to define and classify transitional spaces. Some define them as bridges connecting interior and exterior environments (e.g., balconies, pavilions, lobbies, corridors), emphasising boundary conditions and hybrid environmental characteristics (Akkurt & Akbulut, 2025). Others emphasise transitional spaces as accessory spaces attached to main buildings and highlight distinctions between enclosed and semi-open transitional environments (Han et al., 2024). Transitional spaces have also been classified based on their relationship to buildings (not connected, connected, or inside the building), reflecting differences in environmental exposure and functional use (Diz-Mellado et al., 2020). A shared characteristic across these accounts is that transitional spaces tend to show greater variability and instability due to stronger influence from the external environment, which affects comfort and usability (Han et al., 2024).

Within university campuses, transitional spaces connect functional zones and shape everyday mobility patterns. As learning increasingly extends beyond classrooms, these spaces may evolve from pass-through corridors into low-threshold learning-support environments where students wait, study briefly, meet peers, or conduct short discussions between classes. In Malaysia, Ibrahim et al. (2018) discuss learning activities outside classrooms on campus grounds and the contribution of outdoor and semi-open environments to learning-related use. Abdul Munir et al. (2018) further reported that learning-space attributes are associated with students' satisfaction and perceived performance, reinforcing the planning importance of learning-support spatial quality, while Yaman et al. (2018) discussed outdoor learning settings in Malaysian universities in relation to pedagogical approaches such as problem-based learning. At a broader level, tertiary education is increasingly framed as requiring social learning-built environments that support interaction and flexibility, implying that learning-support spaces should be planned as a connected system rather than isolated rooms (Ramu et al., 2021). Collectively, these studies support positioning transitional spaces as part of the campus public realm network, where connectivity, comfort, and opportunities for interaction jointly influence learning-support potential.

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Environmental Quality Dimensions and Their Relationships with Behaviour and Satisfaction

Because transitional spaces sit at the indoor–outdoor boundary, environmental quality strongly influences whether students are willing to stay for learning-related activities. Thermal comfort is repeatedly identified as a central constraint in transitional environments, especially in tropical hot–humid contexts where heat, humidity, and radiation can limit usability (Han et al., 2024; Hou et al., 2024). Beyond microclimate, multi-dimensional factors—including colour, lighting, acoustics, spatial size, and ventilation—shape perceived suitability for short study and small-group interaction (Al-Ramahi et al., 2023; Mogas-Recalde et al., 2021; Yewande Bakare & Alibaba, 2020). Accordingly, perceived environmental quality can be operationalised using six dimensions: colour, lighting, temperature, acoustics, size, and ventilation.

To translate environmental quality into planning-relevant evidence, transitional space studies should link space attributes to behavioural outcomes and user satisfaction. In campus learning research, "student behaviour" is commonly operationalised through learning-related outcomes (e.g., perceived productivity, focus, task completion) and social/interaction outcomes (e.g., communication, collaboration, peer exchange) (Areche, 2022; Iberahim & Sulaiman, 2023). Learning outcomes refer to knowledge, competencies, or skills developed through learning activities and can be assessed through perceived effectiveness in specific settings (Sturrock & Zandvliet, 2023). Interaction can be examined through perceived communication efficiency, collaboration, depth of discussion, and thereby whether a space supports productive peer engagement (Baanqud et al., 2020; Rothouse, 2020). Student satisfaction is widely used as an indicator of environmental performance in higher education contexts and is relevant for evaluating whether campus spaces meet user expectations and support educational experience (Ou et al., 2026).

Overall, existing literature indicates that transitional spaces should be treated as planning objects within campus master planning due to their network role in connecting destinations and their emerging function as informal learning-support settings. Multi-dimensional environmental quality—particularly microclimate and lighting in tropical contexts—can influence whether students use transitional spaces for learning and interaction, and these relationships can be assessed through behaviour and satisfaction measures to inform prioritised, system-level campus public realm optimisation.

Conceptual Framework and Underlying Theory

Guided by SCT, this study conceptualises student behaviour and satisfaction in transitional spaces as outcomes associated with environmental influences. SCT explains behaviour through reciprocal relationships among environmental

conditions, behavioural engagement, and experienced outcomes (Bandura, 1989). In this study, the "environment" component is operationalised as perceived environmental quality of transitional spaces (colour, lighting, temperature, acoustics, size, and ventilation). Based on the reviewed literature, these perceived environmental qualities are expected to be associated with students' behaviours in transitional spaces—captured through learning outcomes and interactions—and students' behaviours are expected to be associated with overall satisfaction. To strengthen planning relevance, zone-based comparisons (Zone 1–Zone 3) are used to support prioritised intervention decisions across the campus public realm network (Figure 1).

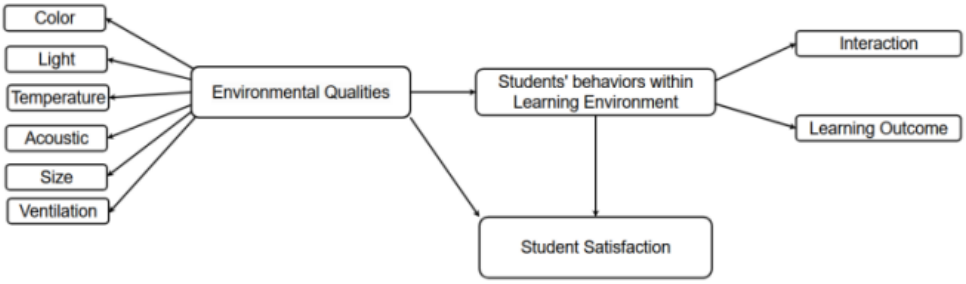


Figure 1: Conceptual Framework
Source: By Author

RESEARCH METHODOLOGY

Study Area and Research Design

This study was conducted at the USM main campus in Penang, Malaysia. The campus is located on Penang Island in the north-west of Peninsular Malaysia and represents a tropical hot–humid university environment. As a campus-scale learning ecosystem, students frequently move between academic buildings and shared facilities through covered walkways and semi-open circulation networks, where short-duration activities (e.g., waiting, brief study, and peer discussion) commonly occur between scheduled classes. A quantitative case study design was adopted, combining on-site observation with a questionnaire survey to evaluate transitional spaces and examine relationships between perceived environmental quality, student behaviour, and satisfaction.

To capture spatial variability for planning interpretation, a zone-based approach was applied. Three campus zones were selected based on (i) differences in campus function and activity patterns (faculty-based academic cluster, creative/arts cluster, and a campus-core public facility cluster), (ii) variations in transitional-space typologies and degrees of enclosure (e.g., corridors, covered walkways, semi-open terraces, courtyard edges), and (iii) high pedestrian

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movement and frequent short stays observed during preliminary site visits. The selected zones were: (i) the School of Housing, Building and Planning (HBP) area, (ii) the School of Arts area, and (iii) the Main Hall and Library area. Figure 2 shows the USM main campus study area and the zoning of the three selected areas.

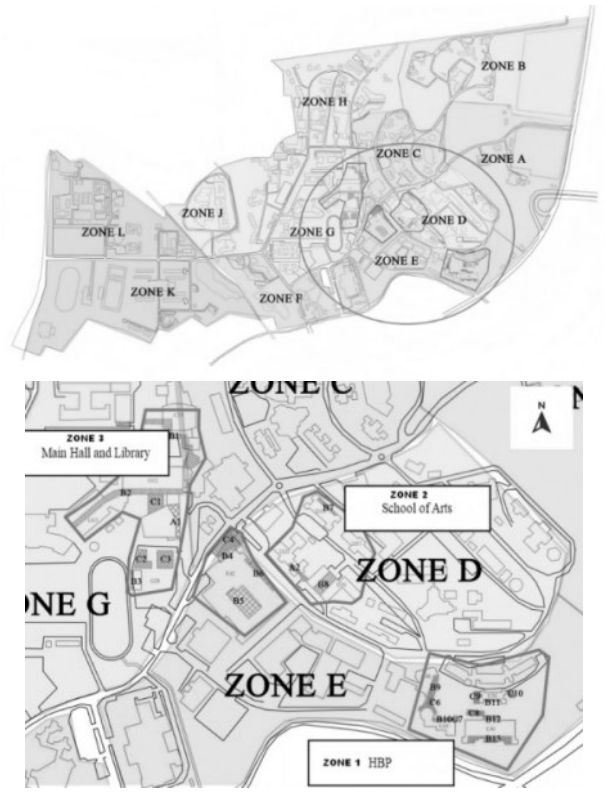


Figure 2: Study Area (USM Main Campus) and Zoning of the Three Selected Campus Areas: Zone 1 (HBP), Zone 2 (School of Arts), and Zone 3 (Main Hall & Library)
Source: By Author

Transitional Space Identification and On-Site Observation

Field observation was conducted prior to the survey to identify and document transitional spaces within the three zones. A walk-through inventory was undertaken to locate outdoor and semi-open in-between spaces that mediate movement between buildings and support short stays. For each identified space, basic attributes were recorded (e.g., location, degree of enclosure, shading condition, lighting availability, ventilation exposure, surrounding noise sources, and observed user activities such as waiting, studying, or social interaction). A

total of 25 transitional spaces were inventoried and categorised into three space types (Type A–C) based on spatial characteristics and contextual relationships (e.g., degree of enclosure and functional role). These space types describe transitional-space typologies, whereas Zone 1–Zone 3 refer to the three spatial study zones illustrated in Figure 2. The identified spaces served as the settings for survey administration and supported interpretation of zone-level differences. It should be noted that environmental quality in this study refers to students' perceived environmental quality, measured through questionnaire responses. On-site observation was used to identify, classify, and document transitional spaces and to contextualise the survey findings; it did not involve objective instrumental measurements such as air temperature, humidity, illuminance, or sound level monitoring. The observation results were organised into a transitional-space typology to clarify the physical characteristics and planning relevance of the identified spaces (Table 1).

Table 1: Typology of observed transitional spaces

Space type	Defining characteristics	Typical examples
Type A: Linear circulation spaces	Semi-open or covered movement corridors connecting buildings	Covered walkways, corridors
Type B: Building interface spaces	Transitional areas attached to building entrances or edges	Entrance forecourts, verandas, lobby edges
Type C: Open/semi-open stay spaces	Wider transitional spaces with potential for short stay or social use	Courtyard edges, semi-open terraces, sheltered nodes

Source: By Author

Sampling and Participants

The target population comprised students at the USM main campus. A zone-based stratified approach was used, with respondents recruited in the identified transitional spaces within each zone. A total of 300 valid and complete questionnaires were included in the final analysis (Zone 1/HBP = 101; Zone 2/School of Arts = 105; Zone 3/Main Hall & Library = 94). Given an estimated student population of approximately 30,000 at the USM main campus, the minimum required sample size was determined using G-power. Based on this calculation, approximately 190 completed questionnaires were required to obtain a sufficiently representative sample. The present study analysed 300 valid and complete responses, which exceeds this minimum requirement.

Measures and Instrument Development

The questionnaire consisted of five sections: (1) respondent background and usage profile; (2) perceived environmental quality; (3) student behaviour; (4) satisfaction. All main constructs were measured using a five-point Likert scale.

Survey items were developed through a review of prior studies on informal/transitional learning settings, environmental comfort/quality, and

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learning-support outcomes. Items for perceived environmental quality were adapted and contextualised for semi-open campus transitional settings, covering six dimensions frequently discussed in the literature: colour, size, temperature, ventilation, acoustics, and lighting (Al-Ramahi et al., 2023; Han et al., 2024; Hou et al., 2024; Mogas-Recalde et al., 2021). Student behaviour was operationalised as self-reported behavioural functioning in transitional spaces, measured through two dimensions: learning outcomes (six items) and interaction (five items). Learning outcomes captured students' perceived ability to study, focus, and complete learning-related tasks in transitional spaces, while interaction captured perceived opportunities for peer communication, discussion, and collaboration. A composite student behaviour score was computed by averaging the learning outcome and interaction dimension scores (Areche, 2022; Iberahim & Sulaiman, 2023; Sturrock & Zandvliet, 2023). Satisfaction was measured for the six environmental dimensions and overall satisfaction, aligning with learning-space satisfaction approaches used in Malaysian higher-education studies (Abdul Munir et al., 2018) and recent campus satisfaction literature (Ou et al., 2026).

Statistical Analysis

Data were analysed using descriptive and inferential statistics in IBM SPSS Statistics 24. Reliability testing was conducted for multi-item subscales using Cronbach's alpha. Descriptive statistics (means, standard deviations, and frequencies) were used to profile perceived environmental quality, behaviour, and satisfaction. In addition, partial least squares structural equation modelling (PLS-SEM) was conducted using SmartPLS 4. Before assessing the structural model, the PLS-SEM measurement model was evaluated using outer loadings, internal consistency reliability, convergent validity, and discriminant validity. The assessment criteria followed established PLS-SEM guidelines, including outer loadings above 0.70, composite reliability above 0.70, AVE above 0.50, and HTMT for discriminant validity (Hair et al., 2022). Bootstrapping with 5,000 resamples was applied to test the significance of path coefficients and indirect (mediation) effects, with statistical significance set at $p < 0.05$. One-way ANOVA was used to test differences across the three zones; homogeneity of variance was assessed using Levene's test, and Tukey HSD post-hoc comparisons were applied where the omnibus test was significant.

ANALYSIS AND DISCUSSION

Sample Profile and Descriptive Statistics

A total of 300 valid questionnaires were analysed (Zone 1/HBP = 101; Zone 2/School of Arts = 105; Zone 3/Main Hall & Library = 94). Table 2 summarises the descriptive statistics of the study constructs.

Table 2: Descriptive Statistics of Study Constructs

Construct / Dimension	No. of items	Mean	SD
Colour	3	2.38	0.93
Size	3	2.43	0.78
Temperature	2	1.93	0.90
Acoustics	3	2.64	0.98
Ventilation	2	3.06	0.91
Lighting	3	1.85	0.86
Environmental qualities (composite)	-	2.38	0.73
Learning outcome	6	2.47	0.96
Interaction	5	2.32	1.05
Students' behaviour (composite)	-	2.40	0.96
Overall satisfaction	-	2.10	0.72

Source: By Author

Overall perceived environmental quality of transitional spaces was moderate-to-low (M = 2.38, SD = 0.73). Among the six dimensions, ventilation (M = 3.06) and acoustics (M = 2.64) were rated relatively higher, while temperature (M = 1.93) and lighting (M = 1.85) received the lowest ratings, indicating the most critical constraints on usability.

Students' behaviour in transitional spaces was rated moderate-to-low (overall M = 2.40; learning outcome M = 2.47; interaction M = 2.32). Overall satisfaction was low (M = 2.10, SD = 0.72), suggesting that current transitional spaces do not adequately support students' learning-related use and experience.

PLS-SEM Measurement Model Assessment

The measurement model was assessed at the first-order construct level before evaluating the structural model. As shown in Table X, all retained questionnaire items achieved acceptable outer loadings, ranging from 0.736 to 0.928. The first-order constructs also met the recommended reliability and convergent validity thresholds, with Cronbach's alpha values ranging from 0.745 to 0.909, CR values ranging from 0.854 to 0.932, and AVE values ranging from 0.594 to 0.861.

Table 3: PLS-SEM Measurement Model Assessment

First-order construct	Item	Outer loading	Cronbach's α	rho_A	CR	AVE
EQ_Colour	B.A1	0.858	0.747	0.753	0.855	0.664
	B.A2	0.784				
	B.A3	0.801				
EQ_Size	B.B1	0.819	0.745	0.750	0.854	0.661
	B.B2	0.834				
	B.B3	0.787				
EQ_Temperature	B.C1	0.903	0.804	0.812	0.910	0.836
	B.C2	0.925				
EQ_Acoustics	B.D1	0.869	0.805	0.816	0.884	0.718
	B.D2	0.837				
	B.D3	0.836				

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First-order construct	Item	Outer loading	Cronbach's α	rho_A	CR	AVE
EQ_Ventilation	B.E1	0.928	0.838	0.838	0.925	0.861
	B.E2	0.928				
EQ_Lighting	B.F1	0.858	0.853	0.855	0.911	0.773
	B.F2	0.888				
	B.F3	0.892				
BEH_LearningOutcome	C.G1	0.779	0.863	0.864	0.898	0.594
	C.G2	0.736				
	C.G3	0.758				
	C.G4	0.787				
	C.G5	0.783				
	C.G6	0.778				
BEH_Interaction	C.G7	0.862	0.909	0.909	0.932	0.733
	C.G8	0.823				
	C.G9	0.865				
	C.G10	0.854				
	C.G11	0.876				

Source: By Author

Discriminant validity was further supported by HTMT values below the recommended threshold. The HTMT value was 0.768 between Environmental Quality and Students' Behaviour, 0.563 between Students' Behaviour and Overall Satisfaction, and 0.406 between Environmental Quality and Overall Satisfaction. These results indicate acceptable discriminant validity among the constructs.

Structural Model Results (PLS-SEM)

PLS-SEM results indicate that Environmental Quality significantly predicts Students' Behaviour ($\beta = 0.703$, $t = 17.456$, $p < 0.001$), explaining 49.4% of the variance in behaviour ($R^2 = 0.494$). When predicting Satisfaction, Students' Behaviour remains a significant predictor ($\beta = 0.523$, $t = 6.940$, $p < 0.001$), whereas the direct effect of Environmental Quality on Satisfaction is non-significant ($\beta = 0.022$, $t = 0.255$, $p = 0.799$), with $R^2 = 0.290$ for Satisfaction. Bootstrapping further confirmed a significant indirect effect of Environmental Quality on Satisfaction via Students' Behaviour ($\beta = 0.367$, $t = 5.833$, $p < 0.001$), indicating an indirect-only (full mediation) pattern in which environmental improvements enhance satisfaction primarily by improving what students can do in transitional spaces (learning outcomes and interactions).

Table 4: PLS-SEM Structural Model Results (Bootstrapping, 5,000 Resamples)

Path	β (Original sample)	t	p
Direct Effect			
Environmental Quality → Students' Behaviour	0.703	17.456	< 0.001
Students' Behaviour → Satisfaction	0.523	6.940	<0.001
Environmental Quality → Satisfaction	0.022	0.255	0.799
Indirect Effect			
Environmental Quality → Students' Behaviour → Satisfaction	0.367	5.833	< 0.001

R^2 (Students' Behaviour) = 0.494; R^2 (Satisfaction) = 0.290.

Source: By Author

Zone Comparison Results (ANOVA)

One-way ANOVA showed significant differences across the three zones for environmental quality, students' behaviour, and satisfaction (Table 5). Effect sizes ranged from small to moderate, with the largest effect observed for student satisfaction (η^2= 0.124). Tukey HSD post-hoc comparisons indicated that Zone 1 performed significantly higher than Zones 2 and 3 across all three outcomes, supporting spatially targeted prioritisation rather than uniform campus-wide upgrades.

Table 5: One-Way ANOVA Results Comparing Environmental Quality, Students' Behaviour, and Satisfaction Across the Three Campus Zones

Variable	Zone 1 Mean (SD)	Zone 2 Mean (SD)	Zone 3 Mean (SD)	F(df)	p	η^2	Post-hoc (Tukey)
Environmental Qualities	2.55 (0.72)	2.31 (0.68)	2.27 (0.76)	F(2,297)= 4.379	0.013	0.029	Z1 > Z2; Z1 > Z3
Students' Behaviour	2.70 (1.04)	2.26 (0.89)	2.23 (0.89)	F(2,297)= 7.779	0.001	0.050	Z1 > Z2; Z1 > Z3
Student Satisfaction	2.45 (0.85)	1.96 (0.58)	1.88 (0.56)	F(2,297)= 21.007	<0.001	0.124	Z1 > Z2; Z1 > Z3

η^2 = eta squared effect size. Tukey HSD post-hoc tests were used for pairwise comparisons.

Source: By Author

DISCUSSION AND PLANNING IMPLICATIONS

To translate the empirical findings into a planning-oriented output, Figure 3 synthesises the evidence into key planning levers and priority implementation focuses for campus-scale optimisation of transitional spaces.

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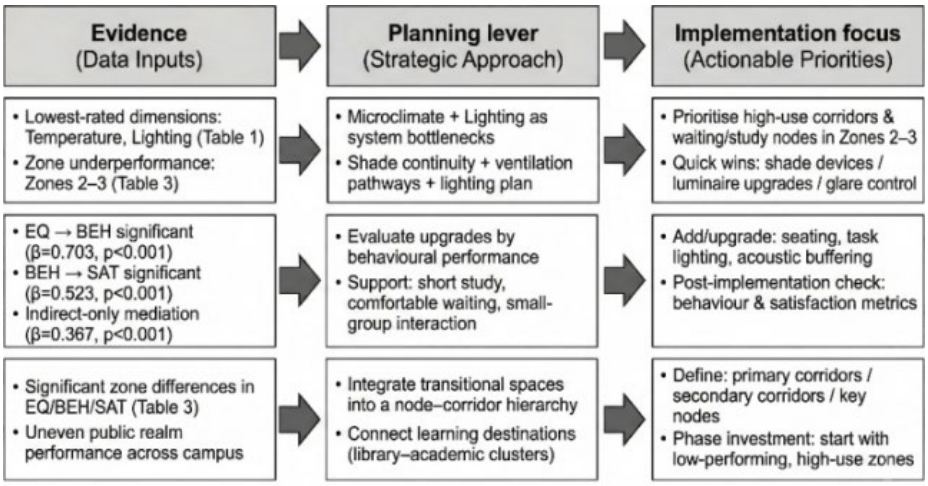


Figure 3: Evidence-To-Action Framework for Transitional-Space Optimisation
Source: By Author

Table 6 synthesises the empirical findings into evidence-based campus design actions by linking priority issues with targeted interventions, implementation locations, and expected performance outcomes. The recommendations emphasise microclimatic comfort, visual legibility, seating provision, and short-stay usability, positioning transitional spaces as integral components of the campus public realm system that support learning, interaction, and everyday movement.

Table 6: Campus design actions for transitional-space optimisation

Priority issue	**Evidence**	**Campus design action**	**Priority location**	**Expected outcome**
Thermal discomfort	Temperature was the lowest-rated environmental dimension	Provide continuous shade structures, and heat-reducing surface materials; improve natural ventilation paths	Zones 2–3; high-use corridors and waiting nodes	Improved thermal comfort, longer stay duration, higher behaviour scores
Poor lighting	Lighting received the lowest mean score after temperature	Upgrade walkway lighting, add task lighting at seating/study nodes, and improve night-time visibility	Key pedestrian links and transitional nodes in Zones 2–3	Improved perceived safety, usability, and satisfaction
Limited short-stay support	Behaviour mediates the relationship between environmental quality and satisfaction	Provide shaded seating, informal discussion spots, small tables, and flexible short-stay areas	Building edges, courtyard edges, lobby/entrance interfaces	Improved learning outcomes and interaction

Priority issue	Evidence	Campus design action	Priority location	Expected outcome
Uneven zone performance	Significant differences across zones from ANOVA	Implement phased corridor–node upgrading based on performance gaps	Start with Zones 2–3, then expand campus-wide	Reduced spatial inequality and improved public realm performance

Source: By Author

The matrix operationalises the PLS-SEM pathway by using behavioural functioning as the key performance indicator, supporting phased investment that targets lower-performing yet high-use areas rather than uniform upgrades. This is consistent with the non-significant direct path from Environmental Quality to Satisfaction, indicating that "cosmetic" improvements may not raise satisfaction unless they generate observable behavioural gains. From a campus master planning perspective, three planning implications follow:

1) Prioritise microclimate and lighting as system bottlenecks through shade continuity, ventilation-supportive corridor design, and a campus-wide lighting strategy for comfort and night-time legibility.
2) Adopt behaviour-based performance criteria to guide and evaluate upgrades, focusing on measurable improvements in short study, comfortable waiting, and small-group interaction.
3) Integrate transitional spaces into a corridor–node hierarchy and phase investments by targeting lower-performing yet high-use zones (Zones 2–3) and key links between major learning destinations.

CONCLUSION

This study repositions campus transitional spaces as a critical component of the campus public realm network and evaluates how perceived environmental quality relates to students' learning-related behaviour, interaction, and satisfaction in a tropical university setting. Using a case-based assessment across three zones of USM main campus and a questionnaire survey (n = 300), the findings show that overall environmental quality, student behaviour, and satisfaction in transitional spaces are moderate-to-low. Among the six assessed dimensions, temperature and lighting emerged as the most problematic constraints, indicating that microclimate and illumination performance are key bottlenecks limiting the usability of transitional spaces for informal learning and everyday student life.

The analysis further indicates that environmental quality is strongly associated with students' behaviour in transitional spaces, and that students' behaviour is the direct predictor of satisfaction when considered together with environmental quality. In practical terms, this suggests that campus public realm improvements are most likely to increase student satisfaction when interventions

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measurably enhance what students can actually do in transitional spaces—such as brief study, waiting in comfort, and small-group discussion—rather than merely improving appearance. In addition, significant differences across the three zones highlight uneven performance within the campus spatial system. The HBP zone performed comparatively better, while the School of Arts zone and the Main Hall and Library zone showed lower outcomes, supporting a planning approach that prioritises investments by location and performance.

Building on the evidence-to-action framework and the intervention priority matrix (Figure 3; Table 6), campus master planning should prioritise microclimate and lighting bottlenecks, adopt behaviour-based performance criteria for evaluating upgrades, and implement a phased corridor–node programme starting from lower-performing yet high-use zones (Zones 2–3). These recommendations support targeted, system-level optimisation of transitional spaces as part of the campus public realm network in tropical university contexts.

This study has limitations. The assessment focused on three zones and relied on self-reported perceptions and behaviours; thus, findings may not represent all campus areas or capture objective microclimatic conditions. Future research can extend the approach by combining subjective measures with objective environmental monitoring (e.g., thermal indices and illuminance measures), expanding zoning coverage across the full campus, and testing intervention scenarios to strengthen causal interpretation. Nevertheless, the study provides evidence-based guidance for integrating transitional spaces into campus public realm optimisation and supports more targeted, system-level decisions in campus master planning within tropical university contexts.

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DISCLOSURE STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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THE IMPACT OF SPATIAL FACTORS ON STUDENTS' PERCEIVED RESTORATION IN CAMPUS TRANSITIONAL SPACES

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Abstract

University academic buildings contain extensive transitional spaces such as corridors, entrance halls, and terraces that students use daily between classes. However, how the spatial conditions of these everyday environments are associated with students' perceived restoration remains insufficiently understood. Drawing on Attention Restoration Theory (ART), this study develops and tests a conceptual model linking spatial factors, student preferences, and perceived restoration in academic building transitional spaces. A questionnaire survey was conducted among undergraduate students at Hunan University of Science and Engineering (HUSE), a comprehensive public university in Hunan Province, China, capturing their evaluations of key spatial conditions and activity-related preferences across different transitional space types. Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed to examine the proposed direct and indirect associations. The results indicate that supportive spatial conditions are positively associated with students' perceived restoration, with this relationship partially mediated by preferences for using transitional spaces for informal learning and social interaction. Spatial attributes related to legibility and accessibility, short-stay usability (including layout and furniture), and basic study-support facilities emerge as particularly important. This study extends ART to routine academic building contexts and offers design implications for supporting students' everyday restorative experiences.

Keywords: Campus transitional spaces; Spatial factors; Perceived restoration; Student preferences

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INTRODUCTION

University students increasingly experience sustained psychological strain and attention fatigue amid academic demands and continuous task switching (An et al., 2025; Pérez-Jorge et al., 2025). A large body of restoration research indicates that exposure to natural cues and restorative environments is associated with attention restoration, lower mental fatigue, and concentration and emotional regulation (Ahmad et al., 2025; Wen et al., 2025). Yet, many students spend substantial time in academic buildings during a typical study day, which may limit their opportunities for prolonged contact with nature (Makaremi et al., 2024). In this context, transitional spaces in academic buildings—such as corridors, terraces, and entrance halls—form an interface between indoor learning settings and the outdoor environment, and may provide opportunities for brief, everyday exposure to restorative cues (Bell et al., 2025). Accordingly, understanding how spatial factors in academic building transitional spaces relate to students' perceived restoration is of both practical and theoretical importance.

Despite growing interest in restorative campus environments, current evidence largely concentrates on campus landscapes, and much less is known about how restorative mechanisms operate in everyday academic building transitional spaces (Aghabozorgi et al., 2024; Xu et al., 2024). From an ART perspective, restorative experience is commonly linked to exposure to natural or nature-related cues; in academic building transitional spaces, such cues may be encountered through outside visibility, openness, and less effortful spatial use (Rhee et al., 2023). It is also unclear whether students' activity preferences across transitional space types play an indirect role in the association between spatial factors and perceived restoration.

These issues are also relevant in Chinese higher education, where academic buildings are intensively used and transitional spaces function as high-frequency settings for short breaks, circulation, and informal stays (Lu et al., 2026; Ou et al., 2025). Recent evidence also suggests that campus environments may be associated with stronger restorative experience compared with other common daily activity settings, underscoring the value of examining restorative experience within university premises (Zhu et al., 2026). However, transitional spaces in many Chinese academic buildings are still often organised primarily for circulation (Li et al., 2025), underscoring the need to identify which spatial factors most strongly associated with students' perceived restoration.

This study develops and tests an ART-informed model linking spatial factors, student preferences, and perceived restoration in university academic building transitional spaces. PLS-SEM examines direct and indirect associations. The findings contribute to restorative-environment research in everyday academic-building settings and offer design considerations for supporting students' perceived restoration.

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LITERATURE REVIEW

In this study, transitional spaces refer to the in-between areas within a university academic building (e.g., corridors, terraces, and entrance halls) that are used for circulation and short informal stays between classes (Hou et al., 2024; Pitts & Saleh, 2006). Consistent with typology-based approaches in campus space research, four transitional space types (Type I–IV), illustrated in Figure 2, were identified in the study setting and used as anchors for measuring students' activity preferences (Jiao et al., 2023).

Spatial Factors in Campus Transitional Spaces

In this study, spatial factors refer to perceived conditions in academic building transitional spaces, including outside visibility, furniture provision, space layout, Wi-Fi connection, power-point availability, and visibility/ease of access (Alnusairat et al., 2021; Lei Peng et al., 2022; Salih et al., 2024). Here, outside visibility refers to visual connection to the outdoors, visibility/ease of access to how easily the space is found and entered, and space layout to how circulation and short stays are supported.

These spatial factors were selected as salient, actionable conditions associated with students' brief use of academic building transitional spaces, providing a parsimonious basis for examining associations with preferences and perceived restoration.

Student Preference across Transitional Space Types

In this study, student preference reflect students' evaluative inclination (approach tendency) to choose and use transitional spaces for specific non-classroom purposes (Ramu, 2022; Wu et al., 2021). It is conceptualised with reference to two common activity domains in transitional settings: informal learning (e.g., brief individual study, reading, checking course materials) and social activities (e.g., short conversations, meeting peers, informal interaction) (Wu et al., 2020). Prior research indicates that beyond circulation, informal learning and social interaction are among the most commonly reported activity domains in university transitional/in-between spaces (Valtonen et al., 2020).

Accordingly, student preferences measure activity-specific preferences across four transitional space types (Type I–IV) for informal learning and social activities. This typology-based approach reflects context-dependent preferences and allows examination of associations among spatial factors and perceived restoration.

Perceived Restoration

In this study, perceived restoration refers to students' self-reported restorative experience in a transitional space—namely the extent to which the setting is

perceived as associated with emotional ease, relaxation, interest, and focus during short inter-class intervals (Han, 2003; Xu et al., 2024). Operationally, perceived restoration is measured using a validated perceived-restoration measure adapted for built settings, reflecting both affective responses (e.g., feeling comfortable and relaxed) and attention-related responses (e.g., staying focused) (Li et al., 2024).

Perceived restoration is particularly relevant to academic building transitional spaces because restoration on campus often is reported during brief, everyday exposures rather than prolonged breaks, and students' restorative judgments are associated with how the space feels and functions in-the-moment (Ning et al., 2023). Recent campus-based research continues to use perceived restoration to assess how everyday environmental experiences relate to students' psychological states, indicating its relevance as an outcome construct in university contexts.

Attention Restoration Theory and Hypotheses Development

Attention Restoration Theory (ART), proposed by Rachel and Stephen Kaplan (1989), offers a lens for understanding perceived recovery from directed-attention fatigue in environments perceived as restorative, particularly when they are compatible with users' purposes (Kaplan, 1995). Although ART has often been applied to natural and campus green spaces, recent restorative-environment research has extended ART to urban and built settings, where perceived legibility, compatibility, outside visibility, and lower directed-attention demands are relevant to restorative evaluation (Liu et al., 2024). Academic building transitional spaces are appropriate for this extension because they connect indoor learning areas with outdoor conditions and may contain restorative cues such as outside visibility, openness, ease of access, and short-stay compatibility. This study therefore applies ART to examine associations between spatial factors, student preferences, and perceived restoration in everyday academic-building transitional spaces.

Spatial factors and perceived restoration

Under ART, perceived restoration is more likely when a setting is perceived as less demanding of directed attention and more compatible with users' purposes (Ohly et al., 2016). In academic building transitional spaces, legibility/access, short-stay support (layout and furniture), and basic study facilities (Wi-Fi and power points) may be associated with lower perceived friction and more compatible inter-class pauses (Gath-Morad et al., 2024; Yin et al., 2025). Evidence from recent built-environment research further suggests that everyday environmental qualities and short exposures can be associated with restoration-related evaluations and attention outcomes (Bell et al., 2025; Rhee et al., 2023),

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providing a basis for expecting a positive association between spatial factors and perceived restoration in routine campus contexts.

H1: Spatial factors in academic building transitional spaces are positively associated with students' perceived restoration.

The mediating role of student preferences

From an ART perspective, spatial qualities that are perceived as easier to find and use, workable for short stays, and supportive of everyday tasks may be associated with stronger approach tendencies, reflected in higher preferences for using specific space types for informal learning and social activities (Salih et al., 2024); accordingly, spatial factors are expected to be positively associated with student preferences, consistent with evidence that perceived design qualities are related to students' preference evaluations and well-being-relevant responses (Mt Akhir & Amir, 2025). In turn, when students prefer a space type for their intended activities, the setting is more likely to feel compatible with their purposes and to be associated with brief attentional recovery (Stragà et al., 2023), implying a positive association between student preferences and perceived restoration. Together, these arguments suggest that spatial factors may indirectly associated with perceived restoration through students' activity-based preferences for transitional spaces.

H2: Spatial factors are positively associated with student preferences.
H3: Student preferences are positively associated with perceived restoration.
H4: Student preferences play an indirect role in the association between spatial factors and perceived restoration.

Based on these hypotheses, Figure 1 presents the conceptual framework linking spatial factors, student preferences, and perceived restoration in academic-building transitional spaces.

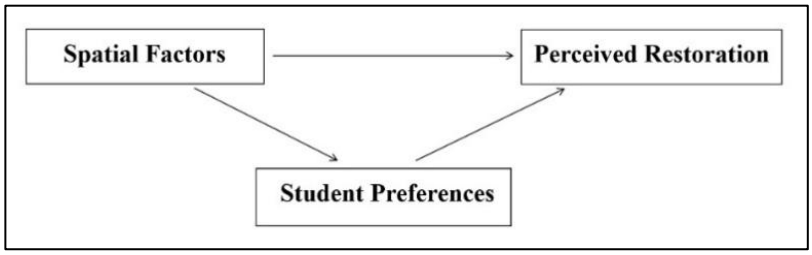


Figure 1: Conceptual Framework Linking Spatial Factors, Student Preferences, and Perceived Restoration in Academic Building Transitional Spaces.
Source: Author's illustration.

RESEARCH METHODOLOGY

Study Setting and Sampling

This study was conducted in a teaching building at Hunan University of Science and Engineering （HUSE）, a public university located in Yongzhou, Hunan Province, China. The study area comprised academic building transitional spaces routinely used by students between scheduled activities, such as circulation, brief waiting, short stays, and informal interaction. The building was selected based on two criteria: it housed the target college whose undergraduate students formed the sampling frame, and it contained all four transitional space types examined in the student preferences construct. This provided a consistent typology-based evaluation within one academic setting. Figure 2 illustrates the four transitional space typologies in the selected academic building through simplified diagrams and representative site photographs.

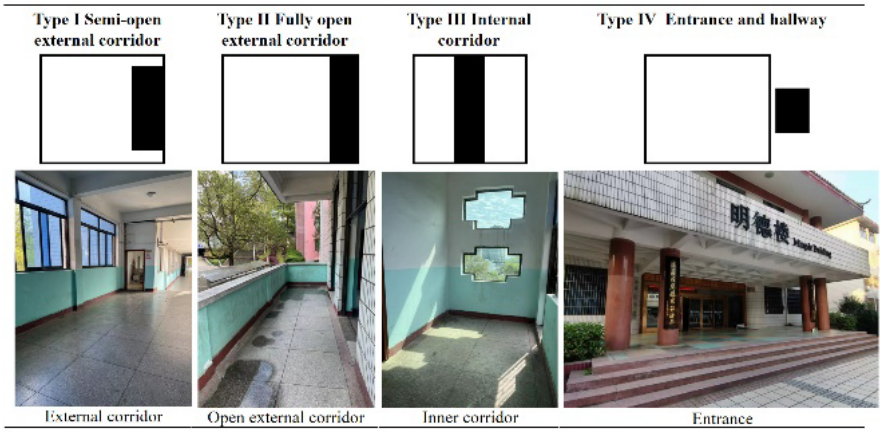


Figure 1: Transitional Space Typologies in the Selected Academic Building: Simplified Diagrams and Representative Photographs
Source: Author's photograph.

Note. *The upper row shows simplified schematic diagrams of the four transitional space typologies, and the lower row presents representative site photographs.*

The sampling frame comprised Year 1–4 undergraduate students from the college housed in the selected building (N = 1,531, according to college administrative records). Convenience sampling with voluntary participation was used through two channels: an online questionnaire link distributed through class communication channels and on-site paper surveys administered in the building's transitional spaces. A total of 394 questionnaires were received, and all passed screening and were retained as valid responses for analysis.

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Questionnaire Design

The questionnaire was developed to measure the three constructs in the proposed model. It contained 20 items covering spatial factors, student preferences, and perceived restoration (Table 1), all referring to students' perceptions of the academic building transitional spaces under study.

Table 1: Constructs and questionnaire items

Construct	Item code	Item	Source
Spatial Factors (SF)	SF1	How would you describe the outside visibility in the transitional space?	(Velusamy, 2022)
	SF2	How would you describe the available furniture in this space?	
	SF3	How would you describe the space layout in this space?	
	SF4	The space has a good wireless internet connection.	
	SF5	The space has enough electrical power points.	
	SF6	The place is visible and easily accessible.	
Student Preference (SP)	SP1	Preference for Type I transitional space for informal learning	(Beckers et al., 2016; Velusamy, 2022)
	SP2	Preference for Type II transitional space for informal learning	
	SP3	Preference for Type III transitional space for informal learning	
	SP4	Preference for Type IV transitional space for informal learning	
	SP5	Preference for Type I transitional space for social activities	
	SP6	Preference for Type II transitional space for social activities	
	SP7	Preference for Type III transitional space for social activities	
	SP8	Preference for Type IV transitional space for social activities	
Perceived restoration (PR)	PR1	I feel emotionally comfortable in this space.	(Han, 2003)
	PR2	I feel relaxed in this space.	
	PR3	I am interested in the design of this space.	
	PR4	This space helps me stay focused.	
	PR5	I would like to visit here more often.	
	PR6	I would like to stay here longer.	

Source: Authors' compilation based on the studies cited in the "Source" column.

All questionnaire items used five-point response scales, tailored to each construct (Table 1). For spatial factors, quality-oriented items (SF1–SF3: outside visibility, furniture availability, and space layout) were rated from 1 = very poor to 5 = excellent, while facility-oriented items (SF4–SF6: Wi-Fi connection, power points, and visibility/accessibility) were rated from 1 = strongly disagree to 5 = strongly agree. For student preferences, eight items were rated from 1 =

absolutely not preferred to 5 = definitely preferred, capturing preferences for informal learning (SP1–SP4) and social activities (SP5–SP8) across four transitional space types. For perceived restoration, six items were rated from 1 = extremely disagree to 5 = extremely agree, reflecting comfort, relaxation, design interest, focus, and approach tendencies (e.g., willingness to revisit and stay longer).

To test the hypothesised associations among spatial factors, student preferences, and perceived restoration, partial least squares structural equation modelling (PLS-SEM) was employed. PLS-SEM allows simultaneous assessment of measurement quality (indicator reliability; internal consistency; convergent and discriminant validity) and estimation of structural paths in a single model. Accordingly, the Analysis and Discussion section reports measurement model evaluation followed by bootstrapped tests of direct and indirect associations.

RESULTS

Descriptive statistics

Descriptive statistics were computed using latent variable scores exported from SmartPLS. The mean scores were above the scale midpoint for spatial factors (M = 3.183, SD = 0.688), student preferences (M = 3.217, SD = 0.577), and perceived restoration (M = 3.283, SD = 0.719), indicating generally positive evaluations of academic building transitional spaces. For all constructs, observed responses spanned the full scale range (minimum = 1.000; maximum = 5.000), suggesting adequate variability for subsequent PLS-SEM analyses. The valid sample size was 394 (listwise).

Measurement Model

The measurement model was evaluated in terms of indicator reliability, internal consistency reliability, convergent validity, and discriminant validity (Table 2–3). Indicator loadings were generally acceptable. Most loadings exceeded 0.70, while several student preferences indicators fell within the lower but acceptable range of 0.40–0.70 (Hair Jr. et al., 2021). Internal consistency reliability was confirmed for all constructs, with Cronbach's alpha, rho_A, and composite reliability values exceeding the recommended thresholds (Table 2). Convergent validity was adequate for spatial factors and perceived restoration. Although the average variance extracted for student preferences was slightly below the conventional 0.50 criterion, its composite reliability remained high; therefore, the construct was retained for further analysis following Fornell and Larcker's (1981) guideline, which has also been applied in prior structural equation modelling research (Pervan et al., 2017).

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Discriminant validity was assessed using the heterotrait–monotrait ratio (Table 3). All values were below the recommended threshold of 0.85, indicating the distinctiveness of the three latent constructs (Franke & Sarstedt, 2019; Henseler et al., 2015).

Table 2: Measurement model results for the latent constructs

Constructs	Indicators	Outer Loadings	Cronbach's Alpha	rho_A	CR	AVE
Spatial Factors (SF)	SF1	0.756	0.833	0.848	0.878	0.546
	SF2	0.797				
	SF3	0.823				
	SF4	0.698				
	SF5	0.672				
	SF6	0.672				
Perceived Restoration (PR)	PR1	0.884	0.945	0.945	0.956	0.783
	PR2	0.903				
	PR3	0.890				
	PR4	0.854				
	PR5	0.885				
	PR6	0.893				
Student Preferences (SP)	SP1	0.767	0.832	0.844	0.872	0.463
	SP2	0.586				
	SP3	0.692				
	SP4	0.620				
	SP5	0.778				
	SP6	0.587				
	SP7	0.741				
	SP8	0.638				

Note. *rho_A = reliability coefficient rho_A; CR = composite reliability; AVE = average variance extracted.*
Source: Author's calculation

Table 3: Discriminant Validity (HTMT)

Constructs	1	2	3
1. Spatial Factors			
2. Perceived Restoration	0.752		
3. Student Preferences	0.356	0.443	

Note. *HTMT = heterotrait-monotrait ratio. All values were below the recommended threshold of 0.85.*
Source: Author's calculation

Structural Model

The structural model was evaluated using collinearity diagnostics, explanatory power, direct and indirect associations, and predictive assessment. Inner variance inflation factor values were low (Table 4), indicating no multicollinearity concerns. Bootstrapping with 10,000 resamples and 95% confidence intervals provided support for all direct hypotheses (Table 4) (Ringle et al., 2022). As shown in Figure 3, spatial factors showed a strong positive association with

perceived restoration, supporting H1 with a large effect size. Spatial factors also positively associated with student preferences, and student preferences positively predicted perceived restoration, supporting H2 and H3 with small effect sizes.

The mediation test further indicated a significant indirect association between spatial factors and perceived restoration via student preferences (Table 5). Since the direct effect remained significant and the variance accounted for value was modest (VAF = 0.096), H4 was supported, consistent with partial mediation in the PLS-SEM model (Ramayah et al., 2018). The model explained 50.1% of the variance in perceived restoration ($R^2 = 0.501$; adjusted $R^2 = 0.498$) and 9.2% of the variance in student preferences ($R^2 = 0.092$; adjusted $R^2 = 0.090$). PLS-Predict showed positive out-of-sample predictive relevance for both endogenous constructs, with PLS producing lower prediction error than the naïve benchmark and performing comparably to the linear model benchmark (Table 6) (Shmueli et al., 2019).

Table 4: Hypothesis Testing of Direct Effects

Hs	Relationship	β	M	STDEV	t-value	p-values	2.5%	97.5%	VIF	f^2
H1	SF →PR	0.614	0.614	0.042	14.700	< .001	0.524	0.688	1.102	0.684
H2	SF →SP	0.304	0.312	0.057	5.372	< .001	0.180	0.404	1.000	0.102
H3	SP →PR	0.212	0.213	0.053	4.021	< .001	0.109	0.316	1.102	0.082

Note: β = original sample coefficient; M = bootstrap sample mean; STDEV = bootstrap standard deviation; VIF = inner variance inflation factor; f^2 = effect size. Confidence intervals are based on 95% bootstrap confidence intervals with 10,000 resamples. SF = spatial factors; SP = student preferences; PR = perceived restoration.

Source: Author's calculation

Table 5: Hypothesis Testing for Indirect Effect

Hs	Mediating Path	β	M	STDEV	t-value	p-values	2.5%	97.5%	VAF
H4	SF →SP→PR	0.065	0.066	0.019	3.370	0.001	0.033	0.107	0.096

Note: β = original sample coefficient; M = bootstrap sample mean; STDEV = bootstrap standard deviation; VAF = variance accounted for. Confidence intervals are based on 95% bootstrap confidence intervals with 10,000 resamples. SF = spatial factors; SP = student preferences; PR = perceived restoration.

Source: Author's calculation

Table 6: PLS-Predict Results

Construct	Q^2_predict	PLS Loss	LM Loss	IA Loss	PLS–LM	PLS–IA
PR	0.454	0.433	0.430	0.667	0.003	-0.235
SP	0.080	0.695	0.704	0.722	-0.008	-0.027

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Note. PLS–LM and PLS–IA are calculated as PLS minus the benchmark loss; negative values indicate better predictive performance of PLS. SP = student preferences; PR = perceived restoration.

Source: Author's calculation

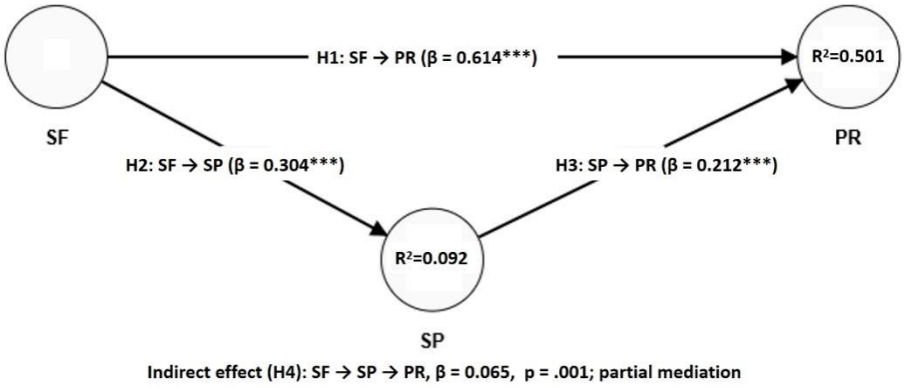


Figure 3. Structural model results for the relationships among Spatial Factors (SF), Student Preferences (SP), and Perceived Restoration (PR).
Source: Author's calculation.

***Notes**: Path values are standardised coefficients (β); values inside circles indicate R^2. *** p < .001. The indirect effect indicates partial mediation via student preferences (β = 0.065, p = .001).*

DISCUSSION

The results indicate that spatial factors were the strongest predictor of students' perceived restoration in the model in academic building transitional spaces, with student preferences showing a significant but modest indirect role. This pattern aligns with restoration research suggesting that everyday built settings are associated with attention recovery when they are perceived as less demanding of directed attention and compatible with users' purposes (Herzog et al., 2003; Ohly et al., 2016).

The strong spatial factors–perceived restoration association (H1) can be interpreted through the spatial factors items. Outside visibility and visibility/ease of access may be associated with greater legibility, lower uncertainty, and lower perceived mental effort during brief pauses—conditions linked to restorative experience in routine settings (Gath-Morad et al., 2024; Jain Kwon, 2025). Furniture provision and layout are related to functional compatibility for waiting (Hamida et al., 2024), brief study, or informal interaction; compatibility is a key component of restorative environments (Liu et al., 2024; Pham & Sanocki, 2024). Reliable Wi-Fi and sufficient power points may be associated with lower practical friction, short purposeful study, and longer stays—patterns reported in

informal learning and non-classroom study settings (Akkurt & Akbulut, 2025; L. Peng et al., 2022).

Beyond the direct association involving spatial factors, the findings also support H2 and H3, indicating that spatial factors are positively associated with student preferences, and student preferences are positively associated with perceived restoration. Together, these results suggest that evaluative judgments and approach tendencies are relevant to restorative experience in academic building transitional spaces. However, because the indirect association represented only a modest share of the total association, the supported mediation (H4) is consistent with partial mediation: spatial qualities appear to associated with restoration not only through students' liking for or selection of space types for intended activities, but also via more immediate experiential conditions (e.g., legibility, comfort, and attentional support) (Zhang et al., 2024). This interpretation accords with ART-based accounts that restoration may be reported during brief, everyday exposures when settings are perceived as less demanding of directed attention and compatible with users' purposes (Bell et al., 2025).

Practically, the findings point to three design priorities for academic-building transitional spaces: improving legibility and access through clear entrances, visible routes, and unobstructed sightlines; strengthening short-stay usability through appropriately placed seating and layouts that do not block circulation; and providing basic study-support facilities, particularly stable Wi-Fi and accessible power points, in high-use transitional areas.

CONCLUSION

This study developed and tested an ART-informed PLS-SEM model linking spatial factors, student preferences, and perceived restoration in academic building transitional spaces. The findings contribute to extending ART within everyday academic-building contexts, indicating that perceived restoration is associated with practical spatial conditions related to lower friction during inter-class use, with student preferences showing a partial evaluative role.

For stakeholders, the findings offer a clear way forward: audit transitional areas using the three design priorities identified in this study—legibility/access, short-stay usability, and basic study-support facilities—then prioritise low-cost upgrades in high-traffic locations and monitor perceived changes through brief pulse surveys and simple occupancy checks. These actions align with China's current directions on student mental-health support and improved educational environments (State Council Information Office (China), 2025; Yuan et al., 2024). A limitation is the cross-sectional, single-building design; future research should test the model across universities and seasons and combine perceptual, behavioural, and objective measures.

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A STUDY ON THE STRUCTURAL GAPS BETWEEN OFFICIAL PARTICIPATION NARRATIVES AND RESIDENTS' PARTICIPATION PERCEPTIONS IN THE MICRO-RENEWAL OF PUBLIC SPACES IN OLD RESIDENTIAL COMMUNITIES

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Abstract

With the transition of urban renewal in China from large-scale redevelopment to micro-renewal of existing built-up areas, public participation has become an increasingly institutionalized component in the renewal of public spaces in old residential communities. However, how institutionalized participation translates into residents' lived participation experiences remains insufficiently understood, resulting in persistent discrepancies between official participation narratives and residents' participation perceptions. This study adopts an exploratory cross-case analysis based on preliminary site observations, unstructured interviews, and official narrative materials from six micro-renewal projects in Shanghai to examine how public participation operates in practice. The findings identify three recurring types of structural gaps: information gaps, procedural gaps, and meaning gaps. These gaps emerge from mismatches in information transmission, limited visibility of participatory processes, and differences in how participation is interpreted and experienced by residents. The results suggest that participation effectiveness is not determined solely by the presence of formal procedures, but is shaped by the interaction of communication practices, institutional implementation, professional translation, and trust relationships. By conceptualizing these discrepancies as structurally recurrent gaps, this study provides a mechanism-oriented explanation of the divergence between institutionalized participation and lived experiences. It advances existing public participation research by shifting the focus from procedural arrangements to experiential processes, and contributes to a more nuanced understanding of participation–design interaction in micro-renewal contexts. The findings also offer practical implications for improving participation mechanisms and design communication.

Keywords: Public spaces in old residential communities, Micro-renewal, Public Participation, Structural Gaps, Participation Perception

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INTRODUCTION

With the transition of urban development in China toward the regeneration of existing built-up areas, urban renewal practices have shifted from large-scale physical transformation to micro-renewal approaches that emphasize incremental spatial improvement and community-level interventions (Sun et al., 2022; Wu et al., 2023). In this context, public spaces in old residential communities function as critical settings for everyday life, social interaction, and grassroots governance (Carmona, 2019). However, many of these spaces are characterized by aging infrastructure, limited functionality, and declining social use, making their renewal a pressing issue in contemporary urban governance (Zhang et al., 2022).

Micro-renewal has therefore emerged as a governance approach that prioritizes small-scale, adaptive interventions while promoting community engagement. Within this transition, public participation has become a central governance mechanism, implemented through instruments such as consultations, public displays, and community planner systems (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2021; Shanghai Planning and Natural Resources Bureau, 2020). Existing studies suggest that public participation can enhance social acceptance and long-term sustainability in urban renewal processes (Innes & Booher, 2018; Parés et al., 2012).

However, empirical research indicates that participation in practice is often proceduralized and instrumentalized, characterized by limited channels for expression, weak feedback mechanisms, and low visibility of participatory processes (Boland & Zhu, 2012; Chen et al., 2021; Lu, 2020; Marzukhi et al., 2022). Even where participation is institutionally established, residents' perceptions remain highly uneven: some residents recall participation processes clearly, while others are unaware of them or perceive renewal as a top-down intervention.

This divergence suggests that the key issue lies not in whether participation occurs, but in how participation is communicated, interpreted, and experienced. Although existing studies have examined participation from perspectives such as collaborative governance, responsive design, and participatory planning (Carmona, 2019; Innes & Booher, 2018; Yang et al., 2025), they primarily focus on participation forms or outcomes, with limited attention to the mechanisms through which institutionalized participation is translated into lived experience.

Against this background, this study adopts an exploratory research approach to examine recurrent discrepancies between official participation narratives and residents' participation perceptions in micro-renewal practices in old residential communities. Through a cross-case analysis of six cases in Shanghai, it aims to identify recurring types of structural gaps, analyze how these

gaps are manifested across different contexts, and provide a mechanism-oriented explanation of participation–design interaction processes.

The main contribution of this study lies in shifting the analytical focus from participation procedures to participation experience, and in developing a process-oriented perspective that explains how institutionalized participation may formally exist while remaining experientially unrecognized. This provides an empirical basis for further research on interaction mechanisms between public participation and spatial design in micro-renewal contexts.

In this study, official participation narratives refer to the institutional representations of public participation produced by governmental agencies, community committees, project organisers, and related professional actors. These narratives are commonly expressed through policy documents, project reports, official WeChat posts, public notices, community records, and publicity materials. They describe how participation was organised, communicated, and documented from an institutional perspective. By contrast, residents' participation perceptions refer to residents' subjective awareness, recollection, interpretation, and evaluation of whether and how they were involved in the renewal process.

LITERATURE REVIEW

Existing research on public participation in the micro-renewal of public spaces in old residential communities has examined this issue from multiple perspectives, including institutional design, governance practices, and perceived participation. However, these studies remain largely fragmented and provide limited explanation of how discrepancies emerge between institutional arrangements and residents' lived experiences.

Public Participation: From Institutional Procedures to Participatory Experiences

Public participation has long been regarded as a key mechanism for enhancing governance legitimacy and decision-making quality. Since Arnstein (1969) proposed the "ladder of participation," subsequent research has expanded to address issues of power distribution, deliberative processes, and collaborative governance (Prilenska & Liias, 2015). At the theoretical level, participation is conceptualized as a process of communication, negotiation, and social learning.

However, in the context of urban renewal in China, public participation is often characterized by consultative and proceduralized practices (Boland & Zhu, 2012; Chen et al., 2021; Lu, 2020). Empirical studies indicate that participation is frequently limited to formal procedures such as questionnaires, public notices, and consultations, with restricted channels for expression and

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weak feedback mechanisms. As a result, participation may be institutionally present while remaining experientially unrecognized. Although some studies have begun to consider residents' subjective perceptions and the role of trust (Hamideh, 2020), most research continues to focus on participation forms or levels, rather than explaining how participation is understood and experienced in practice (Boland & Zhu, 2012; Zanudin et al., 2022).

Micro-Renewal as a Governance Context

Micro-renewal refers to a form of urban intervention characterized by small-scale, incremental, and adaptive improvements within existing built-up areas (Wu et al., 2023; Yue et al., 2021). Compared with large-scale redevelopment, it emphasizes community-level governance, resource constraints, and multi-actor collaboration, making participatory processes particularly complex.

Existing studies show that participation outcomes in micro-renewal are shaped not only by institutional design but also by governance conditions, including administrative capacity, organizational resources, and information coordination (Wang et al., 2025; Xue et al., 2021; Yao & Li, 2024; Zanudin et al., 2024). In addition, contextual factors such as demographic composition and neighborhood relations influence residents' willingness to engage and their trust in participatory processes (Zhu, 2023). However, these studies primarily focus on external conditions, with limited attention to the internal processes through which participation is communicated, interpreted, and experienced.

Participation Perceptions, Trust, and Interpretive Processes

Recent research has increasingly emphasized the importance of perceived participation and trust in shaping participatory outcomes. Residents' evaluations of participation are closely associated with whether they perceive their opinions as being heard, understood, and reflected in decision-making processes (Hamideh, 2020; Sun et al., 2022).

At the same time, interpretive differences between professional knowledge and residents' lived experiences often result in mismatches in how participation is understood. In spatial renewal practices, professional design logic may not be effectively translated into forms recognizable to residents, leading to shifts in meaning during the participation process (Carmona, 2019; Chen, 2025; Yang et al., 2025). These studies suggest that participation is not only a procedural arrangement but also a process of meaning construction. However, existing research still fails to explain how such interpretive differences produce systematic discrepancies.

Explanatory Limitations and Research Positioning

Overall, existing research provides valuable insights into public participation in micro-renewal contexts from institutional, governance, and perceptual perspectives. However, most studies adopt single-dimensional approaches and fail to offer integrated explanations of how discrepancies arise between official participation narratives and residents' participation perceptions.

To address this gap, this study adopts a mechanism-oriented perspective and focuses on identifying recurrent structural discrepancies between official participation narratives and residents' participation perceptions. By conceptualizing these discrepancies as structural gaps and analyzing their formation processes, this study develops a process-oriented analytical framework for understanding participation–design interaction in micro-renewal contexts.

RESEARCH METHODOLOGY

This study adopts an exploratory qualitative research approach to examine structural gaps between official participation narratives and residents' participation perceptions in micro-renewal practices in old residential communities (Stebbins, 2001; Watson, 2014). The analysis is based on a cross-case comparison of six old residential communities in Shanghai, including Hongxu, Shanbei, Xiuyuan, Sanlinyuan, Boyi, and Bosan, integrating institutional materials, site observation, and preliminary interview data to identify recurrent patterns of discrepancy.

Research Design and Case Selection

A purposive sampling strategy was employed to select six old residential communities that had undergone public space micro-renewal. The selected cases were chosen to reflect typical micro-renewal practices and to ensure relevance to the research focus on public participation processes. In addition, the cases were selected to capture variation in spatial conditions, participation arrangements, and governance contexts, thereby enabling a more robust cross-case comparison of participation dynamics.

Data Collection

The study draws on three types of data: official participation narrative materials, preliminary interviews, and site observations.

Official materials were collected from publicly available project descriptions, policy documents, and community-level records, including information on participation procedures such as consultations, public displays, and voting arrangements.

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Preliminary interviews were conducted with 24 participants across the six selected communities, comprising 18 residents and 6 community committee representatives. In each community, interviews included residents with different ages, lengths of residence, and levels of engagement with the renewed public space, together with one community committee representative who had been directly involved in the planning or implementation of the renewal project. Participants were recruited through purposive sampling to capture a range of institutional and resident perspectives on the participation process. Semi-structured, open-ended interviews encouraged participants to reflect on their awareness of the renewal project, recollection of participation opportunities, perceptions of participatory processes, and trust in decision-making actors.

In addition, two rounds of site observation were conducted to document spatial conditions, usage patterns, and visible traces of participation processes. These observations provided contextual support for interpreting interview data and helped triangulate findings across different data sources.

Analytical Approach

The analysis follows an inductive and iterative process aimed at identifying recurrent discrepancies between institutional narratives and residents' lived experiences.

First, participation processes described in official materials were examined for each case and compared with residents' interview accounts to identify observable inconsistencies between institutional descriptions and perceived experiences.

Second, these discrepancies were compared across cases to identify recurring patterns. Rather than applying a predefined coding framework, the analysis focused on pattern recognition and conceptual grouping based on similarities in how discrepancies were manifested.

Third, through iterative comparison and abstraction, these recurring patterns were categorized into three types of structural gaps: information gaps, procedural gaps, and meaning gaps. These categories emerged inductively from empirical materials and were subsequently interpreted with reference to existing literature.

To enhance analytical robustness, findings were cross-checked across data sources (official materials, interviews, and observations) to ensure consistency in the identification of recurring patterns.

This analytical process is consistent with exploratory qualitative research, where the aim is to identify structurally recurrent patterns rather than to test causal relationships.

To enhance the transparency of the analytical process, representative empirical evidence from interview materials was selected to illustrate how each

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structural gap was identified. Interview accounts were examined alongside official participation narratives and field observations through iterative cross-case comparison. Recurrent patterns identified across the six cases were subsequently synthesised into three structural gap categories: information gap, procedural gap, and meaning gap. Representative empirical evidence for each structural gap is presented in the Results section (Table 1).

Limitations

Given the exploratory nature of the study, the number of interviews is limited and systematic sampling was not employed, which restricts generalizability. The findings should therefore be understood as indicative of recurrent patterns rather than statistically representative conclusions. Residents' accounts may also be influenced by recall bias and contextual factors. Future research may build on these findings through more systematic data collection and in-depth qualitative analysis.

RESULTS

This study identifies three recurrent types of structural gaps between official participation narratives and residents' participation perceptions across six cases: information gaps, procedural gaps, and meaning gaps. These gaps are consistently observed across different communities, indicating that they are structurally recurrent rather than case-specific phenomena.

Information Gap

Information gaps refer to inconsistencies between officially disseminated participation information and residents' awareness. Across cases such as Xiuyuan and Sanlinyuan, although participation information was formally communicated through channels such as WeChat groups, public notices, and voting arrangements, residents' awareness remained uneven. Some residents recalled no participation-related information, while others reported partial or unclear knowledge. This suggests that the presence of information dissemination mechanisms does not guarantee effective recognition or accessibility of participation-related information. The findings indicate that information transmission alone is insufficient without ensuring that information is accessible, understandable, and meaningfully received by residents.

For example, one resident in Xiuyuan stated, "I only knew that the space had been renovated; I did not know there had been any consultation before that." Another resident in Sanlinyuan similarly noted, "Maybe some people were informed, but I personally did not receive any clear notice." These accounts indicate that information channels existed, but participation-related information was not equally received or recognised by all residents.

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Procedural Gap

Procedural gaps are observed where participatory procedures exist institutionally but fail to generate perceptible participation experiences. In cases such as Sanlinyuan and Hongxu, formal procedures including voting and consultation were documented, yet many residents did not recall participating or did not associate these procedures with decision-making processes. These findings indicate that institutionalized procedures may exist formally without being experienced as meaningful participation by residents. This reflects a disconnection between procedural completion and experiential engagement in participation processes.

A resident in Hongxu recalled that "there were notices and discussions, but I was not clear about how the final plan was decided." In Sanlinyuan, another resident stated, "I heard there was voting, but I did not take part, and I do not know what influence it had." These comments suggest that formal procedures may be documented institutionally while remaining weakly perceived by residents.

Meaning Gap

Meaning gaps arise from divergent understandings of what constitutes participation. While official narratives define participation in terms of procedural completion, residents tend to evaluate participation based on whether their opinions were acknowledged and responded to. In several cases, residents expressed satisfaction with renewal outcomes but still stated that they "did not participate," indicating a disconnect between procedural participation and perceived participation. This suggests that participation effectiveness is closely linked to processes of interpretation, recognition, and response, rather than procedural fulfillment alone.

Some residents evaluated participation not by whether formal consultation had taken place, but by whether their concerns were taken seriously. One resident commented, "The renovation is good, but participation should mean that our opinions are actually listened to." Another stated, "If the problem we mentioned was not responded to, I would not really call it participation." Such responses show that residents tend to associate participation with recognition, responsiveness, and visible influence.

As summarized in Table 1, three recurrent structural gap types and their underlying mechanisms were identified across the six cases. Figure 1 synthesizes these findings into an integrated conceptual framework illustrating the relationships among official participation narratives, structural gaps, and residents' participation perceptions. To further illustrate how these structural gaps were manifested across individual cases, Table 2 summarizes the dominant

structural gaps identified in each community, while recognizing that multiple gap types may coexist.

Table 1: Structural Gaps and Underlying Mechanisms in Participation between Official Narratives and Residents' Perceptions

Structural Gap Type	Official Participation Narrative Focus	Residents' Participation Perceptions	Representative Resident Statements	Underlying Mechanism
Information Gap	Participation information is disseminated through formal channels such as public notices, meetings, and online platforms	Limited awareness or recall of participation opportunities	"Did not know there was participation"; "Only heard about the outcomes"; uneven awareness among residents	Information is formally provided but fails to be effectively received, understood, or recognized by residents
Procedural Gap	Participation procedures are formally established and completed at the institutional level, with corresponding documentation	Participation is not experienced as a real or perceptible process	"There was voting, but I didn't take part"; "I don't know how decisions were made"	Institutional procedures exist but lack perceptibility and experiential engagement
Meaning Gap	Participation is defined as the completion of procedures	Participation is understood as being listened to and responded to	"I didn't really participate"; "My opinions were not considered," even when procedures existed	Failure to translate procedural participation into meaningful and recognized experiences

Source: Author's analysis based on site observations, unstructured interviews, and official participation narrative materials.

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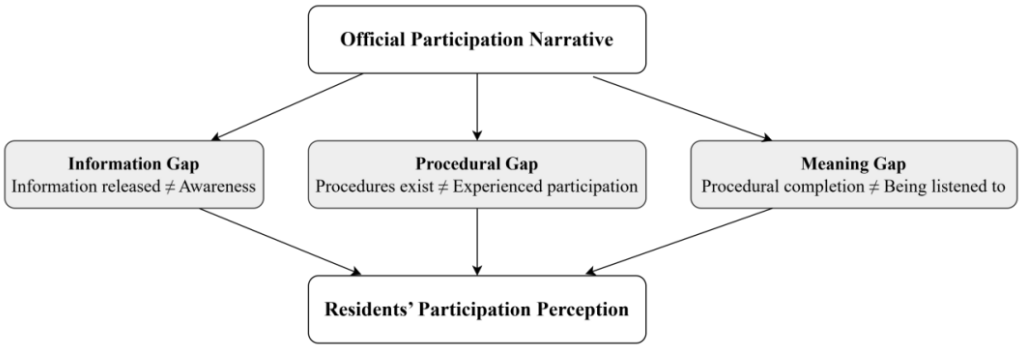


Figure 1: Structural Gaps between Official Participation Narratives and Residents' Participation Perceptions

Source: Author's analysis based on site observations, unstructured interviews, and official participation narrative materials.

Table 2: Cross-Case Comparison of Structural Gaps

Case	Official Participation Narrative	Residents' Participation Perceptions	Dominant Structural Gap
Hongxu	Consultations, public communication, community-based coordination	Some residents recognised participation, while others mainly remembered the completed space	Procedural and meaning gap
Shanbei	Community consultation and public activities	Residents generally recognised improvement but had uneven awareness of decision-making	Information and procedural gap
Xiuyuan	WeChat groups, public notices, offline consultation	Some residents recalled consultation, while others stated they were not informed	Information gap
Sanlinyuan	Voting, questionnaires, community planner involvement	Formal procedures were present, but some residents did not clearly recall participation	Procedural gap
Boyi	Resident and children's representative involvement	Some residents perceived the project as mainly government-led	Meaning gap
Bosan	Representative consultation and community-school cooperation	Residents had limited awareness of the participation process	Information and procedural gap

Source: Author's analysis based on site observations, unstructured interviews, and official participation narrative materials.

DISCUSSION

This study provides a mechanism-oriented explanation of the divergence between institutionalized participation and residents' lived experiences in micro-renewal contexts, contributing to a more nuanced understanding of participation–design interaction. By framing these discrepancies as structurally recurrent gaps, the study also offers a conceptual lens for understanding participation processes beyond case-specific variations.

First, the findings challenge the assumption that the existence of participatory procedures necessarily indicates effective participation. While previous studies often evaluate participation based on procedural arrangements or participation levels (Boland & Zhu, 2012), the results show that participation effectiveness depends on whether these procedures are perceptible and meaningful to residents. This extends existing research by demonstrating that participation must be understood not only as an institutional arrangement but also as an experiential process. It further suggests that participation outcomes are shaped by how institutional arrangements are translated into lived experiences rather than by their formal presence alone.

Second, the identification of information gaps highlights the limitations of communication mechanisms in participatory processes. Existing studies emphasize the importance of communication in collaborative governance (Innes & Booher, 2018), yet often assume that the provision of information is sufficient. The findings of this study suggest that communication effectiveness depends on whether information is accessible, interpretable, and recognized by residents. This refines existing perspectives by emphasizing the experiential dimension of communication. It also indicates that participation communication should be understood not merely as information provision, but as a process of recognition and cognitive accessibility.

Third, the procedural gap reveals limitations in institutional implementation. While collaborative governance frameworks highlight the role of institutional platforms and participatory procedures, the findings indicate that such arrangements may remain invisible or insignificant to residents if they are not effectively experienced. This supports and extends critiques of procedural participation by demonstrating how proceduralization can lead to the formal existence but practical absence of participation. This indicates that institutional design alone is insufficient without ensuring that participatory processes are experientially visible and socially recognizable.

Fourth, the meaning gap contributes to discussions on responsive design and participatory planning by highlighting the importance of interpretive processes. Previous studies have focused on functional responses to users' needs (Carmona, 2019; Yang et al., 2025), whereas the findings suggest that participation also involves processes of meaning construction and recognition.

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Participation becomes meaningful only when residents perceive that their voices are acknowledged and translated into outcomes. This highlights the importance of interpretive alignment between institutional intentions and residents' experiential expectations.

Taken together, the three types of structural gaps—information, procedural, and meaning—represent interconnected dimensions of participation processes, corresponding to communication, institutional implementation, and interpretation. Together, these dimensions form a coherent analytical framework that links these processes as interrelated mechanisms shaping participation outcomes. This integrated perspective advances existing research by connecting previously fragmented discussions into a unified explanatory structure.

From a practical perspective, the findings suggest that improving participation mechanisms requires not only the establishment of procedures but also attention to participation visibility, interpretability, and responsiveness. Enhancing communication effectiveness, strengthening feedback mechanisms, and improving the translation of professional knowledge into accessible forms are essential for reducing structural gaps. In addition, building trust through continuous interaction and transparent decision-making processes is critical for aligning institutional narratives with residents' lived experiences (Hamideh, 2020). These insights highlight the need for a shift from procedure-oriented governance toward process-oriented and experience-sensitive participation practices.

CONCLUSION

This study examines the structural gaps between official participation narratives and residents' participation perceptions in the micro-renewal of public spaces in old residential communities through an exploratory cross-case analysis. The findings identify three recurrent types of structural gaps—information gaps, procedural gaps, and meaning gaps—that are consistently observed across different cases.

The results demonstrate that public participation should not be understood solely as the implementation of formal procedures, but as a process shaped by the interaction of information dissemination, institutional visibility, interpretive communication, and trust relationships. In particular, the study shows that even when participatory arrangements are institutionally established, they may fail to be recognized or experienced as meaningful participation by residents in the absence of effective communication, perceptible processes, and responsive interpretation.

From a theoretical perspective, this study contributes to public participation research by conceptualizing the discrepancies between institutionalized participation and lived experiences as structurally recurrent

gaps, and by providing a process-oriented framework for understanding participation–design interaction in micro-renewal contexts. This shifts the analytical focus from procedural arrangements to experiential processes, thereby extending existing discussions on the procedure–experience gap.

From a practical and policy perspective, the findings highlight the need to move beyond procedural compliance toward enhancing the visibility, accessibility, and interpretability of participation processes. Improving communication strategies, strengthening feedback mechanisms, and enhancing the translation of professional knowledge into forms that are understandable and meaningful to residents are essential for reducing structural gaps. In addition, fostering trust through continuous engagement and transparent decision-making is critical for aligning institutional narratives with residents' lived experiences.

This study is exploratory in nature and is based on a limited number of preliminary interviews and case observations, which constrains the generalizability of the findings. Future research may build on this study by employing more systematic qualitative methods, expanding the number of cases, and examining the formation mechanisms and contextual conditions of structural gaps across different urban settings.

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DESIGN INTERVENTIONS AND HERITAGE REVITALIZATION IN HISTORIC URBAN PARKS: A COMPARATIVE STUDY OF SUZHOU DONGYUAN PARK AND SHANGHAI PEACE PARK

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Abstract

In the process of urban renewal in China, the redevelopment of historic urban parks concerns not only the enhancement of public space quality but also the preservation and regeneration of historical and cultural heritage. However, existing studies have primarily focused on the post-renewal spatial form and landscape effects, with limited exploration of how design interventions specifically influence the processes and outcomes of heritage revitalization. This paper takes Suzhou Dongyuan Park and Shanghai Peace Park, two representative historic urban parks in the Yangtze River Delta region, as case studies. Through field observation, document analysis, and comparative research, it examines the mechanisms by which different design intervention approaches affect the revitalization of heritage values. The findings show that Dongyuan Park's renewal, centred on cultural continuity, strengthens local identity and historical perception by restoring garden patterns and extending traditional spatial imagery. In contrast, Peace Park's renovation, guided by functional activation, enhances public accessibility and vitality through boundary openness and facility reorganization, but to some extent weakens historical narratives and cultural memory. These two approaches represent distinct renewal models: context oriented and function-oriented design interventions. The study argues that the landscape design process serves as a key mediating mechanism in heritage revitalization, balancing the tension between historicity and contemporaneity. The research provides process-based insights and practical references for the future design and management of historic urban parks.

Keywords: Historic Urban Parks, Design Intervention, Heritage Revitalization, Suzhou Dongyuan Park, Shanghai Peace Park

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INTRODUCTION

Amid the accelerating pace of global urbanization and the growing demand for sustainable transformation, the renewal and regeneration of historic urban parks have become a crucial topic in urban heritage conservation and public space governance. These parks serve not only as vital components of the urban ecological and recreational system, but also as key carriers of historical memory, collective emotions, and cultural identity（Ripp et al., 2025）.

Since the introduction of UNESCO's Historic Urban Landscape (HUL) framework in 2011, urban heritage conservation has shifted from static preservation toward dynamic integration, emphasizing coordination between heritage conservation and urban development (UNESCO, 2011; Cunha Ferreira et al., 2023). Within this perspective, historic urban parks are understood as dynamic cultural landscapes that mediate between past and present, where heritage value is continuously rearticulated through spatial continuity, place identity, public life, and user experience shaped by urban design principles (Rodwell, 2022; Liang et al., 2023; Hashim et al., 2025).

As Chinese cities enter a phase of urban regeneration focusing on existing built-up areas (so-called "stock renewal"), the revitalization of historic urban parks has become an integral component of broader urban renewal agendas. In practice, however, achieving a balance between modern functional improvement and the continuity of historical and cultural values has emerged as a central challenge for both design and management (Zhao et al., 2023). Studies on urban regeneration and public space have highlighted the importance of governance mechanisms, community participation, and multi-dimensional design considerations in sustaining public space transformation (Lim et al., 2024; Sabri & Ponrahono, 2024). Against this background, some projects emphasize openness and accessibility through spatial reconfiguration and facility upgrading (Zhu, 2023), whereas others prioritize cultural identity by restoring traditional layouts, landscape imagery, and local memory. These varied approaches reflect the multiplicity of design strategies adopted in the renewal of historic urban parks.

In this context, exploring how design interventions can mediate the balance between "historicity and contemporaneity" has become a key topic in understanding the mechanisms of revitalizing China's historic urban park heritage. This involves not only spatial and functional renewal, but also the reproduction of heritage value through design processes.

LITERATURE REVIEW

Research on Historic Urban Parks and Heritage Revitalization

As an integral component of the urban cultural landscape, historic urban parks not only embody the spatial patterns and aesthetic traditions of specific historical

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periods but also bear witness to the evolution of urban social life (ICOMOS-IFLA, 2017). International scholarship generally regards them as multifaceted heritage systems that integrate ecological, social, and cultural functions, emphasizing the regeneration of heritage and the reproduction of values within the broader context of urban renewal (Graham, Ashworth, & Tunbridge, 2016). From this perspective, the conservation of parks extends beyond morphological restoration to focus on the continuity of cultural processes and social practices (Ginzarly et al., 2024).

Within the Chinese academic discourse, relevant research has primarily focused on topics such as "historic park renewal," "urban renewal and cultural heritage continuity," and "renovation and redesign of old parks" (Ma et al., 2024). Chinese studies largely focus on balancing historical preservation with contemporary functional demands, yet remain predominantly outcome-oriented, with most analyses centred on spatial form and design results rather than on how the renewal process itself shapes the generation and expression of heritage values (Lian et al., 2024; Li, 2024; Wang et al., 2023).

While both international and Chinese studies acknowledge the importance of historic urban park revitalization, limited attention has been paid to how design mediates the generation and expression of heritage values within the renewal process. Existing scholarship conceptualizes heritage value as a multidimensional and dynamic construct, shaped through social practices and collective memory rather than static preservation. This perspective underpins the examination of design intervention as a mediating mechanism in this study.

Research on Design Intervention in the Context of Urban Park Renewal

With the shift in urban renewal paradigms, design has increasingly been recognized as a key driver shaping social and cultural systems. The term design intervention emerged prominently in design activism and design for social innovation, denoting strategic and spatial actions through which designers engage existing systems to catalyze new values and behavioral patterns (Markussen, 2013; Manzini, 2015). Within landscape and heritage studies, this notion has been mobilized to explain how design helps negotiate a balance between historicity and contemporaneity in the interplay between conservation and renewal (Ripp et al., 2025).

Existing research generally recognizes that design interventions not only alter the material fabric but, more importantly, shape public perception and the reproduction of heritage values (Ginzarly et al., 2024). Through the reorganization of space, the reshaping of experiences, and the fostering of social participation, design transforms heritage from a static historical object into a dynamic cultural practice. This perspective has driven a shift in heritage research from outcome-oriented analysis toward process-oriented inquiry.

In China, research on design intervention in urban park renewal remains limited, with studies largely focusing on spatial composition and technical solutions (Wen et al., 2023), while paying insufficient attention to how design actions mediate the generation of heritage values within renewal processes.

Theoretical Implications and Research Gaps

In summary, existing research reveals three major gaps: a prevailing focus on spatial outcomes with limited attention to design processes and value reproduction; insufficient empirical examination of historic urban parks as a distinct heritage category; and the absence of conceptually interpretable frameworks within Chinese scholarship on design processes.

Addressing these gaps, this study adopts a process-oriented perspective and proposes a two-layer analytical framework—*Design Intervention and Heritage Value Presentation*—to examine how design interventions mediate the manifestation of heritage values. Through a comparative analysis of Suzhou Dongyuan Park and Shanghai Peace Park, the study explores differentiated outcomes and shared mechanisms of design-led heritage revitalization.

RESEARCH METHODS

Research Design

This study adopts an interpretive comparative case study approach to explore the underlying logic linking design actions to the regeneration of heritage values in the renewal of historic urban parks, through the lens of design intervention. Drawing on a comprehensive analysis of multi-source data, it conducts an in-depth examination of two representative cases to reveal how design intervention operates at the project level.

Specifically, the research design of this study comprised four main steps:(1) Defining the research questions and analytical logic;(2) Selecting two representative historic urban parks as case studies: Suzhou Dongyuan Park and Shanghai Peace Park in the Yangtze River Delta region;(3) Collecting multi-source data, including field observations, informal conversations with park users, and documentary materials; (4) Conducting a comparative analysis of the identified types of design interventions, manifestations of landscape change, and pathways of heritage value regeneration in the two cases. Multiple data sources were cross-referenced to enhance interpretive robustness.

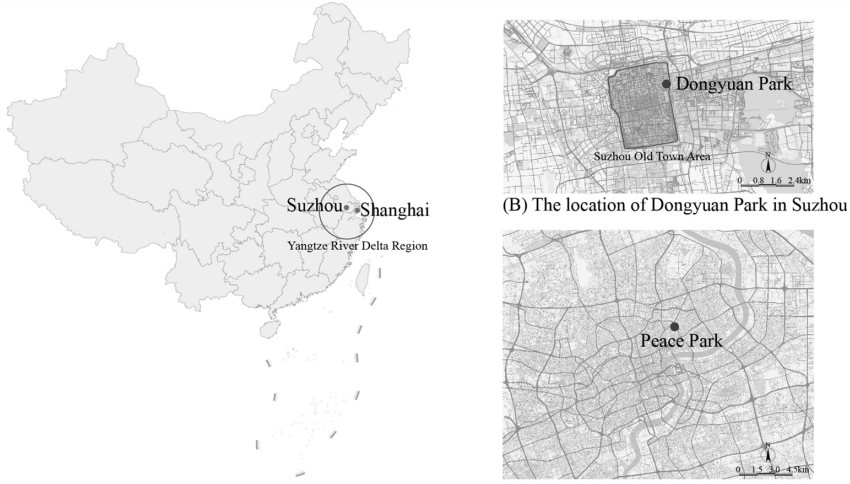
Case Selection

Figure 1 shows the locations of Suzhou Dongyuan Park and Shanghai Peace Park, the two case study parks in the Yangtze River Delta region of China.

The selection criteria were as follows: (1) Each park possesses notable historical and cultural significance, exemplifying the typical attributes of a

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historic urban park; (2) Both have undergone recent processes of renovation or revitalization, providing representative examples of design intervention and heritage revitalization; (3) Their geographical proximity within the same urban agglomeration (the Yangtze River Delta) helps to minimize potential variations arising from differences in regional culture and policy environments, thereby providing a comparable context for examining different design interventions in historic urban park renewal. Together, these characteristics make the two parks appropriate case studies for exploring the relationship between design intervention and heritage revitalization under a shared regional context.



(A) The location of Suzhou and Shanghai in China

(B) The location of Dongyuan Park in Suzhou

(C) The location of Peace Park in Shanghai

Figure 1: Locations of Dongyuan Park (Suzhou) and Peace Park (Shanghai) in the Yangtze River Delta Region

Source: Base map adapted from a commercially licensed Chinese vector map, modified by the author for academic use

Case 1: Suzhou Dongyuan Park

Suzhou Dongyuan Park is located in Suzhou's Old Town (Figure 2). As an early public park, it incorporates Suzhou's local garden traditions. The park underwent a renewal beginning in 2017, followed by a smaller-scale adjustment completed in 2024.



Figure 2: Location and spatial context of Dongyuan Park, Suzhou
Source: Google Earth, 2025. Annotated and modified by the author for research use.

Case 2: Shanghai Peace Park

Shanghai Peace Park is located in Hongkou District, Shanghai (Figure 3). Established in 1958, Peace Park is a historic urban park within Shanghai's inner ring area. The park underwent a major landscape renewal in 2022.



Figure 3: Location and spatial context of Peace Park, Shanghai
Source: Google Earth, 2025. Annotated and modified by the author for research use.

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Data Sources and Collection

Field observations were conducted from March to August 2025 to examine spatial configuration, functional use, and user activities in the two parks. Observations focused on key elements related to design intervention, including spatial structure, circulation, functional nodes, and landscape features. Field notes and photographs were used to capture representative spatial conditions and patterns of use.

User perceptions were explored through informal, open-ended conversations with park users and nearby residents during field visits. These conversations aimed to understand users' experiences of spatial change, sense of place, and daily use patterns. Key impressions were noted and synthesized to support interpretive analysis.

Documentary materials, including official planning documents, design reports, and relevant academic literature, were used to contextualize observed changes and identify intended design strategies.

Field notes and photographs were reviewed iteratively to identify recurring patterns of spatial change and user behaviours, which informed the subsequent analytical categorization.

Analytical Framework

Design interventions were identified through interpretive analysis of field observations, documentary materials, and user perceptions. Observable changes in spatial patterns, functional organization, and landscape imagery before and after renewal were treated as empirical indicators of underlying design actions.

Based on this identification process, this study establishes an analytical framework entitled "*Design Intervention–Heritage Value Manifestation*" (Figure 4). The framework adopts a process-oriented perspective to examine how design actions in historic urban park renewal influence heritage value manifestation.

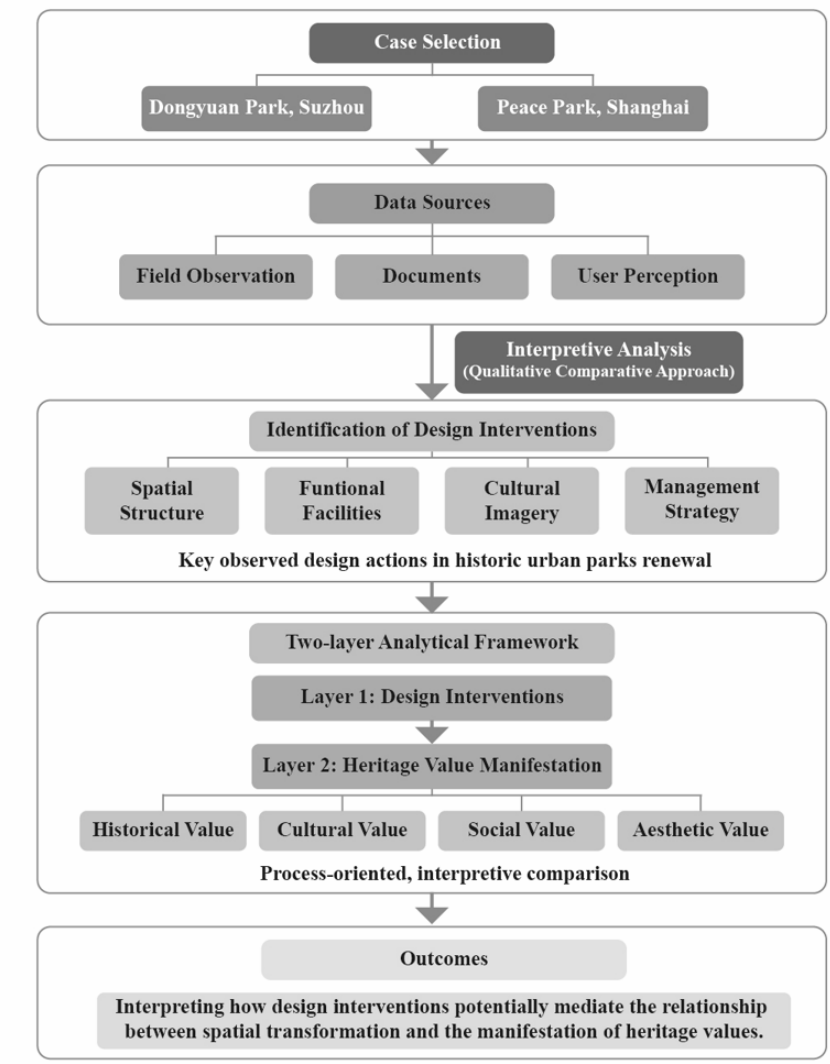


Figure 4: Analytical framework of the study
Source: Drawn by the author.

The framework consists of two analytical layers. The design layer categorizes design interventions into four dimensions: spatial structure, functions and facilities, landscape imagery, and management strategies. The value layer examines how these interventions shape heritage value manifestation across historical, cultural, social, and aesthetic dimensions.

In the analytical process, empirical observations and documentary evidence were first organized according to the four dimensions of design

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intervention. Key patterns of spatial change, functional transformation, and landscape modification were then identified for each case. These identified interventions were subsequently interpreted in relation to corresponding heritage value dimensions, allowing the study to trace how specific design actions contribute to the manifestation of different types of heritage values.

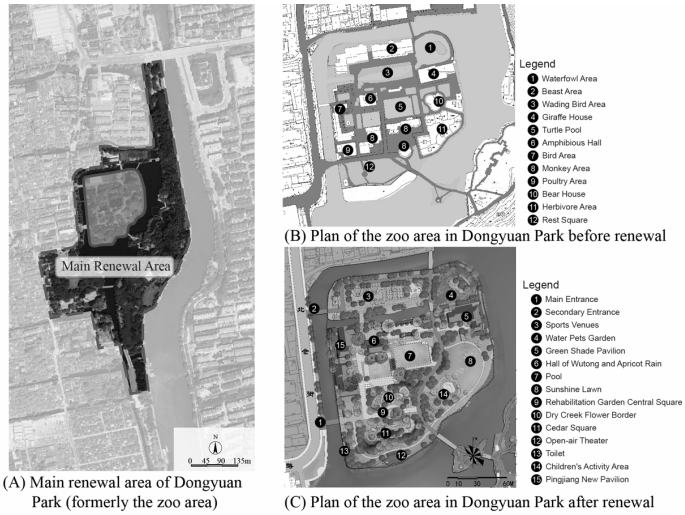
Using this two-layer framework, a comparative analysis of Suzhou Dongyuan Park and Shanghai Peace Park was conducted to examine similarities and differences in design intervention approaches and their associated heritage value outcomes. This process enabled the identification of underlying mechanisms linking design intervention to heritage revitalization.

FINDINGS: DESIGN INTERVENTIONS AND HERITAGE REVITALIZATION IN TWO HISTORIC URBAN PARKS

Design Intervention Characteristics of Suzhou Dongyuan Park

Design Intervention

a. Spatial Structure Intervention: The spatial renewal of Dongyuan Park retained the original garden pattern while reorganizing the former zoo area through an open spatial framework informed by traditional Chinese landscape principles. As illustrated in Figure 5, the renovation transformed the zoo area from an enclosed and fragmented layout into a permeable core space structured by an east–west axis, enhancing spatial continuity, orientation, and hierarchy. The original water system was preserved, reinforcing the "water-surrounding-island" landscape pattern.



(A) Main renewal area of Dongyuan Park (formerly the zoo area)

(B) Plan of the zoo area in Dongyuan Park before renewal

(C) Plan of the zoo area in Dongyuan Park after renewal

Figure 5: Spatial transformation of Dongyuan Park's former zoo area.
Source: Drawn by the author based on field survey and design documents.

b. Functional and Facility Intervention: Integrating Ecology and Everyday Life. Following the renovation, Dongyuan Park evolved from a single-purpose recreational space into a multifunctional landscape serving diverse user needs. New play, leisure, sports, and rehabilitation facilities were introduced, while sponge city measures, including rain gardens and bioswales, enhanced stormwater management and ecological resilience.

c. Landscape Imagery Intervention: Cultural Continuity and Place Narrative. Although the zoo area was substantially reorganized, representative historical landscape elements were retained to preserve the park's historic character. Traditional garden-style service buildings were introduced to reinforce the character of Suzhou's classical garden heritage, while the redesigned aquatic pet garden retained elements of the site's former zoo identity.



Figure 6: Functional and cultural interventions in the renewed area of Dongyuan Park.
Source: Photos taken by the author, 2025.

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d. Management Strategy Intervention: From Enclosure to "*Boundlessness*". Dongyuan Park was historically enclosed by boundary walls that separated it from the surrounding urban space. The 2024 "Boundless Park" renovation removed these walls and renewed the pavement, strengthening physical and visual connections between the park and the surrounding urban fabric.

Heritage Value Presentation

a. Historical Value: Continuity of Spatial Pattern and Regeneration of Memory. The renewal of Dongyuan Park maintains the overall historic garden pattern by preserving the original water system, axial structure, and key landscape elements. The former zoo area has been reorganized through the reintegration of fragmented spaces into the traditional garden framework, incorporating historical features such as ancient trees, stone inscriptions, and the wisteria trellis as material references to urban memory and historical continuity. These interventions reinforce historical value by maintaining the continuity of the park's spatial identity while accommodating contemporary public use. Informal conversations with park users further suggested that the retained landscape elements strengthened their memories of the former park.

b. Cultural Value: Contemporary Interpretation of Traditional Imagery. The renewal of Dongyuan Park reinterprets traditional Suzhou Garden imagery through contemporary architectural expression. Newly added service buildings adopt the form and scale of traditional garden structures while using modern materials, enabling a cultural continuity that connects historic garden aesthetics with contemporary urban life.

c. Social Value: Enhancement of Publicness and Everyday Life. The renewal of Dongyuan Park enhances publicness by increasing openness and functional diversity. The removal of boundary walls strengthens connections with surrounding neighbourhoods, allowing everyday activities to extend into the park. A range of shared spaces, including children's play areas, rehabilitation gardens, and sports facilities, supports diverse user groups and facilitates everyday social interaction. Several nearby residents reported that the open layout and diversified facilities made the park more convenient for daily recreation and social interaction.

d. Aesthetic Value: Reconstruction of Landscape Experience and Renewal of Spatial Aesthetics. The renewal of Dongyuan Park enhances aesthetic experience through the reorganization of spatial structure and landscape hierarchy. Axial vistas and the reconnected water system generate layered visual sequences, while

the integration of traditional garden composition with open contemporary spaces creates a balanced aesthetic combining classical ambience and modern leisure qualities.

The renewal of Dongyuan Park reflects a design logic centred on cultural continuity, reinforcing local identity and heritage value.

Design Intervention Characteristics of Shanghai Peace Park

Design Intervention

a. Spatial Structure Intervention: Integrating Patterns and Strengthening Connectivity. The renewal of Peace Park reorganized its spatial structure through a loop-based circulation system that integrated functional zones while retaining the original topography and water system. Boardwalks and waterfront platforms further strengthened spatial continuity and the relationship between land and water.

b. Functional and Facility Intervention: Constructing an Integrated Activity System. The renewal of Peace Park introduced multifunctional facilities for all-age users, including play, fitness, leisure, and cultural spaces, creating a more diverse and inclusive public environment. Rain gardens and bioswales further enhanced ecological performance while supporting everyday park use.



(A) Plan of Peace Park before renewal (B) Plan of Peace Park after renewal

Figure 7: Spatial transformation of the Peace Park.
Source: Adapted and annotated by the author based on planning documents from the Hongkou District Greening Management Affairs Centre（2020）

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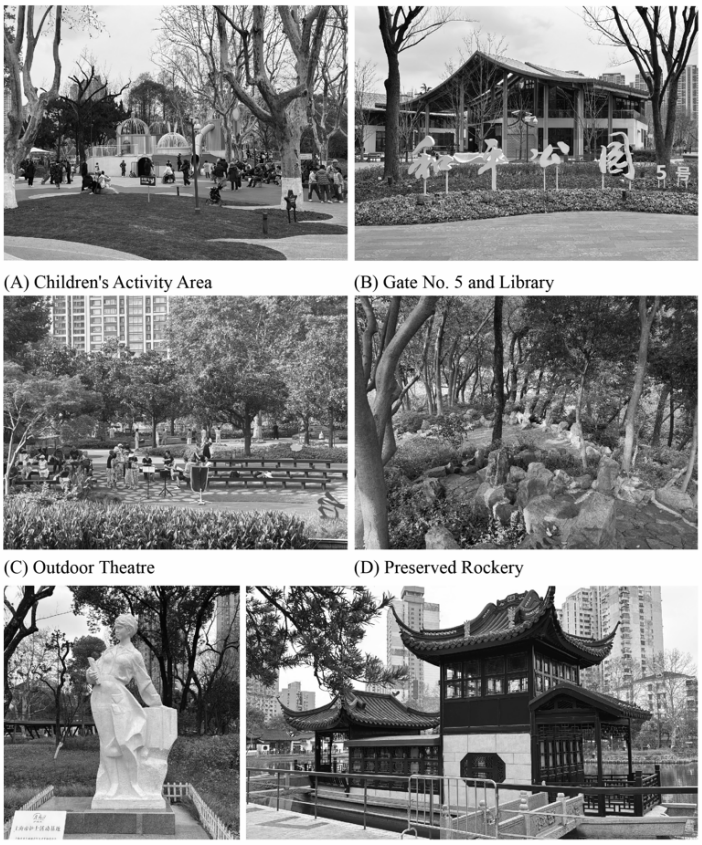


Figure 8: Functional and facility interventions in the renewed Peace Park.
Source: Photos taken by the author, 2025.

c. Landscape Imagery Intervention: Contemporary Interpretation of Historical Context. The renewal of Peace Park reinterprets historical landscape imagery by preserving key garden structures and heritage features while introducing contemporary architectural elements with restrained forms and materials. Traditional elements such as pavilions, rockeries, and waterside structures are retained as historical references, while animal sculptures introduced in the former Animal Island area symbolically recall the site's original identity.

d. Management Strategy Intervention: From Enclosure to Shared Openness. The renewal of Peace Park is defined by its boundary opening strategy, which serves as the key to achieving urban integration. By removing perimeter walls, expanding entrances, and redesigning the street interfaces, the park establishes a seamless connection with the surrounding urban fabric.

The renewal of Peace Park adopts a "park–community" model that integrates physical openness with community-oriented functions. This integrated approach has transformed the park from an enclosed green enclave into a shared urban public space supporting accessibility, social inclusiveness, and long-term vitality.

Heritage Value Presentation

a. Historical Value: Preserving Memory and Continuing Spatial Structure. The renewal of Peace Park preserves historical continuity by retaining the original water system, topography, and key landscape elements. Iconic features such as the stone boat, lakeside pavilion and rockery are reintegrated into the circulation structure, sustaining the site's traditional mountain–water garden pattern. In reorganized areas, in-situ renewal through axial alignments and circular pathways maintains historical legibility and spatial continuity. Informal conversations with long-term users suggested that the retention of familiar landscape elements helped maintain their sense of connection with the former park.

b. Cultural Value: Modern Reinterpretation of Urban Memory. The renewal of Peace Park reinterprets urban cultural memory through a contemporary design language informed by the city's modern urban context. Cultural interventions such as public sculptures, themed gardens, and night lighting embed cultural expression into everyday use, shifting heritage representation toward experiential and life-oriented engagement.

c. Social Value: Enhancing Publicness and Inclusiveness. The renewal of Peace Park enhances social value by integrating multifunctional programs within an open management framework. The park shifts from a closed, single-purpose recreational space to an all-day urban public node that supports diverse user groups and everyday social interaction, reinforcing publicness, inclusiveness, and spatial equity. Several nearby residents reported that the removal of boundary walls and the addition of new public facilities encouraged more frequent daily visits.

d. Aesthetic Value: Reconstructing the Vitality of Landscape Experience. The renewal of Peace Park enhances aesthetic experience through improved spatial order and visual coherence. Circular pathways, lake surfaces, and varied topography generate layered visual perspectives, while seasonal planting and lighting introduce temporal variation, contributing to a dynamic urban park landscape.

The renewal of Peace Park reflects a shift toward functional activation and socially driven regeneration.

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DISCUSSION

Common Mechanisms: How Design Interventions Drive Heritage Revitalization

Despite differing renewal orientations, both cases show that design interventions promote heritage revitalization through a "space–experience–value" transmission chain. This mechanism is consistent with the Historic Urban Landscape (HUL) approach, which emphasizes the dynamic interaction between spatial transformation, social practices, and heritage value reproduction (UNESCO, 2011; Ripp et al., 2025). It also supports the view that heritage is continuously constructed through everyday use and experience rather than statically preserved (Ginzarly et al., 2024). By restructuring spatial patterns and boundaries, design actions generate renewed spatial experiences that encourage everyday use and emotional attachment, aligning with research on public engagement in urban spaces (Lim et al., 2024; Hashim et al., 2025). This study further extends existing research by identifying a process-based mechanism linking spatial change, experiential engagement, and heritage value regeneration, thereby providing a theoretical explanation of how design interventions mediate heritage revitalization in historic urban parks.

Differentiated Focuses: Diverging Points of Value Activation

While both parks promote revitalization through spatial restructuring, they differ in value activation. Dongyuan Park emphasizes cultural continuity, whereas Peace Park prioritizes functional activation. This reflects the tension between conservation-oriented and function-oriented approaches in urban renewal (Wang et al., 2023; Zhu, 2023). Unlike previous studies, this research highlights these approaches as complementary pathways, revealing a dual logic balancing cultural continuity with socially driven regeneration.

Implications

The findings suggest that effective revitalization requires integrating cultural continuity with functional adaptability, reflecting the need to balance historicity and contemporaneity within the HUL perspective (Sabri & Ponrahono, 2024). Future research could extend this process-oriented approach by incorporating a broader range of cases and mixed methods to further explore the dynamics of design-led heritage revitalization across different contexts.

For conservation authorities, heritage conservation objectives should be incorporated into the early stages of park renewal to ensure that historically significant landscape elements and spatial patterns are systematically identified and retained. For park managers, adaptive management strategies should balance heritage conservation with contemporary public use, thereby supporting the long-term sustainability of historic urban parks.

CONCLUSION

This study examines how design interventions contribute to heritage revitalization in historic urban parks through a comparative analysis of Suzhou Dongyuan Park and Shanghai Peace Park. Using a two-layer analytical framework, it identifies two renewal approaches: culturally oriented and function-oriented design interventions.

The findings show that both approaches promote heritage revitalization through spatial restructuring and experiential renewal, linking spatial transformation with user engagement and everyday use. This study develops a process-based analytical framework that explains how design interventions mediate heritage value manifestation through a "space–experience–value" mechanism.

From a practical perspective, the results highlight the need to balance cultural continuity with functional adaptability, ensuring that historic urban parks remain both culturally meaningful and socially active. Future research could expand the range of cases and integrate mixed methods to further explore design-led heritage revitalization across different contexts.

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EXPLORING CHILD-FRIENDLY ENVIRONMENTS THROUGH MIGRANT CHILDREN'S OUTDOOR ACTIVITIES AND ENVIRONMENTAL AFFORDANCES IN A CHINESE URBAN VILLAGE

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Abstract

Urban village accommodated a large number of migrant families in Chinese rapid urbanization, but the outdoor environments often fail to support migrant children's daily activities and development. Migrant children living in these dense environments commonly experience limited access to safe, diverse, and child-friendly outdoor spaces. More importantly, little is known about how environmental affordances shape their outdoor activities. Guided by affordance theory, this study explores the relationship between the outdoor environment and migrant children's activities in Liutan Village which is an urban village in Wuxi City, China. A qualitative approach was employed which combined children's mapping, walkabout interviews and non-participant observations. Twenty-four migrant children aged 8-12 years participated in this study. The results show that migrant children mainly engaged in cognitive activities in the urban village. The playground afforded the most balanced mix of affordances, while the hanging garden and grassland provided more limited and uneven affordances. As a result, migrant children adapted their play behaviours to available conditions. It revealed the environmental deficiencies that constrained their opportunities for play, learning and social interaction. This study highlights the need for child-friendly environmental design that better supports the holistic development of migrant children in urban villages.

Keywords: Migrant Children, Urban Village, Affordance Theory, Child-friendly Environment, City of Wuxi

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INTRODUCTION

China's urban villages originate from rural settlements, and their name can be literally understood as "village encircled by the city." They emerged during China's rapid urbanization in the 1980s and 1990s. To accommodate the growing demand for new construction land, local governments requisitioned farmland on the urban fringe while retaining the residential plots within village boundaries. This strategy minimized compensation costs and political resistance (Buckingham & Chan, 2018). As cities expanded, these villages became embedded within urban areas and functioned as transitional neighbourhoods between rural and urban areas. Following land requisition, villagers rebuilt or renovated houses for rental income, primarily targeting migrant workers. To maximize economic returns, the newly built houses were usually of poor quality and lacked overall planning. Urban villages generally presented narrow interior roads, face-to-face buildings, and a cluttered physical environment (Liu et al., 2010).

Although urban villages are widely known for their poor sanitation, overcrowded conditions, disordered landscape, and generally untidy environment (Sun & Zhao, 2023), they continue to attract large numbers of low-income migrants because rental housing is highly affordable (Buckingham & Chan, 2018). Better medical services and educational resources in nearby urban areas encourage many migrant workers to bring their children to live in these communities. According to the Chinese Action Plan for Strengthening the Care and Protection of Migrant Children, over 13 million migrant children of compulsory school age attended urban schools in 2024. However, these migrant children face unequal access to resources and opportunities due to national structural and systemic barriers (Bengoa & Rick, 2020). They have limited access to safe, accessible, and developmentally supportive outdoor environments in urban villages (F. Wang et al., 2017). All these in turn constrain migrant children's physical, social, and cognitive developments.

Outdoor activities are widely recognized as essential for children's physical, social, cognitive, and emotional development (Santoso, 2023). The outdoor environment not only provides a physical site for their outdoor activities, but also shapes what they are able to do by affording functions, safety conditions, spatial diversity and sensory qualities that influence the types, richness, and frequency of their activities (Fjørtoft, 2004; James J. Gibson, 1979). In this regard, UNICEF emphasizes the provision of child-friendly environments that are safe, accessible, inclusive, developmentally supportive, and responsive to their needs, rights, and capabilities (UNICEF, 2004).

However, little is known about how environmental affordances affect migrant children's outdoor activities. Existing studies on China's urban village focus on the redevelopment, management and migrant children's education (Lai

et al., 2021; Ma & Wu, 2020; Stefano Zaccaria, 2020; Yuan et al., 2021). However, the reciprocal relationship between migrant children and outdoor environment in urban village is often overlooked. With the growing number of migrant children and the introduction of China's Guideline on Promoting the Development of Child-Friendly Cities in 2021, this research gap has become increasingly important. Because it provides a foundation for building child-friendly communities, enhancing children's outdoor activity experiences, and supporting their social integration.

From the ecological perspective, affordance theory builds a bridge between migrant children's behaviours and child-friendly environments. Based on this, the taxonomy proposed by Heft (1988) provides a functional classification of environmental features that helps researchers interpret why certain places support specific children's activities. It links actualized affordances to the physical properties of the environment. To reveal the transactional relationship between migrant children and outdoor environment in Chinese urban villages, this research attempts to investigate the types of migrant children's outdoor activities and environmental features that support their behaviours from the perspective of affordance theory of ecological psychology.

LITERATURE REVIEW

Affordance Theory

Affordance theory, first proposed by Gibson (1979), offers a lens for understanding the functional relationship between individuals and their environments. In his view, environments are not passively constructed by people but rather action possibilities emerging from the interaction between environmental properties and individual abilities (Morgenthaler et al., 2023). Environmental features afford specific opportunities for action, and these opportunities depend on individual capability. Thus, affordances are invariant and individual behaviours are constrained or extended based on how the surrounding environment is perceived (James J. Gibson, 1979).

In affordance theory, environmental functionality is understood from both physical and social aspects (Baggs, 2021). It provides an effective framework for analysing migrant children's interactions with daily outdoor environments. In this research, the functional significance of the outdoor environments for migrant children in urban villages will be examined to gain insight into how migrant children engage with different outdoor settings.

Taxonomy of Affordance

Gibson's theory offers a way to understand the functional meaning of environments by examining the behaviours they support from the perspective of environmental psychology. Based on this, Heft (1988) developed a taxonomy to

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describe the functionally significant properties of children's environments. Drawing on seminal books including 'One Boy's Day' (Barker & Wright, 1951), 'Children's Experience of Place' (Hart, 1979), and 'Childhood's Domain' (Moore, 1986), Heft synthesised observed links between environmental features and children's activities into a preliminary taxonomy of outdoor affordances. Kyttä (2002) expanded this taxonomy by adding social affordance as a new affordance type which was defined as opportunities for interaction provided by surrounding people. It includes the opportunities to play various games, make noise, and share or follow adults' affairs. Table 1 presents the ten functional categories will be used in this study.

Table 1: Taxonomy of affordances in 10 categories

Author	Category	Examples of affordances
Heft (1988)	1. Flat, relatively rigid, smooth surfaces	Afford running, skating, etc.
	2. Graspable/detached objects	Afford drawing, throwing, etc.
	3. Attached objects	Afford sitting, jumping on, etc.
	4. Non-rigid attached objects	Afford swing, etc.
	5. Climbable features	Afford climbing, looking out, etc.
	6. Shelter	Afford microclimate, privacy, etc
	7. Mouldable material	Afford pouring, modifying
	8. Water	Afford splashing, floating, etc
	9. Aperture	Afford locomoting, etc.
Kyttä (2002)	10. Affordances for sociality	Afford chatting, learning, etc.

Three Types of Children's Outdoor Activities

Children's activities are usually categorized into physical, social, and cognitive activities (Uzzell, 1988). Physical activities involve bodily movements and are closely linked to children's motor development, physical fitness, and health like running, playing, and structured physical education (Malone & Tranter, 2003; Martinez-Merino & Rico-González, 2024). Social activities emerge through interactions with peers, family member, and the wider community, where children learn how to communicate, cooperate, and navigate social relationship (Malone & Tranter, 2003; Opstoel et al., 2020). Cognitive activities relate to how children think, remember, communicate, and solve problems, developing through maturation and daily experiences (Martinez-Merino & Rico-González, 2024). The three types of activities are interconnected and develop dynamically during childhood (Kuzik et al., 2020). Engagement in one type often supports developments in the others.

Child-friendly Environment

The concept of a child-friendly environment has gained increasing attention in urban planning and design (Niu et al., 2025; Zhang et al., 2021, 2023). UNICEF defines such environment as safe, accessible, and inclusive settings that support

children's daily play, learning and social interaction. From the perspective of planning, such environments provide appropriate spaces and features that enable children's regular outdoor activities. Key attributes identified in previous studies included open space, a combination of man-made and natural elements, safety, and visibility (Morgenthaler et al., 2023; Tang & Woolley, 2023; X. Wang et al., 2024). These attributes shape how children perceive and actualize the environment affordances. However, the child-friendly principle can hardly be actualized due to the temporariness, exclusion, and privatized survival in Chinese urban villages (Lai et al., 2021). Consequently, children's outdoor activities are often constrained in the urban village (F. Wang et al., 2017), particularly in terms of physical play and social interaction. Thus, it is necessary to apply the perspective of a child-friendly environment to understand migrant children's outdoor experiences in urban villages.

RESEARCH METHODOLOGY

Case Study Site

This study was conducted in Liutan village, Wuxi City, Jiangsu Province, China (Figure 1). Wuxi City is a major industrial and economically advanced city in Chinese eastern coast (Figure1). Its strong manufacturing base has attracted over 2.2 million migrants according to the 2020 Census. In 2022, Wuxi recorded a GDP of 146.51 billion RMB and the highest per capita GDP in China. It was recognized as a first-tier city by China Business News and was officially included in the national list of child-friendly city in 2023 (The CPPCC Wuxi Committee, 2023). This policy heightened concern for migrant children's well-being in urban villages, particularly their access to supportive outdoor environment.

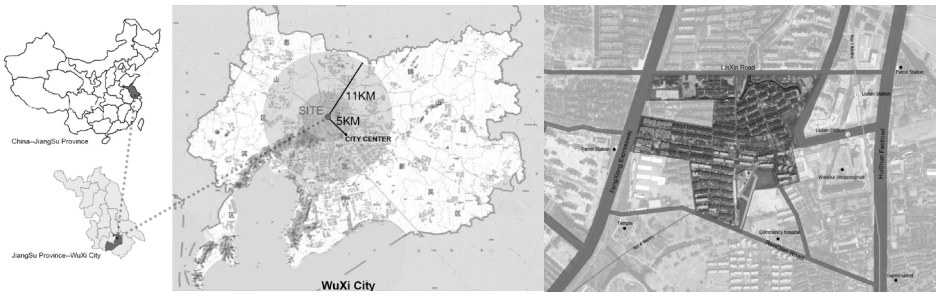


Figure 1: The location of study area in WuXi city(left); Master plan of Liutan village(right)

Liutan village is the largest remaining urban village in Wuxi and is considered a typical example. It is characterized by its long history, various building styles, convenient location between the city centre and the industrial zone, as well as high accessibility (Figure 1). Due to these characteristics, it has

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become an ideal choice for migrant workers and their children. Therefore, Liutan village provides an important context for examining how urban-village outdoor environment supports or constraints migrant children's outdoor experiences.

Research Design

This study adopts qualitative methods to explore migrant children's outdoor play experience in Liutan village. Twenty-four migrant children (17 boys and 7 girls) were purposively selected based on the Chinese national definition of migrant children. All participants were rural-to-urban migrant children aged 8-12 years who had lived in the Liutan village for over six months. All participants were required to understand and respond to basic instructions from the class teacher. They were also required to express thoughts, opinions and needs. Children with cognitive or communicative impairments, or psychological or behavioral issues, were excluded.

Two primary school teachers in the research team conducted the initial screening, as they had access to students' background information. Ethical approval was obtained from Universiti Sains Malaysia (USM; protocol no. USM/JEPeM/PP/25040379). Participation was voluntary. Written parental consent and child assent were obtained prior to data collection. Verbal assent was also obtained from all participants. All data were anonymized to protect participants' privacy and confidentiality.

Three qualitative methods were used to collect the data. Mapping was conducted first to visually present migrant children's activity places and spatial preferences. Then walkabout interviews were conducted at the mapped locations to explore activities and place experiences in context. Finally, non-participant observation was undertaken in familiar settings to document actual play behaviours and to cross-check earlier data.

DATA COLLECTION

Data collection was conducted between August and October 2025. Before the mapping activity, assistants prepared snacks to help the migrant children relax. The objectives and procedures of this study were explained using process cards. Each child received a map, an aerial image, and a pen. A 3D real-scene map was displayed to assist place identification. Children individually marked their regular outdoor play places on the map with guidance provided when necessary.

After the mapping activity, each child participated in a walkabout interview at the places they had identified. The child guided the assistant to the location and described the activities undertaken, playmates, materials used, and reasons for using the place. Field notes and audio recordings were used to document the interviews. Each mapping and walkabout session lasted approximately 15 minutes.

Finally, non-participant observation was conducted at the identified play places after school on weekdays and throughout weekends for one week. An observation guide was used to record play activity, peer interactions, and spatial use. Each child was observed once for approximately 20 minutes. Observers remained unobtrusive and did not interfere with ongoing activities.

ANALYSIS AND DISCUSSION

Migrant Children's Outdoor Activities in Urban Village

The data collected through migrant children's mapping, walkabout interview and non-participant observation are summarized in Table 2. Among all identified 120 activities, cognitive activities accounted for the largest proportion which was 46% of all responses (n=55). Physical activities occupied 28% (n=34) while social activities represented 26% of all (n=31).

Table 2: Types of migrant children's activities in Liutan village

	Number of activities reported by migrant children			Total
	Physical activities	Social activities	Cognitive activities	
Number	34	31	55	120
Per cent	28%	26%	46%	100%

The results suggest that migrant children mainly engaged in exploratory and imaginative activities such as catching insects, collecting specimens, picking flowers, and playing with animals. The dominance of cognitive activities suggests that the outdoor environments in urban villages may offer fewer opportunities for physical and social activities. This may be explained by the limited availability of play facilities and open spaces which restrict the affordances for running, climbing, and muscular actions. This is consistent with Fan et al. (2025), who linked lower levels of physical activity to fewer outdoor playfields and inadequate equipment. Xiao and Han (2019) also noted that urban village often provide insufficient space for children's physical and social activities. These findings highlight the importance of improving outdoor environments to support children's diverse play experiences.

Mapping the Spatial Affordances of Outdoor Environment in Urban Village

By integrating the activity data collected through walkabout interviews and spatial information generated from migrant children's mapping, Figure 2 illustrates the spatial concentration of migrant children's outdoor engagement within the urban village. Totally, three primary concentrations of migrant children's outdoor activities were identified. The most intense hotspot appeared around the playground where presented 71 activities. It was followed by hanging garden and grassland where 66 and 60 activities were recorded respectively. Figure 3 further analyses the physical, social, and cognitive activities in the three

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places. In the playground, physical (n=21) and social activities (n=22) appeared at similar levels, while cognitive activity was slightly higher (n=29). In Hanging Garden, cognitive activity (n=41) clearly dominated over physical (n=12) and social activities (n=13). Similarly, cognitive activity (n=40) in the Grassland exceeded physical (n=11) and social activities (n=9).

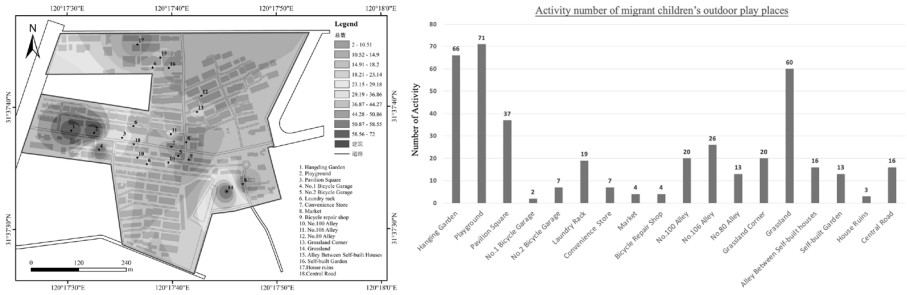


Figure 2: The distribution of migrant children's outdoor activities in Liutan village

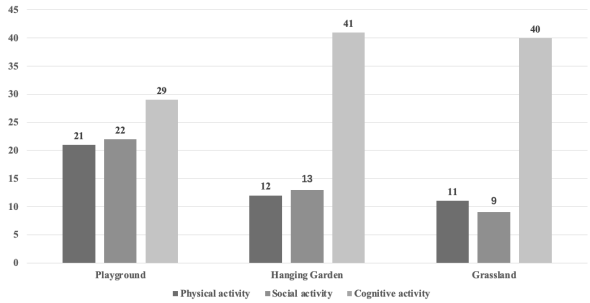


Figure 3: The three types of activities in Playground, Hanging Garden and Grassland

The spatial distribution suggests that migrant children's outdoor activities are shaped by the affordances of different places in Liutan village. The playground presents a relatively balanced pattern of activities (Figure 3). Its flat rubber surface, fixed play structures, fitness equipment and a racetrack afforded diverse functional possibilities that supported crawling, racing, structured play, and team games requiring space, stability, and spatial boundaries (Figure 4). This supports Gibson's (1979) assertion that environmental properties specify possible actions. The playground was also perceived as a social arena. Children repeatedly described it as a meeting point where friendships formed and play decisions were made. As a girl said, *"See you at the old place tomorrow! Then we decide what to play."* It reflected that migrant children felt safe in the playground. As Aziz and Ahmad (2012) stated that an enhanced sense of safety supports children's

social interaction, and Q. Zhang et al. (2021) similarly argued that higher perceived safety improves the usability of outdoor spaces.

In contrast, the Hanging Garden and Grassland strongly afforded cognitive activities (Figure 3). The natural and semi-natural elements such as vegetation, varied terrain and flowerbeds invited migrant children's exploration (Figure 4), team play and imaginative engagement, consistent with previous findings on the value of natural play environments(Ridgers et al., 2010). They performed more creative, constructive, and imaginative activities such as making bird nests, modifying microtopography, contacting nature, feeding insects, planting flowers, and collecting specimens. The lower levels of physical and social activities in these two areas implied that children primarily used these settings for exploration and imaginative play. These findings further demonstrate that outdoor environments with natural features offered richer affordances for in Liutan village.

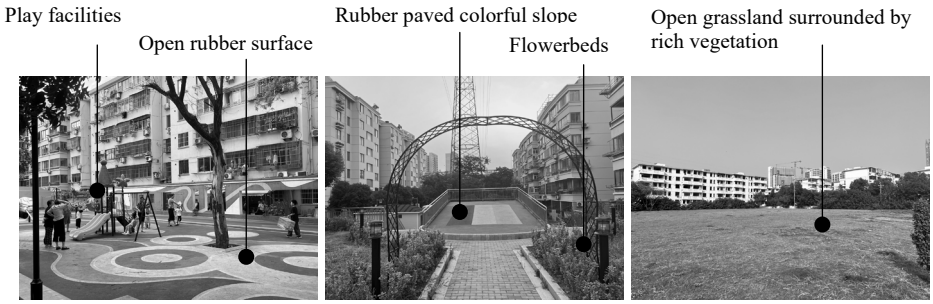


Figure 4: New built playground in Liutan village(left); Hanging Garden with paved surface and natural flowerbed(middle); Grassland with open and level terrain(right)

Interpreting Activity Hotspots via Functional Taxonomy

Since a single activity often involves multiple environmental functions, each observed activity was further broken down into micro-actions. These micro-actions were then categorized into one or multi-categories of functional taxonomy. Consequently, 263 affordances were extracted from the data (Table 3). The category of flat, relatively rigid, smooth surfaces presented the largest number (n=96) which suggested that surfaces were the most popular functional features in Liutan village. Graspable or detached objects (n=55) and affordances for sociality (n=50) showed the similar recordings. Attached objects (n=39) appeared to offer additional possibilities for physical engagement. In contrast, only a small number of mouldable materials (n=4), water-related features (n=3) and non-rigid attached objects (n=1) were observed. Climbable features (n=1) were almost absent, and no aperture-related affordances were identified.

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Table 3: Relationships between categories of functional taxonomy, environmental features, and activities

Category	Environmental features	Activities
1. Flat, relatively rigid, smooth surfaces (N=96)	Rubber surface, paved ground, concrete roads, racetrack	Diverse locomotor activities, sports games, role play games, explorative play, and team games
2. Graspable/detached objects (N=55)	Animals, insects, vegetation, soil, stones, bricks, balls, chess, chalk, skipping rope, collected materials, toys, bottles and cans.	Catching insects, feeding insects, playing with animals, making grills, drawing, loose-parts play
3. Attached objects (N=39)	Flowerbeds, benches, fitness equipment, playground structures	Sitting, lying, hanging, swing, sliding, jumping, displaying and sensory experience
4. Non-rigid attached objects (N=1)	Swing	Swinging
5. Climbable features (N=1)	Rockery	Climbing
6. Shelter (N=14)	Pavilion, building overhangs, tree shade	Taking a rest, sensory experience
7. Mouldable material (N=4)	Soil, snow, sand, paper	Modifying microtopography, snow building, moulding paper
8. Water (N=3)	Puddles after rain, small water accumulation areas	Trading water
9. Aperture (N=0)	-	-
10. Affordances for sociality (N=50)	Open space, semi-open space, seating areas	Sharing secrets, learning dialect, holding a lecture, grocery shopping, visiting shops and markets, attending knowledge corner, group study, team games

The distribution of affordances presents an uneven trend and a clear dominance of surfaces in the urban villages. It indicates that migrant children's activities were strongly shaped by the availability of flat, relatively rigid, smooth surfaces in crowded, narrow, and irregularly built Liutan village. That may explain why playground, hanging garden and grassland are the three highest valuable activity locations on the hotspot map. The three places enabled migrant children to actualize a wide range of essential movements, including running, skipping, hopping, crawling, lying, dancing, jogging, racing, jumping and walking. Multiple studies have suggested similar association (Morgenthaler et al., 2023; Tang & Woolley, 2023; X. Wang et al., 2024), reinforcing that flat paving surfaces and large site scales enhance children's engagement by facilitating easier navigation and various play options. Particularly, playgrounds with rubber surfaces further enhanced perceived safe and children's confidence to perform more vigorous actions. As a 10-year-old boy explained, *"I don't need to worry about getting hurt or bleeding when I practice skateboarding in the playground*

because of the soft ground." This aligns with Storli et al. (2024), who reported that rubber surfaces are positively associated with children's play. Additionally, the openness of these areas improved visibility and parental supervision. It further encouraged children's use, even in limited spatial resources (Zhang et al., 2023).

The second-highest category of affordances was graspable objects, which included animals (i.e., dogs, cats, ducks, chicken), insects, vegetation (i.e., flowers, branches, leaves, vines), soil, stones, bricks, balls, chess, chalk, skipping rope, collected materials, toys, bottles and cans. These objects afforded diverse actions, such as catching, feeding, searching, manipulating, twisting, throwing, drawing, grabbing, tapping, and constructing. For example, they moved bricks and stones to create improvised seating, and used long branches to establish game boundaries. It indicates that migrant children can differentiate the affordances of various natural elements. Such natural features stimulate curiosity and support various forms of play (Fjørtoft, 2004).

They also actively explored and creatively transformed available materials to serve different play purposes. For instance, empty plastic bottles were repurposed in multiple ways. In pseudo-football game, an empty bottle functioned as a football or was filled with soil to act as bowling pins, while balls and larger bottles were similarly repurposed. These practices indicate that children not only perceived the affordances of single objects but also combined and reconfigured multiple affordances to support evolving play scenarios. This capacity for autonomous material play aligns with studies highlighting its role in improving children's agency and creativity (Ernst & Burcak, 2019).

The affordance for sociality emerged from migrant children's interactions with material elements and the broader social context in the urban village. For instance, in war-themed games, migrant children teamed up, negotiated rules and roles, and collected environmental objects (e.g., toys, branches, rope, bottles, cards), attributing special functions to them. These activities required communication and shared interpretation of how materials should be used. Beyond this, migrant children also engaged socially with local residents through grocery shopping, visiting shops and markets, learning dialect, and exchanging daily information. The findings suggest that migrant children actively perceived and utilized environmental opportunities for sociality. It aligns with Kyttä, (2003) concept of social affordance, which enhances children's cooperation, communication, and strategic thinking.

However, it is notable that six categories show low affordances. It suggests that the outdoor environment in Liutan village provides migrant children with a narrow range of functional affordances. This finding reveals that migrant children encounter limited spatial variation, minimal natural features, and few designed play structures within the urban village. Pan and Du (2021) pointed out that such outdoor environment functions primarily as practical functions for daily

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use rather than as areas for children to relax, explore, and interact with others. The absence of environmental features such as climbable elements, mouldable materials, and water further restricted opportunities for children's physical skills, sensory learning, problem-solving, and emotional growth (Morgenthaler et al., 2023; Ramsden et al., 2025).

Taken together, the findings indicate that playground, hanging garden, and grassland emerged as key activity places because they concentrate the most valuable environmental affordances within the urban village. Their relatively open surface and combination of natural and man-made graspable objects support a wider range of movement-based and object-based play. It explains why playground and hanging garden enabled more diverse activities. This is consistent with Watts (2022), who found that children prefer and benefit most from play setting combining natural elements with designed structures. These affordances appeared to create favourable conditions for spontaneous social interaction by facilitating shared movement and material engagement (Hazlehurst et al., 2023).

Nevertheless, environmental affordances appear limited at the scale of the urban village as a whole. Most places observed in Liutan village support basic movements and offered limited opportunities for more varied play experience. As a result, many opportunities for physical challenges and social engagement remain underdeveloped.

CONCLUSION

This study demonstrates migrant children's good adaptability and creativity even in the urban village with constrained space and limited resources. The imbalance in affordance categories suggests that outdoor environment has great potential for improvements in the aspects of physical play and social interaction.

From a child-friendly environment perspective, the dominance of practical functions in urban villages often comes at the expense of migrant children's developmental needs. Thus, targeted design and planning interventions are needed to improve surface quality and quantity, diversify material affordances, and strengthen social affordances in urban village. These improvements are essential for creating a safe, diverse, and inclusive outdoor environment that supports the holistic development of migrant children in urban villages.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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FROM IMAGE TO LOYALTY: THE SERIAL MEDIATING ROLES OF PERCEIVED QUALITY AND SATISFACTION IN CHENGDU'S URBAN PARKS

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Abstract

Urban parks play an important role in sustainable urban development, yet the psychological mechanisms underlying visitor loyalty in the context of "Park City" remain insufficiently examined. This study uses the stimulus-organism-response (S-O-R) model to explore how park image and perceived quality affect the satisfaction and loyalty of visitors in Chengdu, China. A total of 513 valid questionnaires were collected through on-site surveys of two representative urban parks. Partial least squares structural equation modelling (PLS-SEM) was applied to examine the hypothesised relationships among the constructs. The results indicate that park image significantly predicted perceived quality ($\beta = 0.600$, $p < 0.001$), while park image ($\beta = 0.337$) and perceived quality ($\beta = 0.264$) significantly enhanced visitor satisfaction. Satisfaction also had a significant positive effect on loyalty ($\beta = 0.400$). The validated serial mediation pathway (Park Image → Perceived Quality → Satisfaction → Loyalty) demonstrates that park image is a foundational driver of visitor loyalty, whose influence is translated through perceived quality and satisfaction with the park experience. These findings suggest that Park City planning should align image construction with everyday experiential quality, enabling positive park perceptions to support satisfaction, revisit intention, and public recommendation.

Keywords: Park City, Park Image, Perceived Quality, Visitor Satisfaction, Loyalty, PLS-SEM

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INTRODUCTION

In the process of rapid urbanisation, urban parks are no longer limited to ecological functions, but increasingly serve as everyday public spaces for restoration, social interaction, and quality-of-life improvement (Geng et al., 2024). Since China proposed the concept of "Park City", the positioning of urban parks has changed from traditional green space to a comprehensive carrier of ecological welfare, urban brand and public happiness. In this context, visitors' continued use and recommendation intentions provide useful evidence for understanding how park experience contributes to the everyday performance of urban parks and the implementation of Park City development (Bi et al., 2024; Geng et al., 2024; Zhan et al., 2024).

However, although park image has been confirmed as an important factor influencing visitors' behavioural intentions in urban park and leisure studies (Davras & Özperçin, 2023; Plunkett et al., 2019), its internal mechanism has not been fully explored in the context of non-commercial urban parks. Unlike commercial attractions, the "image" of urban parks is more public and everyday, and its formation is not only derived from physical facilities, but also from visitors' overall perception of natural experience and social atmosphere (Plunkett et al., 2019). Currently, there is still limited integrated research clarifying how park image is transformed into perceived quality, and how this perceptual chain ultimately supports visitors' loyalty through satisfaction.

Based on the above considerations, this paper takes the practice of Chengdu Park City construction as the background to explore how visitors' perception of park image and quality shapes their loyalty. To achieve this goal, this study sets three specific objectives: (1) to analyse the relationships among park image, perceived quality, satisfaction, and visitor loyalty; (2) to test the simple and serial mediating roles of perceived quality and satisfaction in the formation of visitor loyalty; and (3) to provide theoretical and planning implications for improving urban park experiences under Park City development.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Theoretical Framework

This study adopts Mehrabian and Russell's (1974) S-O-R framework, which links environmental stimuli (S), internal cognitive or emotional states (O), and behavioural responses (R). In landscape, tourism, and environmental behaviour research, the S-O-R model has been widely used to explain how physical environments and perceived experiences influence satisfaction and behavioural intentions (Aziz & Niazi, 2024).

In the context of urban green space, park image (PI) and perceived quality (PQ) constitute external stimuli that shape visitors' cognition; satisfaction, as an internal psychological mechanism, reflects emotional

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satisfaction (SAT); and loyalty (LOY) reflects behavioural intentions such as revisiting, recommending, and sharing (Bi et al., 2024; Wu et al., 2018). This framework provides a systematic theoretical basis for analysing how environmental cues affect visitor behaviour in the construction of Chengdu's "Park City". This study created a conceptual model shown in Figure 1.

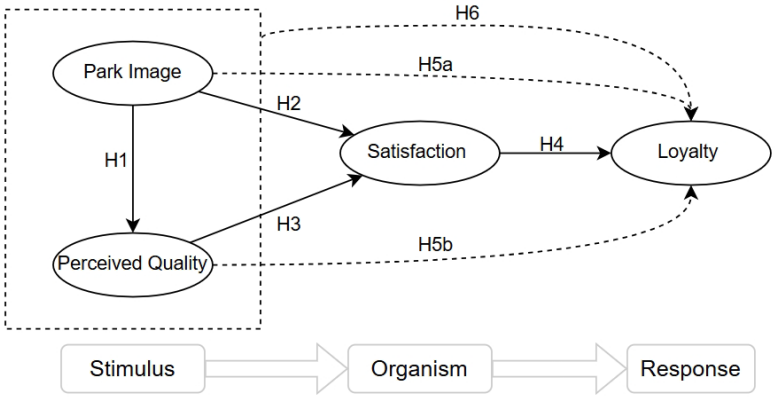


Figure 1: Conceptual model and hypotheses.
Note: Solid lines-direct hypothesised paths, dashed lines-indirect hypothesised paths.
Source: Adapted from Mehrabian and Russell (1974) and modified by the author.

Park Image

Park image describes visitors' overall mental impression of a park, including both cognitive judgements and affective responses (Bigart et al., 2023; Qu et al., 2011). The cognitive dimension reflects the rational cognition of visitors on the physical and symbolic characteristics of the park, while the emotional dimension reflects emotional reactions such as pleasure and excitement (Zhang et al., 2024).

Under the framework of Chengdu's "Park City", parks integrate ecological, cultural and technological values (Bi et al., 2024). A strong park image not only affects emotional satisfaction but also affects quality perception. Empirical studies have shown that a good image can significantly improve visitors' evaluation of park facilities by shaping their interpretive reference framework (Wei & Zhang, 2023). Based on this, the hypothesis is formulated:

H1: PI has a significant positive influence on PQ.
H2: PI has a significant positive influence on SAT.

Perceived Quality

In this study, perceived quality is understood as visitors' assessment of how well the park environment, facilities, accessibility, safety, and maintenance meet their expectations (Sugiama et al., 2023; Wu et al., 2018). Visitors form satisfaction

judgments by comparing on-site experiences with expectations, where higher perceived quality means functional completeness, environmental comfort, and management effectiveness, thereby triggering positive emotional responses (Geng et al., 2024). Du and Zhao (2022) found that visitors' perception of the park's service and quality has a significant positive impact on their overall satisfaction with the park.

Based on contemporary urban landscape research, this study conceptualizes perceived quality as three interrelated dimensions: (1) support for recreation functions: assessing the completeness of facilities such as fitness areas and leisure areas; (2) spatial accessibility and safety: reflecting the clarity of the signage system and the sense of perceived safety; and (3) ecological landscape and maintenance: capturing perceptions of vegetation management and environmental hygiene (Bi et al., 2024; Zhan et al., 2024). We propose:

H3: PQ has a significant positive influence on SAT.

Satisfaction

Satisfaction represents the emotional evaluation generated by the comparison between visitors' expectations and experience (Geng et al., 2024). In the context of public parks, satisfaction includes both the emotional pleasure brought by leisure activities and the satisfaction of aesthetic or cultural needs (Davras & Özperçin, 2023). Studies have confirmed that satisfaction, as a core organism variable, closely links environmental perception with behavioural outcomes (Bi et al., 2024; Wu et al., 2018). Thus, the following hypothesis is formulated:

H4: SAT has a significant positive influence on LOY.

Mediation Mechanisms of Perceived Quality and Satisfaction

In the S-O-R framework, behavioural loyalty (R) is formed through the dual mediation mechanism of parallel and sequence. Specifically, park image may directly trigger the emotional response of satisfaction, and may also indirectly affect loyalty through the cognitive evaluation of perceived quality. At the same time, perceived quality itself can be used as a leading variable of satisfaction to form an independent cognitive path to loyalty (Sugiama et al., 2023). This dual-processing structure is supported by environmental behaviour research, which shows that visitors' behavioural intentions can be formed through direct emotional resonance or shaped through a cognitive-emotional complex chain (Afshardoost & Eshaghi, 2020). Therefore, this study tests both simple mediation paths (H5a, H5b) and a sequential mediation path (H6), capturing the multi-layered psychological process underlying park-based experiences. Accordingly, we propose:

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H5a: SAT mediates the relationship between PI and LOY.
H5b: SAT mediates the relationship between PQ and LOY.
H6: PI, PQ, and SAT form a serial mediation path (PI → PQ → SAT → LOY) that influences visitor LOY.

RESEARCH METHODOLOGY

Study Area

Quantitative empirical research was adopted in this study based on the S-O-R framework. The study site was located in Chengdu (30°05′–31°26′N, 102°54′–104°53′E), which is the first national demonstration city of China's "Park City" initiative (Figure 2). The questionnaire survey was carried out in two comprehensive urban parks: People's Park and Tianfu Art Park. People's Park was built in 1911 and is a historical urban park with long-established social functions. It has undergone renewal and quality enhancement under Chengdu's Park City development. Tianfu Art Park, on the other hand, was built in 2018 and embodies a contemporary park type characterised by modern landscape design. These two parks were selected because they have high visitor volumes and represent different trajectories of Chengdu's urban park development.

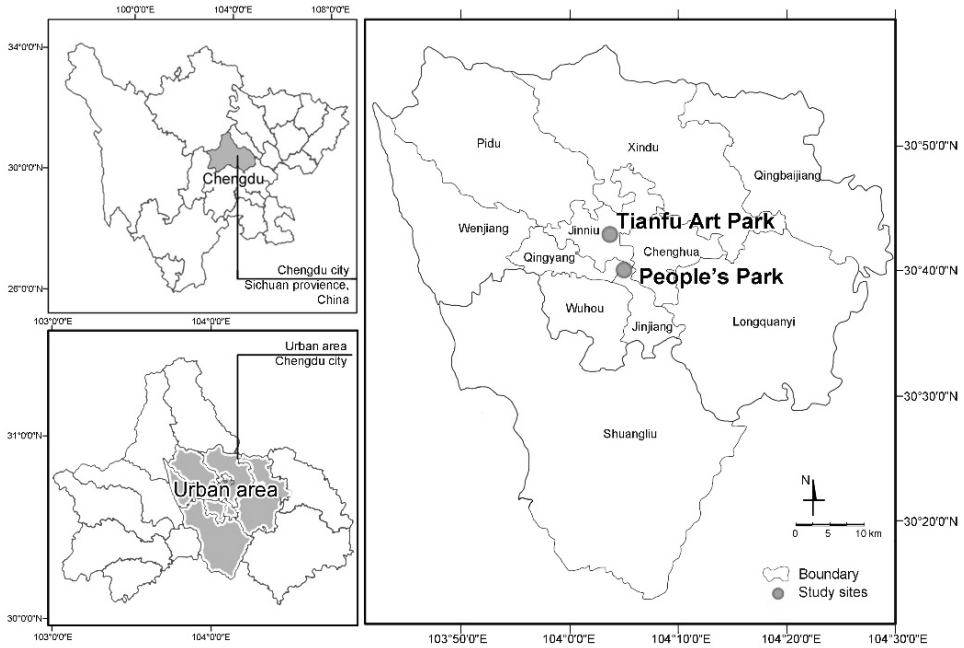


Figure 2: Location of the Study Sites
Source: Author, 2026

Data Collection and Sampling

The on-site survey was conducted in the two parks from March to April 2025 using the convenience sampling method, and the survey subjects were adult visitors. To improve the diversity of responses and reduce time-location bias, questionnaires were distributed on both weekdays and weekends, covering morning, midday, afternoon, and evening periods. Within each park, respondents were approached at different locations, including entrances, walking areas, leisure spaces, and activity zones. After data screening and quality control, a total of 513 valid questionnaires were retained for analysis. The final sample size was adequate for PLS-SEM analysis and met the statistical power recommendation (Hair et al., 2019).

Measurement of Variables

This study measured the four core latent constructs by using a five-point Likert scale questionnaire (1 = "strongly disagree" to 5 = "strongly agree"). Park image captures the overall impression of urban parks by visitors through cognitive and emotional dimensions (Bigart et al., 2023). Perceived quality, as a reflective construct, is composed of three composite dimensions: recreational function, accessibility and safety, and ecological landscape maintenance (Qiu et al., 2023; Ramkissoon, 2020; Wei & Zhang, 2023). Visitor satisfaction is the overall evaluation of visitors on the park experience, reflecting their overall pleasure, decision satisfaction and satisfaction relative to the expected goals, using three items which were adapted from Wu et al. (2018) and Davras & Özperçin (2023). Loyalty is defined as a multidimensional behavioural construct of revisit intention, recommendation intention, and positive word-of-mouth (WOM) behaviour, adapted from Zhan et al. (2024) and Wu et al. (2018).

Data Analysis

The questionnaire data were analysed in SmartPLS 4.0 using a PLS-SEM procedure. This technique was chosen because it is suitable for structural models with mediating variables, limited sample sizes, and non-normal data distributions (Hair et al., 2019). Model assessment proceeded in two stages: the measurement model was evaluated using Cronbach's alpha, composite reliability (CR), average variance extracted (AVE), and the heterotrait-monotrait ratio (HTMT); the structural model was then assessed using bootstrapping with 5,000 resamples.

ANALYSIS AND DISCUSSION

Descriptive Analysis

A total of 513 valid questionnaires were collected from visitors to two representative urban parks in Chengdu. Since this study aims to examine the general structural relationships among park image, perceived quality,

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satisfaction, and loyalty rather than park-specific effects, the data from the two parks were combined for the main PLS-SEM analysis. The two sites differ in historical background and design orientation, but both are major public urban parks within Chengdu's Park City context, with nearly balanced sample sizes.

The sample demonstrates a balanced distribution across gender, age, education, and occupation, indicating a diverse respondent profile among the surveyed park users. As shown in Table 1, the respondents were almost evenly distributed between the two study sites, with 49.7% surveyed in People's Park and 50.3% in Tianfu Art Park. In addition, the sample was almost evenly distributed by gender, with 49.9% of respondents being male and 50.1% being female. The vast majority of participants were aged between 25 and 54 (64%), indicating that urban parks in Chengdu mainly attract visitors of working age. In terms of education, more than half of the visitors (56.5%) had a college or bachelor's degree, and 15.6% had completed postgraduate studies, indicating that the overall education level of park users was high. In terms of occupational distribution, the proportion of enterprise employees was the highest (35.5%), followed by employees of public institutions (15.8%) and retirees (13.8%), showing a wide social mix of working and leisure people. Overall, the sample has a balanced age structure, a high level of education and a diverse social background, which laid a good foundation for the structural model analysis.

Table 1: Demographic Profile of Respondents (N = 513).

Type		No.	Percentage (%)
Park	People's Park	255	49.71
	Tianfu Art Park	258	50.29
Gender	Male	256	49.90
	Female	257	50.10
Age	18 – 24	57	11.10
	25 – 34	124	24.20
	35 – 44	99	19.30
	45 – 54	107	20.90
	55 – 64	73	14.20
	≥ 65	53	10.30
Education	Middle school or under	30	5.90
	High school or equivalent	113	22.00
	Diploma or undergraduate	290	56.50
	Postgraduate or above	80	15.60
Occupation	Enterprise employee	182	35.50
	Public institution staff	81	15.80
	Retired	71	13.80
	Student	68	13.30
	Self-employed	49	9.60
	Freelancer	27	5.30
	Jobless / Other	35	6.80

Source: Author's calculation

Measurement Model Assessment

The measurement model evaluation focused on indicator reliability, internal consistency, convergent validity, and discriminant validity. Indicator reliability was assessed by outer loadings. Table 2 shows that all loading values exceeded the 0.65 threshold, indicating that the reliability was within an acceptable range. Although the factor loadings of some items of the park image and ecological maintenance dimensions (e.g., PI-A2 and PQ-E2) were between 0.65 and 0.70, they were retained because the removal of these items would not significantly improve the CR or the AVE, and they were theoretically necessary for the content validity of the constructs.

Table 2: Outer loadings.

No.	Item	Statement	Loading
1	PI-A1	Visiting this park is relaxing.	0.685
2	PI-A2	Visiting this park is exciting.	0.657
3	PI-A3	Visiting this park is delightful.	0.664
4	PI-A4	Visiting this park is interesting.	0.65
5	PI-C1	The park has contributed to ecological health and environmental sustainability.	0.745
6	PI-C2	The park represents Chengdu's unique culture and heritage.	0.729
7	PI-C3	The park is inclusive and accessible to everyone.	0.759
8	PI-C4	The park contributes to the local economy.	0.747
9	PI-C5	The park is attractive and provides diverse recreational functions.	0.724
10	PI-C6	The park integrates modern technology to enhance visitor experience and sustainability.	0.728
11	PQ-F1	The park provides well-designed fitness and exercise facilities.	0.764
12	PQ-F2	The park offers sufficient leisure amenities and a shaded area.	0.761
13	PQ-F3	The park includes diverse social and commercial spaces.	0.754
14	PQ-S1	The park's lighting system makes nighttime visits safe and comfortable.	0.761
15	PQ-S2	The park provides a clear and user-friendly signage system.	0.767
16	PQ-S3	Feeling safe and secure while spending time in this park, both during the day and at night	0.787
17	PQ-E1	The park provides clean, well-maintained, and easily accessible restrooms and public facilities.	0.672
18	PQ-E2	Plants, lawns, and facilities are well-maintained in the park.	0.661
19	PQ-E3	Fresh and clean environment and good air quality.	0.654
20	SAT1	Generally, I am satisfied with the park.	0.872
21	SAT2	Overall, I am satisfied with the decision to go to the park.	0.859
22	SAT3	Compared to my expectations before the visit, I am satisfied with my experiences in this park.	0.843
23	LOY1	Willing to revisit this park	0.851
24	LOY2	Willing to recommend the park to others	0.850
25	LOY3	Willing to share experience via social media	0.875

Source: Author's calculation

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Note: PI-A = Affective Image; PI-C = Cognitive Image; PQ-F = Recreational & Functional Support; PQ-S = Spatial Access & Safety; PQ-E = Eco-Landscape & Maintenance; SAT = Satisfaction; LOY = Loyalty.

Internal consistency was confirmed by Cronbach's alpha (0.821 - 0.891) and CR (0.824 - 0.891), both exceeding the 0.70 benchmark. Convergent validity was established as all AVE values (0.504 - 0.737) surpassed the 0.50 requirement (Table 3). Furthermore, discriminant validity was assessed by using the HTMT Ratio, which was below the strict threshold of 0.85 (Table 4), proving that the constructs are empirically distinct from one another (Hair & Sarstedt, 2021).

Table 3: Construct reliability and validity.

Construct	Cronbach's α	CR	AVE
Park Image	0.89	0.891	0.504
Perceived Quality	0.891	0.891	0.537
Satisfaction	0.821	0.824	0.736
Loyalty	0.822	0.825	0.737

Source: Author's calculation

Table 4: Discriminant validity assessment: HTMT ratios.

	Loyalty	Park Image	Perceived Quality	Satisfaction
Loyalty				
Park Image	0.518			
Perceived Quality	0.551	0.669		
Satisfaction	0.484	0.578	0.537	

Source: Author's calculation

Structural Model Assessment

After confirming the reliability and validity of the measurement model, bootstrapping with 5,000 resamples was used to evaluate the direct and indirect effects. The results are summarised in Table 5. The hypothesised relationships and the results of the structural model analysis are illustrated in Figure 3. Path coefficients (β), significance levels, and the coefficient of determination (R^2) for each endogenous variable are clearly presented to show the overall model performance.

The bootstrapping results showed significant effects for all hypothesised direct paths ($p < 0.001$), providing strong support for the proposed relationships. Specifically, park image exerted a substantial positive effect on perceived quality ($\beta = 0.600$, $t = 20.501$, $p < 0.001$) and satisfaction ($\beta = 0.337$, $t = 7.063$, $p < 0.001$). Perceived quality significantly influenced satisfaction ($\beta = 0.264$, $t = 5.576$, $p < 0.001$), while satisfaction had a significant positive effect on loyalty ($\beta = 0.400$, $t = 11.409$, $p < 0.001$).

The f^2 effect size further reveals that park image had a large effect on perceived quality (f^2 = 0.563), while its effect on satisfaction was small to medium (f^2 = 0.102). The effect of satisfaction on loyalty was also moderate (f^2 = 0.190). The variance inflation factor (VIF) values ranged from 1.000 to 1.563, which were below the recommended threshold of 5.0, indicating that multicollinearity was not a serious concern among the predictor constructs.

Table 5: Structural Model Results and Mediation Effects

Relationship	Std. Beta	Std. Dev.	t-value	p-value	BCI LL	BCI UL	f^2	VIF	Support
Direct									
H1: PI -> PQ	0.600	0.029	20.501	< 0.001	0.537	0.652	0.563	1.000	Yes
H2: PI -> SAT	0.337	0.048	7.063	< 0.001	0.240	0.427	0.102	1.563	Yes
H3: PQ -> SAT	0.264	0.047	5.576	< 0.001	0.172	0.358	0.063	1.563	Yes
H4: SAT -> LOY	0.400	0.035	11.409	< 0.001	0.329	0.465	0.190	1.000	Yes
Indirect									
H5a: PI -> SAT -> LOY	0.135	0.024	5.659	< 0.001	0.090	0.183	/	/	Yes
H5b: PQ -> SAT -> LOY	0.105	0.022	4.843	< 0.001	0.066	0.151	/	/	Yes
H6: PI -> PQ -> SAT -> LOY	0.063	0.014	4.549	< 0.001	0.039	0.093	/	/	Yes

Source: Author's calculation

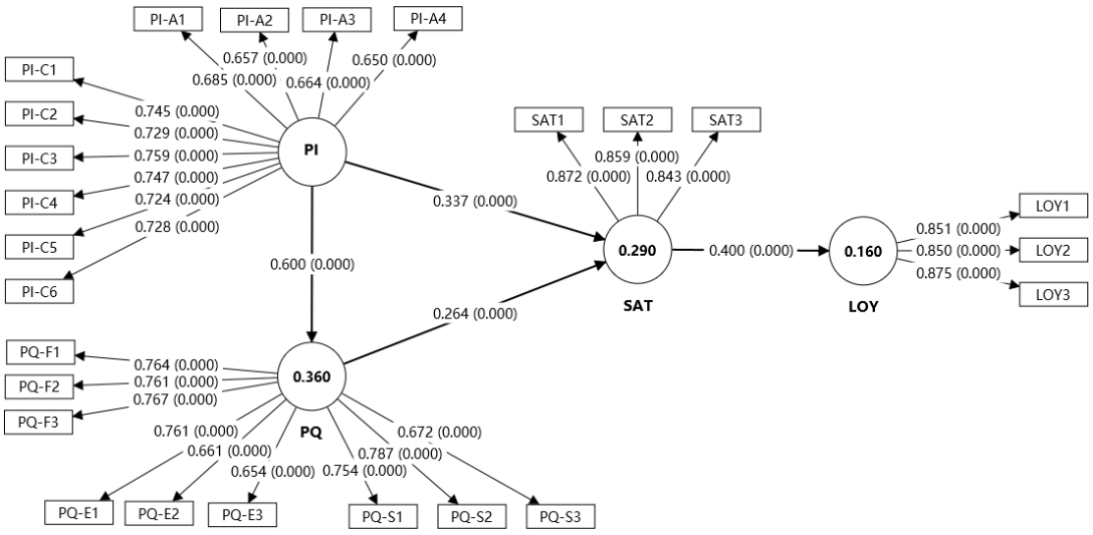


Figure 3: Structural Equation Model with Bootstrapping Results
Source: Author's calculation

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Mediation Analysis

The indirect-effect results further confirmed the mediating functions of satisfaction and perceived quality in the relationship between park image and loyalty. The results of the bootstrap method showed that all mediating paths were statistically significant (see Table 5). Specifically, the indirect effect of park image on loyalty through satisfaction was significant (H5a: $\beta = 0.135$, $t = 5.659$, $p < 0.001$), confirming that visitors' emotional satisfaction mediated the impact of the overall park image on their loyalty intentions. Similarly, the indirect path of PQ→SAT→LOY was significant (H5b: $\beta = 0.105$, $t = 4.843$, $p < 0.001$), which indicated that the perception of facility quality and environmental maintenance indirectly improved visitors' loyalty through satisfaction. In addition, the serial mediation effect (H6: PI → PQ → SAT → LOY) was also significant ($\beta = 0.063$, $t = 4.549$, $p < 0.001$), indicating that park image indirectly drove loyalty through the cognitive-emotional sequence: improved quality perception enhanced satisfaction and ultimately promoted revisit intention and public recommendation behaviour. The above results jointly support the proposed serial mediation mechanism based on the S-O-R theoretical framework.

Explanatory Power and Predictive Relevance

The explanatory power of the structural model was assessed using R^2 and adjusted R^2 values. As shown in Figure 3, the model explained 36.0% of the variance in perceived quality, 29.0% of the variance in satisfaction, and 16.0% of the variance in loyalty, with adjusted R^2 values of 0.359, 0.287, and 0.158, respectively. In addition to explanatory power, predictive relevance was assessed using Q^2 values. The Q^2 values for perceived quality, satisfaction, and loyalty were 0.353, 0.240, and 0.135, respectively, all exceeding zero and therefore indicating predictive relevance. Overall, the model showed moderate explanatory and predictive relevance for perceived quality and satisfaction, while the explanatory power for loyalty was relatively limited.

DISCUSSION

The empirical results of this study validate the structural relationships proposed within the S-O-R framework and clarify the psychological mechanism by which park image, perceived quality, and satisfaction jointly shape visitors' loyalty. The establishment of the H1 hypothesis confirms that the park image is a strong leading factor of perceived quality. In the context of Chengdu, perceived quality is not only an assessment of physical facilities, but also a social constructivist cognitive judgment influenced by the symbolic meaning carried by the park image. When visitors internalise the image of "modern, ecological, and cultural park" (PIC2, PIC6), they still tend to think that the maintenance level and facility quality are excellent, even if there are minor defects. This finding confirms Wei

and Zhang (2023), who argue that symbolic authenticity often surpasses functional practicality in shaping urban visitors' perceptions.

The study found that both park image and perceived quality were significant drivers of visitor satisfaction, supporting hypotheses H2 and H3. It is worth noting that the influence of park image is slightly stronger than that of perceived quality (see Figure 3), which is different from the view that traditional landscape research emphasises the dominant role of physical space patterns (Bi et al., 2024). This suggests that in high-density urban environments such as Chengdu, the emotional resonance and cultural connotations carried by the image of the park may provide a stronger sense of psychological satisfaction than simple functional facilities. Therefore, satisfaction becomes a complex result jointly shaped by the physical supply and symbolic meaning of the park (Wu et al., 2018).

The positive relationship between satisfaction and loyalty (H4) is consistent with findings in park, tourism, and environmental behaviour studies (Zhan et al., 2024), confirming satisfaction as the critical organismic response that triggers the behavioural response, like revisiting and recommending. However, the relatively low explanatory power for loyalty ($R^2 = 0.160$) should be interpreted cautiously. It suggests that satisfaction explains only part of visitors' loyalty intentions, as continued park use may also be shaped by residential proximity, travel time, daily routines, accessibility, and activity opportunities. This finding indicates that loyalty in public urban parks is influenced by both psychological evaluation and spatial use conditions, which is consistent with the park accessibility perspective (Tan et al., 2022).

The mediation analysis further clarified the influence mechanism of park image and perceived quality on visitors' loyalty. The significant simple mediation effect of satisfaction (H5a and H5b) confirmed that emotional satisfaction is the core path of image and quality affecting loyalty intention, which is consistent with the existing research conclusions in the fields of tourism and environmental psychology (Jaafar et al., 2025).

In addition to the above verification results, the key theoretical contribution of this study is the verification of the serial mediation path (H6: PI→PQ→SAT→LOY). Although the effect size of this path is relatively small ($\beta = 0.063$), it reveals the cumulative and sequential characteristics of cognitive-emotional processing in the urban park experience. Visitors are first attracted by the symbolic image of the park, and then assess its credibility through perceived quality, and finally form satisfaction based on experience verification, and then generate loyalty intentions. In this sequence, perceived quality becomes the key bridge between image construction and emotional response, indicating that image attractiveness alone is not enough to maintain loyalty, and it must be achieved through continuous experience verification.

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From a planning perspective, this hierarchical mechanism is consistent with the Park City approach. Park image can create initial recognition, but sustained visitor loyalty depends on whether perceived quality and satisfaction are supported by the everyday park experience. Therefore, urban park planning should align image construction with improvements in recreational functions, accessibility, safety, ecological landscape maintenance, and culturally meaningful public-space experience.

CONCLUSION

This study shows that visitor loyalty in Chengdu's urban parks is formed through a structured cognitive-emotional process rather than an isolated direct effect. Park image serves as the initial cognitive anchor, perceived quality verifies this image through on-site experience, and satisfaction translates these evaluations into loyalty intentions. The validated serial mediation path from park image to perceived quality, satisfaction, and loyalty extends the application of the S-O-R model to non-commercial urban green spaces and shows that loyalty to public parks depends on the fit between symbolic image and experiential confirmation (Zhao et al., 2025).

From a planning perspective, the findings suggest that Park City development should not rely only on image construction or physical provision, but should continuously improve the everyday quality of park experience. Planning actions should strengthen recreational functions, accessibility, safety, ecological landscape maintenance, and culturally meaningful public-space experiences, so that positive park perceptions can be translated into satisfaction, revisit intention, and public recommendation (Bi et al., 2024; Zhan et al., 2024).

Several limitations should be acknowledged. This study focused on two representative comprehensive parks, adopted a cross-sectional design, and used convenience sampling, which may limit the generalisability of the findings. Although the survey covered different locations and time periods, the sample mainly represents surveyed park users rather than all Chengdu residents or non-users of urban parks. In addition, because People's Park and Tianfu Art Park differ in historical background and design orientation, the aggregated model should be interpreted as an overall mechanism across the two selected parks rather than as park-specific evidence. Future research could include a wider range of park types and use longitudinal, comparative, or probability-based sampling methods to further examine differences in the formation mechanism of visitor loyalty.

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ANALYZING THE IMPACT OF SLOW-TRAFFIC NETWORK CONFIGURATION ON TOURIST EXPERIENCE AND COMMERCIAL VITALITY: A SPACE SYNTAX STUDY OF WUHAN'S HUBU LANE HISTORIC DISTRICT

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Abstract

Based on the theory of Space Syntax, this study takes the Hubu Lane historic district in Wuhan as a case study. Through axial line analysis, spatial characteristics of the pedestrian and non motorized network were quantified, including connectivity (mean 2.84±1.70), integration (global mean 0.89±0.16), and intelligibility (R^2=0.66). Combined with 401 tourist questionnaires, the impact of these spatial features on commercial vitality and tourist experience was examined. The results show that 62.58% of slow traffic routes near scenic entrances have a depth value between 5 and 10, indicating relatively poor accessibility. Areas with high integration (e.g., the intersection of Jiefang Road and Minzhu Road) show a significant correlation with shop density ($r=0.42$, $p<0.05$). Accordingly, recommendations such as adding wayfinding signage and improving the connectivity of branch roads are proposed.

Keywords: Space Syntax, Historic District, Pedestrian Network, Tourist Experience, Commercial Vitality

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INTRODUCTION

Historic districts are essential components of urban spatial structure, preserving era-specific architecture and street layouts while sustaining mixed-use patterns of residential and commercial activities(Lyu et al., 2023; Khan et al., 2022). Culturally, they embody unique local lifestyles and collective social memory (Rosetia, 2025)

Slow-traffic networks are increasingly important in historic districts facing urban renewal challenges (Lim et al., 2024). In tourism contexts, the quality of slow-traffic networks directly influences walking experience, visitor perception, and consumption behaviour (Yoshimura et al., 2025). Well-designed pedestrian environments extend visitors' dwell time, improve satisfaction, and increase commercial spending (Aranburu et al., 2016). Studies in diverse cultural heritage destinations, such as Madaba in Jordan, further confirm that spatial configuration significantly shapes tourist movement patterns and overall experience ((Jamhawi et al.,2023). Similarly, research on inclusive pedestrian network design in emerging urban districts of Bangkok (Nophaket et al., 2024) underscores the universal challenges and importance of integrated planning for walkability, which is also a key concern for historic districts like Hubu Lane.

Space Syntax Theory (Hillier, & Hanson, 1984) quantifies spatial characteristics such as connectivity, integration, and intelligibility, which influence human activities in urban spaces (Hillier, 1985). In tourism research, high-integration networks enhance tourist accessibility, while intelligibility correlates with exploration willingness (Chen et al., 2025; Zhang et al., 2023).

This paper employs space syntax to investigate the impact of slow-traffic network configuration on tourist experience and commercial vitality in historic districts.

Despite growing Space Syntax literature in urban studies, limited attention has been paid to its application in historic commercial districts from the tourist experience and commercial vitality perspective. This study addresses three research gaps: (1) lack of empirical studies linking Space Syntax metrics to tourist perceptual data; (2) insufficient understanding of how spatial indicators impact tourist experience; and (3) absence of integrated optimization strategies balancing tourism development with heritage conservation. Accordingly, this study addresses:

(1) How do spatial characteristics of slow-traffic networks influence tourist behaviour?
(2) What are the relationships between spatial indicators and tourist experience?
(3) How can spatial optimisation promote tourism development and cultural preservation?

This study advances research by: (1) integrating objective spatial analysis with subjective tourist survey data; (2) proposing a "double-helix" framework bridging efficiency and experience; and (3) providing empirically-grounded spatial parameter thresholds for historic district planning.

Synthesis of Existing Research and Research Gaps

A critical review reveals three gaps in existing literature. First, studies on pedestrian environment and tourist satisfaction focus on general urban contexts, overlooking historic commercial districts with unique spatial constraints (Chen et al., 2025). Second, Space Syntax applications in tourism emphasize macroscopic tourist flows, with limited attention to micro-level relationships between spatial configuration and perceptual experience (Hillier & Hanson, 1984; Lyu et al., 2023). Third, spatial efficiency and cultural experience are treated as separate dimensions, lacking an integrated framework capturing their synergistic effects.

OVERVIEW OF THE STUDY AREA AND METHODOLOGY

Overview of the Study Area

The Hubu Lane historic district, located in Wuchang District along the Yangtze River, began taking shape during the Ming Dynasty. Its slow-traffic network radiates outward from the central axes of Minzhu Road and Jiefang Road.

Today, Hubu Lane is one of Wuhan's most bustling commercial areas, home to numerous time-honoured brands. It attracts large numbers of visitors to historical landmarks such as the Yellow Crane Tower and the Wuchang Uprising Memorial Hall, while also functioning as a residential neighbourhood with high population density.

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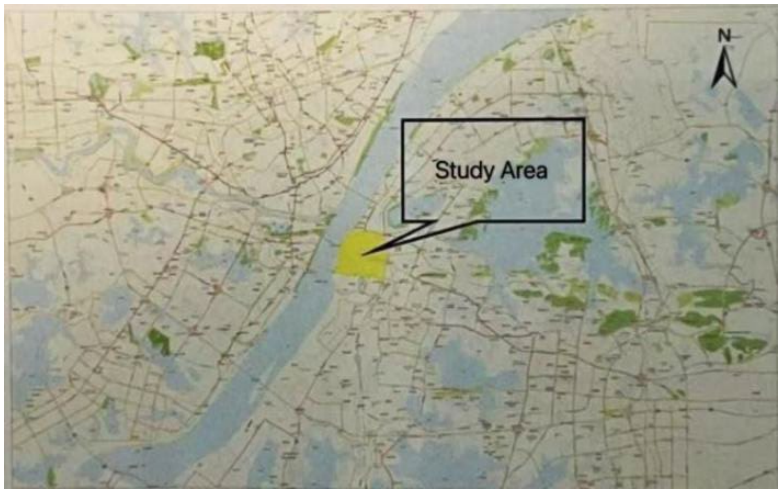


Figure 1: Location and Boundary Map of Hubu Lane Historic District, Wuhan, showing the study area boundary (red dashed line), the axial network of slow-traffic passages, and key road names. The map includes a scale bar and north arrow for spatial reference. Base map source: Wuhan Urban Planning Bureau (2024), processed by the authors.

Overview of Research Methods

Space Syntax Theory is a method for describing and analysing spatial layouts, first proposed by Bill Hillier (1984).As a theoretical approach to analysing urban spatial structure, it is fundamentally based on graph theory principles. The theory divides the overall space into a series of local units according to human movement patterns and calculates the distributional relationships among these local spaces (Hillier, 1985).Through research expansion by scholars both in China and internationally, Space Syntax has been widely applied in fields such as urban planning (Ramdlani et al., 2025; Zhang et al., 2023), road network design (Niu & Wang, 2025), and land use optimization (Gao & Fang, 2025).

Axial analysis was conducted using Depthmap 10.0. First, an axial map of all slow-traffic passages within the study area was created in AutoCAD, based on road network data from the Wuhan Urban Planning Bureau and calibrated by on-site surveys. The axial map was then imported into Depthmap to compute Connectivity, Control Value, Global Integration (radius R=n), and Local Integration (radius R=3) for each axial line. Intelligibility was derived from the linear regression of Global Integration on Connectivity, with the coefficient of determination (R^2) indicating the extent to which local spatial cues enable inference of the global layout. Finally, each of the 401 questionnaire responses was geolocated to its nearest axial line, assigning corresponding spatial metrics to each respondent for subsequent association analysis.

Questionnaire Survey Design and Implementation

A questionnaire survey was conducted in October 2024 to complement spatial analysis with tourist perceptual data. Designed based on established tourism experience scales (Aranburu et al., 2016; Jamhawi et al., 2023) the instrument comprised four sections: (1) demographic characteristics; (2) spatial behavior patterns; (3) perceptual evaluations of the slow-traffic network (accessibility, wayfinding ease, comfort, safety) measured on a 5-point Likert scale; and (4) open-ended suggestions.An overall Tourist Experience Score was computed as the mean of all items across the four dimensions, with higher scores indicating better tourist experience. This operationalization follows established practice in urban tourism perception studies (Aranburu et al., 2016; Jamhawi et al., 2023).

A pilot test with 30 respondents refined question wording. The final survey was administered at 12 purposively selected locations covering high-integration zones (Jiefang Road, Minzhu Road, Dushuyuan Road), medium-integration zones (Yanzhi Road, Qipan Road, Dezheng Bridge), and low-integration zones (Hongxiang Lane, Doujiying, Houzhangmen, Dezheng Lane, Sanfo Lane, Tiyu Street, and the entrance of Tanhualin), ensuring perceptual data collection across varied network configurations. Of 450 distributed questionnaires, 401 valid responses were collected (response rate: 89.1%), exceeding the minimum requirement for 95% confidence level ($n > 384$).

Data Integration Strategy

Spatial and questionnaire data were integrated using a mixed-methods approach. Each response was geo-located to the nearest axial line, assigning spatial metrics (connectivity, integration, depth) to perceptual data. Statistical analyses examined relationships between spatial metrics and tourist perceptions, including Pearson correlation for continuous variables and one-way ANOVA comparing perceptual ratings across integration zones. All statistical analyses were performed using SPSS version 26.0, with significance set at $p < 0.05$. Commercial vitality was operationalized as a multi-dimensional construct comprising shop density (establishments per 100m), retail variety (number of business categories), observed pedestrian flow, and tourist dwell time (minutes, n=401), derived from field surveys and questionnaire responses.

SPATIAL ANALYSIS OF THE SLOW-TRAFFIC NETWORK

Analysis of Connectivity and Control Value

Connectivity refers to the number of direct connections a space has with other spaces, indicating spatial permeability. Control value reflects the degree of influence a space exerts over its directly connected spaces.

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Table 1: Descriptive Statistics of Connectivity and Control Values in Hubu Lane District

Metrics	Mean	Variance	Maximum	Minimum
Connectivity	2.8405	1.7014	11	1
Control Value	0.9995	0.6543	4.1667	0.1111

Source: Depthmap axial analysis.

The connectivity analysis revealed a clear hierarchy in the slow-traffic network. As shown in Table 2, primary routes such as Jiefang Road and Minzhu Road exhibited high connectivity values (9-11), indicating strong spatial permeability. Secondary routes including Dushuyuan Road (connectivity=11), Yanzhi Road (connectivity=8), and Qipan Road (connectivity=7) serve as important connectors between major arteries and local spaces. Tertiary lanes such as Hongxiang Lane (connectivity=1) and Doujiying (connectivity=2) showed minimal connectivity, reflecting their limited role as dead-end residential alleys.

Control values followed the same hierarchical pattern. Dushuyuan Road exhibited the highest control value (4.17), indicating strong influence over surrounding spaces, while Hongxiang Lane showed the lowest (0.11), reflecting minimal spatial influence. The connectivity hierarchy across the network is spatially structured as follows. Primary routes (Jiefang Road, Minzhu Road, Dushuyuan Road) exhibit the highest connectivity values (9–11), serving as the main axes of the slow-traffic system. Secondary routes (Yanzhi Road, Qipan Road) show moderate values (7–8), functioning as connectors between primary and tertiary spaces. Tertiary lanes (Hongxiang Lane, Doujiying) display the lowest values (1–2), reflecting their role as dead-end residential alleys with limited permeability. This three-tier spatial structure is consistent with observed pedestrian flow patterns and road classification.

Table 2: Connectivity and Control Values by Road Classification in Hubu Lane District

Road/Lane Name	Classification	Connectivity Value	Control Value
Jiefang Road (central)	Primary	11	4.02
Minzhu Road (central)	Primary	10	3.89
Dushuyuan Road	Secondary	11	4.17
Yanzhi Road	Secondary	8	3.25
Qipan Road	Secondary	7	2.89
Doujiying	Tertiary	2	0.23
Hongxiang Lane	Tertiary	1	0.11

Note: Values calculated using Depthmap software (version 10.0). Higher connectivity indicates greater spatial permeability; higher control value indicates stronger influence on adjacent spaces.

Source: Depthmap axial analysis.

Analysis of Integration

In Space Syntax, integration is commonly used to represent the degree of spatial clustering. It is a standardised measure based on the average depth from one spatial element to all others within the system and can be categorised into global integration and local integration. Areas with higher integration values generally exhibit greater spatial accessibility and tend to attract more spatial exploration activities. Global integration reflects the overall spatial cohesion of the entire system, while local integration indicates the concentration of accessibility within a subsystem over a defined topological radius (typically 3 or 5 steps).

$$RA_i = \frac{2(MD_i - 1)}{n - 2} \quad (1)$$

Where MDi is the mean depth value of axial line i (see Section 2.2), and n is the total number of axial lines in the system. To eliminate the influence of network scale on the results, RAi is further standardized into the real relative asymmetry RRAi:

The normalization $RRAi = \frac{RA_i}{D_n}$ coefficient Dn is calculated as: (2)

$$D_n = \frac{2\{n[\log_2(\frac{n+2}{3} - 1) + 1\}}{[(n-1)(n-2)]} \quad (3)$$

Integration Ii is typically defined as 1/RRAi. The "integration" values computed in this study using Depthmap software correspond to this standardized result, with global integration (radius R=n) used to analyze the overall spatial structure of the district.

The integration analysis reveals that core axial lines account for 8.28% of the network, with a mean global integration value of 0.88 (SD=0.16). High-integration areas are concentrated in the western part of the district, particularly along Jiefang Road and Minzhu Road, where values are highest. Integration decreases outward from these corridors, indicating they serve as the main arteries of the slow-traffic network. The intersection of these two roads demonstrates the highest accessibility and pedestrian flow, aligning with the distribution of major commercial facilities. Low-integration areas are located in interior residential zones, characterised by limited accessibility and lower spatial exploration.

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Table 3: Analysis of Integration Data

Integration Value Range	Number of Axial Lines	Percentage (%)
0-0.69018	27	8.28
0.69018-0.85923	128	39.26
0.85923-1.02828	112	34.36
1.02828-1.19733	47	14.42
1.19733-1.36637	12	3.68

Note: Mean = 0.88768, SD = 0.15933, Min = 0.54308, Max = 1.33667.
Total number of axial lines (N) = 326.

In summary, the integration analysis reveals a clear "single-core radial" structure centred on the Jiefang-Minzhu Road intersection, with values decreasing outward. This pattern aligns with road hierarchy and pedestrian flow, confirming that high-integration areas (>1.197) correspond to commercial zones, while low-integration areas (<0.690) are interior residential alleys. This spatial structure fundamentally shapes pedestrian distribution and provides a topological basis for analysing impacts on commercial vitality and tourist experience.

The spatial distribution of integration values across the axial network is described as follows. High-integration areas (values > 1.197) are concentrated along Jiefang Road, Minzhu Road, and their intersection, corresponding to the primary commercial corridors. Medium-integration areas (0.859–1.197) cover the surrounding secondary streets, including Yanzhi Road, Qipan Road, and Dushuyuan Road. Low-integration areas (values < 0.690) are located in interior residential lanes such as Hongxiang Lane and Doujiying. This gradient pattern is numerically summarised in Table 3, and its relationship with commercial vitality is reported in Table 4.

Statistical Validation of Integration-Commercial Vitality Relationship

Given the exploratory nature of this study and the limited spatial extent of the Hubu Lane historic district (approximately 0.5 km²), the analysis focuses on bivariate and stratified correlation analyses rather than multivariate regression modelling. The spatial scale — comprising 326 axial lines within a compact historic district — makes spatial regression approaches designed for large-scale urban networks less critical, as spatial autocorrelation effects are substantially reduced at this micro-scale. Nevertheless, the correlation patterns reported in Table 4 provide robust empirical evidence for the associations between spatial configuration, commercial vitality, and tourist experience, which aligns with the study's primary objective of identifying key spatial indicators rather than establishing causal relationships.

To empirically validate the relationship between spatial integration and commercial vitality, shop density data were collected along each axial line in the study area. Commercial vitality was operationalized as the number of retail establishments per 100 meters of street frontage. Pearson correlation analysis revealed a statistically significant positive correlation between global integration values and shop density ($r = 0.42$, $p < 0.05$), confirming that areas with higher spatial accessibility tend to concentrate more commercial activities. This finding is consistent with previous research (Zhang et al., 2023) and provides empirical support for the theoretical proposition that spatial configuration influences commercial agglomeration.

Further analysis revealed a non-linear pattern: the positive correlation was strongest for integration values between 0.8 and 1.2 ($r = 0.51$, $p < 0.01$), but weakened for values exceeding 1.2 ($r = 0.23$, $p > 0.05$). This suggests that beyond a certain threshold, further increases in integration may yield diminishing returns for commercial vitality, potentially due to congestion effects or spatial homogenization.

Table 4: Correlation between Integration Values and Commercial Vitality

Commercial Indicator	Correlation with Global Integration (r)	p-value	Sample Size (n)
Shop density (per 100m)	0.42	0.012	326
Retail variety (number of categories)	0.38	0.024	326
Pedestrian flow (observed count)	0.47	0.008	48 observation points
Tourist dwell time (minutes)	0.35	0.031	401 respondents

Source: Field survey data collected in this study, October 2024 (n=401).

Intelligibility, also referred to as intelligibility or intelligibility measure, generally describes the extent to which what is visible from a local space (its immediate connections) correlates with its position in the global spatial system. It quantifies how easily pedestrians can infer the overall layout from their local vantage point, thereby guiding navigation. Typically, intelligibility is measured by the correlation between a local variable (Connectivity, C) and a global variable (Global Integration, I).

It is mathematically defined as the coefficient of determination (R2) of the linear regression of global integration on connectivity. The formula is given by:

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$$R^2 = \frac{[\sum(C_i - \bar{C})(I_i - \bar{I})]^2}{\sum(C_i - \bar{C})^2 \sum(I_i - \bar{I})^2} \quad (4)$$

The intelligibility of the Hubu Lane district's slow-traffic network was quantified by calculating the coefficient of determination (R2) from the linear regression of global integration on connectivity. The key statistical results of this analysis are presented in Table 5.

Table 5: Key Metrics for Intelligibility Analysis

Metric	Value
Sample Size (N)	326
Coefficient of Determination (R^2)	0.66
Regression Slope	2.58
Regression Intercept	0.24

Source: Depthmap axial analysis.

The R^2 value of 0.66 indicates a moderate correlation between connectivity and global integration, signifying a moderate level of network intelligibility. This implies that pedestrians can reasonably infer the overall spatial structure from local settings, reflecting a logical and human-centric layout that aids wayfinding.

OPTIMIZATION SUGGESTIONS FOR THE SLOW-TRAFFIC NETWORK IN THE HUBU LANE DISTRICT

Based on Space Syntax analysis and questionnaire surveys, the following optimisation proposals are put forward for Hubu Lane.

Enhancing Accessibility of Slow-Traffic Spaces

Based on the survey results (Figure 4) , areas with low connectivity — including Hongxiang Lane and Doujiying — were identified by respondents as having severely limited tourist accessibility.Accessibility to key destinations (Yellow Crane Tower, Hubu Lane commercial street, Tanhualin Cultural and Creative Park) is hindered by low connectivity values due to enclosed spaces (old residential compounds, schools, hospitals). Priority should be given to opening enclosed areas and installing visitor guidance systems with wayfinding signage and digital navigation (e.g., QR-code-linked maps).

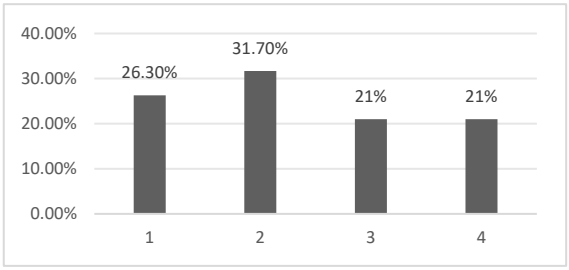


Figure 4: Survey Results on Spatial Accessibility Optimization Priorities (n=401, multiple responses allowed)

Survey respondents identified key accessibility improvements, including establishing additional slow-traffic routes, opening enclosed zones to improve connectivity, enhancing public transit integration through bus stop signage, providing bicycle parking points, and implementing digital guidance systems with wayfinding signs.

Optimising the Intelligibility and Experience of Slow-Traffic Spaces

The intelligibility analysis ($R^2 = 0.66$) indicates a moderate correlation between local connectivity and global integration, suggesting that visitors can partially infer the overall layout from local cues, yet wayfinding remains challenging in low-connectivity alleys, as reflected in the safety concerns raised by survey respondents (Figure 5). Safety concerns ranked highest in the survey, with 17.8% of respondents prioritizing separation of vehicle, bicycle, and pedestrian lanes, and 16.2% requesting additional crosswalks and footbridges to public institutions.

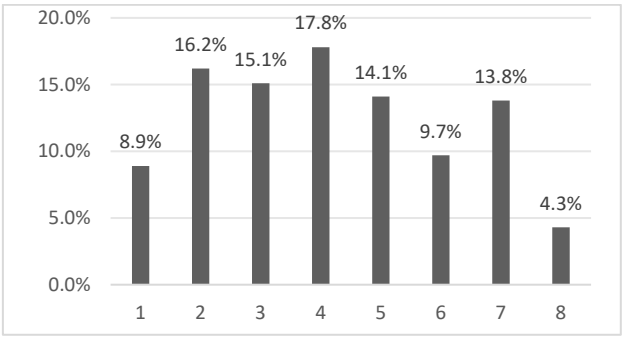


Figure 5: Survey Results on Safety Optimization for the Slow-Traffic Network.

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Safety priorities ranked by respondents include separating vehicle, bicycle, and pedestrian lanes (17.8%), adding crosswalks and footbridges to public institutions (16.2%), improving traffic signals and road markings, increasing police presence during peak hours, enhancing nighttime lighting, and improving bus stop environments.

Improvement of Slow-Traffic Service Facilities

The correlation analysis shows that integration values between 0.8 and 1.2 have the strongest positive correlation with commercial vitality ($r = 0.51$, $p < 0.01$), which aligns with survey respondents' facility improvement priorities (Figure 6). Survey results indicate that 51.32% of users primarily use the slow-traffic network for leisure, highlighting the importance of user-friendly facilities. In densely commercialised areas, expanding pedestrian spaces and enhancing street amenities (benches, green shading) can improve visitor comfort, extend dwell time, and boost surrounding businesses.

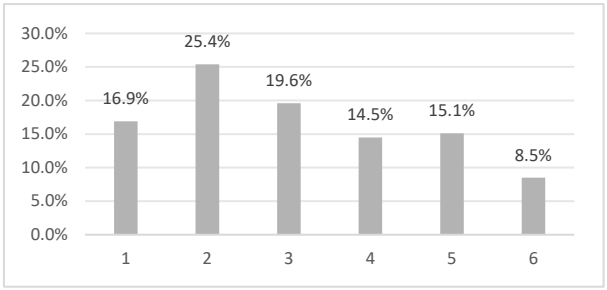


Figure 6: Survey Results on Facility Optimization Priorities for Slow-Traffic Network (n=401, ranked by frequency of mention)

Facility improvement priorities identified in the survey include clearer signage, wider walkways, disability facilities such as tactile paving and wheelchair ramps, rest amenities including benches, drinking fountains and public toilets, tree planting for shading, streetscape aesthetic enhancements, and widened pedestrian spaces in commercial areas.

MANAGEMENT IMPLICATIONS AND TOURISM DEVELOPMENT STRATEGIES

This study, through spatial syntax analysis and visitor behaviour surveys, reveals the intrinsic relationship between the spatial characteristics of the slow-traffic network in the Hubu Lane district and the tourist experience.

In terms of tourism route optimization, the study found that slow-traffic routes with depth values greater than 8 (e.g., Hongxiang Lane, Doujiying, etc.)

significantly hinder the tourist experience. To address this issue, a systematic transformation of tourism circulation paths is recommended. High-depth routes (e.g., Hongxiang Lane, Doujiying) should be transformed into thematic pedestrian paths connecting major attractions, incorporating heritage elements and AR technology to enhance visitor experience and extend dwell time. This approach not only addresses accessibility issues but also enriches the tourism experience. Furthermore, establishing a comprehensive multilingual tourism signage system is crucial. Installing guide signs in Chinese, English, Japanese, and Korean at key nodes, clearly indicating walking times to major attractions, would significantly enhance the convenience for international visitors.

The construction of a smart tourism service system must fully account for spatial characteristics. Research indicates that areas with integration values between 0.8 and 1.0 (such as Jiefang Road) are most suitable for establishing tourist service centres. These zones naturally attract high pedestrian traffic and can provide visitors with essential services such as luggage storage and guided tours. When planning rest nodes at points where depth values change abruptly, it is advisable to install resting benches and drinking water facilities that reflect local characteristics. This approach not only meets basic visitor needs but also strengthens regional cultural identity.

Developing a "Strolling Hubu Lane" WeChat mini-program is a crucial measure to enhance service efficiency. By integrating features such as AR-based real-scene navigation, audio commentary, and merchant recommendations, the program can effectively compensate for areas with lower intelligibility in the district.

For integrated cultural-tourism-commercial development, spatial characteristics suggest differentiated formats. Core areas with integration values greater than 1.0 exhibit the strongest commercial vitality and are ideal for focusing on cultural-creative retail and specialty catering, including formats like intangible cultural heritage demonstration and experience shops. Secondary road areas are more suitable for developing traditional handicraft stores following the “shop-in-front, workshop-in-back” model, which enhances authenticity while ensuring commercial viability. Preserving original residential neighbourhoods and developing immersive tourism products such as the “Old Wuhan Life Experience” further allows visitors to engage with authentic urban culture.

Tourism safety management requires addressing mixed pedestrian-vehicle traffic, survey results recommend restricting vehicle access during peak tourism hours (10:00–20:00) and establishing dedicated tourist passageways. Distinct pavement materials can separate pedestrian and cycling zones within limited spaces, while tourist police points at major intersections can enhance safety and provide visitor assistance.

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THEORETICAL CONTRIBUTIONS AND RESEARCH OUTLOOK

This study contributes to tourism and spatial planning theory by adapting space syntax metrics to historic districts. It proposes increasing depth-value tolerance by 30% and reveals a nonlinear integration-experience relationship: beyond 0.95, further integration risks damaging historic features despite commercial gains. These findings provide key parameters for balancing tourism development with heritage conservation.

In terms of the theoretical framework, this study innovatively proposes a "double-helix" development model that organically integrates the two dimensions of spatial efficiency and cultural experience. It is important to emphasize that this model is presented as a conceptual framework derived from the empirical findings of this study, rather than a pre-validated theory. The spatial-efficiency helix emphasizes enhancing visitor flow capacity through node improvements, while the cultural experience helix focuses on strengthening tourism appeal through heritage preservation. The synergistic development of these two helices is identified as key to improving tourism quality. Future research should empirically test the validity and generalizability of this model across different historic districts and cultural contexts.

This study also has certain limitations that warrant improvement. In terms of data collection, future research could incorporate behavioural data, such as eye-tracking trajectories of visitors, to more precisely capture the relationship between spatial features and tourism behaviour. Methodologically, there is a need to develop more refined quantitative tools for cultural variables, such as deep-learning-based street-view image analysis. Furthermore, long-term tracking studies will help reveal the interactive evolution between tourism activities and spatial form.

Future research should explore the impact of intelligent technologies on tourism space, cross-cultural differences in spatial cognition, and the development of tourism-specific spatial evaluation systems.

The theoretical value of this study lies in establishing an analytical framework of "tourism space syntax," achieving a transition from physical spatial analysis to tourism-experience research. In practical terms, the results provide a scientific basis for decision-making in tourism planning for historic districts, particularly the proposed spatial parameter thresholds and the "double-helix" development model, which can directly guide specific planning practices. Follow-up research may further explore pathways for integrating traditional Chinese spatial wisdom with modern tourism planning, laying the groundwork for developing a tourism spatial theory system with Chinese characteristics.

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CONFLICT OF INTEREST STATEMENT
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THE RELATIONSHIP BETWEEN STREETSCAPE QUALITY AND PLACE ATTACHMENT IN THE HISTORIC TOURIST CITY, CHINA

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Abstract

Streetscape quality is crucial for fostering residents' place attachment. The research explores the influence of perceived streetscape quality on residents' place attachment. Streetscape quality contains four dimensions: safety, comfort, walkability, and imageability. Place attachment includes place identity and place dependence. A total of 428 valid questionnaires were collected from residents in Zhengding Ancient City, China. The data were analysed using structural equation modelling (SEM). The results indicate that different dimensions of streetscape quality have differential effects on place identity and place dependence. Comfort and imageability positively impact place identity. Safety, comfort and walkability positively influence place dependence. These results provide valuable guidance for local governments to enhance streetscape quality.

Keywords: Streetscape Quality, Place Attachment, Historic Tourist City

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INTRODUCTION

Place attachment (PA) refers to the emotional bond that people develop with a place (Castro et al., 2023). It plays an important role in shaping residents' attitudes toward spatial changes and urban development (Darabaneanu et al., 2024). The success of urban planning and governance initiatives often depends on residents' acceptance of spatial changes and their willingness to participate in maintaining local environments. In this sense, PA can serve as an important link between spatial policies and residents' behavioural responses.

Many historic cities have encouraged tourism to preserve cultural heritage and strengthen local economies (Kholis & Nugroho, 2023). As tourism expands, historic streets, as the main public spaces, accommodate visitors' activities and residents' everyday lives. Tourism development often reshapes streets through changes in land use, commercial activities, and spatial organisation, which may alter how residents use and experience street spaces.

As shown in Figure 1, residents previously used the street for daily activities such as shopping and social interaction, and leisure. However, these activities have declined after tourism development. The street has become quieter outside peak tourist periods. This suggests that the relationship between residents and the street is changing, making it important to understand how streetscape quality (SQ) influences residents' PA.



Figure 1: Changes in Residents' Street Use after Tourism Development
Source: Author

Previous research has examined a range of factors influencing PA, grouped into three categories: social, demographic, and physical (Lewicka, 2010). Social factors, such as social ties and community interaction, are associated with stronger emotional connections to place (Novotný et al., 2026). Demographic characteristics, including length of residence, age, homeownership,

community size, and socioeconomic status, also influence PA (Pacheco, 2025; Casakin et al., 2015). Physical environmental factors, such as spatial quality and urban features, affect people's experience and evaluation of their environments (Akoz & Ulusoy, 2025; Latip et al., 2023).

Despite these advances, limited research has examined the role of SQ in shaping PA (Lewicka, 2010). Most existing studies focus on neighbourhood characteristics or general urban environments, while relatively few examine streetscape directly. This gap is particularly evident in historic tourist areas, where tourism development changes the physical environment of streets. Moreover, the concept of SQ remains unclear, and a clear framework for understanding its dimensions and their influence on PA is still lacking. These limitations make it difficult to understand how changes in streetscape affect residents' emotional connections to place.

To address this gap, this study conceptualises SQ through four key dimensions: safety, comfort, walkability, and imageability. Based on place attachment theory, a model was developed to examine the effects of perceived SQ on PA. By examining residents' perceptions in a historic tourist city in China, this study provides new insights into the relationship between streetscape and PA in tourism contexts. It also contributes to theory and offers practical guidance for streetscape planning and management.

LITERATURE REVIEW

Streetscape Quality (SQ)

SQ refers to people's perception and evaluation of street environments. These perceptions are influenced by surrounding physical elements such as buildings, sidewalks, vegetation, and street facilities. Previous studies used different attributes to describe streetscapes, and no single framework has been widely accepted (Fidelista et al., 2025). However, safety, imageability, walkability, and comfort are among the attributes most frequently discussed in studies of streetscape perception (Abass & Tucker, 2021; Fu et al., 2024).

These attributes are also supported by research in urban design and environmental perception. Urban design studies show that people's experience of streets is influenced by safety conditions, pedestrian accessibility, environmental comfort, and the visual character of urban spaces (Harvey et al., 2015). Research on environmental perception also shows that visual and spatial features influence how people perceive urban environments (Qiu et al., 2021). These studies indicate that safety, walkability, comfort, and imageability are important elements in people's experience of streets.

These attributes are especially relevant in historic tourist areas. Tourism development often changes street functions, pedestrian activities, and the visual appearance of streets. Such changes affect residents' daily use and experience of

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street spaces. In this context, safety, walkability, comfort, and imageability are key aspects through which residents perceive changes in the street environment. Therefore, this study adopts these four dimensions to examine residents' perceived SQ in a historic tourist city.

Safety refers to the perceived risk of crime and public disorder (Jansson, 2019). Comfort is individuals' subjective evaluation of physical and psychological conditions (Yuhan et al., 2021). Walkability refers to the ease of movement along a street. Imageability is the quality of being distinct, recognisable, and memorable (Ewing & Handy, 2009).

Place Attachment (PA)

PA refers to the emotional bonds that individuals form with particular places (Williams & Roggenbuck, 1989). Humanistic geographers and sociologists have shown increasing interest in the relationship between people and place (Huang et al., 2025; Hoff & Løvoll, 2026). PA consists of three psychological components: affective, cognitive, and behavioural, which lead individuals or groups to develop attachment to a place (Low & Altman, 1992; Nguyen-Viet & Nguyen, 2026). Among these, the emotional component is the most commonly assessed (Chen & Dwyer, 2018).

Numerous researchers regard PA as a complex, multidimensional concept, although there remains no consensus on the exact dimensions involved (Soonsan & Somkai, 2023). Several theoretical approaches conceptualise PA as having one, two, three, or more dimensions (Castro et al., 2023; Chen & Dwyer, 2018). Among them, the bi-dimensional framework is the most widely used in tourism research. It has been validated and supported by empirical studies.

In the present research, PA was measured using two dimensions: place dependence (PD) and place identity (PI). PD reflects how well a location meets users' needs and goals (Khaidzir & Kamal, 2023). It is reflected in the physical features that support functional attachment, such as architecture, neighbourhoods, and local culture, which make a place distinct from others. PI refers to the symbolic significance of a place as a source of emotional attachment, which can make people's lives meaningful and support their sense of purpose (Ali et al., 2022).

Streetscape Quality and Place Attachment

PA develops progressively as individuals engage with their surrounding environment. Among public spaces, streets are the most frequently used by residents. They affect environmental experiences. SQ not only determines how people interact with these spaces, but also influences their emotional bonds with them. Thus, SQ provides a basis for strengthening users' PA.

SQ has a significant impact on residents' psychological states (Pereira et al., 2024). A well-designed streetscape can enhance residents' comfort during routine activities. This helps residents develop positive emotions. Emotional experiences form the basis for residents' PA. Previous studies suggest that better SQ encourages residents to use these spaces more actively. This can increase residents' frequency of use and length of stay. As a result, residents become more familiar with the street and develop functional dependence on it.

Research on the relationship between various dimensions of SQ and residents' PA remains limited. The existing literature suggests that perceived safety is a prerequisite for residents to walk and interact in public spaces (Khemri et al., 2020). Safety positively influences residents' emotional bonds with a space (Wei et al., 2025). Public spaces with comfortable microclimates and accessible resting areas can enhance users' positive feelings during activities in these spaces (Alsadun, 2019). Greater preference for a space is associated with stronger emotional attachment (Chen et al., 2020). Street walkability affects residents' frequency of use, and higher walkability increases their reliance on street functions (Eng & McCormack, 2025). Moreover, distinct and recognisable spaces contribute to users' emotional experiences (Zhang et al., 2024). Thus, the following hypotheses are proposed:

H1: Safety positively influences PI.
H2: Safety positively influences PD.
H3: Comfort positively influences PI.
H4: Comfort positively influences PD.
H5: Walkability positively influences PI.
H6: Walkability positively influences PD.
H7: Imageability positively influences PI.
H8: Imageability positively influences PD.

The research model of this study is shown in Figure 2.

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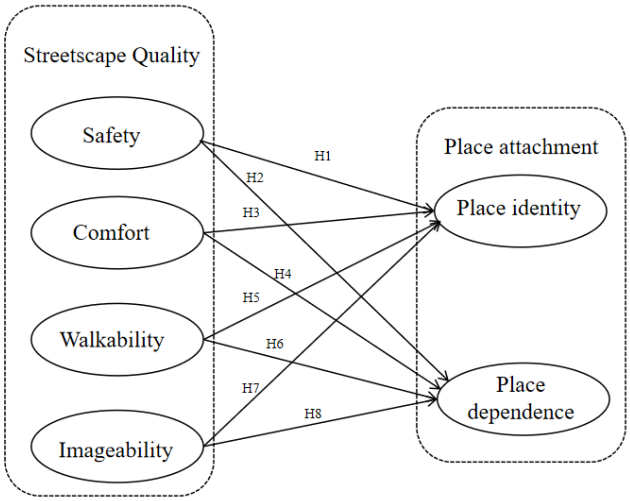


Figure 2: The Research Model
Source: Author

METHODOLOGY

Study Area

This research was conducted in Zhengding Ancient City. It is located in Zhengding County in the northern part of Shijiazhuang City, as shown in Figure 3. It is a nationally designated historic city. There are nine main streets in Zhengding (see Figure 4). The overall urban pattern follows a double-cross axis structure, and Yanzhao South Street lies along this axis (see Figure 5). Figure 6 shows the historical landscape conservation area of Zhengding Ancient City. Among the nine main streets, Yanzhao South Street is the only one located both along the urban axis and within the historical conservation area (see Figure 7).



Figure 3: Location Map
Source: Author



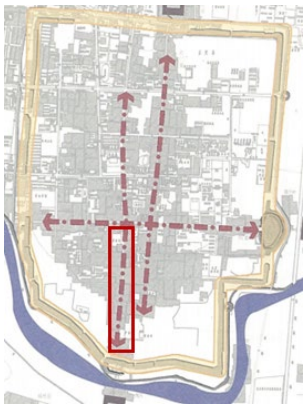




Figure 4: Main Streets **Figure 5:** Urban Axis **Figure 6:** Historic Reserve
Source of Figure 4-6: Adapted from Nichun (2016)

Street	Zhen Zhou	Zhong Shan	Yan Zhao	Dong Yuan	Dasi Qian	Wei Qian	Yang He	Kai Yuan	Zhao Yun
Historic Streets	√	√	√	√	√	×	√	√	√
Axis	√	√	√	×	×	×	×	×	×
Protection Area	×	×	√	×	√	×	×	×	×

Figure 7: Selection of Yanzhao South Street as the Study Site
Source: Author

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Following tourism development in 2013, Yanzhao South Street underwent major changes in its physical environment (Figure 8). Building façades were restored, street lighting and tourist facilities were upgraded, roadside parking was restricted, and the street layout for pedestrians and vehicles was reorganised. These changes created the physical setting in which residents experience and evaluate the current SQ.



Figure 8: Yanzhao South Street before Tourism Redevelopment (left) and after Tourism Redevelopment (right)
Source: Local government archives (left) and photograph by the author (right)

Sample and Design

Because this study examined residents' perceptions of SQ in a tourism development context, purposive sampling was used to select residents who were familiar with the street and had experienced its transformation over time. Since Yanzhao South Street was developed for tourism in 2013, this research focused on residents aged 30 years or above who had lived on Yanzhao South Street or in the surrounding residential communities for at least 15 years. These criteria were adopted to ensure that participants had sufficient knowledge of the street environment to provide informed evaluations of current SQ (Eisenhart et al., 2019).

The questionnaires were distributed in person in Yanzhao South Street and the surrounding residential communities. It included two sections. The first one collected demographic information. The second one contained items measuring perceptions of SQ and PA.

The questionnaire was adapted from existing scales reported in previous studies and modified for the context of historic tourist streets. The measurement items for SQ were drawn from previous research on streetscape perception (Kyle et al., 2004; Lalicic & Garaus, 2022). The PA items were based on established scales (Williams & Roggenbuck, 1989). All items were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). This survey received a total of 451 responses. Questionnaires with

incomplete responses or identical answers were removed. 428 valid responses were retained for analysis.

Data Analysis

The researchers first used SPSS to analyse the respondents' demographic characteristics. The measurement and structural models were then examined using SmartPLS. Gender, age, and length of residence were included as control variables in the structural model to account for potential demographic differences among residents.

RESULTS

Sampling Profile

Table 1 shows the demographic information. Among them, 238 were male (55.61%), and 190 were female (44.39%). By age, participants aged 31-40 years constituted the largest group (43.22%). It was followed by those aged 41-50 (32.71%) and 51-60 (17.06%). Moreover, most participants had lived in the area for more than 25 years (61.92%).

Table 1: Demographic Information of the Participants

		Number	%
Gender	Male	238	55.61
	Female	190	44.39
Age	31-40 y	185	43.22
	41-50 y	140	32.71
	51-60 y	73	17.06
	above 60 years old	30	7.01
Years of Residence	15-20 y	58	13.55
	21-25 y	105	24.53
	> 25 years	265	61.92
	Total	**428**	**100**

Source: Author's Calculation

Measurement Model

This study tested the reliability and validity of the measurement model. As shown in Table 2, the values of Cronbach's alpha, composite reliability (CR), factor loadings, and average variance extracted (AVE) exceeded 0.7, 0.7, 0.6, and 0.5, respectively. This indicates that the measurement model has satisfactory internal consistency and convergent validity (Sekaran & Bougie, 2010; Nunnally & Bernstein, 1994; Fornell & Larcker, 1981). The research employed the Fornell-Larcker criterion and the heterotrait-monotrait (HTMT) ratio to examine discriminant validity. The square root of AVE for each construct was higher than its corresponding correlation coefficient (Table 3). Moreover, all HTMT values

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were below 0.85 (Table 4). These findings indicate that the discriminant validity of the model is acceptable.

Table 2: Results of Reliability and Convergent Validity Analysis

Construct	Items	Factor Loadings	α	CR	AVE
SA	SA1	.804	.917	.934	.669
	SA2	.813			
	SA3	.803			
	SA4	.824			
	SA5	.797			
	SA6	.878			
	SA7	.803			
CO	CO1	.874	.878	.912	.674
	CO2	.830			
	CO3	.845			
	CO4	.813			
	CO5	.737			
WA	WA1	.854	.828	.886	.661
	WA2	.786			
	WA3	.873			
	WA4	.732			
IM	IM1	.862	.891	.925	.754
	IM2	.882			
	IM3	.889			
	IM4	.839			
PD	PD1	.805	.882	.911	.629
	PD2	.821			
	PD3	.741			
	PD4	.793			
	PD5	.797			
	PD6	.801			
PI	PI1	.824	.864	.907	.710
	PI2	.841			
	PI3	.883			
	PI4	.821			

Note: SA=safety, CO=comfort, WA=walkability, IM=imageability, PD=place dependence, PI=place identity
Source: Author's Calculation

Table 3: Discriminant Validity Using the Fornell-Larcker Criterion

Constructs	CO	IM	PI	PD	SA	WA
CO	.821					
IM	.402**	.868				
PI	.576**	.558**	.843			
PD	.563**	.458**	.452**	.793		
SA	.469**	.553**	.427**	.581**	.818	
WA	.401**	.380**	.303**	.545**	.365**	.813

Note: SA=safety, CO=comfort, WA=walkability, IM=imageability, PD=place dependence, PI=place identity
Source: Author's Calculation

Table 4: Discriminant Validity Using the HTMT Ratio

Constructs	CO	IM	PI	PD	SA	WA
CO						
IM	.455					
PI	.660	.633				
PD	.638	.515	.514			
SA	.520	.610	.477	.644		
WA	.467	.438	.353	.635	.413	

Note: SA=safety, CO=comfort, WA=walkability, IM=imageability, PD=place dependence, PI=place identity

Source: Author's Calculation

Structural Model

The study examined the explanatory and predictive power of the structural model (Table 5). The R^2 values for PI and PD were 0.460 and 0.527, both exceeding the recommended threshold of 0.33. This indicates that the model has acceptable explanatory power (Chin, 1998). The Q^2 values of these two endogenous latent variables were 0.316 and 0.325, both above zero. This suggests that the model has meaningful predictive capability (Henseler et al., 2009).

Table 5: R^2, R^2 Adjusted, and Q^2

	R^2	R^2 Adjusted	Q^2
PI	0.460	0.451	0.316
PD	0.527	0.519	0.325

Note: PD=place dependence, PI=place identity

Source: Author's Calculation

Collinearity among the predictor constructs was assessed using inner variance inflation factor (VIF) values. All inner VIF values ranged from 1.003 to 1.633, which were below the recommended threshold of 3.3, indicating that multicollinearity was not a concern in the structural model (Hair et al., 2022). The structural model showed an SRMR value of 0.042, which was below the recommended threshold of 0.08, indicating acceptable model fit (Hair et al., 2022).

Gender, age, and length of residence were included as control variables in the structural model. As shown in Table 6, none of these variables showed significant effects on PI or PD. The inclusion of the control variables did not materially change the structural relationships, the R^2 values, or the Q^2 values, indicating that the model remained robust after accounting for demographic characteristics.

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Table 6: Effects of Control Variables on Place Attachment

Path	β	t-Value	p-Value
Gender -> PI	-.024	.346	.729
Gender -> PD	.063	.924	.355
Age -> PI	-.021	.603	.546
Age -> PD	.004	.107	.914
Length of Residence -> PI	-.007	.208	.835
Length of Residence -> PD	.023	.766	.444

Source: Author's Calculation

Table 7 shows the results of the hypothesis tests. Safety had no significant effect on PI ($\beta = 0.026$, $p = 0.652$). H1 was rejected. Safety exhibited a significant positive effect on PD ($\beta = 0.308$, $p < 0.001$), supporting H2. Comfort was positively and significantly associated with both PI ($\beta = 0.418$, $p < 0.001$) and PD ($\beta = 0.273$, $p < 0.001$), supporting H3 and H4. Additionally, walkability had a significant effect on PD ($\beta = 0.299$, $p < 0.001$), while imageability significantly influenced PI ($\beta = 0.383$, $p < 0.001$), supporting H6 and H7. Conversely, no significant associations were found between walkability and PI ($\beta = 0.020$, $p = 0.676$) or between imageability and PD ($\beta = 0.064$, $p = 0.135$), leading to the rejection of H5 and H8. The overall structural model is illustrated in Figure 8.

Table 7: Hypotheses Testing

Hypotheses	Hypothesized path	β	f^2	t-Value	p-Value	Result
H1	SA -> PI	.026	.001	0.457	.647	Reject
H2	SA -> PD	.307	.122	5.972	.000	Support
H3	CO -> PI	.417	.227	7.364	.000	Support
H4	CO -> PD	.274	.112	5.412	.000	Support
H5	WA -> PI	-.021	.001	0.425	.671	Reject
H6	WA -> PD	.298	.145	5.993	.000	Support
H7	IM -> PI	.384	.175	6.736	.000	Support
H8	IM -> PD	.065	.006	1.539	.124	Reject

Note: SA=safety, CO=comfort, WA=walkability, IM=imageability, PD=place dependence, PI=place identity

Source: Author's Calculation

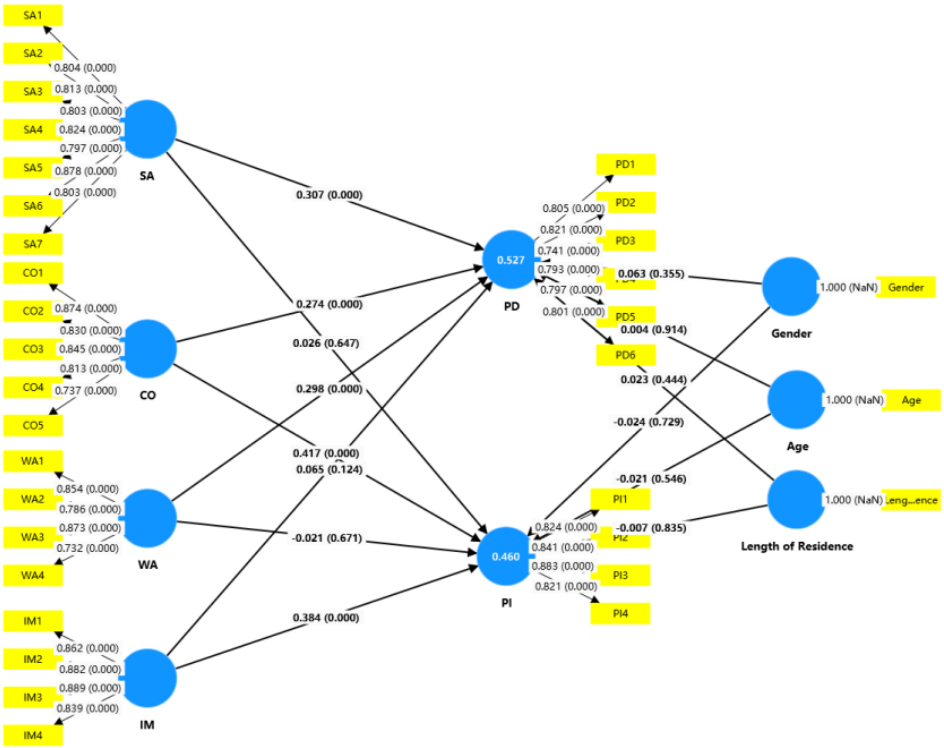


Figure 8: Structural Model Results
Source: Author

DISCUSSION

The research explores the influence of various dimensions of SQ on residents' PI and PD, drawing on place attachment theory. These findings show that different streetscape attributes affect the two components of PA in distinct ways.

The results show no significant relationship between safety and PI. A possible reason is that safety is often seen as a basic condition for using public space. When a place is considered safe enough, residents may take it for granted and pay less attention to safety as they form PI. Previous studies suggest that basic environmental conditions are less important for PI than symbolic and experiential factors (Lewicka, 2011; Hernández et al., 2007). Place attachment theory further suggests that PI is more closely related to emotional meaning and personal experience (Kyle et al., 2004). Therefore, while safety supports daily use, it may not directly contribute to residents' PI. In contrast, safety significantly influences PD. This suggests that when residents perceive a street as safe, they are more willing to use it for daily activities, thereby increasing their functional

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dependence on the street. This finding supports previous studies (Eng & McCormack, 2025).

Comfort has significant positive effects on both PI and PD. This finding supports the conclusions of Alsadun (2019). Comfortable street environments may improve residents' experiences of the space and encourage them to spend more time there. As a result, residents may develop stronger emotional connections to the street environment and greater dependence on it.

Walkability is not significantly related to PI. It mainly reflects the ease of pedestrian movement along a street. PI develops through repeated experiences and meaningful activities (Korpela, 1989). Therefore, although walkability improves movement, it may not directly strengthen residents' PI.

The relationship between imageability and PI was supported. The finding supports previous studies (Zhang et al., 2024). Streets with distinctive visual elements and memorable features can create clear mental images for residents, strengthening their emotional ties to the place. However, imageability did not show a significant relationship with PD. Imageability mainly reflects the visual and symbolic qualities of a place (Ewing & Handy, 2009). These qualities can make a street memorable, but do not necessarily support everyday use. Previous studies suggest that PD is more closely related to practical functions and activity needs (Khaidzir & Kamal, 2023). Therefore, a visually distinctive street may attract attention but not increase residents' functional reliance on the space.

In this study, gender, age, and length of residence showed no significant effects on PI or PD after being included as control variables. This differs from previous studies suggesting that demographic characteristics, particularly age and length of residence, may influence PA (Pacheco, 2025). One possible explanation is that this study focused on residents with long residence duration who were already familiar with the local street environment, resulting in relatively little variation in these characteristics. This finding suggests that the relationships between perceived SQ and PA remained stable after controlling for demographic characteristics.

This research has valuable theoretical and practical implications. The results show that the influence of different SQ dimensions on PA varies. Functional attributes, such as safety and walkability, primarily influence residents' PD, whereas experiential attributes, such as comfort and imageability, are more closely related to residents' emotional attachment to place. These findings help explain how different aspects of streetscape contribute to the development of PA.

The findings provide practical guidance for street regeneration in historic tourist cities. As comfort was the only streetscape dimension associated with both PI and PD, it should be prioritised by improving microclimate conditions, reducing noise, and providing adequate public seating when resources

are limited. Measures to improve safety and walkability, such as better street lighting and reducing pedestrian-vehicle conflicts, can help support residents' everyday use of the street. In addition, preserving distinctive landmarks, historic character, and cultural features can strengthen residents' PI.

This research has limitations. The study was conducted in Zhengding Ancient City. The results may not fully apply to other types of spaces. Future research could examine streetscapes in other types of urban spaces, such as parks or educational districts. This survey used self-reported measures, which may have introduced potential bias. Future studies could adopt multiple research methods to provide a more comprehensive understanding of the relationship between SQ and PA. Moreover, other resident characteristics, such as homeownership and tourism exposure, were not measured in the present study and therefore could not be included as control variables. Future research could incorporate these characteristics to further examine their influence on residents' PA.

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BRIDGING THE GREEN GAP: ACCESSIBILITY ASSESSMENT AND BLIND SPOT IDENTIFICATION OF URBAN PARKS IN KUNMING, CHINA

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Abstract

Urban green spaces (UGS) are critical infrastructure for sustainable high-density living, yet traditional assessment metrics often obscure spatial inequities and service gaps. In rapidly urbanizing contexts, the lack of fine-grained demographic data further hinders the accurate identification of service "blind spots" where resident demand exceeds accessible supply. Addressing these challenges, this study evaluates UGS accessibility in Kunming's central district. Innovatively, the research utilizes "total floor area" derived from building footprints as a high-resolution proxy for population distribution to overcome census limitations. By integrating Weighted Kernel Density Estimation (KDE) and network analysis within a GIS framework, a supply-demand raster overlay model is constructed to precisely delineate service deficits. The findings reveal a significant spatial mismatch: while the city core benefits from a strong "North-South Green Axis," peripheral areas exhibit severe polarization. Notably, the Tuodong sub-district, despite its high density of elderly residents, suffers from a "green vacuum" with only 7% service coverage. This study confirms that aggregate statistical compliance does not ensure spatial justice. It advocates for a paradigm shift from quantity-oriented to efficacy-oriented planning, proposing targeted "urban acupuncture" and transport integration strategies to foster a more equitable built environment.

Keywords: Multi-source data, Urban green space, Accessibility, Service blind spot

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INTRODUCTION

Urban Green Spaces (UGS) are essential ecological and social infrastructure in high-density cities, contributing to microclimate regulation, air quality improvement, public health, and social cohesion (Ibrahim et al., 2024; Jabbar et al., 2022; Y. Li et al., 2025; Pinto et al., 2022). With the increasing emphasis on sustainable urbanism and quality of life, green-space evaluation has shifted from quantity-based indicators to spatial equity, accessibility, and service effectiveness (Gong & Sun, 2025; J. Wang et al., 2025). In this context, identifying accessibility gaps and service blind spots is critical for optimising green-space allocation and supporting more equitable urban regeneration.

Traditional green-space planning has often relied on aggregate indicators, such as per capita green-space area. Although these indicators are useful for city-level assessment, they tend to conceal micro-scale spatial heterogeneity and supply-demand mismatches (Hassan & Jombach, 2025). In dense urban areas, statistical compliance does not necessarily indicate effective service provision. Low-income, ageing, or high-density communities may still face limited access to nearby green resources, creating spatial mismatch and environmental injustice (Das, 2025; Gong & Sun, 2025; Y. Wang et al., 2025). Therefore, accessibility has become an important tool for evaluating the actual performance and equity of urban green-space systems (Lu et al., 2025; Yiqiu et al., 2025).

The development of Geographic Information Systems (GIS) and multi-source spatial data has improved the precision of green-space accessibility assessment. Compared with buffer analysis or Euclidean distance, network analysis can better reflect actual pedestrian routes, travel time, and physical barriers in high-density urban environments (Ghadzlie et al., 2024; Z. Li et al., 2021; Zhang et al., 2020). However, many studies in developing urban contexts still rely on low-resolution census data at the street or township level, which may distort the estimation of local service demand (Meng, 2025; Xu & Wang, 2023). Identifying a finer-grained proxy for population demand therefore remains an important methodological issue.

To address these gaps, this study develops a GIS-based evaluation framework for Kunming's central district. By integrating park point-of-interest data, green-space patches, road network data, and building information, the study uses total floor area derived from building footprints and storey data as a proxy for population distribution. Weighted Kernel Density Estimation, network analysis, and raster overlay analysis are then applied to evaluate the spatial relationship between green-space supply and resident demand, and to identify service blind spots. The findings provide evidence for optimising green-space provision and supporting targeted urban regeneration in high-density built environments.

Study Area and Data

Study Area

As a gateway city in Southwest China, Kunming's central district exhibits typical high-density development characteristics. This study focuses on the core area of Kunming's main city, encompassing the intersection of Wuhua, Panlong, Xishan, and Guandu districts. The study area spans approximately 64.04 km², comprising 16 sub-districts (Figure 1A).

This study selected this area based on the following criteria. First, the area is densely populated, with 1,182,875 permanent residents according to census data, resulting in acute land-use conflicts. Second, as a mature urban zone, the area contains numerous high-density, ageing communities. These neighbourhoods typically suffer from low green coverage and a deficiency of public activity spaces, creating a significant spatial mismatch between resident demand for quality parks and current supply. Consequently, identifying service blind spots within this sample area holds significant representative value for guiding urban regeneration and improving the built environment.

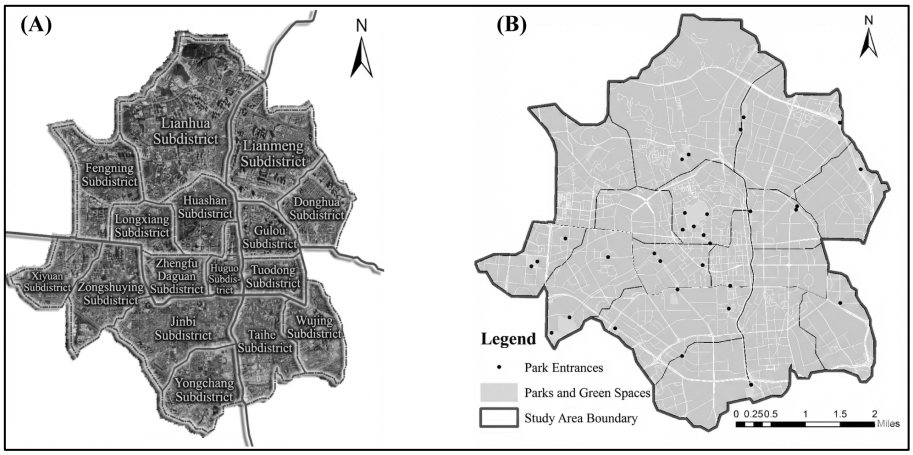


Figure 1: Overview of The Study Area and Dataset
(A) The Scope of the Study Area in Central Kunming
(B) Spatial Distribution of the 25 Selected Urban Park Green Spaces
Source: Data and Author's Figure

Data Acquisition and Pre-processing

Public urban park data were obtained from Amap point-of-interest records in 2025 and cross-validated using high-resolution satellite imagery and manual visual interpretation. Following the Standard for Classification of Urban Green Space (CJJ/T-85-2017), this study selected comprehensive and specialised parks with public accessibility and neighbourhood-level service capacity. To avoid

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overestimating green-space provision, fragmented greenery was excluded, and only parks larger than 0.5 ha were retained. Park boundaries were manually corrected, and entrance points were checked using satellite imagery and field verification where available. Finally, 25 urban parks were identified, covering approximately 97.64 ha in total (Figure 1B, Table 1).

Road network and building footprint data were downloaded from OpenStreetMap in 2025. In ArcGIS 10.4, non-walkable or irrelevant road segments were removed, and the road network was topologically cleaned by correcting disconnected segments, duplicate lines, and dangling nodes. Building footprints were clipped to the study boundary and used to calculate total floor area. Citing international standards and relevant literature (Bohannon, 1997), the study set the average adult walking speed at 1 m/s as the time impedance parameter for accessibility calculations.

Supplementary Data: Ancillary data includes park entrance coordinates (calibrated via field surveys) and public transport stop locations. The study sourced population data from official sub-district census statistics for subsequent demand intensity analysis. All spatial datasets were projected into WGS 1984 UTM Zone 48N before spatial analysis.

Table 1: Overview of Surveyed Parks and Green Spaces in the Central District of Kunming

Park Name	Area (ha)	Location (Sub-district)	Park Name	Area (ha)	Location (Sub-district)
Danxia Popular Science Park	0.51	Zhongshuying	Dongsita Camellia Garden	2.10	Jinbi
Kunming Daguan Park	22.50	Zhongshuying	Xihua Garden	2.35	Jinbi
Faguanlin Park	0.55	Zhengfu daguan	Kunming Green Lake Park	22.17	Huashan
Jingxing Park	0.77	Zhengfu daguan	Liuying Xima Linear Park	0.96	Huashan
Zhuantang Rule of Law Park	0.83	Zhengfu daguan	Wuhua Square	0.97	Huashan
Yongchang Ecological Garden	0.97	Yongchang	Shengli Square	0.82	Huashan
Ranweng Garden	4.22	Yongchang	Jinbi Park	0.87	Huguo
Biji Park	6.42	Xiyuan	Qicai Pocket Park	0.93	Gulou
Xishan Rule of Law Corridor	0.84	Xiyuan	Xiziying Pocket Park	0.67	Gulou

Park Name	Area (ha)	Location (Sub-district)	Park Name	Area (ha)	Location (Sub-district)
Jinzhi River Linear Park	1.06	Wujing	Taoyuan Square	2.08	Gulou
Lianhuachi Park	5.78	Lianhua	Jinleng River Park	5.85	Donghua
Jiang'an Park	0.69	Lianhua	Guilong Lake Park	5.63	Lianmeng
Milesi Park	4.08	Jinbi	Xiahegeng Park	3.02	Lianmeng

Source: Data and Author's Table

RESEARCH METHODOLOGY

Spatial Coupling Analysis via Weighted KDE

To quantify the spatial correspondence between green space supply and population demand, this study employs Weighted Kernel Density Estimation (Weighted KDE) incorporating area weights (H. Xu et al., 2024). Park area was used as the weight to reflect differences in park service capacity. The study defines the density function as follows:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} w_i K\left(\frac{x - x_i}{h} \right) \quad (1)$$

Where: $\hat{f}(x)$ represents the kernel density value at spatial point x; $K(\cdot)$ is the spatial weight Kernel function; h is the search bandwidth; n is the total number of park green spaces within the study area; $(x - x_i)$ is the distance from the valuation point to the park i; w_i is the park area weight, representing differences in service capacity. The bandwidth was set at 1.0 km in this study with reference to commonly used walking-based park accessibility thresholds, as 1000 m is widely adopted to represent a neighbourhood-scale park catchment(Gao et al., 2024; Hassan & Jombach, 2025). Alternative bandwidths were also considered during the preliminary analysis, and 1.0 km was retained because it yielded a more balanced spatial pattern.

Accessibility Assessment

Given the scarcity of high-precision demographic data in high-density built environments, the study proposes "total floor area" as a proxy variable for population distribution. This approach is methodologically supported by previous building-scale population estimation research, which has used building footprints and floor area to estimate fine-grained population distribution (Shang et al.,

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2021). Using network analysis based on time impedance, park entrance points were used as service origins, and walking time was calculated using road length and an average walking speed of 1 m/s. The study then constructed a service coverage index to quantify green space service efficacy for each sub-district:

$$C_i = \frac{S_{covered}}{S_{total}} \times 100\% \tag{2}$$

$$S_{covered} = \sum_{j=1}^{m} A_j \cdot \delta_j \tag{3}$$

Where: S_{total} represents the total floor area within the sub-district; $S_{covered}$ represents the effective served floor area falling within the 15-minute isochrone; A_j is the product of a single building's footprint area and its storey count; δ_j is a binary function: taking the value 1 when the building sits within the 15-minute service area, and 0 otherwise.

Blind Spot Identification via Raster Overlay

To delineate service blind spot boundaries precisely, the study established a bivariate "demand-supply" raster overlay model. The study area was divided into 250 m × 250 m grid cells, a size selected to approximate the neighbourhood block scale while balancing spatial detail and computational efficiency. The comprehensive score was calculated as follows:

$$Score_{overlay} = \alpha \cdot D_{norm} + \beta \cdot A_{norm} \tag{4}$$

$$\text{Subject to: } \begin{cases} D_{norm} \in \{-5, -4, ..., -1\} \\ A_{norm} \in \{1, 2, ..., 5\} \end{cases} \tag{5}$$

Where, D_{norm} is the standardized building density score (negative values indicate demand urgency); A_{norm} is the standardized accessibility score (positive values indicate service convenience); α, β is the weighting coefficient (set to 0.5 in this study).

Cells with $Score_{overlay} \leq -1.0$ were defined as service blind spots, while cells with $Score_{overlay} \leq -1.5$ were classified as severe blind spots, indicating areas with high population concentration and insufficient park accessibility.

ANALYSIS RESULTS

Spatial Coupling Analysis of Park Layout and Population Distribution

Kernel Density Estimation (KDE) analysis (Figure 2A) reveals a distinct 'dual-core' clustering pattern within the green space layout of Kunming's central district. In terms of overall spatial structure, a clear 'North-South Green Axis' emerges. Extending from Lianhuachi Park through Wuhuashan, Daguanlou, and Jinbi Parks to Xihua Park, this belt constitutes a coherent, dense ecological service backbone for the region. However, beyond this core axis, the study area exhibits a marked 'centre-edge' disparity. Park distribution remains sparse across the eastern and western flanks of the core area, failing to establish an effective service network. This spatial imbalance directly constrains environmental quality improvements in peripheral areas, indicating significant scope for optimising the current green system's spatial coverage.

A comparative analysis of population density and park layout (Figures 2A, 2B) indicates that central sub-districts—specifically Huashan, Daguan, Jinbi, and Donghua—exhibit the highest population agglomeration. These areas follow a north-south distribution, maintaining a strong macro-level spatial coupling with the 'North-South Green Axis'.

However, incorporating a socio-demographic perspective to analyse vulnerable groups (the elderly and children) reveals severe structural spatial mismatches (Figures 2C, 2D). The Tuodong sub-district warrants particular attention. Data indicates this area holds the highest proportion of elderly residents (>65 years) yet lies within a 'green space depression' devoid of large-scale park support. This spatial overlap between an 'ageing, high-density community' and a 'green service vacuum' demonstrates that the current system fails to address the urgent needs of groups most dependent on park facilities. Consequently, this area presents a high risk of environmental injustice and represents a critical planning mismatch requiring immediate intervention.

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Figure 2: Spatial Distribution Patterns of Urban Park Green Space Supply and Multi-Dimensional Demographic Demand in the Study Area.
(A) KDE of Park Green Space Distribution
(B) Total Population Density Distribution
(C) Elderly Population Density Distribution
(D) Children Population Density Distribution
Source: Data and Author's Figure

Identification of Park Green Space 'Blind Spots' via Network Accessibility Analysis

Accessibility assessment based on the actual road network (Figure 3A) quantifies extreme disparities in service levels across sub-districts. As indicated in Table 2 and Figure 3C, core sub-districts within the First Ring Road exhibit exceptional service efficiency. Notably, Zhengfu Daguan and Huguo sub-districts achieve service area building coverage rates of 0.99 and 0.98, respectively, demonstrating near-saturation levels of high-quality service (see high-coverage zones in Figure 3B).

Conversely, ageing sub-districts on the urban periphery face acute service deficits. For instance, despite high population density, Tuodong and Fengning sub-districts register 15-minute park service coverage rates of merely 0.07 (7%) and 0.11 (11%), indicating severe deprivation. Furthermore, the Panlong River delineates a significant East-West developmental imbalance (Figure 3C). While the western region benefits from a relatively comprehensive green network and high road connectivity, the eastern region (particularly Tuodong and Wujing) lags significantly in park provision and capillary road accessibility. This spatial differentiation severely compromises the equalisation of urban public services.

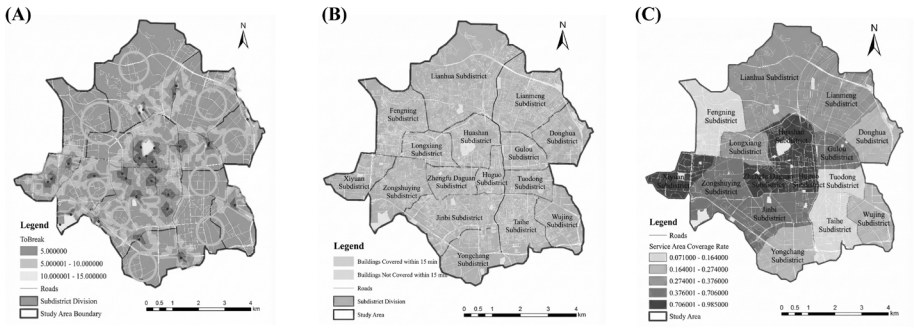


Figure 3: Accessibility Assessment Based on Network Analysis
(A) Walking Accessibility Analysis (showing 5, 10, and 15 min isochrones)
(B) Buildings Covered by 15-min Service Zones
(C) Accessibility Service Level Grading by Sub-District
Source: Data and Author's Figure

Table 2 further shows that park service coverage varies markedly across the 16 sub-districts, forming a clear gradient from high-service areas in the urban core to low-service areas on the periphery. While Zhengfu Daguan and Huguo achieve near-complete coverage, several sub-districts, particularly Tuodong, Fengning, and Taihe, remain seriously underserved. This indicates that park

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accessibility inequality in the study area is not only spatially uneven, but also structurally differentiated across sub-districts.

Table 2: Statistics of Park Service Coverage Rates by Sub-District

Sub-district	Covered Floor Area（㎡）	Total Floor Area（㎡）	Service Coverage Ratio
Zhengfu Daguan Subdistrict	3314958.24	3363940.58	0.99
Huguo Subdistrict	3499264.76	3580024.29	0.98
Huashan Subdistrict	3363778.63	3725511.55	0.90
Xiyuan Subdistrict	2354417.52	2661225.54	0.88
Gulou Subdistrict	2731494.88	3866582.37	0.71
Jinbi Subdistrict	4589704.35	6957057.27	0.66
Zongshuying Subdistrict	2699952.37	4638379.24	0.58
Longxiang Subdistrict	1442522.18	3835496.80	0.38
Lianhua Subdistrict	2973113.68	8392470.22	0.35
Lianmeng Subdistrict	2869442.18	8978567.62	0.32
Donghua Subdistrict	1233205.46	4501811.03	0.27
Yongchang Subdistrict	818536.08	3378286.08	0.24
Wujing Subdistrict	637165.44	2700447.45	0.24
Taihe Subdistrict	923365.50	5623161.07	0.16
Fengning Subdistrict	559893.72	4990368.16	0.11
Tuodong Subdistrict	207824.06	2943318.63	0.07

Note: Floor Area = Building Footprint Area × Average Number of Storeys
Source: Data and Author's Calculation

Geographically, these severe blind spots concentrate primarily along the eastern periphery (centred on Tuodong) and the north-western fringe. This visual analysis confirms that residents in these high-density zones suffer from 'green poverty', enduring the dual pressures of overcrowded living environments and scarce recreational space. Consequently, this raster map provides a precise evidence base for site selection, facilitating 'urban acupuncture' interventions

such as pocket park provision and the optimisation of public transport connections.

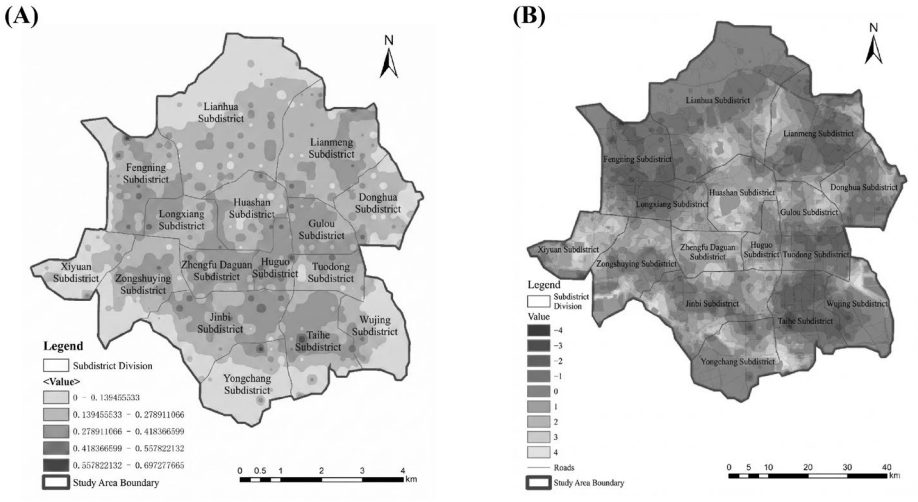


Figure 4: Identification of Service Blind Spots Via Raster Overlay Analysis
(A) Reclassified Building Density Raster Map
(B) Final Distribution of Service Blind Spots
Source: Data and Author's Figure

DISCUSSION

From Quantity Compliance to Spatial Justice

According to 2023 statistics, Kunming's per capita park green space reached 10.93 m², meeting aggregate planning standards. However, the raster overlay results reveal extensive service blind spots in high-density sub-districts such as Tuodong and Taihe. This finding confirms that aggregate green-space indicators may obscure micro-scale spatial inequality. In other words, green space can be statistically sufficient at the city level but functionally inaccessible for residents in specific neighbourhoods.

The sharp variation in sub-district coverage further shows that the key problem is not only the total amount of green space, but also the mismatch between residential demand and effective service reach. Some central sub-districts achieve high levels of park service coverage, whereas peripheral and ageing communities remain seriously underserved. This supports the need to shift from an indicator-oriented approach to an accessibility-oriented and justice-oriented planning framework. Incorporating blind spot identification into green-space evaluation can help reveal locational bias, spatial segregation, and unequal access to public environmental resources (Zhang et al., 2020). However, spatial

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accessibility does not necessarily equal actual park use. Park quality, including facilities, maintenance, safety, shade, seating, lighting, and age-friendly design, may affect residents' willingness to use nearby parks. Physical barriers, such as major roads, rivers, gated communities, discontinuous sidewalks, limited crossings, and insufficient entrances, may also weaken real accessibility. Therefore, the identified blind spots mainly reflect insufficient spatial accessibility, while future studies should incorporate park quality and access barrier assessments.

Planning Implications for Blind Spot Areas

For high-density blind spots such as Tuodong, large-scale demolition or new park construction is often constrained by limited land availability and high redevelopment costs. Therefore, urban acupuncture offers a practical micro-regeneration strategy (Hemingway & De Castro Mazarro, 2022). Underutilised street corners, fragmented plots, derelict spaces, and residual land within communities can be transformed into pocket parks or age-friendly green spaces. This approach can improve daily access to recreational space at relatively low cost while supporting community-level public service equalisation (Ma et al., 2025; Wan Ali @ Yaacob et al., 2025).

For peripheral blind spots and areas east of the Panlong River, the main challenge is not only insufficient green-space supply, but also weak pedestrian connectivity. Planning interventions should therefore improve last-mile connections by upgrading pedestrian routes, reconnecting cul-de-sacs, increasing safe crossings, and optimising links between residential areas and existing large parks. Community shuttles, bus stop optimisation, and walking-transit integration can further expand access to high-quality green resources for residents located beyond convenient walking distance (Umrigar & Pitroda, 2023). These differentiated strategies can help transform the results of accessibility assessment into more targeted urban renewal actions. Based on the service coverage results, Tuodong, Fengning, and Taihe should be treated as the highest-priority intervention areas because their 15-minute coverage ratios are below 0.20. These sub-districts require pocket parks, residual-space renewal, and age-friendly community green spaces. Wujing, Yongchang, Donghua, Lianmeng, Lianhua, and Longxiang should prioritise pedestrian connectivity, park entrances, and last-mile links. Sub-districts with high coverage, such as Zhengfu Daguan, Huguo, Huashan, and Xiyuan, should focus on maintenance and quality improvement.

CONCLUSION

This study developed a GIS-based evaluation framework to assess urban park accessibility and identify service blind spots in Kunming's central district. By integrating multi-source spatial data, total floor area was used as a proxy for

population distribution, and Weighted Kernel Density Estimation, network analysis, and raster overlay analysis were applied to examine the spatial relationship between green-space supply and resident demand.

The results show two major findings. First, urban park distribution in Kunming's central district is spatially uneven. Although a relatively strong north-south green axis exists in the urban core, sub-districts such as Tuodong and Taihe show a pattern of high residential demand and low park service coverage. Second, meeting aggregate per capita green-space standards does not necessarily guarantee equitable access. Substantial blind spots persist because of uneven park distribution, insufficient pedestrian connectivity, and mismatches between residential density and service reach.

These findings suggest that future green-space planning should move beyond quantity-based indicators and incorporate accessibility and blind spot identification into urban regeneration decision-making. The proposed framework can help local governments prioritise underserved areas, guide pocket park provision, improve pedestrian connections, and allocate green-space resources more efficiently.

Several limitations remain. The accessibility assessment mainly focuses on walking access and does not fully incorporate cycling or public transport. In addition, total floor area cannot completely replace individual-level population data or capture the activity patterns of different demographic groups. Future research should integrate park quality assessment, user perception data, and spatiotemporal mobility data to support a more comprehensive evaluation of urban green-space equity.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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CONSTRAINING EFFECTS OF POPULATION DECLINE AND POPULATION AGEING ON RURAL AGRICULTURAL INDUSTRIAL PROSPERITY: EVIDENCE FROM PROVINCIAL PANEL DATA IN CHINA, 2008–2023

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Abstract

Rural revitalization evaluation has expanded rapidly in China, yet increasingly large indicator systems can reduce interpretability and weaken policy operability. To address this issue, this study focuses on rural agricultural industrial prosperity (AIP) and measures it using observable agricultural and production-condition indicators from statistical yearbooks. Using provincial panel data for 31 provinces from 2008 to 2023 (excluding Hong Kong, Macao, and Taiwan), this study estimates a two-way fixed effects model to examine the relationship between rural population decline, rural ageing, and AIP. It also tests whether human capital, proxied by the average years of schooling of rural residents, conditions these demographic effects. The results show that population decline is negatively and robustly associated with AIP across alternative index construction methods, ageing measures, lagged specifications, and treatments for census-year or breakpoint shocks and outliers. In contrast, the direct effect of ageing is unstable and mostly insignificant. Moderation results show that the interaction between ageing and education is negative and significant, whereas the interaction between population decline and education is not significant. Regional interaction models further show stronger negative effects in specific regions. Overall, population decline is the more consistently supported demographic correlate of lower AIP, whereas the relationship between ageing and AIP appears to be more conditional. By focusing on AIP within a unified framework, this study provides more interpretable evidence for rural planning and governance under demographic change.

***Keywords**:* Population Decline, Population Ageing, Agricultural Industrial Prosperity, Regional Heterogeneity

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INTRODUCTION

Since the 19th National Congress proposed the Rural Revitalization Strategy, related evaluation studies have expanded rapidly in China. At the same time, increasingly large indicator systems have raised interpretive complexity and weakened policy operability (Sarfo et al., 2024; Cai et al., 2024). In response, some studies have argued for a "key goals–key levers" approach that prioritises core policy orientations, such as agricultural labour productivity, the urban–rural income gap, and the equalisation of basic public services, rather than relying on overly composite indicators that may blur policy logic (Liu et al., 2020; Tang & Han, 2023).

Demographic change is one of the key structural factors shaping rural revitalization. Population decline, population ageing, and labour out-migration may reshape factor supply and local development conditions (Liu et al., 2020). Their implications, however, appear to vary across contexts, and existing studies suggest that migration ties, place attachment, counter-urbanisation, digital infrastructure, and broader regional conditions may reshape demographic pressures under specific circumstances(Wu et al., 2022; Guo et al., 2023; Yu et al., 2024; Wang et al., 2025; Lichter & Johnson, 2025).

Against this background, this study focuses on rural agricultural industrial prosperity (AIP), which is measured through observable agricultural and production-condition indicators from statistical yearbooks. This narrower focus is intended to reduce disputes over measurement scope and to improve consistency between concept and measurement (Zhang et al., 2020; Tang & Han, 2023). Using provincial panel data for 2008–2023, this study examines the relationship between population decline, population ageing, and AIP, and tests the conditional role of human capital (Wang, Zheng, et al., 2024). This focus helps provide more interpretable evidence for rural planning and governance.

LITERATURE REVIEW

Rural Revitalization Evaluation and the Need for a More Bounded Target

Rural revitalization research has expanded rapidly and produced a large number of indicator-based evaluations and reviews (Sarfo et al., 2024; Cai et al., 2024). At the same time, this literature has increasingly emphasised the population–land–industry nexus in rural transformation and governance. However, increasingly large indicator systems may reduce interpretability and blur the link between empirical findings and policy levers, especially for broad dimensions such as "industrial prosperity" (Tang & Han, 2023). Against this background, focusing on AIP through observable agricultural-sector indicators offers a more clearly bounded target for empirical analysis.

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Population Decline, Ageing, and Their Possible Constraints on Agricultural Industrial Prosperity

Existing studies suggest that population decline, ageing, and labour out-migration may constrain rural development by weakening factor supply and local development foundations. Areas with revitalization potential may still face labour shortages, limited technical support, and uneven institutional conditions (Bai et al., 2021; Tao & Wu, 2023; Hu et al., 2023). International research reports similar concerns, linking population loss and ageing to poverty, deprivation, regional divergence, and barriers to generational renewal in agriculture (Gkatsikos et al., 2022; Murtagh et al., 2023; Pollnow et al., 2023; Consentino et al., 2023; Lichter & Johnson, 2025). Overall, the literature suggests that population decline and ageing may be associated with lower AIP through labour constraints, weaker innovation adoption, and lower organisational capacity.

Conditional Factors and the Role of Human Capital

Demographic constraints are not necessarily deterministic. Migration ties, place attachment, counter-urbanisation, digital infrastructure, and spatial governance tools may partly offset or reshape these effects under specific conditions (Wu et al., 2022; Yuan et al., 2022; Guo et al., 2023; Wang et al., 2025). Human capital may improve rural revitalization performance, but its effects vary across regions and may not automatically translate into local agricultural productivity or organisational capacity (Hu et al., 2023; Wang, Zheng, et al., 2024). This suggests that the relationship between population decline, ageing, and AIP, as well as the conditional role of human capital, should be examined empirically within a unified panel framework.

Hypotheses

H1: Population decline constraint. Higher population decline is associated with lower rural AIP.
H2: Ageing constraint. Greater population ageing is associated with lower rural AIP.
H3: Conditional role of human capital. Human capital conditions the effects of population decline and ageing; the direction of this moderation is an empirical question.

RESEARCH METHODOLOGY

Research Design and Data

This study uses provincial panel data for China from 2008 to 2023, covering 31 provincial-level administrative units and excluding Hong Kong, Macao, and Taiwan. The dataset is organised as a province–year panel. The analysis focuses

on AIP as the dependent variable and treats it as a more clearly bounded outcome than broader rural revitalization composite indices. Within a two-way fixed effects framework, the study examines the relationship between population decline, population ageing, and AIP, while also testing the conditional role of human capital and exploring regional heterogeneity. This strategy improves comparability and reduces time-invariant omitted bias, although the results should still be interpreted as association rather than definitive causal identification. The number of observations varies across specifications due to data availability for the population-decline series and the use of smoothing and lag constructions.

Variables and Measurement

As shown in Table 1, the dependent variable is the level of agricultural industrial prosperity (AIP), denoted as IP_{it}. AIP is constructed from observable agricultural performance and production-condition indicators reported in statistical yearbooks. Before aggregation, the indicators are aligned in direction and standardised to improve comparability across provinces and years. The baseline AIP measure is constructed using the entropy-weighted method, while a PCA-based score is used in the robustness analysis as an alternative measure.

The core explanatory variables are rural population decline, denoted as $\mathrm{PCS\_pos\_adj}_{it}$ and rural ageing, denoted as Aging_{it}. Population decline is measured as the negative change in rural population size; specifically, it is constructed from the first difference of the logarithm of rural population multiplied by -1, so that larger values indicate stronger decline. Aging_{it} is measured by the share of the rural population aged 65 and above and is alternatively proxied in the robustness analysis by the old-age dependency ratio, denoted as OADR_{it}.

The moderating variable is human capital, denoted as HC_{it}. In this study, it is proxied by education-related indicators of rural educational attainment. This specification is used to assess whether the association between demographic constraints and AIP varies with human capital conditions. The control variable set, denoted as X_{it}, includes key contextual factors related to economic development, industrial structure, and fiscal support for agriculture, so as to reduce confounding bias.

Table 1. Variable Definitions, Index Construction, and Data Sources (2008–2023)

Variable	Dimension	Indicator	Code	Source
Dependent variable	Industrial output scale	Value added of the primary industry	X1(+)	Fiúza et al. (2023); Wang, Wu, et al., (2024); Chen and Wang (2025)
		Gross output value of agriculture, forestry, animal husbandry and	X2(+)	Wang, Zhang, et al. (2023); Wang, Zheng, et al. (2024)

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Variable	Dimension	Indicator	Code	Source
		fishery		
	Industrial efficiency and productivity	Total agricultural machinery power	X3(+)	Liu et al. (2022); Tao and Wu (2023); Chen and Wang (2025)
		Share of effectively irrigated area	X4(+)	Wang, Zhang, et al. (2023)
	Industrial upgrading and factor input	Share of agriculture, forestry and water expenditure	X5(+)	Tao and Wu (2023)
Independent variable	Population shrinkage	Population growth rate	PCS (+)	Wang, Xu, et al. (2023); Wang and Li (2024); Wang, Wu, et al., (2024); Qi et al. (2025)
		Intensity of population shrinkage	PCS_pos_adj (-)	
	Population ageing	Share of population aged 65 and above	Aging (-)	Li et al. (2022); Osanai and Yu (2023); Cai et al. (2024)
		Old-age dependency ratio	OADR (-)	Zhang and Wang (2022)
Control variable	Economic development level	Income–expenditure ratio	X6(+)	Gao et al. (2022)
	Industrial structure	Share of secondary and tertiary industry value added in provincial GDP	X7(+)	Shi and Yang (2022); Wang, Wu, et al., (2024); Chen and Wang (2025)
	Fiscal support for agriculture	Per capita fiscal expenditure	X8(+)	Wang, Zhang, et al. (2023)
	Resource–environment and ecological constraints	Fertilizer application amount	X9(-)	Shi and Yang (2022); Wang, Zheng, et al. (2024); Chen and Wang (2025)
Moderating variable	Human resources	Average years of schooling of rural residents	HC (+)	Tao and Wu (2023); Wang, Zheng, et al. (2024)

Source: Data and Author's Table

Models

Baseline Two-Way Fixed Effects Model

To assess the average relationship between population decline, ageing, and agricultural industrial prosperity, this study uses a two-way fixed effects (TWFE) model. The model controls for time-invariant provincial differences, and common year shocks. Although this framework helps reduce bias from time-invariant unobserved heterogeneity, the estimates should still be interpreted as panel-based evidence of association rather than strict causal effects. Standard errors are cluster-robust at the provincial level.

$$\mathrm{IP}_{it} = \alpha + \beta_1 \mathrm{PCS\_pos\_adj}_{it} + \beta_2 \mathrm{Aging}_{it} + \acute{\gamma} \mathrm{X}_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

Interaction Tests for the Conditional Role of Human Capital

To test H3, this study examines whether the relationship between demographic constraints and agricultural industrial prosperity varies with human capital conditions. Human capital is proxied by rural educational attainment. Interaction terms are added to assess the conditional role of human capital.

$$\mathrm{IP}_{it} = \alpha + \beta_1 \mathrm{PCS\_pos\_adj}_{it} + \beta_2 \mathrm{Aging}_{it} + \beta_3 \mathrm{HC}_{it} + \beta_4(\mathrm{PCS\_pos\_adj}_{it} \times \mathrm{HC}_{it}) + \beta_5(\mathrm{Aging}_{it} \times \mathrm{HC}_{it}) + \acute{\gamma}\mathrm{X}_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

To improve interpretability, this study reports marginal effects at selected levels of human capital, including representative quantiles and the mean plus or minus one standard deviation. These estimates help show whether the relationship varies across human capital conditions.

Robustness and Heterogeneity Tests

To examine whether the main findings depend on specific indicators or model settings, this study conducts robustness checks in three ways. First, the ageing variable Aging_{it} is replaced by the old-age dependency ratio OADR_{it}, and the dependent variable is re-measured using an alternative index-construction method for agricultural industrial prosperity. Second, lagged specifications are estimated to examine whether the main associations remain stable when explanatory variables are shifted by one period. Third, regional heterogeneity is examined using region-based analyses to assess whether the relationship between demographic constraints and agricultural industrial prosperity differs across major regions of China. The provincial composition of each region is reported separately for transparency and replication.

Together, these tests assess whether the main findings remain stable across alternative measures, specifications, and regional contexts (Tang & Han, 2023; Luo et al., 2023).

ANALYSIS AND DISCUSSION

Baseline Effects (H1–H2)

The baseline TWFE results (Table 2) show a significant negative association between population decline and AIP. With controls and two-way fixed effects, the smoothed population-decline indicator $\mathrm{PCS\_pos\_adj}_{it}$ remains significant at the 5% level with a negative coefficient. The estimated coefficient is about -0.246 ($p < 0.05$), suggesting lower AIP in provinces with stronger population decline under the current specification.

Table 2. Baseline Model Results (Dependent Variable: Entropy-Weighted AIP Index)

Variable	PCS_pos_adj	Aging	PCS_pos_adj + Aging	PCS_pos_adj + Aging + Controls
PCS_pos_adj	-0.4026**		-0.4116**	-0.2463**
	(0.1923)		(0.1887)	(0.1061)
Aging		0.2068	0.1671	-0.2052
		(0.3154)	(0.2880)	(0.2607)
X6				-0.0646**
				(0.0238)

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Variable	PCS_pos_adj Aging		PCS_pos_adj + Aging	PCS_pos_adj + Aging + Controls
X7				-0.4037
				(0.4448)
X8				-0.0334***
				(0.0108)
X9				-0.00009
				(0.00027)
Constant	0.2917***	0.2549***	0.2702***	0.8730*
	(0.0022)	(0.0401)	(0.0373)	(0.4304)
Observations	465	496	465	465
R-squared	0.9611	0.9531	0.9614	0.9687
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Notes: *Standard errors in parentheses. Standard errors are clustered at the provincial level. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.*

Source: Authors' calculation based on the data.

This result is broadly consistent with H1. Population decline may be associated with reduced labour supply, weaker local demand, and lower factor allocation efficiency. These should be understood as plausible channels rather than directly identified mechanisms in the present model. Among the control variables, X6 and X8 remain negative and statistically significant, whereas X7 and X9 do not show robust significance. Taken together, these results suggest that AIP is related not only to demographic structure but also to broader contextual conditions.

By contrast, the coefficient on Aging_{it} changes sign across specifications and is mostly insignificant. Accordingly, the baseline results do not provide robust evidence of a direct net association between ageing and AIP, and H2 is therefore not robustly supported. One possible interpretation is that the relationship between ageing and AIP may operate through indirect or context-dependent channels, such as fiscal structure, population decline, or industrial restructuring. In addition, offsetting supply- and demand-side adjustments, together with limited within-province variation in ageing, may weaken statistical significance in a fixed-effects framework.

Conditionality: Human Capital (H3)

To test H3, this study examines the conditional role of human capital, proxied by the average years of rural schooling. Two interaction terms are included in the baseline model: "$\text{PCS\_pos\_adj}_{it} \times \text{HC}_{it}$" and "$\text{Aging}_{it} \times \text{HC}_{it}$". As shown in Table 3, the interaction between population declines and human capital is not statistically significant, whereas the interaction between ageing and human capital is negative and significant.

Table 3. Moderation Results: Human Capital and Demographic Constraints

Variable	Coefficient	Standard Error	p-value
PCS_pos_adj	-0.1842	0.0960	0.064
HC_c	0.0490	0.0277	0.087
PCS_pos_adj × HC_c	-0.0184	0.0310	0.558
Aging	0.0629	0.2976	0.834
Aging × HC_c	-0.4190	0.1583	0.013
X6	-0.0542**	0.0222	0.021
X7	-0.3282	0.4531	0.474
X8	-0.0338***	0.0080	<0.001
X9	-0.00009	0.00027	0.743
Constant	0.7552*	0.4425	0.098
Model Diagnostics			
Province fixed effects	Yes		
Year fixed effects	Yes		
Observations	465		
Joint Significance Test（Interaction Terms）			
F-statistic	3.61		
p-value	0.0393		

Source: Authors' calculation based on the data.

To improve interpretation, this study further reports marginal effects at selected levels of human capital. The marginal effects of population decline remain negative across education levels, but the non-significant interaction term does not support a stable moderating role of human capital in the relationship between population decline and AIP (Table 4). By contrast, the negative interaction coefficient for ageing suggests that the relationship between ageing and AIP may vary with human capital conditions, although the marginal effects reported in Table 5 are not consistently statistically significant.

Table 4. Marginal Effects of Population Decline across Human-Capital Levels

HC_c	Marginal effect	Standard error	p-value
25th percentile (-0.2775)	-0.1791	0.0963	0.063
50th percentile (0.1564)	-0.1871	0.0961	0.052
75th percentile (0.4428)	-0.1923	0.097	0.047

Source: Authors' calculation based on the data.

Table 5. Marginal Effects of Ageing across Human-Capital Levels

HC_c	Marginal effect	Standard error	p-value
25th percentile (-0.2775)	0.1792	0.3125	0.566
50th percentile (0.1564)	-0.0026	0.2918	0.993
75th percentile (0.4428)	-0.1226	0.2864	0.669

Notes: *HC_c denotes the centred human-capital variable.*

Source: Authors' calculation based on the data.

Overall, H3 is better understood as evidence of a conditional role of human capital rather than as support for a simple buffering mechanism. The results do not support a stable moderating effect of human capital in the case of

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population decline, but they provide tentative evidence that the relationship between ageing and AIP may vary across human-capital conditions.

Robustness Checks

This study conducts robustness checks using alternative index construction, alternative variable measurement, lagged specifications, and adjustments for possible data-definition shocks. First, when the entropy-weighted AIP index is replaced by a PCA-based score and ageing is alternatively measured by the old-age dependency ratio, the negative association between population decline and AIP remains stable, whereas ageing remains mostly insignificant (Table 6).

Second, lagged specifications show that the lagged population-decline measure remains negatively associated with current AIP, while ageing does not show robust significance in either contemporaneous or lagged terms (Table 7).

Third, additional checks for census-year and breakpoint shocks, as well as winsorisation and trimming, remain broadly consistent with the baseline model (Table 8 and Table 9).

Table 6. Robustness Checks: Alternative AIP Measure (PCA) and Alternative Ageing Measure (OADR)

Variable	PCA: PCS_pos_adj	PCA: OADR	PCA: PCS_pos_adj + OADR	PCA: PCS_pos_adj + OADR+Controls
PCS_pos_adj	-4.5697**		-4.6389**	-2.5298**
	(1.8526)		(1.8447)	(1.0013)
OADR		0.0121	0.0101	-0.0030
		(0.0093)	(0.0084)	(0.0060)
X6				-0.6299***
				(0.2218)
X7				-0.2203
				(0.4074)
X8				-0.3411***
				(0.1116)
X9				-0.00236
				(0.00267)
Observations	465	496	465	465
R-squared	0.9614	0.9534	0.9619	0.9700
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Source: Authors' calculation based on the data.

Table 7. Robustness Checks: One-Period Lagged Explanatory Variables

Variable	$PCS\_pos\_adj_{i,t-1}$	$PCS\_pos\_adj_{i,t-1}$ +Controls	$PCS\_pos\_adj_{i,t-1}$ + $Aging_{i,t-1}$	$PCS\_pos\_adj_{i,t-1}$ + $Aging_{i,t-1}$ + Controls
$PCS\_pos\_adj_{i,t-1}$	-0.3910**	-0.2148	-0.3932**	-0.2095
	(0.1748)	(0.1212)	(0.1753)	(0.1197)
$Aging_{i,t-1}$			0.1604	-0.2453
			(0.2776)	(0.2351)

Variable	PCS_pos_adj$_{i,t-1}$	PCS_pos_adj$_{i,t-1}$ +Controls	PCS_pos_adj$_{i,t-1}$ + Aging $_{i,t-1}$	PCS_pos_adj$_{i,t-1}$ + Aging $_{i,t-1}$ + Controls
Aging $_{i,t}$	0.1111	-0.1972		
	(0.2755)	(0.2595)		
X6		-0.0634***		-0.0663***
		(0.0222)		(0.0212)
X7		-0.3926		-0.4076
		(0.3860)		(0.3830)
X8		-0.0274***		-0.0280***
		(0.0083)		(0.0080)
X9		-0.00017		-0.00018
		(0.00028)		(0.00029)
Observations	465	496	465	465
R-squared	0.9678	0.9736	0.9679	0.9737
Province fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Source: Authors' calculation based on the data.

Table 8. Robustness Checks A: Census-Year and 2015 Breakpoint Adjustments

Variable	Coefficient	Standard error	p-value
PCS_pos_adj（raw）	-0.2135*	0.1220	0.090
Aging	-0.2275	0.2857	0.432
X6	-0.0689***	0.0259	0.013
X7	-0.4190	0.4802	0.390
X8	-0.0333***	0.0111	0.005
X9	-0.0001	0.0003	0.666
Fixed Effects & Controls			
Province FE × Census Shock	Yes		
Province FE × 2015 Break	Yes		
Province fixed effects	Yes		
Year fixed effects	Yes		
Observations	465		

Source: Authors' calculation based on the data.

Table 9: Robustness Checks B: Winsorisation and Trimming versus the Baseline Model

Model	Contraction Measure	Coefficient	Standard error	p-value	Observations
Winsorised model	PCS_pos_w	-0.1454**	0.0657	0.035	465
Trimmed-sample model	PCS_pos	-0.1655**	0.0710	0.027	457
Main Model	PCS_pos_adj	-0.2667**	0.1105	0.022	465

Source: Authors' calculation based on the data.

Taken together, the robustness checks reinforce the main empirical pattern of the study: population decline is consistently associated with lower AIP, whereas the relationship between ageing and AIP does not exhibit stable

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statistical significance. Although these checks cannot fully eliminate endogeneity concerns, they show that the main findings remain stable across alternative specifications.

Heterogeneity Tests

This study examines whether the relationship between population decline and AIP varies across regions. The 31 provinces are grouped into six regions (Region1–Region6). Because some regional subsamples contain few provinces and limited clusters, group-wise regressions may weaken statistical inference. For this reason, this study estimates a full-sample TWFE model with interaction terms, in which region dummies are interacted with population-decline intensity, to assess regional heterogeneity within a unified framework.

As shown in Table 10, the interaction terms for Region4 and Region5 are negative and statistically significant relative to the baseline region (Region1), suggesting a stronger negative association in these two regions. The marginal effects reported in Table 11 are significantly negative in Region5 and marginally significant in Region4, whereas the remaining regions are also negative but not well supported statistically.

Table 10. Heterogeneity Analysis: Regional Differences in the Association between Population Decline and AIP

Model	Coefficient	Standard error	p-value
PCS_pos_adj（Baseline:Region1）	-0.0353	0.1329	0.792
Region2×PCS_pos_adj	-0.1102	0.2021	0.59
Region3×PCS_pos_adj	-0.1057	0.0905	0.252
Region4×PCS_pos_adj	-0.2457**	0.0913	0.012
Region5×PCS_pos_adj	-0.2849**	0.115	0.019
Region6×PCS_pos_adj	-0.0627	0.087	0.477
Control variables included	Yes		
Observations / Province clusters	465 / 31		

Notes: Standard errors are clustered at the provincial level. Region1 is the baseline region. The six regional groupings are defined as follows: Region1 = North China; Region2 = Northeast China; Region3 = East China; Region4 = Central and South China; Region5 = Southwest China; and Region6 = Northwest China.
Source: Authors' calculation based on the data.

Table 12. Regional Marginal Effects of Population Decline (lincom)

Region	lincom	Standard error	p-value	95% CI	Interpretation
Region1	-0.0353	0.1329	0.792	[-0.3068, 0.2362]	Not significant
Region2	-0.1455	0.2623	0.583	[-0.6812, 0.3902]	Not significant
Region3	-0.141	0.1198	0.248	[-0.3858, 0.1037]	Not significant
Region4	-0.2810*	0.1433	0.059	[-0.5737, 0.0117]	Marginally significant（$p < 0.10$）
Region5	-0.3202**	0.1318	0.021	[-0.5894, -0.0510]	Significant (negative)
Region6	-0.0981	0.1496	0.517	[-0.4036, 0.2075]	Not significant

Source: Authors' calculation based on the data.

Taken together, these results suggest that the relationship between population decline and AIP varies across regional contexts rather than operating uniformly across space.

CONCLUSION

Key Findings

Based on panel data for 31 provinces in China from 2008 to 2023, this study uses a two-way fixed effects (TWFE) model to examine how rural population decline, ageing, and human capital are associated with agricultural industrial prosperity (AIP). It provides a structured assessment of demographic constraints under a unified framework.

First, population decline shows a significant and robust negative association with AIP, which is consistent with H1. This result remains stable across alternative measures, lagged specifications, and different data treatments. Population decline appears to be the more stable demographic correlate of lower AIP.

Second, the effect of ageing is unstable and mostly insignificant across specifications, so H2 is not robustly supported. Ageing may therefore be linked to AIP through indirect or context-dependent channels rather than through a stable direct net association.

Third, the interaction between population decline and education is not significant, while the interaction between ageing and education is significantly negative. H3 is therefore better understood as evidence of conditionality rather than support for a simple buffering mechanism. The results do not support a stable moderating role of human capital for population decline but provide tentative evidence that the relationship between ageing and AIP may vary across human-capital conditions.

Fourth, the regional interaction results show that the relationship between population decline and AIP is not spatially uniform, with more negative associations in some regions than in others. Demographic constraints therefore vary across regional contexts rather than operating uniformly across space.

Overall, the results suggest that population decline is the more consistently supported demographic constraint on AIP in this study, whereas ageing appears to be more conditional in its relationship with AIP. This study provides more interpretable evidence on demographic constraints and their relevance for planning under demographic change.

Policy Implications

The findings suggest that rural industrial planning should treat demographic change, especially population decline, as a practical constraint rather than

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assuming continued growth by default. In planning terms, agricultural development strategies need to be aligned with changing population capacity, service thresholds, and spatial demand.

First, policy responses should focus on measures closely related to AIP, including agricultural organization, processing and circulation systems, value-chain linkages, and infrastructure efficiency. In areas with sustained out-migration, labour-saving and moderately scaled approaches may be more realistic than expansion-oriented strategies. Rural spatial planning may prioritise agricultural service nodes, storage and cold-chain facilities, irrigation and mechanisation infrastructure, and land consolidation arrangements that support moderate-scale and labour-saving production.

Second, human capital policy should not focus only on raising education levels. It should also consider whether education can be converted into local employment, industrial upgrading, and talent retention. Otherwise, higher education may coexist with continued out-migration. Planning and governance should therefore pay greater attention to the local conversion of human capital through employment platforms, entrepreneurship support, and public-service improvement in rural areas.

Third, because demographic constraints differ across regions, rural industrial governance should adopt more differentiated strategies. For more constrained areas, planning may need to focus on maintaining key functions, improving networks, and strengthening important nodes. Differentiated regional strategies may include adjusting village-system layouts, concentrating selected services in viable centres, and coordinating industrial land, service facilities, and infrastructure according to local demographic conditions.

Limitations and Future Research

This study has several limitations. First, the direct effect of ageing is not stable in the present models, so future research should further examine its indirect channels.

Second, although the interaction analysis shows a conditional relationship between education and demographic constraints, this study does not distinguish human capital stock, mobility, and return. Finer-scale data may help clarify these processes.

Third, the heterogeneity analysis is based on broad regional groupings. Future studies may extend the analysis to smaller spatial units to improve local relevance. More explicit regional classifications and finer spatial comparisons may also help connect demographic analysis with planning practice.

In sum, the findings suggest that demographic change is associated with AIP in differentiated ways. Population decline appears to be the more consistently

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supported constraint, while the relationship between ageing and AIP appears to be more conditional.

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LANDSCAPE ELEMENTS AS DETERMINANTS OF STREETSCAPE IDENTITY: A DESIGN FRAMEWORK FOR MALAYSIA'S HISTORIC ROYAL URBANISM

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Abstract

Street landscapes are pivotal in shaping the character of historic urban environments, particularly in royal towns where cultural heritage is embedded in the urban fabric. However, within the field of urban design, the role of landscape structures in shaping streetscape identity has received limited empirical attention, leading to a gradual decline in spatial and cultural distinctiveness in many heritage towns. This study aims to examine how landscape structures influence the visual-spatial and functional qualities of streets within the historic royal urban context of Kuala Kangsar, Perak, Malaysia. A mixed-methods approach involving field observations, historical analysis, 21 semi-structured interviews, and a survey of 330 respondents was employed to identify key landscape features and assess their role in reinforcing spatial identity. The analysis is guided by a conceptual framework that interprets landscape structures through four urban design attributes: attractiveness, visibility, human scale, and comfort. The findings demonstrate that landscape components enhance visual appeal, human scale, comfort, and social engagement, revealing a strong interdependence between physical aesthetics and street performance. The study proposes a landscape-oriented design framework tailored to heritage settings, contributing both theoretically to urban design discourse and practically to policy formulation for Malaysia's royal towns. It concludes by advocating a holistic, context-sensitive approach to preserving street character and cultural continuity in historic urban landscapes.

Keywords: cultural heritage, landscape, royal towns, street character, urban identity

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INTRODUCTION

Streets are more than circulation corridors. They are public realms where social, spatial, and symbolic elements come together (Gehl, 2010; Mehta, 2020). Street character in a heritage setting, such as Malaysia's Royal Towns, is not only characterised by its buildings, but also by its landscape features that add vitality to the visual-spatial space in-between and around buildings. The urban landscape, including trees, plantings, pavement, furniture, water features, and transitional spaces, is an important contributor to the experiential and aesthetic character of a street (Carmona et al., 2021). Within the discipline of urban design, streetscape identity is understood as the distinctive visual and spatial character of streets formed through the interaction between buildings, landscape structures, and street patterns.

However, the urban landscape has received limited attention in mainstream urban design discourse and practice in Malaysia, where architectural conservation has dominated, while its contribution to the reinforcement of cultural continuity, spatial memory, and place attachment has been overlooked (Shamsuddin et al., 2018; Khalid et al., 2023). Recent research has underscored the need to recognize streetscapes informed by culturally embedded landscape design as critical to ensuring the perpetuation and sustenance of the character and usability of heritage environments (Ma et al., 2023; Ismail et al., 2018). In historic royal towns, landscape structures such as ceremonial tree plantings, riverfront corridors, and shaded pedestrian routes often serve both symbolic and functional roles in reinforcing cultural identity and spatial hierarchy.

This research therefore focuses on the role of landscape structures within the field of urban design, specifically examining how these elements contribute to the formation of streetscape identity in historic royal urban environments. This study aims to examine how landscape structures influence the visual-spatial and functional qualities of streets within the historic royal urban context of Kuala Kangsar, Perak, Malaysia. To achieve this aim, the objective of this article is to identify key landscape components and evaluate their contribution to streetscape identity through four urban design attributes: attractiveness, visibility, human scale, and comfort. This evaluation focuses specifically on Kuala Kangsar, a municipal town functioning as a historic royal urban center.

OPERATIONAL DEFINITION

For the purpose of this study, several operational definitions are adopted. "Royal Town" refers to a historic urban settlement associated with royal institutions and ceremonial functions, where urban form, architecture, and landscape elements collectively express royal symbolism and cultural heritage. "Historic Royal Urbanism" refers to the spatial and morphological characteristics of towns shaped

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by royal governance, ceremonial routes, and cultural institutions. "Streetscape identity" refers to the distinctive visual and spatial character of streets formed through the interaction between buildings, landscape structures, and street patterns within the public realm. 'Urban Design Attributes' are operationalized into four dimensions: (i) Attractiveness (aesthetic, natural, and cultural appeal), (ii) Visibility (spatial legibility and orientation clues), (iii) Human Scale (spatial proportion and enclosure relative to human dimensions), and (iv) Comfort (physical and microclimatic environmental protection)

PROBLEM STATEMENT

Urban design challenges in Malaysia's Royal Towns, such as Kuala Kangsar, have increasingly raised concerns regarding the gradual loss of streetscape identity due to modernization pressures and insufficient recognition of landscape elements in urban design practice. Although various studies have focused on architectural conservation in Malaysia's Royal Towns, the visual-spatial importance of streetscape elements such as tree canopies, boundary hedges, riverfront spaces, and culturally significant paving materials has received comparatively limited attention in urban design studies (Ismail & Adam, 2020; Abd Karim & Abdul Rahman, 2021).

The lack of integrated urban design strategies that incorporate landscape structures has contributed to a gradual erosion of spatial identity within Malaysia's historic royal towns. As landscape elements are altered or replaced without consideration of cultural and spatial significance, the visual coherence and symbolic character of royal streetscapes become increasingly fragmented (Ismail et al., 2018; Ma et al., 2023). Consequently, landscape structures are often treated as supplementary aesthetic elements rather than as fundamental determinants of urban morphology and streetscape identity within historic urban environments. This gap highlights the need for research that systematically examines the role of landscape structures in shaping the visual-spatial identity and experiential quality of streets within royal towns functioning as urban centers.

VISUAL-SPATIAL FOCUS AND CASE STUDY CONTEXT

This research has a specific focus on the visual-spatial qualities associated with landscape elements used to create street character in historic royal towns of Malaysia. The study emphasises landscape structures as key visual-spatial components that influence spatial legibility, orientation, and experiential quality within streetscapes. By focusing on physical attributes such as vegetation structure, pavement materials, street furniture, and open space boundaries, the study identifies specific landscape components that contribute to legibility, coherence, and cultural identity in the public realm.

Kuala Kangsar, Perak, was selected as the case study because it is officially recognised as the Royal Town of Perak and functions as an important ceremonial and cultural centre of the Perak Sultanate. Although modest in scale, Kuala Kangsar functions as a historic royal urban centre where landscape, architecture, and ceremonial routes collectively shape the character of the town. Three streets were selected for detailed analysis. Istana Street represents the royal and ceremonial corridor connecting the royal palace and mosque in Zone A, while Laksamana Street and Shahbandar Street represent commercial and communal streets located in Zone B near the Perak River edge. This variation in street function provides an opportunity to examine how landscape structures operate differently across ceremonial, commercial, and communal street environments within the same royal urban context.

RESEARCH METHODOLOGY

This study adopts a mixed-methods research design combining qualitative and quantitative approaches to examine the role of landscape structures in shaping streetscape identity within the historic royal town of Kuala Kangsar. The research design integrates visual-spatial observation, historical document analysis, semi-structured stakeholder interviews, and a questionnaire survey involving 330 street users. Visual-spatial observation was conducted to document key landscape structures and street attributes including vegetation, water elements, pavement materials, street furniture, and spatial configurations. The 21 semi-structured interviews targeted key urban development experts, planners, designers, and local heritage stakeholders. Qualitative interview data was structured through thematic coding, assigning specific indicators to individual respondents (coded sequentially from R-1 to R-21) to capture expert perspectives on cultural, planning, and historical significance. Quantitative reporting utilizes empirical descriptive frequencies from the field survey (n=330) to establish public consensus across four urban design domains. The analysis is guided by a conceptual framework (Figure 1) which proposes that landscape structures influence urban morphology and streetscape identity through four primary urban design attributes: attractiveness, visibility, human scale, and comfort. By triangulating spatial observation, stakeholder perspectives, and user perception surveys, the study integrates physical analysis with experiential understanding.

LITERATURE REVIEW

The presence and arrangement of landscape elements, such as tree canopies, paving, street furniture, and softscapes, are critical to the visual character and spatial organization of historic streetscapes. Within the field of urban design, streetscape identity is understood as the result of interactions between buildings, landscape structures, and street patterns that collectively shape the visual-spatial

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character of urban environments (Carmona et al., 2021; Punter, 2011). From the heritage urbanism perspective, these elements not only contribute to environmental aesthetics but also embody cultural meaning, historical continuity, and spatial memory (Ismail et al., 2018). Contemporary urban design literature further emphasises the importance of landscape elements in shaping human scale, walkability, environmental comfort, and visual enclosure, which are essential considerations in culturally sensitive environments such as Malaysia's Royal Towns (Punter, 2021; Mohd Nor et al., 2020).

Urban morphology studies highlight that the character of historic streets emerges from the spatial configuration of street networks and the relationship between buildings, landscape structures, and public spaces (Mohd Nor et al., 2020). However, despite growing recognition of the significance of heritage landscapes, conservation approaches in Southeast Asia have often prioritised architectural preservation while giving comparatively limited attention to landscape character, resulting in visual fragmentation and gradual identity loss (Ismail & Adam, 2020). Recent studies advocate a more landscape-responsive approach that integrates vernacular design principles and ecological knowledge into the management of historic urban environments (Ma et al., 2023; Khalid et al., 2023). In the context of Malaysian Royal Towns, landscape elements such as ceremonial tree planting, indigenous vegetation, riverfront spaces, and shaded pedestrian corridors play both symbolic and functional roles in reinforcing royal identity and cultural continuity. Nevertheless, empirical research examining how these landscape structures shape the visual-spatial identity of historic streets remains limited. This study therefore contributes to the literature by examining landscape structures as key determinants of streetscape identity within the historic royal town of Kuala Kangsar.

INTEGRATED SOFT AND HARD LANDSCAPE VARIABLES IN SHAPING HERITAGE STREETSCAPE CHARACTER AND FUNCTIONALITY

Soft landscape variables such as topography, vegetation type, planting arrangements, scale, and spatial placement are of critical importance in creating the attractiveness, visibility, and human scale of the heritage streetscapes. Natural landscape elements such as hills and rivers can influence the alignment of streets and symbolic order, while vegetation can enhance the spatial experience through color, texture, and leaf canopies, which provide shelter from the sun, enclosure, and cultural significance (Ismail et al., 2018; Khalid et al., 2023; Ismail & Adam, 2020). Planting arrangements can influence formal and informal patterns of streetscapes, which can directly influence the streetscape characteristics such as visibility, attractiveness, and spatiality. The soft landscape variables can be

revealed not only as landscape modifiers but also as spatial ordering devices that can articulate hierarchy, rhythm, and symbolic significance of the royal streets.

Other variables, which are part of the hard landscape, including lighting, pavement, signage, gateways, routes for pedestrians, and street furniture, all play a part in the functionality of the street and the expression of the street's culture. Lighting improves the street's safety, pavement improves the street's texture, aesthetics, and comfort; while signage helps improve the street's recognition (Carmona et al., 2021; Celik & Yildirim, 2025; Mohd Nor et al., 2020). All these variables create a holistic approach to the design of the street, which is not only functional but also culturally significant to the royal heritage of Malaysia. The landscape has been identified as the significant physical feature associated with the concept of visual appearance, with various components of the landscape affecting the physical characteristics of streets, as conceptually presented in Figure 1. Hard landscapes play a mediating role as an interface between movement, perception, and cultural expression, with the tangible expression of heritage values being converted to spatial experience. The integration of hard and soft landscapes has been critical in creating streetscapes with both functional resilience and identity richness.

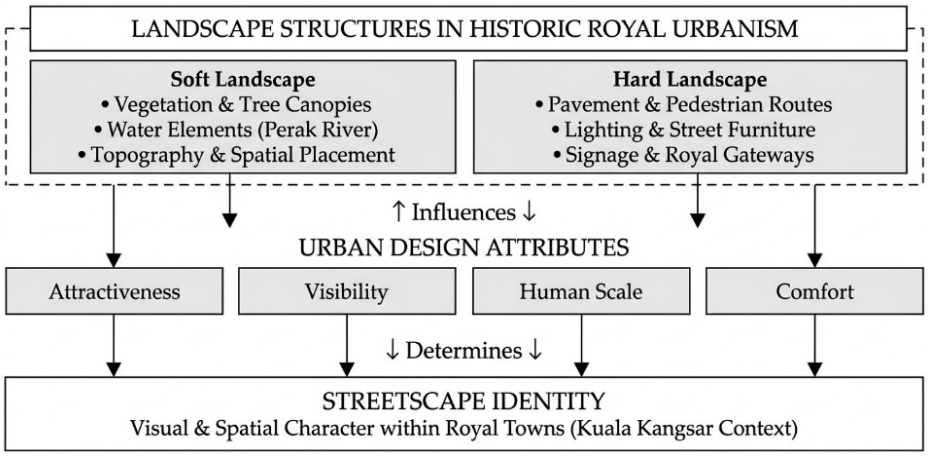


Figure 1: Conceptual model linking landscape components to the physical character of royal town streets
Source: Author's own work

ANALYSIS AND DISCUSSION

The study reveals that the visual layout of landscape structures in the royal town of Kuala Kangsar comprises important physical attributes which play an essential role in the formation of streetscape identity. Comprehensive data triangulation

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demonstrates a clear alignment between physical mapping, historical legacy, expert stakeholder statements, and user survey frequencies.

a. Attractiveness Attributes

Quantitative survey data indicates a unanimous public consensus (100%, n=330) that the local landscape configuration is highly attractive, a finding reinforced by all 21 qualitative interviewees. Attractiveness attributes are structurally divided into soft landscape and hard landscape factors.

Soft Landscape: Water Element, Topography, and Vegetation

Water Elements: The empirical analysis verifies that natural water systems strongly underpin local aesthetic value, backed by 95.5% (n=315) of survey respondents and all 21 interviewees. Expert stakeholder R-10 emphasised that the natural aesthetics of the town are anchored by the Perak River, creating highly attractive panoramic views across multiple viewing corridors (Figure 2). Historical document analysis confirms the river's deep cultural symbolism, acting as the primary transit corridor and traditional royal stage for historic Coronations and Councils of Rulers since the 1870s (McNair, 1878). Physical mapping shows that streets parallel to the water edges maximize user experience, with pedestrian corridors along the river banks creating highly memorable node areas.

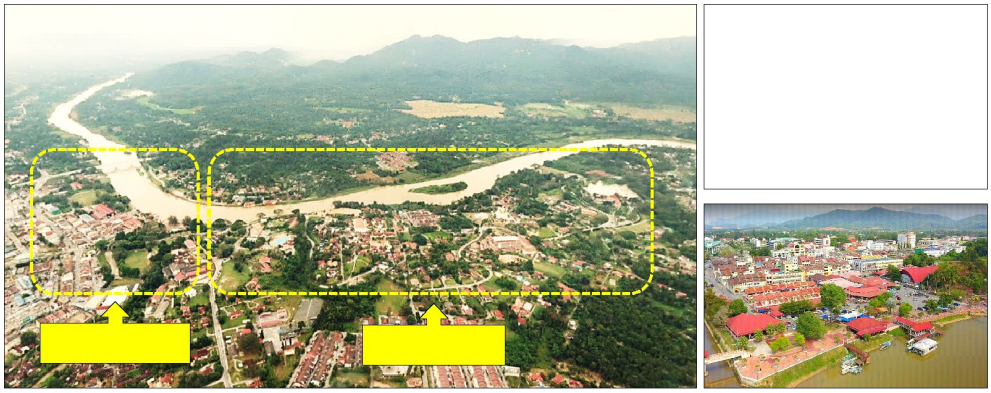


Figure 2: Street pattern network framed by Perak River creating scenic views and vibrant riverfront nodes in Zone A and Zone B
Source: Author's own work

Topographic Variation: Acts as another significant element, supported by 73.6% (n=243) of survey respondents as a key driver of visual interest. Stakeholder R-10 observed that layout development following the natural hilly contours produces beautiful vistas when moving from the palace hilltop down to the river plain (Figure 3). Physical observations confirm that topography directly influences development density patterns; the undulating terrain of Zone B

maintains low-density royal civic compounds, while the flat terrain of Zone A accommodates high-density mixed commercial clusters. This spatial pattern projects a strong visual hierarchy that represents royal sovereignty.

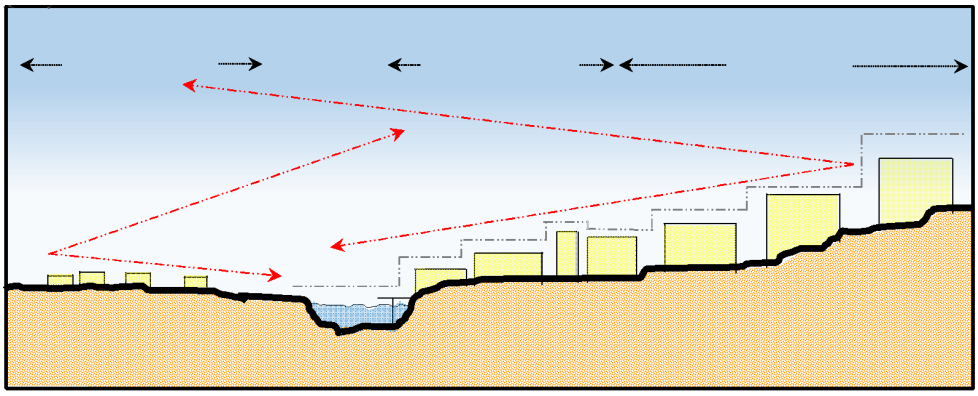


Figure 3: Topographic variation influencing development density patterns and scenic street views across Zones A and B
Source: Author's own work

Planting Patterns: Contribute substantially to local distinctiveness, endorsed by 66.6% (n=220) of survey respondents. Specific design guidelines require highly formal and structured layouts along the Zone B ceremonial axis (Istana Street), using official royal flora featuring distinct gold-yellow tones (e.g., Royal Palm, and Yellow Canna) to reinforce civic identity (Figure 4). Conversely, Zone A utilises informal planting layouts using domestic potted plants near old shophouses to add greenery within tight commercial spaces.



Figure 4: Landscape diversity in type and colour enhancing place identity and street character in Zone B.
Source: Author's own work

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Hard Landscape: Lighting and Pavement Design

Decorative Lighting: Statistical survey analysis shows that 64.5% (n=213) of users explicitly associate decorative lighting with streetscape attractiveness, supported by 16 qualitative interviewees. Zone B utilises formal ceremonial lighting layouts to mark the protocol route. In Zone A, practical design rules control lighting configurations along the Perak riverfront by placing light fixtures at a fixed height of 2.8 meters at 4-to-5-meter intervals, successfully drawing night pedestrian crowds and establishing an active public node.

Pavement Design: Acts as an essential hardscape modifier, validated by 14 interviewees. Field observations indicate that Zone B pedestrian paths utilise red permeable pavement surfaces that control storm runoff while enhancing aesthetic continuity. Conversely, Zone A relies on interlocking precast elements, which frequently show poor installation quality, water ponding, and maintenance cracks, reducing pedestrian safety.



Figure 5: Permeable pavement along pedestrian paths in Zone B enhances pedestrian comfort, surface drainage, and streetscape attractiveness.
Source: Author's own work

b. Visibility Attributes

Visibility within the historic public realm relies on softscape legibility and hardscape wayfinding markers.

Soft Landscape: Water Element and Vegetation Layout

The Perak River Landmark: User surveys show that 88.78% (n=293) of respondents link the Perak River to high streetscape visibility, supported by all 21 interviewees. Expert stakeholder R-11 verified that the broad river system functions as a permanent reference landmark that aids spatial orientation (Figure 6). Historical archival records from the 1870s confirm the river's long-standing role as the foundational landmark of the town.

Vegetation Layout: Regarding landscape layouts, 79.1% (n=261) of users link planting layouts to visibility. Formal planting lines along Istana Street (Zone B) signal entry into royal civic zones, while loose configurations in Zone A mark mixed-use commercial spaces.

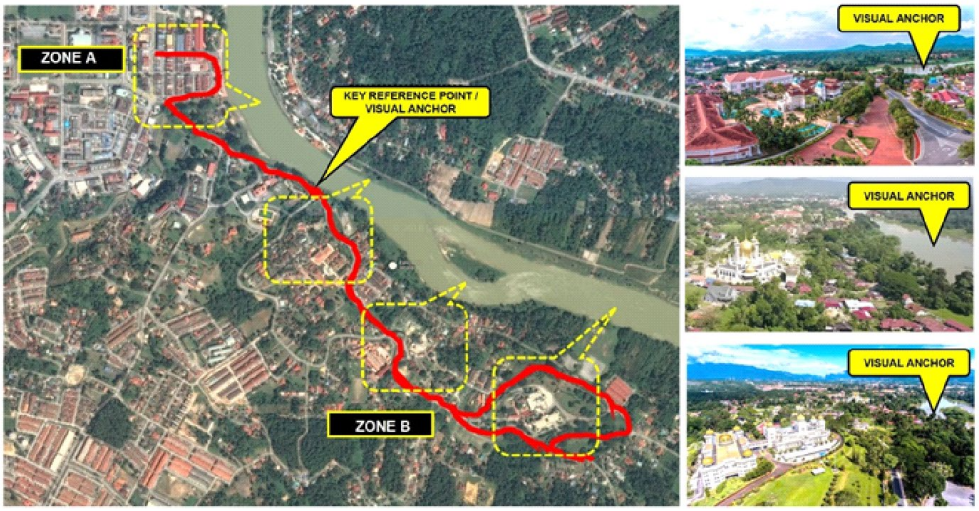


Figure 6: The presence of the Perak River serves as a key reference point in the Royal Town of Kuala Kangsar, enhancing visibility quality across both Zone A and Zone B.
Source: Author's own work

Hard Landscape: Gateways and Signage Units

Decorative Gateways: Gateways significantly improve wayfinding legibility, as stated by 68.2% (n=225) of survey respondents and 18 interviewees. Field observations mapped 22 decorative gateways across the town (Figure 7). The primary gateway at the base of Bukit Chandan uses durable stone and timber, standing 4.5 meters high with bold state colours and royal crests to signal entry into the royal core. Wrought iron arches in Zone B stand 6.5 meters high but lack strong colours, making them less visible. In Zone A, white precast concrete gateways standing 3 to 4 meters high mark key intersections.

Street Signage: Serves as a key wayfinding element, supported by 45.5% (n=150) of respondents. Expert R-11 noted that while signage is useful, the presence of more than five competing, non-uniform sign shapes along Istana Street (Zone B) creates visual confusion. Uniform signage in Zone A utilises consistent sizing, royal emblems, and distinct colours, improving legibility.

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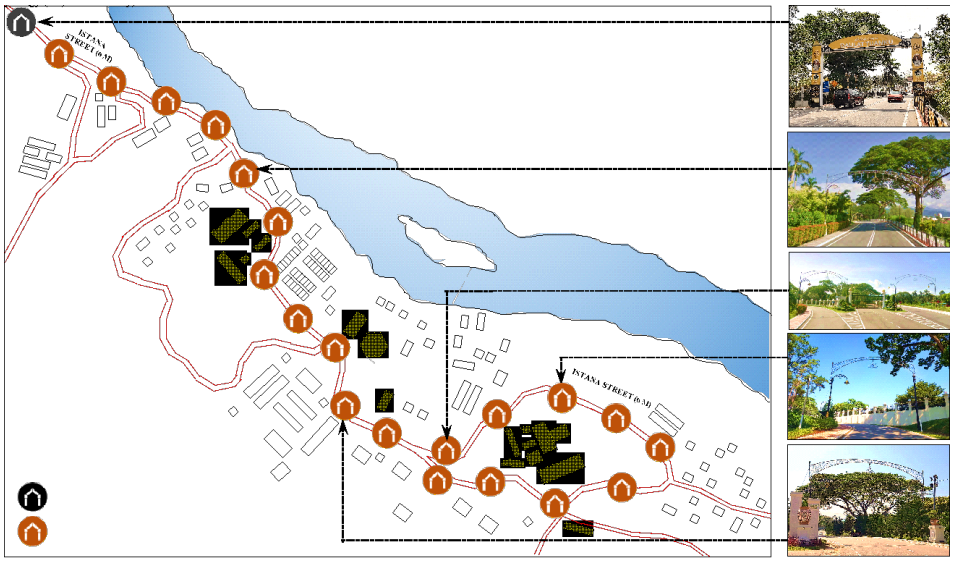


Figure 7: Royal-themed gateway design, which includes material, height, colour, quantity and location, enhances visibility and supports street recognition along Zone B.
Source: Author's own work

c. Human Scale Attributes

Field observations and survey responses from 86.9% (n=287) of users show that spatial enclosure and human scale depend heavily on tree size and configuration. The empirical analysis reveals a clear descriptive alignment between plant sizing parameters and human scale perception:

Vegetation Sizing Parameters: Spatial mapping shows that medium-height vegetation controlled between 1.5 to 3.0 meters effectively bounds the pedestrian path without obstructing historic sightlines. In contrast, large canopy trees (such as *Samanea saman* reaching 7-10 meters in height with a 6-9 meter radius) shift the spatial profile away from an intimate human scale, though they provide exceptional shade.

Linear Planting Patterns: Linear planting analysis is strongly associated with user preferences for enclosure. In Zone B, formal rows of *Araucaria columnaris* and royal palms standing 5 to 7 meters high form distinct vertical street walls (Figure 8). This configuration generates processional corridors that connect the riverfront to royal landmarks, enhancing the entry experience.



Figure 8: Tree-lined planting creates a sense of enclosure with defined street edges, forming an entry point and a welcoming atmosphere in Zone B.
Source: Author's own work

d. Comfort Attributes

Environmental comfort is comprehensively evaluated across softscape elements and four specific hardscape infrastructure categories.

Soft Landscape Comfort: Microclimatic Elements

Evaporative Cooling: Sidewalk comfort is tied directly to natural water features by 86.1% (n=284) of respondents and 18 interviewees. Respondent R-13 observed that the Perak River and the historic clock tower fountain provide evaporative cooling, which reduces ambient heat and creates a comfortable pedestrian environment.

Hard Landscape Comfort: Infrastructure Controls

Pedestrian Pathways: Traditional five-foot walkways along the shophouses (Zone A) are highly valued for pedestrian comfort, endorsed by 95.5% (n=315) of survey respondents and all 21 interviewees. Specific design rules dictate sheltered commercial arcades with clear human-scaled overhead heights of 2.5 to 3.0 meters, shielding users from heavy rain and direct sun while encouraging active shopfront interactions (Figure 9). Conversely, standalone paths in some parts of Zone B narrow down to a minimum width of 600 mm and are frequently blocked by utilities and parked vehicles.

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Figure 9: Human-scale, sheltered, and continuous five-foot walkways contribute to a comfortable pedestrian environment in Zone A.
Source: Author's own work

Pedestrian Amenities: Rest shelters provide clear comfort benefits, supported by 47.6% (n=157) of respondents. Design guidelines require an extended roof overhang of 900 to 1000 mm and a functional height of 2300 to 2500 mm to protect users from the elements (Figure 10). Public toilets (61.81%, n=204 survey dissatisfaction) require flat, zero-step entries to ensure universal access, avoiding the steep stairs found near the commercial bazaar. Seating (26.4%, n=87 support) is often placed directly in the sun near parking bays, forcing pedestrians to sit on shaded planter walls instead. Trash bins (20.9%, n=69 support) suffer from low-quality materials and poor maintenance, leading to vandalism and odour issues.



Figure 10: Comfortable atmosphere created by rest shelters along streets in Zones A and B enhancing a lively pedestrian environment.
Source: Author's own work

Traffic Amenities: Pedestrian crossings are prioritized by 23.6% (n=78) of users. In Zone B, narrow streets measuring 6 to 7 meters wide slow traffic down naturally, allowing safe crossings without painted lines. However, wider streets in Zone A require dedicated crossings due to faster vehicle speeds. Universal access ramps (16.1%, n=53 support) must maintain a maximum slope of 1:12 and a minimum width of 1500 mm to comply with universal design standards.

Utility Amenities: Open concrete drainage slabs and poorly placed electrical feeder pillars create major trip hazards in Zone B. In contrast, Zone A integrates utility pillars directly into the structural softscape beds behind the kerb line. This

shows that infrastructure elements can be integrated seamlessly into the cultural landscape through careful design coordination, preventing visual clutter while ensuring safe and continuous walkways.

LANDSCAPE STRUCTURES FRAMEWORK FOR HISTORIC ROYAL URBANISM

To fulfil the research objective of evaluating landscape components through specific urban design attributes, this framework provides direct design controls tailored to historic royal urban settings. Rather than treating landscapes as cosmetic additions, these empirical parameters translate the findings into actionable municipal planning policies to protect streetscape identity (refer to Table 1):

Table 1: Framework of Empirical Metric and Design Controls for Urban Design Attribute

Urban Design Attribute	Component Type	Empirical Performance Metric & Design Controls
a. Attractiveness	Soft Landscape	Preservation of natural river corridors and undulating topography; use of royal yellow flora (e.g., Royal Palm, Yellow Canna).
	Hard Landscape	Decorative lighting fixtures fixed at a height of 2.8 meters at 4-to-5-meter intervals; red permeable pavement.
b. Visibility	Soft Landscape	Preservation of the Perak River as a permanent landmark; formal linear rows of trees to signal civic transitions
	Hard Landscape	Standardized gateways (4.5m height using stone/timber with royal crests); uniform, non-competing signage sizes and emblems.
c. Human Scale	Vegetation Layout	Medium-height softscape controlled between 1.5 to 3.0 meters; formal lines of trees (5–7m) for street enclosure.
d. Comfort	Infrastructure	Continuous, sheltered five-foot walkways with 2.5 to 3.0m overhead height; rest shelters with 900–1000mm roof overhang.
	Accessibility	Universal access ramps with a strict maximum slope of 1:12 and minimum width of 1500 mm; zero-step public toilet entries.

Source: Author's own work

CONCLUSION

This study demonstrates that landscape structures function as primary visual-spatial and functional determinants of streetscape identity within historic royal urban environments. By systematically isolating the specific structural contributions of soft and hard landscape features, the empirical findings reveal

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how integrated public realms shape overall urban distinctiveness. Triangulating these findings yields the significant conclusion that streetscape identity relies on a dynamic system where landscape aesthetics directly dictate public space usability and spatial hierarchy. The variables execute distinct structural roles across the town fabric: formal softscapes project civic protocol and symbolic sovereignty along ceremonial corridors, while integrated hardscape infrastructure ensures pedestrian continuity, universal safety, and microclimatic comfort within high-density communal hubs. Ultimately, to halt the gradual loss of cultural character caused by modernization pressures, municipal frameworks must shift from purely building-centric architectural conservation to embedding targeted, empirical landscape design controls into local planning guidelines. This balanced approach guarantees that historic royal towns successfully preserve their unique cultural continuity and spatial memory while maintaining highly practical, human-scaled public realms for contemporary users.

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LIVING ON DISPLAY: NEGOTIATING GENTRIFICATION AND CULTURAL RESILIENCE IN CHEW JETTY, GEORGE TOWN, MALAYSIA

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Abstract

The designation of World Heritage Sites often precipitates a paradox where tourism capital threatens the very living heritage it aims to safeguard. This study examines Chew Jetty, a historic clan settlement within the George Town UNESCO World Heritage Site, Malaysia, to analyse how residents negotiate the tension between economic opportunism and cultural continuity. Adopting a qualitative case study approach with a sample representing a significant majority of the population, the research identifies a distinctive phenomenon of 'commercial gentrification from below'. Motivated by the 'rent gap', residents actively commodify domestic spaces, leading to phenomenological displacement within the home. However, findings indicate that this does not equate to cultural erasure. Instead, the community exhibits 'negotiated resilience', employing strategies such as spatial regulation and the bifurcation of rituals to sustain their intangible heritage. The study challenges existing facade-oriented planning frameworks, arguing that true heritage sustainability in UNESCO sites depends on recognising resident agency. It concludes that governance must support community-led adaptation to prevent the 'museumification' of living settlements.

Keywords: Gentrification, Cultural, Resilience, Heritage Sustainability, UNESCO

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INTRODUCTION

The designation of World Heritage Sites often precipitates a 'preservation paradox', while global recognition seeks to protect cultural value, the subsequent influx of tourism capital frequently threatens the very living heritage it aims to safeguard. In historic cities across Southeast Asia, this tension manifests as tourism-driven gentrification, a process that reconfigures urban space to prioritise visitor consumption over local social reproduction (Lin et al., 2023; Lo & McKercher, 2023; Raja Othman, 2017). More recent studies further highlight how tourism-driven gentrification reshapes socio-spatial dynamics in heritage cities, particularly in Southeast Asia, where increased global visibility intensifies pressure on local communities and traditional practices (Chan et al., 2017; Suyadnya, 2021). George Town, Penang, inscribed as a UNESCO World Heritage Site in 2008, exemplifies this dynamic. While designation has catalysed economic revitalisation, it has simultaneously introduced intense market pressures that commodify local culture and displace traditional lifestyles, particularly within the fragile waterfront settlements known as the Clan Jetties (Lim & Pan, 2017; Salim & Rahman, 2022).

Among these settlements, Chew Jetty stands as a critical case study. Established in the 19th century, this clan-based maritime community is now a focal point of global tourism. However, unlike standard gentrification narratives where residents are displaced by external developers, Chew Jetty presents a more complex phenomenon. Here, residents remain physically present but face 'phenomenological displacement' as their domestic spaces are repurposed into commercial enterprises to capture tourism revenue, a process this study identifies as 'commercial gentrification from below'.

Despite the growing literature on heritage tourism, current scholarship often frames residents as passive victims of structural change. Limited attention has been given to the internal mechanisms of cultural resilience specifically, how communities actively negotiate the 'rent gap' and adapt their intangible heritage to survive. In particular, there is a lack of empirical studies that examine how residents who remain physically present within heritage sites actively negotiate and adapt to tourism pressures through everyday spatial and cultural practices. This paper addresses this gap by asking: How do the residents of Chew Jetty negotiate the tension between economic opportunism and cultural continuity?

Adopting a qualitative case study approach, this research examines the interplay between gentrification pressures and community agency. By situating resident experiences at the centre of analysis, the study contributes to theoretical debates on heritage sustainability by demonstrating that resilience is not a static resistance, but a dynamic process of 'negotiated adaptation' (Holtorf, 2018a)

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LITERATURE REVIEW

Tourism-Driven Gentrification: From Displacement to Self-Commodification

Gentrification has evolved from its original formulation as a process of middle-class reinvestment in working-class neighbourhoods to a broader framework encompassing economic restructuring and symbolic displacement. N. Smith (1987) Rent Gap Theory provides the structural basis for this analysis, conceptualising gentrification as a capital-driven process triggered when the 'potential ground rent' of a site exceeds its current use value.

In heritage cities, this gap is frequently widened by tourism. Heritage designation revalorises historic districts, transforming cultural assets into economic resources, a process Wilson (2014) terms 'aesthetic consumption'. While classical gentrification involves the physical eviction of residents by external developers, recent scholarship in Asian heritage cities, such as Hoi An and George Town, identifies a more complex dynamic. Here, gentrification often manifests as 'commercial gentrification', where residential spaces are converted into cafes, boutique hotels, and souvenir outlets (Rahman, 2018). This transformation is often driven by the physical characteristics of the heritage fabric itself, where the tangible heritage value of shophouses and timber structures is leveraged to determine their most profitable usage (Yun & Marzuki, 2025).

Crucially, this process is not always externally imposed. Emerging research suggests that residents themselves may act as agents of gentrification, exploiting the rent gap by converting their domestic spaces into commercial ventures (Chan et al., 2016). This internal commodification reconfigures the home from a lived space into a 'performative landscape', prioritising visitor experience over social reproduction. In George Town, this has led to a distinctive morphology where traditional trades vanish, replaced by a monoculture of tourism, threatening the 'intangible' qualities that justified the UNESCO listing in the first place.

Cultural Resilience as Negotiated Adaptation

While gentrification literature has historically focused on displacement and loss, contemporary resilience thinking emphasises the adaptive capacities of communities. Cultural Resilience is defined not merely as the ability to withstand shock, but as the capacity of a social system to absorb disturbance, reorganise, and retain core identity (Adger, 2000; Magis, 2010).

In the context of living heritage, resilience is increasingly understood as a process of negotiation. Wilson (2014) argues that communities do not simply 'resist' change; rather, they engage in 'pathway creation', adapting cultural forms to ensure survival. For instance, Cerchiaro & Houtman (2021) and Surata et al., (2024) observes that in tourism-heavy environments, rituals are often bifurcated:

simplified ‘front-stage’ performances are presented for tourists, while complex ‘back-stage’ traditions are maintained privately for the community.

This perspective shifts the analytical focus from vulnerability to agency. It suggests that modifications to intangible heritage, such as the shortening of rituals or the regulation of spatial boundaries, are not necessarily signs of cultural erosion, but strategic adaptations that allow the community to coexist with the tourism economy.

Heritage Sustainability: The Missing Link of Community Agency

The concept of Heritage Sustainability extends conservation discourse beyond the preservation of physical fabric to include social and economic vitality. Smith (2006, 2009) critiques the "authorised heritage discourse" which privileges visual authenticity (e.g., facade preservation) while often neglecting the social systems that sustain the place.

Poulios (2014) argues that true heritage sustainability requires recognising communities as active custodians rather than passive beneficiaries. However, existing planning frameworks in Southeast Asia often lack mechanisms to support this agency, focusing heavily on architectural conservation while overlooking the "living" dimensions of heritage. This creates a policy gap where the physical shell of the settlement is preserved, but its social heart is hollowed out, a phenomenon termed ‘museumification’ N. Smith (1987).

Addressing this gap requires an integrated approach that links the structural pressures of the Rent Gap with the adaptive strategies of Cultural Resilience. By synthesising these perspectives, this study positions Chew Jetty as a critical case for understanding how living heritage communities navigate the tension between economic opportunism and cultural continuity.

Theoretical Framework

This study is grounded in three interrelated theoretical perspectives that illuminate the dynamics of heritage transformation and community resilience in Chew Jetty: Gentrification Theory, Cultural Resilience, and Heritage Sustainability.

Tourism-Driven Gentrification and the ‘Rent Gap’: The analysis adopts Smith’s (1987) Rent Gap Theory as a foundational lens. Smith conceptualised gentrification as a structural process driven by capital reinvestment when the ‘potential ground rent’ of a site exceeds its current use value. In heritage settings like George Town, this gap is widened by tourism demand. However, this study extends the framework to consider ‘commercial gentrification from below’ or ‘self-gentrification’. In this iteration, the rent gap is not solely exploited by external developers but also by existing residents who convert domestic space into commercial enterprises to capture tourism revenue. This theoretical nuance

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facilitates the analysis of cultural commodification (Zukin, 1987), where the displacement observed is not necessarily physical eviction, but the phenomenological displacement of private life by commercial activity within the home.

Cultural Resilience as Negotiated Adaptation: To understand community response, the study employs Cultural Resilience Theory, defined as the capacity of communities to absorb disturbance and reorganise while retaining core functions and identity (Adger, 2000; Cubeddu & Martini, 2025; Holtorf, 2018b; Järvelä, 2023; Magis, 2010). Crucially, this framework rejects a binary view of resilience as mere 'resistance' to change. Instead, drawing on Wilson (2014), resilience is conceptualised here as a process of 'negotiated adaptation'. This lens posits that changes to intangible heritage, such as, the modification of rituals or the regulation of social space are not inherently signs of cultural loss, but are adaptive strategies employed by the community to sustain their identity amidst external pressures.

Heritage Sustainability: Beyond the physical, the concept of Heritage Sustainability extends the discourse beyond architectural conservation to include social and economic dimensions (Fabbricatti et al., 2020; Pendlebury, 2012). This perspective critiques the "authorised heritage discourse" that privileges visual authenticity and instead argues that long-term sustainability depends on community agency. It frames the residents of Chew Jetty not as passive objects of preservation, but as active custodians whose economic survival and social adaptability are prerequisites for the survival of the site as a living heritage settlement.

Synthesis together, these theories provide a comprehensive foundation for examining Chew Jetty (see Figure 1). Gentrification identifies the structural pressures; Cultural Resilience explains the community's adaptive mechanisms; and Heritage Sustainability defines the outcome of a living system that balances economic viability with cultural continuity.

While previous studies have applied these theoretical perspectives independently, this study integrates Rent Gap Theory, Cultural Resilience, and Heritage Sustainability into a unified analytical framework. This integration allows for a more comprehensive understanding of both structural pressures and community responses within a living heritage context. Unlike conventional approaches that emphasise external drivers of gentrification or view resilience as passive resistance, this study highlights the active role of residents in shaping spatial, cultural, and social adaptations. As such, the framework advances existing scholarship by demonstrating how internal community dynamics influence heritage outcomes, particularly in contexts where residents remain physically present but experience transformation within their everyday living spaces.

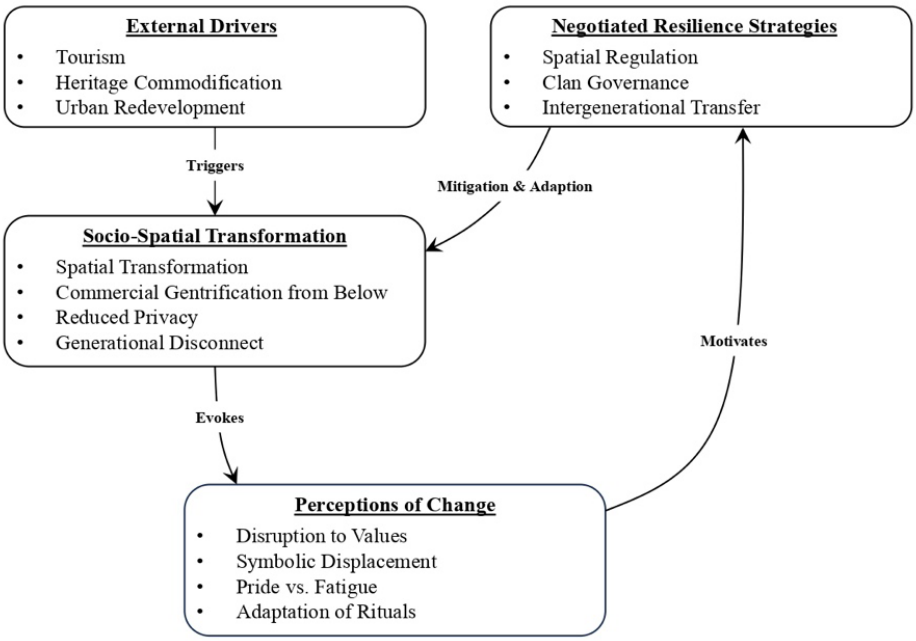


Figure 1: Integrated Theoretical Framework

METHODOLOGY

This study adopts a qualitative case study approach, situated within an interpretivist epistemology, to examine the complex interplay between gentrification and cultural resilience. The single-case design was purposefully selected to capture the 'paradox of living heritage' at Chew Jetty, George Town. As a Clan settlement established in the late 19th century and a focal point of the UNESCO World Heritage Site, the jetty represents a critical microcosm of the tension between traditional maritime lifestyles and the pressures of the modern visitor economy. This approach prioritises subjective meaning-making, allowing for an in-depth exploration of how residents negotiate the "rent gap" and commodification within their own homes.

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Sampling and Respondent Profile

Table 1: Respondent Profile

Characteristic	Category	n
Gender	Male	12
	Female	8
Years of residence	10–20 years	6
	21–40 years	7
	>40 years	7
Role	Clan leader	2
	Business owner	8
	Resident	10

Purposive sampling was employed to recruit respondents with a minimum of 10 years of residence in Chew Jetty. This specific criterion ensured that all respondents possessed substantial, longitudinal knowledge regarding the settlement's historical development, traditional cultural practices, and recent tourism-driven transformations.

The final sample consisted of 20 participants (n=20), purposefully selected to reflect the diverse social structure of the community. The respondent profile encompasses a range of demographic backgrounds, including varying lengths of residence (ranging from 10 to over 40 years) and distinct community roles, refer to Table 1. Specifically, the sample includes clan leaders, elders, business owners, and long-term residents engaged in both traditional and tourism-related livelihoods, ensuring a multifaceted view of the settlement's dynamics.

Sample Representativeness and Saturation

To clarify the representativeness of the sample, it must be contextualised within the specific demographics of the site. Chew Jetty is a compact settlement comprising approximately 30 to 40 active households; therefore, the 20 selected participants represent a significant majority, approximately 50% to 60% of the total resident population. This notably high coverage ensures that the findings capture a comprehensive community consensus rather than isolated narratives, providing extensive coverage of the settlement.

However, consistent with qualitative case study methodologies, this research adopted the principle of information-rich sampling rather than pursuing statistical representativeness. Participants were ultimately selected based on their capacity to provide in-depth, nuanced insights into the lived experiences of tourism-driven gentrification and cultural resilience. Interviews were conducted continuously until thematic saturation was achieved, whereby no substantially new concepts or interpretations emerged from subsequent conversations. Consequently, the high coverage of the sample ensures robust analytical and theoretical insights into the internal dynamics of living heritage communities,

rather than statistical generalisations extending beyond the specific case of Chew Jetty.



Figure 2: Informational Map and Spatial Layout of Chew Jetty, a UNESCO World Heritage Site in George Town, Penang
Source: Field Photo by Researcher, 2025

Data Collection Methods

Data were gathered through a triangulation of semi-structured interviews, participant observation, and document analysis. Interviews explored changes in daily life, ritual adaptation, and spatial usage. Complementary observations were conducted during routine weekdays and major events, such as the Hungry Ghost Festival, to document behavioural patterns and spatial regulation. Planning documents, including the George Town Special Area Plan, were reviewed to contextualise local narratives within the broader policy framework.

The triangulation of semi-structured interviews, participant observation, and document analysis enabled cross-validation of findings, enhancing the credibility and reliability of the study.

Crucially, the researcher possesses linguistic fluency in the local Hokkien dialect, Malay, and English. Interviews were conducted without the mediation of interpreters, facilitating a deeper rapport with elderly residents and allowing for the capture of nuanced 'insider' perspectives on clan politics and ritual modifications that might otherwise remain inaccessible to external observers.

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Data Analysis

Data were analysed using an abductive thematic analysis, which involved engaging in an iterative dialogue between empirical findings and the theoretical constructs of Rent Gap Theory and Cultural Resilience. To ensure systematic and rigorous theme development, the analytical process was guided by Braun & Clarke (2006) six-phase framework. This included familiarisation with the interview transcripts, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final analysis.

While the framework structured the procedural steps, the interpretation itself was theoretically driven through a hybrid coding strategy:

- Deductive Coding: Codes were informed by existing literature on gentrification, cultural resilience, and heritage sustainability. This allowed the study to track established concepts such as displacement, commodification, and community agency.
- Inductive Coding: Simultaneously, inductive coding allowed new, locally grounded concepts to emerge directly from the participants' narratives. This led to the identification of unique mechanisms such as *commercial gentrification from below*, *ritual staging*, and *boundary management*.

To strengthen the theme development process, codes with similar meanings were subsequently grouped into broader categories before being synthesised into overarching analytical themes through a method of continuous comparison across all interviews. To further enhance analytical rigour, this coding was conducted iteratively alongside ongoing data collection, allowing emerging insights to directly inform and refine subsequent interviews, refer to Table 2.

Themes were continuously reviewed against the transcripts, field observations, and documentary evidence until conceptual coherence and thematic saturation were successfully achieved. Ultimately, this hybrid analytical process enabled the study not only to apply existing theoretical perspectives but also to extend them by identifying the context-specific mechanisms through which the Chew Jetty community actively negotiates cultural resilience under tourism-driven gentrification.

Table 2: Example of Coding and Theme Development

Representative Interview Excerpt	Initial Code	Category	Final Analytical Theme
"We have to stay inside because there are too many tourists."	Loss of privacy	Spatial displacement	Commercial Gentrification from Below
"We now do prayers before tourists arrive."	Ritual adaptation	Negotiated cultural practice	Negotiated Resilience

Representative Interview Excerpt	Initial Code	Category	Final Analytical Theme
"Some areas are off-limits for tourists."	Boundary regulation	Community governance	Relational Place-Making
"Young people are less interested in traditions."	Generational change	Cultural continuity	Intergenerational Transmission of Heritage

Limitations

The findings are context-specific to Chew Jetty and not intended for broad generalisation, though they offer theoretical insights relevant to other inhabited heritage sites in Southeast Asia. While temporal limitations constrained the longitudinal scope of fieldwork, the triangulation of interview data with observation and policy analysis provides a robust and credible foundation for the study's conclusions.

ANALYSIS AND DISCUSSION

The analysis reveals that the reshaping of Chew Jetty is not a unilateral process of external displacement, but a complex internal negotiation. While tourism has introduced significant structural pressures, manifesting as overcrowding and the commodification of daily routines, it has also triggered active adaptive responses from the community. The findings are discussed across three interrelated themes: (1) the spatial dynamics of 'commercial gentrification from below', (2) the negotiation of identity through ritual adaptation, and (3) community agency in sustaining intangible heritage. Together, these sections illustrate that cultural resilience acts as a dynamic mediating force, allowing residents to navigate the friction between economic opportunism and the continuity of living heritage.

The Economics of Space: Rent Gaps and Commercial Gentrification from Below

The transformation of everyday life in Chew Jetty offers a distinct localised iteration of N. Smith (1987) Rent Gap Theory. While Smith conceptualised the rent gap as a driver for external capital reinvestment, findings in Chew Jetty indicate an internalised process. Here, the disparity between the 'use value' of the property (as a residence) and its potential 'exchange value' (as a commercial tourism outlet) has driven residents themselves to capitalise on their spatial assets.

This creates a paradox of 'commercial gentrification from below', where residents are not displaced by developers but are spatially displaced within their own homes. Observations revealed that households frequently reorganise interior layouts, compressing private living areas into marginal zones such as upper floors or rear kitchen extensions to surrender prime frontage to souvenir shops and cafes. As shown in Figure 3, the narrowing of walkways by

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merchandise displays physically manifests this encroachment of the commercial upon the domestic.

These spatial reconfigurations empirically validate the concept of 'self-gentrification' proposed in the framework. The displacement observed is *phenomenological* rather than physical: residents remain on-site, but the meaning of 'home' is fundamentally altered by the intrusion of the tourist gaze. Consequently, the threat to heritage sustainability arises not from eviction, but from the internal commodification of space for economic survival.



Figure 3: Visual Evidence of Spatial and Commercial Transformation in Chew Jetty
Source: Field Photo by Researcher, 2025

Negotiating Identity: Rituals, Festivals, and the Performative Turn

Residents' perceptions of cultural change reveal a complex psychological landscape that aligns with the 'negotiated response' described by Wilson (2014). This is most visible in the community's management of temple ceremonies and religious festivals.

Observations during major events, such as the Hungry Ghost Festival, indicate that these rituals have become sites of contestation and adaptation. Residents noted that the scale and timing of certain ceremonies are frequently adjusted to accommodate tourist flows, leading to concerns that rituals are becoming 'performative' spectacles rather than purely spiritual acts. This aligns with the risk of 'museumification' warned of by Pendlebury (2012), where cultural forms are preserved but emptied of social meaning.

However, a critical analysis suggests this is not a simple erosion of authenticity. Participants emphasised a clear distinction between the "outward performance" for visitors and the "inward devotion" for the clan. This bifurcation of ritual space exemplifies Wilson (2014) negotiated resilience, where the community strategically curates a 'front-stage' for tourists to protect the sanctity of the 'back-stage' for themselves. Thus, the Hungry Ghost Festival serves a dual function: it is an economic asset that attracts visitors but simultaneously remains the primary vehicle for reinforcing communal bonds in the face of external change.



Figure 4: Signboard Displaying Public Behaviour Restrictions at Chew Jetty
Source: Field Photo by Researcher, 2025

Community-Based Resilience Strategies

The specific strategies employed by Chew Jetty residents in boundary-making, governance, and intergenerational transfer demonstrate that they are active agents rather than passive victims of gentrification.

Spatial Regulation as Relational Place-Making: The erection of signboards (see Figure 4) and the enforcement of 'no-entry' zones represent a reclaiming of territory. This aligns with Pierce et al. (2011) concept of 'relational place-making', where the community actively regulates the flow of bodies to protect their social reproduction. By enforcing these boundaries, residents disrupt the tourist gaze and reassert the jetty as a living space rather than a theme park.

Institutional Resilience: The role of the Chew Clan Association in mediating conflicts and organising rituals is pivotal. This governance structure provides the collective efficacy required for social resilience, ensuring that individual economic pursuits do not completely fracture community cohesion. Intergenerational Transmission: The deliberate involvement of youth in ritual preparation serves as a countermeasure to the 'generational disconnect' identified in the literature. This strategy moves beyond physical conservation to safeguard the 'intangible heritage' defined by UNESCO (2011), ensuring that the settlement retains its socio-cultural DNA even as its physical skin changes.

The Uneven Burden of Resilience and Internal Inequality: While the community demonstrates significant adaptive capacity, it is crucial to avoid romanticising this resilience as a universally positive, egalitarian, or uniform experience. The internal commodification of Chew Jetty has inadvertently generated socio-economic stratification among its residents. Those strategically positioned to capitalise on the 'rent gap' typically residents who own property in high-footfall areas and possess the capital to convert their frontages into tourist-oriented businesses reap substantial economic benefits.

Conversely, the burden of this spatial transformation disproportionately falls upon the elderly, renters, and those who remain engaged in traditional, non-

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tourist-facing livelihoods. For these individuals, the influx of tourism offers little to no financial gain, yet they are forced to endure the negative externalities of commercial gentrification, including severe overcrowding, noise pollution, and a profound loss of domestic privacy. Consequently, cultural resilience in Chew Jetty is a highly uneven and stratified process. For a subset of the community, resilience is a form of lucrative economic opportunism; however, for others, it merely represents an exhausting, daily struggle to tolerate the disruptions of living on display within a heavily commodified environment.

Implications for Heritage Sustainability

The case of Chew Jetty challenges the predominantly 'facade-oriented' approach of current planning instruments, such as the George Town Special Area Plan. The findings suggest that true heritage sustainability depends less on preserving timber structures and more on supporting the adaptive capacity and social welfare of the living community. If planning frameworks continue to prioritise visual coherence over social vitality, they risk accelerating the 'zombification' or 'museumification' of the site.

To mitigate this trajectory, local management authorities specifically George Town World Heritage Incorporated (GTWHI) and the Penang Island City Council (MBPP) must pivot towards actionable, community-centric policy interventions. Firstly, official governance frameworks must formally legitimise the residents' rights to regulate tourism flows. This could be achieved by institutionalising community-led spatial boundaries, legally backing resident-enforced 'no-entry' private zones, and implementing strict, city-endorsed visiting hours to protect residential privacy.

Secondly, management bodies must directly address the uneven economic impacts of tourism-driven gentrification. GTWHI and MBPP should introduce targeted support mechanisms such as utility subsidies, heritage maintenance grants, or tax relief, specifically for households that sustain traditional maritime livelihoods and do not profit from commercial tourism. By providing a financial safety net for non-commercial residents, the state can prevent the complete monoculture of souvenir shops. Ultimately, a sustainable heritage framework must integrate community agency into the official management apparatus, ensuring that living heritage sites are protected as dynamic, equitable social systems rather than merely architectural backdrops for aesthetic consumption.

CONCLUSION

This study challenges the binary narrative of gentrification as solely an external imposition, revealing instead a complex internal dynamic within Chew Jetty. The findings demonstrate that tourism-driven pressure has triggered a form of

'commercial gentrification from below', where residents themselves act as agents of spatial transformation. Motivated by the 'rent gap' between residential use and commercial potential, households have reorganised their domestic spheres, leading to a 'symbolic displacement' where private life is increasingly pushed to the margins of the home.

However, the study also establishes that this commodification does not equate to a total erasure of identity, nor is it a uniformly positive experience. While the community exhibits 'negotiated adaptation' through spatial regulation, ritual bifurcation, and intergenerational transfer, this resilience is unevenly distributed. The internal commodification of space has stratified the community, disproportionately burdening traditional and elderly residents who endure the loss of privacy without the economic benefits of the tourism rent gap.

From a planning perspective, the case of Chew Jetty underscores the critical limitations of 'facade-oriented' conservation frameworks like the George Town Special Area Plan. Protecting physical structures is insufficient if the social systems within them are allowed to fracture under the weight of uneven gentrification. Sustainable heritage management must therefore pivot towards recognising community agency and addressing socio-economic inequalities. Local authorities, notably GTWHI and MBPP, must legitimise residents' rights to regulate tourism flows and provide targeted socio-economic support to those sustaining traditional livelihoods. Ultimately, the long-term sustainability of UNESCO living heritage sites depends on governance frameworks that protect not just the architectural shell, but the social equity and adaptive capacities of the communities residing within.

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FRAMED VIEWS: NATURE-INSPIRED LATTICE WINDOWS AND LIGHT–SHADOW TRANSLATION IN CONTEMPORARY INTERIOR SPACE

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Abstract

This paper explores how Huizhou lattice motifs can be translated into modular perforated screens for contemporary interior spaces, so that they function as spatial boundaries rather than surface decoration. Based on field photography in southern Anhui, four motifs—ice-crack plum blossom, ancient coin, lingzhi, and begonia—were redrawn and simplified in AutoCAD to generate repeatable modules, which were then developed into screen panels and tested through digital interior scenarios in 3ds Max. To move the study a step beyond digital visualisation, a model-scale physical prototype of the lingzhi-based screen was fabricated from basswood plywood using laser engraving and cutting to examine modular repetition, wall integration, and visual permeability. In addition, a structured visual assessment rubric was used as an analytical aid to compare daylight filtering, shadow readability, visual permeability, and graded privacy under controlled scenario conditions. The findings show that differences in module density, opening distribution, and edge continuity influence how the screens filter daylight, cast readable shadows, and shape graded privacy within interior space. The study proposes a practical motif-to-module process and contributes to the discussion of heritage-sensitive, lightweight, and reversible interior boundary design.

Keywords: Huizhou lattice, modular perforated screen, interior boundary, heritage-sensitive design, design-based research

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INTRODUCTION

Traditional lattice windows and screens in Huizhou architecture demonstrate how interior space can remain connected to nature through patterned openings and daylight. Although many motifs are derived from natural forms, these elements were historically not used as decoration alone; they operated as spatial devices that temper incoming light, support ventilation, and maintain visual links across boundaries, allowing spaces to feel connected without being fully exposed (Wang, 2023; see Figure 1). What makes lattice work especially spatial is its changing behaviour over time: the motif is present as a visible pattern, yet it also reappears as shadows that travel across interior surfaces (Fu, 2017). As daylight shifts throughout the day, the same boundary can feel lighter, softer, or more protective—producing a dynamic experience of framed views and moving shadows. In this sense, lattice screens function as environmental mediators: they shape atmosphere and spatial perception by filtering light, guiding views, and creating degrees of separation rather than a fixed divide (Jiang, 2015; Mohd Nawayai et al., 2020).



Figure 2: Traditional lattice windows in architecture
Source: Author's own work

In many contemporary interiors, however, lattice motifs are often reintroduced mainly as style references—printed, engraved, or applied as decorative panels. Once detached from their original spatial role, the pattern becomes a surface graphic rather than an active boundary, weakening its capacity to filter light, support privacy, and shape atmosphere, while cultural meaning is reduced to a static visual symbol. This gap matters because the strength of lattice work was never only its appearance; it lay in how pattern, light, and permeability worked together to shape everyday comfort. Yet design-based studies that provide a clear and reusable framework for reinterpreting Huizhou lattice logic as buildable interior boundary elements—elements that can be combined and tested across realistic spatial scenarios—remain limited.

This study therefore examines how nature-inspired Huizhou lattice motifs can be reintroduced into modern interior spaces as modular perforated screens that operate as active spatial boundaries. Rather than replicating historical window forms, it translates lattice logic—view filtering, light–shadow

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expression, and graded privacy—into modular units that can be fabricated, assembled, and deployed across interior situations. To keep the exploration specific and comparable, four motifs commonly found in Huizhou lattice windows are selected: ice-crack plum blossom (binglie meihua), ancient coin (tongqian), lingzhi, and begonia (haitang). These motifs represent different geometric logics—networked fragmentation, circular repetition, curvilinear outlines, and density variation—and are abstracted into repeatable units for consistent testing (Figure 2). The study follows a traceable motif-to-module process in which motifs are abstracted into repeatable modules, recomposed into screen panels, and then examined through scenario-based visual comparisons under consistent viewing conditions. It focuses on two questions: how Huizhou lattice motifs can be translated into buildable modular perforated screen units for modern interior spaces, and how module geometry and screen placement shape light–shadow behaviour, visual permeability, and privacy gradients across interior scenarios.

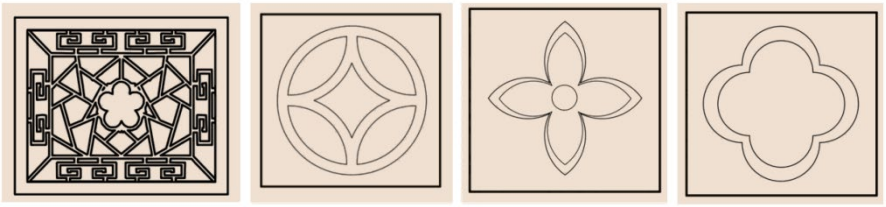


Figure 2: Selected Huizhou lattice motifs and their geometric logics for module translation
Source: Author's own work

This paper proposes a motif-to-module approach that translates Huizhou lattice patterns into working interior boundary elements for contemporary spaces. It focuses on how module geometry and placement affect light filtering, shadow expression, permeability, and privacy within controlled interior scenarios. The main analysis remains qualitative and comparative, but in order to move beyond digital rendering alone, the study also includes a model-scale physical prototype of the lingzhi-based screen. This prototype serves as an initial step in examining motif repetition, panel composition, and spatial integration in a contemporary bedroom setting. The study also introduces a structured visual assessment rubric to make the qualitative comparison more transparent and to support the preliminary design validation of the motif-to-module process. While full-scale testing is beyond the present scope, the study aims to provide a clearer translation path from traditional motif to interior application.

LITERATURE REVIEW

Huizhou lattice windows and framed views: morphology and meaning

Research on Huizhou lattice windows often begins with motif traditions, craft techniques, and symbolic interpretation (Wang & Qin, 2014). For interior space, however, the key point is that these motifs were historically embedded in a boundary system rather than treated as surface graphics. A lattice boundary is formed through an opening frame, a repeatable pattern, and a calibrated relationship between solid and void that is experienced through light, view, and everyday use (Zhao, 2024). This is what makes lattice work spatial: it sustains connection while still shaping separation and comfort (Mao & Sun, 2022).

In this study, framed views do not mean turning an opening into a picture. They refer to the way a boundary organises seeing. A lattice screen does not simply open or close a view; it structures how the view is encountered through partial reveal, filtered contact, and a controlled sense of distance (Fu, 2019). The spatial meaning is therefore not carried by the motif alone, but by how the motif operates as part of a boundary—how it guides attention, softens exposure, and changes the interior's relationship to outside conditions (Chen & Sun, 2018). For contemporary translation, this shifts attention away from surface resemblance and towards boundary logic and spatial effect.

Huizhou lattice work also includes recurring motif families that can be discussed not only by meaning but by geometric structure—networks, circular repetition, curvilinear outlines, and density variation (Yang, 2018). This lens matters for translation because it clarifies what is being carried forward: not the image alone, but the logic that organises openings (Fu & Zhao, 2018). Based on this understanding, the present study selects four motifs—ice-crack plum blossom (binglie meihua), ancient coin (tongqian), lingzhi, and begonia (haitang)—as representatives of distinct geometric logics that can be abstracted into repeatable units and compared under consistent scenarios (Zhao, 2025). Taken together, the literature supports a shift from motif-as-image to motif-as-boundary logic, which provides a clear basis for motif selection and geometric abstraction in this study.

Perforated screens as interior boundaries: daylight, privacy, and atmosphere

Perforated screens are widely used in contemporary interiors because they divide space without full enclosure. They retain continuity while introducing separation, which matches everyday needs where openness and privacy often have to coexist (Hu, 2016). As boundary elements, these screens operate by shaping what passes through them—light, views, and a sense of presence between zones—rather than by blocking everything completely (Zhang, 2019).

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From a daylight perspective, the aim is often not "more light" but usable light. Perforated boundaries can soften direct sun, reduce glare, and create calmer transitions rather than harsh contrast (Feng, 2024). Shadow becomes part of the boundary experience as the screen is read through the pattern it casts; interior atmosphere may shift across the day as daylight changes (Jiang, 2025). In this sense, perforated screens can be time-sensitive and responsive even when the boundary itself does not move (Maria & Prihatmanti, 2017).

Privacy, similarly, is rarely an all-or-nothing condition. Many interior situations require partial concealment rather than full blocking, and porous boundaries are often used to support graded visibility—allowing connection while reducing exposure (Chen & Qian, 2023). Here, permeability is not only visual but also experiential: it shapes how close or distant zones feel and how comfortable occupants feel about being seen or not seen (Zhang & Huang, 2021).

Ventilation is sometimes mentioned as a benefit of porous boundaries, but it is difficult to claim without measurement and context-specific modelling. In this study, airflow is treated as a potential implication rather than an evaluated outcome. The analysis therefore focuses on boundary behaviours that can be examined through design and visual evidence—daylight and light–shadow behaviour, visual permeability, and graded privacy. Overall, the literature frames perforated screens as interior boundary devices whose effects are readable through light–shadow expression and controlled visibility, supporting the evaluation criteria adopted in this study.

Heritage-sensitive translation and research gap

Heritage-inspired interior design often reintroduces traditional motifs as visual identity. The risk is that the motif becomes a surface reference while its original boundary role disappears (Yu & Sha, 2014). An experience-oriented perspective therefore asks a simpler question: when the motif returns, does it still do work at the boundary—shaping light, visibility, and everyday comfort—or does it remain a graphic layer?

Direct replication is rarely effective in modern interiors. Materials, construction constraints, scale, and patterns of use differ from historical contexts, and copying historic forms can produce a mismatch between appearance and performance (Yu, 2014). Translation is often more workable: extract motif logic, simplify it, rebuild it as a modular system, and deploy it in ways that make sense for contemporary interior boundaries (Zhao, 2013). This approach depends on explicit design decisions and benefits from design-based research in which knowledge is produced through making, prototyping, and structured reflection rather than description alone.

Existing studies provide useful foundations—some examine lattice symbolism and craft, while others discuss perforated boundaries as spatial

devices for light and privacy. However, there remains limited work that connects these streams in a reusable way for contemporary interior application (Fu, 2019). What is still missing is a clear and transferable chain that links motif logic to buildable modular screens and to comparable interior experience evidence. In other words, few studies show—through traceable design steps and consistent visual comparisons—how Huizhou lattice motifs can be translated into screen systems that operate beyond stylistic reference. This gap motivates the present study's motif-to-module workflow and its scenario-based comparison method, which together connect heritage logic, buildability, and evaluable interior experience. Figure 3 summarises this conceptual link and clarifies how the literature leads to the motif-to-module workflow and the structured visual assessment focus adopted in this study.

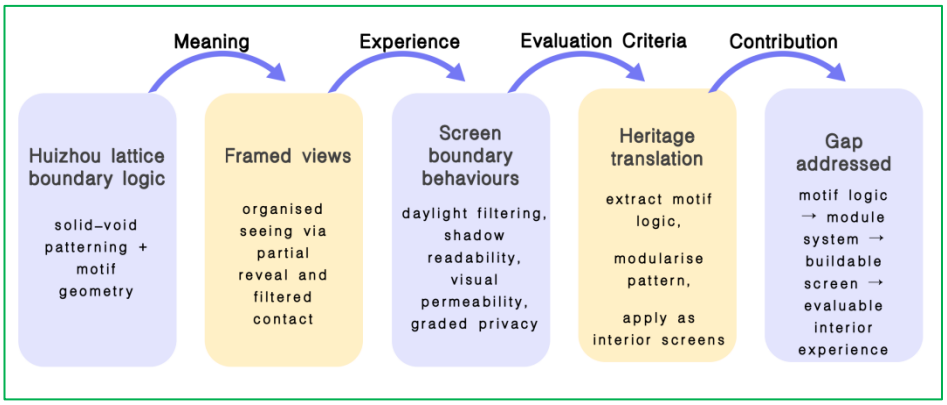


Figure 3: Conceptual link between Huizhou lattice boundary logic, motif-to-module translation, and modular screen evaluation
Source: Author's own work

RESEARCH METHODOLOGY

This study adopts a qualitative, design-based research approach to translate Huizhou lattice window motifs into modular perforated screens for contemporary interior boundary design. The method is structured as a traceable workflow with three phases: field documentation and motif selection, motif-to-module translation and digital prototyping, and scenario-based evaluation through controlled visual comparison. Each phase produces design artefacts—photographs, reconstructed drawings, modules, screen compositions, and scenario visuals—that support the analysis.

Motif-to-module translation and digital prototyping

An extract–transform–apply process is used to translate Huizhou lattice motifs into modular perforated screen units (Figure 4). Four motifs—ice-crack plum

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blossom (binglie meihua), ancient coin (tongqian), lingzhi, and begonia (haitang)—are selected to represent distinct geometric logics (network fragmentation, circular repetition, curvilinear outlines, and density variation) and to enable systematic comparison. Motifs are reconstructed as clean linework in AutoCAD for consistent scaling and alignment, then simplified through geometric abstraction to retain relationships that shape boundary reading at interior scale (opening distribution, edge continuity, and density). Each abstracted geometry is developed into a repeatable module and recomposed into screen panels through rotation, mirroring, and tiling strategies, before being modelled as digital prototypes in 3ds Max.

Model-scale physical prototype

A model-scale physical prototype of the lingzhi-based screen was produced to supplement the digital scenario study. The prototype was fabricated from basswood plywood using a laser engraving and cutting machine. The lingzhi motif was first simplified into modular linework, then repeated into a screen panel and laser-engraved and cut into the plywood surface. The panel was assembled within a bedroom wall model to examine motif repetition, panel composition, wall integration, spatial layering, and visual permeability at model scale. Because the prototype was produced as a model-scale design study rather than a full-scale building component, no fixed architectural scale ratio was applied. Its purpose was to provide preliminary design validation of the motif-to-module translation process, rather than to test structural strength, fire performance, long-term durability, or code compliance.

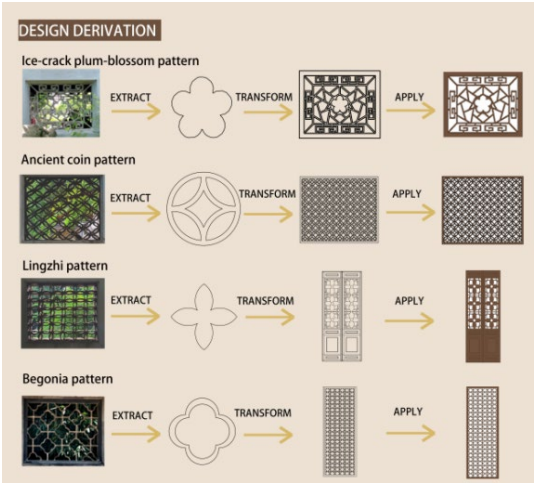


Figure 4: Motif-to-module workflow (extract–transform–apply) for the four Huizhou lattice motifs
Source: Author's own work

Scenario-based evaluation protocol

The screens are tested in a small set of interior scenarios modelled at interior scale. To ensure cross-motif comparability, room layout, screen size and placement, lighting and camera settings are held constant, while only the perforation module (motif logic) is varied. Evaluation focuses on criteria readable through visual evidence: light–shadow behaviour (daylight moderation and shadow legibility), visual permeability (filtered contact across zones), and graded privacy (degrees of visibility rather than open/closed). Comparisons follow a controlled-variation logic: either module geometry is adjusted with deployment fixed, or deployment factors (position, extent, orientation) are adjusted with module logic fixed. Figures 5 and 6 pair dimensioned drawings with scenario views to document scale, positioning, and the evaluation set-up.

To strengthen the transparency of the qualitative comparison, a structured visual assessment rubric was introduced as an analytical aid rather than as an instrument-based measurement method. Four criteria were assessed: daylight filtering, shadow readability, visual permeability, and graded privacy. Each criterion was rated on a three-point scale, where 1 = low, 2 = medium, and 3 = high. Daylight filtering refers to the degree to which the screen softens and distributes incoming light. Shadow readability refers to the clarity and legibility of the cast pattern on adjacent floors and walls. Visual permeability refers to the extent to which views remain partially connected through the screen. Graded privacy refers to the degree to which direct visibility is reduced without fully closing the spatial boundary. The assessment was conducted under the same room model, screen size, lighting conditions, and camera viewpoint, so that differences could be attributed mainly to motif geometry and perforation logic.

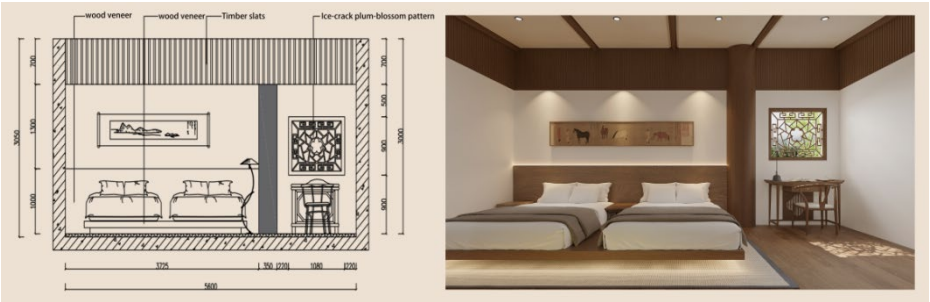


Figure 5: Dimensioned drawing and scenario view used to clarify scale and positioning (ice-crack plum blossom module)
Source: Author's own work

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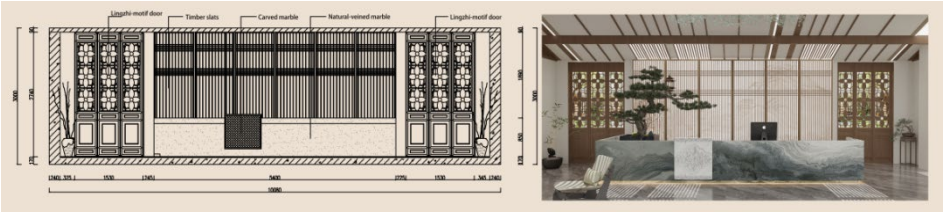


Figure 6: Dimensioned drawing and scenario view used to clarify scale and positioning (lingzhi module)
Source: Author's own work

RESULTS AND DISCUSSION

This section analyses the outcomes of translating four Huizhou lattice motifs into modular perforated screens and discusses how their boundary behaviours become readable at interior scale. The prototypes are derived from ice-crack plum blossom (binglie meihua), ancient coin (tongqian), lingzhi, and begonia (haitang). Each motif is abstracted into a repeatable module and recomposed into screen panels for interior boundary use. Evidence is presented through reconstructed drawings, scenario views produced under controlled comparison conditions, and a model-scale physical prototype.

The model-scale lingzhi-based prototype provides preliminary design validation of the motif-to-module translation process. It shows that the abstracted lingzhi geometry can be repeated as modular units, assembled into a screen panel, and integrated into a bedroom wall setting. Compared with digital scenario views, the physical prototype makes the panel depth, edge condition, repeated openings, and wall relationship more directly observable. However, this validation remains design-based and model-scale. It supports modular composition and visual permeability, but does not verify full-scale construction performance, structural stability, fire safety, long-term durability, or code compliance.



Figure 7: Model-scale lingzhi-based screen prototype showing modular repetition, wall integration, and visual permeability
Source: Author's own work

At close interior scale, boundary effects register most clearly through daylight filtering and shadow readability. In the bedroom scenarios, incoming daylight is moderated into a softer distribution, while cast patterns remain legible on adjacent surfaces, extending the boundary effect beyond the screen (Figure 8). Across motifs, cut-out geometry alters shadow density and edge clarity, producing distinct boundary readings without full enclosure.



Figure 8: Close interior views showing daylight filtering, shadow legibility, and partial visual separation
Source: Author's own work

In larger and more open interiors, the boundary effect relies less on enclosure and more on controlled permeability and spatial layering. The screens maintain continuity across zones while reorganising sightlines and reducing direct exposure, producing a more comfortable privacy gradient. Patterned daylight can spread across wider floor areas, reinforcing boundary presence and spatial legibility in open-plan settings (Figure 9).



Figure 9: Entrance scenario showing filtered sightlines, spatial continuity, and cast patterns
Source: Author's own work

To clarify recurring trade-offs, Table 1 presents a structured visual assessment of the four motif modules using four shared criteria: daylight filtering, shadow readability, visual permeability, and graded privacy. The scores are

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comparative visual judgements rather than instrument-based measurements, derived from the same digital scenario conditions, including room setting, screen placement, daylight direction, and camera viewpoint. This allows the boundary effects of different motif geometries to be compared within the qualitative design-based scope of the study.

Table 1: Structured visual assessment of observed boundary behaviours

Motif module	Daylight filtering	Shadow readability	Visual permeability	Graded privacy
Ice-crack plum blossom	3	2	2	3
Ancient coin	2	3	2	2
Lingzhi	2	2	2	2
Begonia	3	1–2	3	1–2

Note: 1 = low, 2 = medium, 3 = high. Intermediate scores indicate an observed tendency between two levels. Scores are based on controlled visual comparison and should be read as comparative visual judgements rather than instrument-based measurements.
Source: Author's assessment based on controlled scenario comparison.

Overall, the analysis indicates that once Huizhou lattice motifs are translated into modular perforated screens, their value is best interpreted through boundary behaviour rather than surface appearance. Differences in openness, shadow legibility, and graded privacy—together with screen placement—shape interior readings through daylight–shadow expression, perceived permeability, and privacy without full enclosure (Figure 10). This supports the study's focus on framed views and light–shadow translation as experience-oriented outcomes.



Figure 10: Interior application showing porous boundary performance, daylight modulation, and graded privacy
Source: Author's own work

A key implication is a shift from motif-as-decoration to motif-as-working boundary. When positioned at an interior threshold, the translated motifs operate as boundary devices by filtering visibility, clarifying edges between zones, and enabling separation without breaking connection, linking motif geometry to porous boundary performance in interior space (Chen & Sun, 2018).

The findings also inform heritage-sensitive interior renewal. Rather than direct replication or complete replacement, translation carries forward boundary logic—how a porous screen mediates daylight, sightlines, and everyday privacy under contemporary conditions. In adaptive reuse, homestay upgrades, and small refurbishments, modular perforated screens offer a lightweight and reversible way to reorganise zoning and visibility without permanent partitions. In experience terms, the outcomes suggest a passive design direction: softened daylight and readable cast patterns may support comfort and atmosphere through visual and spatial modulation (Zhang & Huang, 2021). The four motifs also function as a practical decision set for balancing daylight filtering, shadow readability, visual permeability, and graded privacy (Yuan, 2021). The physical prototype of the lingzhi-based screen further shows that the translated motif can be organised as a repeated modular system in interior space, rather than remaining only as a graphic composition.

Implementation considerations for real interior application

For real interior implementation, the translated lattice screen should be understood as a non-load-bearing interior boundary element rather than a structural wall. While the model-scale prototype was fabricated from basswood plywood, future full-scale applications may consider locally available native wood, such as Melia wood, to support local material use and cultural continuity. Before application, the selected timber should be properly dried and treated with sealing primer and protective coating to improve dimensional stability, moisture resistance, and surface durability. In terms of installation, simplified mortise-and-tenon joints may be considered for lattice components, while reversible mechanical fixing methods may also support disassembly, maintenance, and replacement. Practical application would still require consideration of panel stability, fire-retardant treatment, material durability, and compliance with relevant local building codes. Therefore, full-scale construction testing, material durability assessment, joinery and fixing assessment, fire-safety verification, and code-compliance review remain necessary before real interior application.

This study has limitations. Evidence remains mainly qualitative and visual, without measured lighting performance, user-perception surveys, or instrument-based privacy evaluation. Although a model-scale prototype was added, the study has not yet reached full-scale fabrication or user-based testing in real interiors. The motif set is selective, and the scenarios are designed for

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comparability rather than full real-world variation. Future work should include quantitative lighting analysis, larger-scale prototyping, local timber verification, material testing, joinery and fixing assessment, safety assessment, code-compliance review, and on-site observation.

CONCLUSION

This study repositions Huizhou lattice motifs from surface styling to working interior boundary devices through a traceable motif-to-module workflow. Four motifs—ice-crack plum blossom (binglie meihua), ancient coin (tongqian), lingzhi, and begonia (haitang)—were documented, abstracted into repeatable modules, and recomposed into modular perforated screen panels for contemporary interior use. The scenario-based comparisons show that motifs become spatially meaningful when treated as boundary logic rather than graphic imagery. At close range, the screens moderate daylight and produce readable cast patterns; in more open settings, they filter sightlines and shape graded privacy through controlled permeability.

The structured visual assessment further clarifies cross-motif trade-offs in daylight filtering, shadow readability, visual permeability, and graded privacy, supporting selection decisions based on intended boundary outcomes. The model-scale physical prototype also supports the motif-to-module process by demonstrating modular repetition, wall integration, and visual permeability. Together, these findings suggest a heritage-sensitive strategy for translating traditional lattice logic into lightweight and reversible interior boundary design.

This study remains limited by its qualitative and visual mode of evaluation. It does not include measured lighting performance, real interior testing, material carbon calculation, life-cycle assessment, or energy-performance analysis. Future work should extend the study through measured lighting evaluation, full-scale prototyping, material testing, safety and durability assessment, code-compliance review, and on-site observation.

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DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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EFFECTIVENESS OF TOURISM PLANNING STIMULI ON TOURISTS' WILLINGNESS TO STAY LONGER IN HOI AN WORLD HERITAGE SITE

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Abstract

Tourism planning in heritage destinations currently faces challenges of reconciling an increasing number of tourists with sustainable economic outcomes. In this regard, tourist length of stay is an indicator which directly engages the growth of tourist expenditure. By encouraging tourists to stay longer, heritage destinations increase, thereby boosting tourist revenue and positively affecting the economy. Thus, this study examines tourists' willingness to stay longer as a tourism planning outcome by applying the Stimulus-Organism-Response model. Tourism planning stimuli include world heritage designation, destination attributes, and social media advertising. A quantitative survey was conducted on 260 tourists in Hoi An, and Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed to test the proposed model. The findings show that all three planning stimuli significantly influence tourists' expectations, which in turn positively affect tourist satisfaction and, subsequently, increase tourists' willingness to extend their length of stay. This study highlights length-of-stay intention as an indicator of destination performance and offers policymakers insights to improve sustainable tourism planning in World Heritage cities such as Hoi An.

Keywords: World Heritage, tourism planning, S-O-R model, PLS-SEM, length-of-stay intention.

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INTRODUCTION

Hoi An ancient town is a UNESCO World Heritage Site, and has experienced sustained growth in tourist arrivals, showing its strong cultural appeal internationally. Despite this growth, tourist revenue has not increased proportionally, particularly among local businesses. Recent reports show that although tourists arrive in large numbers, tourist spending has not grown at the same rate (Thai Ba Dung, 2024). The current issue with this negative trend is that tourists spend less on land services and have a limited length of stay. This imbalance between tourist numbers and economic performance presents a critical challenge for tourism planning in the Hoi An heritage destination.

From a planning perspective, reliance on tourist numbers as the primary indicator of tourism success can lead to structural weaknesses in destination performance. Contemporary tourism planning research increasingly emphasises behavioural indicators which help policymakers and destination managers improve their tourism master plans (Ngan et al., 2022; Ngoc et al., 2024). Among the behavioural indicators, tourists' length of stay has been found to be a more meaningful measure of sustainable outcomes. Longer stays are associated with higher tourist expenditure, and more efficient use of tourism infrastructure and services (Santos, 2024; Gemar et al., 2022). These outcomes are closely aligned with planning objectives related to economic resilience, heritage conservation, and community well-being.

Therefore, this study examines tourists' willingness to stay longer in Hoi An using the Stimulus-Organism-Response (S-O-R) model. It investigates how tourism planning stimuli, such as World Heritage designation, destination attributes, and social media advertising, influence tourists' expectations and satisfaction and, subsequently, their willingness to stay longer. By shifting the analytical focus from tourists' length of stay, this research provides behavioural insights to support more sustainable tourism planning in world heritage cities worldwide.

Heritage destination planning

Heritage destination planning has evolved from a conservation-oriented approach to an intergrated planning framework that balances heritage protection, tourism development, and community well-being. Recent studies emphasise that effective heritage planning requires integrated management and governance (Coimbra et al., 2025). It should incorporate stakeholder engagenemnt, legal frameworks, and sustainable tourism strategies to address increasing pressures on World Heritage Sites. Tourism is now considered an integral part of heritage management. This approach supports heritage conservation while improving visitor experiences. Therefore, heritage planning should balance heritage conservation with

sustainable tourism development to ensure the long-term value of heritage destination.

In heritage destinations, destination attributes extend beyond cultural attractions and tourism services. They also encompass the physical and spatial chracteristics of destination that shap visitors' experiences. Physical attributes include public facilities, heritage interpretation facilities, and environmental quality. Spatial attributes refer to accessibility, pedestrian connectivity, and the spatial organisation of heritage spaces. These attributes facilitate access to heritage resources, improve visitor comfort, and strenghen the overall quality of the destination. As a result, they contribute to shape tourist's expecations before and during their visit (Coimbra et al., 2025; Zhang et al., 2022).

From heritage destination planning perspective, LOS is an important indicator of how visitors respond to the destination environment (Brida et al., 2014). A longer stay enables visitor to experience a wider range of heritage resources and tourism activities. It also indicates that the destination provides physical and spatial attributes that support continued visitor engagement (Zhang et al., 2022). Consequently, LOS provides a useful perspective for assessing whether heritage destination create conditions that engage tourists to remain and explore. Although LOS has traditionally been examined as a behavoural or economic indicator, it can be interpreted as an outcome of heritage destination planning because it may also interpreted as an outcome of hritage destination planning.

Tourists' Length of Stay (LOS) as a Tourism Planning Outcome

Tourists' Length of Stay (LOS) has increasingly been recognised as a key outcome variable in tourism planning and destination management research rather than a descriptive indicator of tourist behaviour (Santos, E., 2024; Gemar et al., 2022). From a planning perspective, LOS reflects the effectiveness of destination planning frameworks, infrastructure, provision, and the organisation of tourism experiences to sustain visitor engagement over time (Fansurya et al., 2024; Mihai et al., 2023)

In the context of heritage and urban tourism, especially in World Heritage Cities, the concept of LOS (level of service) is often linked to the economic sustainability of the area, the regulation of visitor flows, and the spatial and temporal distribution of tourism benefits. These are the major issues in tourism planning and policy formulation currently (Rosselló-Nadal & Sansó-Rosselló, 2025). There is a general association of longer tourist stays with positive planning outcomes. This is because higher per-visitor expenditure makes more efficient use of accommodation facilities and reduces reliance on short-stay or excursionist tourism, which are among the results confirmed in recent work (Santos, 2024).

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Such results also reflect the broader planning goals, which typically include sustainable tourism development, destination resilience, and alleviating problems caused by excessive tourism. In addition, the duration of stay (LOS) has been a feature of strategic indicators for a growing number of tourist destinations. It has also been a symbolic tool for assessing tourism policies and the performance of different tourism destinations, particularly those aiming to strike a balance among economic development, heritage conservation, and community well-being.

Empirical evidence from the cultural and urban destination sectors shows that length of stay (LOS) is influenced by destination attributes that are directly dependent on planning and management decisions. Prior research indicates that the quality of cultural resources, urban services, and the overall attractiveness of the destination are the major factors affecting tourists' length of stay, thereby highlighting the need for collaboration between tourism and urban planning (German et al., 2022). Modern research further examines tourists' willingness to stay longer as a planning outcome and a visionary concept for how visitors, through their evaluations of environments and experiences at destinations, can direct future planning (Darani et al., 2025). Besides that, methodological studies highlight the significance of LOS in tourism planning, arguing that the duration of stay can affect data representativeness and the interpretation of policy and relevant findings (Rosselló-Nadal & Sansó-Rosselló, 2025). In general, prior research confirms that LOC and willingness to extend the length of stay are crucial outcomes of planning in heritage areas facing sustainability and visitor management challenges.

The Stimulus-Organism-Response (SOR) Model in tourism research

The Stimulus-Organism-Response (S-O-R) model, originally developed in environmental psychology (Mehrabian & Russell, 1974), has been increasingly applied in tourism research to explain how destination environments influence tourists' internal evaluations and behavioural intention (Asyraff et al., 2023; Zhao et al., 2025). From a tourism planning perspective, this framework offers a structured approach for linking planning interventions to policy-relevant outcomes by recognising the mediating role of tourists' cognitive and affective responses (Asyraff et al., 2023).

Within this framework, stimuli represent external destination conditions shaped by planning and governance decisions, such as heritage designation, destination attributes, and promotional communication. In heritage destinations, these stimuli are embedded within planning instruments that regulate conservation, urban form, infrastructure provision, and visitor information systems. The organism component captures tourists' internal evaluations, including expectations and satisfaction, reflecting their

interpretations of planned environments and experiences. The response component refers to behavioural intentions that are relevant for tourism planning, including length-of-stay intentions, which indicate the effectiveness of destination planning in sustaining visitor engagement (Fansurya, et al., 2024).

Recent tourism studies extend the application of the S-O-R model beyond immediate consumption behaviour to examine longer-term and planning-relevant outcomes, such as willingness to stay longer (Darani et al., 2025). This approach is particularly suitable for world heritage sites, where planning stimuli are designed to attract visitors, manage visitor flows, enhance experiential quality, and support sustainable tourism objectives. Accordingly, the S-O-R model provides a robust theoretical foundation for examining how tourism planning stimuli influence tourists' length-of-stay intentions through the mechanisms of expectation and satisfaction in the context of the Hoi An World Heritage Site.

Hypothesis development

World Heritage Site (WHS) designation and Tourist Expectation (TE)

World Heritage designation serves as a recognised planning and governance tool that communicates cultural value, authenticity, and conservation standards. From a tourism planning point of view, the designation affects inbound tourists' expectations by offering institutional guarantees of heritage preservation and local community engagement (Mariani & Guizzardi, 2019). At WHS sites, planning instruments associated with a heritage site's status influence the physical setting, the installation of interpretive facilities, and the provision of visitor services, all of which help set expectations. Empirical studies have demonstrated that pre-visits to heritage sites increase tourists' cognitive expectations regarding cultural significance and the quality of the experience (Minh et al., 2023). In the S-O-R model, WHS status is a major planning stimulus that affects tourists' internal assessments.

H1: World Heritage Site designation positively influences tourist expectations.

Destination Attributes (DA) and Tourist Expectation (TE)

Beyond heritage status, destination attributes (DAs) are the physical expressions of planning through which tourists form expectations about how the destination will perform. DAs such as accessibility, historical and cultural attractions, natural uniqueness, and tourist infrastructure are typically the outcomes of planning decisions on land use, transport systems, and public space design, especially in heritage cities or towns (Minh et al., 2023). Past studies indicate that well-planned destination attributes positively influence tourists' pre-visit evaluations by raising their expectations of comfort, convenience, and experiential richness (Germar et

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al., 2022). As discussed in previous section, heritage destination planning encopmasses a broad range of physical and spacial components. However, in context of this study, destination attributes using three components including natural landscape, tourism, services, and pricing, These attributes represent the tangible characteristics of the destination that tourist directly experience before and during their visit. According to the S-O-R framework, destination attributes are the physical planning stimuli that affect tourists' cognitive assessments before arrival.

H2: Destination attributes positively influence tourist expectations.

Social Media Advertising (SMA) and Tourist Expectation (TE)

Beyond physical planning features, communication strategies are also progressively shaping tourists' expectations. Social media advertising has become a major planning communication tool that destination management organisations use to communicate official narratives and representations of places to the public (Chu et al., 2020). From a tourism planning perspective, such content mirrors planning priorities, destination branding strategies, and policy-driven images of heritage destinations (Chu et al., 2020). In world heritage settings, digitally curated messages impact tourists' anticipations of cultural authenticity, experiential quality, and the range of services available. Several empirical studies indicate that social media plays a major role in shaping tourists' cognitive expectations and their perceptions of destination value (Narangajavana et al., 2017). Hence, social media advertising positively influences tourists' expectations.

H3: Social media advertising positively influences tourist expectations.

Tourist Expectation (TE) and Tourist Satisfaction (TS)

Tourist expectation refers to an internal mental evaluation shaped by planning stimuli such as heritage designation, destination attributes, and social media advertising. On the other hand, satisfaction is tourists' after-visit evaluation of whether the planned settings and experiences correspond to, or even surpass, these expectations. Planning literature has highlighted that tourists' satisfaction largely depends on how well their expectations match the destination's actual performance. This is particularly important for heritage cities, where environmental planning directly affects visitors' experience (Minh et al., 2023). In the S-O-R context, an expectation is an organism variable that determines how evaluative responses are moderated after a visit.

H4: Tourist expectation positively influences tourist satisfaction.

Tourist Expectation (TE) and Willingness to Stay Longer (WTL)
Tourist expectations also play a major role in directly influencing behavioural intentions that are associated with tourism planning outcomes. From a planning perspective, realistic expectations regarding destination quality, experiential richness, and service provision will encourage tourists to be more engaged with the destination. One study shows that pre-visit positive evaluations make tourists more interested in spending more time at a destination, especially when it is a cultural or urban heritage site that is well-managed (Li & Du, 2025). In the S-O-R model, expectation is therefore a cognitive mediator that connects the stimuli to the length-of-stay intentions.

H5: Tourist expectation positively influences willingness to stay longer.

Tourist Satisfaction (TS) and Willingness to Stay Longer (WTL)
Tourist satisfaction is the overall judgment of the destination's different elements, i.e., planning effectiveness, service quality, and experiential coherence. Satisfaction is acknowledged in tourism planning research as one of the main factors for favourable behavioural outcomes, such as extended stay and continued engagement with the spatial environment (Darani et al., 2025). Moreover, at heritage destinations, the more delighted a tourist is, the more willing they are to extend their trip, leading them to visit more cultural assets and urban spaces. Therefore, they are effectively contributing to the sustainability of the tourism industry and also to the solution of the visitor dispersal problem. In the context of the S-O-R framework, satisfaction is considered to be an evaluation at the organism level, leading directly to behavioural responses.

H6: Tourist satisfaction positively influences willingness to stay longer.

RESEARCH METHODOLOGY
This study employed a quantitative research approach using a structured questionnaire to collect data. The questionnaire comprised two parts. The first part collected respondents' personal information, while the second focused on the main research constructs. It applied established measurement items from previous studies to examine three tourism planning stimuli that influence tourists' expectations, as well as the relationships among tourists' expectations, satisfaction, and willingness to stay longer.

Based on several explanations and developments in hypotheses, the study framework in Figure 1 was proposed. The questionnaire was developed based on the constructs in Figure 1. The items to examine the latent variables were adapted from previous studies, including World Heritage designation,

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destination attributes, social media advertising, tourist expectation, tourist satisfaction, and willingness to stay longer. All measurement items were adapted from previous studies and were rated on a five-point Likert scale ranging from "strongly disagree" to "strongly agree". The questionnaire was prepared in English and Vietnamese to ensure respondent comprehension.

The study included both domestic and international tourists who had visited Hoi An world heritage site. A total of 260 usable questionnaires were collected, comprisng 177 domestic tourists and 83 international tourists. Both groups were pooled into a signle analytical sample because the primary objective of this study was evaluate the effectiveness of tourism planning stimuli at the destination level rather than to compare behavioural differences between tourist segments. Pooling the two groups also enhanced the statistical power and stability of the PLS-SEM estimation.

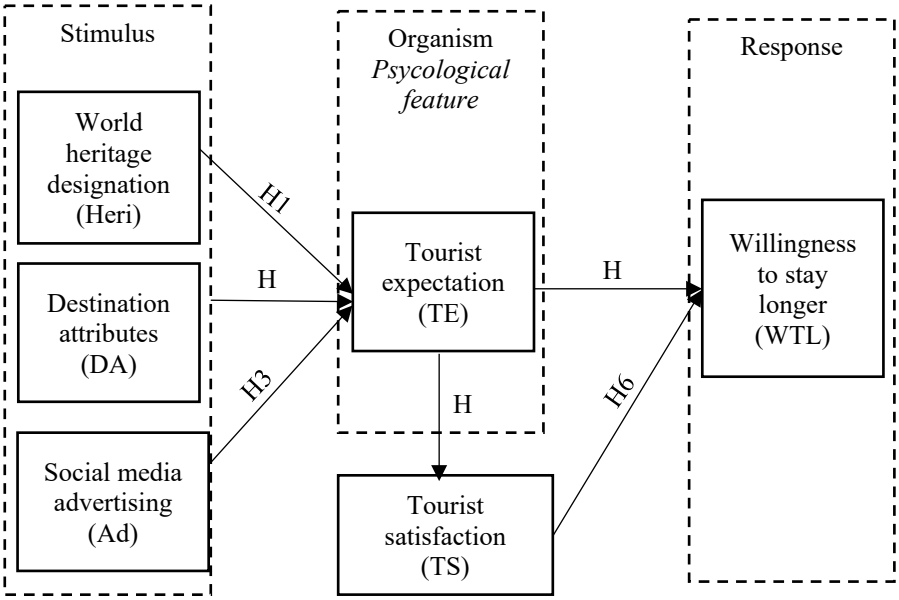


Figure 1: Proposed research model

Data were collected from tourists visiting the Hoi An World Heritage Site in Vietnam over a four-week period (July 2025). Respondents were approached directly at the tourism site and invited to participate in the survey as part of the research. Convenience sampling was employed to access tourists present at the destination. This method allowed respondents to be contacted on the spot and invited to participate after their immediate experience of the destination.

Among Vietnam's World Heritage sites, Hoi An ancient town is a unique case in that local residents still live within the heritage area, allowing direct interaction between hosts and guests. The town's cultural charm has been acknowledged worldwide, and Hoi An is one of the most popular destinations for domestic and international tourists. Its World Heritage status has not only brought global recognition to the town but has also led to continuous promotional and marketing activities by both the government and private stakeholders.

In total, 260 questionnaires were completed and usable. A descriptive analysis was undertaken to determine the demographic characteristics of respondents. Partial Least Squares Structural Equation Modelling (PLS-SEM) was then applied to analyse the relationship among the variables in the research model. PLS-SEM is particularly suitable for this study, attributable to its ability to handle complex models with latent variables measured indirectly by indicators. It is also appropriate for non-normally distributed data and relatively small sample sizes, providing consistent and reliable estimates and supporting the external validity of the research model.

ANALYSIS

Table 1 represents demographic information and travel preferences for the sample. Among 260 samples, international tourists accounted for 68.1% while Vietnamese tourists accounted for 31.9%.

Table 1. Demographic profile of respondents

Category	Description	No of respondents	%
Nationality	Vietnamese	83	31.9
	International	177	68.1
Gender	Male	142	54.6
	Female	118	45.4
Age	Under 20	23	8.8
	21- 30	91	35.0
	31- 40	79	30.4
	41 – 50	49	18.8
	Above 50	18	6.9
Education	High school and under	7	2.7
	Bachelor	239	91.9
	Master	11	4.2
	Doctor	3	1.2
Income	Under 10 million Dong	37	14.2
	10 – 30 million Dong	153	58.8
	30 – 50 million Dong	65	25.0
	Above 50 million Dong	5	1.9
Travel frequency	First time to Hoi An	181	69.6

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	Second time to Hoi An	62	23.8
	Third time and above	17	6.5
Length of stay	One day	75	28.8
	2 days 1 night	141	54.2
	3 days 2 nights	41	15.8
	Above 3 days	3	1.2

In general, the respondents are under 40 years old (74.2%) and well-educated (97.3% have university degrees). Participants with a monthly income of less than 30 million Dong numbered 190, representing 73%. Regarding travel preferences, 69.6% of respondents reported it was their first time travelling to Hoi An, and 30.3% had already visited the destination. Regarding length of stay, over half of the respondents (54.2%) stayed one night in Hoi An, 15.8% stayed two nights, and 28.8% made a day trip without staying the night.

Descriptive statistics of individual question items and latent constructs

Table 2 shows the detailed individual question items and latent constructs. Descriptive statistics provide information of measurement scores for each question item in the study. This study used SPSS 26 software to conduct a descriptive analysis. Overall, based on a five-point Likert scale, the mean values for the five constructs, including world heritage designation, destination attributes, social media advertising, and willingness to stay longer, are all above 3.0. The standard deviation ranges from 1.27 to 0.79. A standard deviation of less than 2.0 indicates that the data points are clustered closely around the mean, with significantly low variability and high consistency in the dataset. In other words, most values are relatively close to the average, indicating a tight distribution rather than a wide spread. The highest mean value (3.64) was recorded for Heri 3, indicating that the world heritage designation leads tourists to expect that Hoi An has more unique values than other destinations. The lowest mean value (2.81) was observed for TS3, indicating that respondents were not completely satisfied with service quality in Hoi An.

Table 2: The results of descriptive statistics of individual question items and latent constructs

Latent variable	Item	Mean	SD
World Heritage designation (Heri)	Heri1: World heritage site designation makes me find that the destination becomes more attractive.	3.54	1.15
	Heri2: Knowing Hoi An is a World Heritage Site makes me expect a unique experience	3.62	1.13
	Heri3: The World Heritage designation makes me expect that Hoi An has more unique values than other destinations.	3.64	1.15

Latent variable	Item	Mean	SD
Destination attributes (DA)	DA1: Hoi An World Heritage has a very impressive natural landscape	3.41	1.22
	DA2: Hoi An world heritage provide high-quality tourism services	3.49	1.27
	DA3: Hoi An World Heritage has reasonable pricing	3.59	1.17
Social Media Advertising	Ad1: Advertisements about Hoi An world heritage that appear on my social media feeds are very interesting and engaging	3.04	0.79
	Ad2: Advertisements about Hoi An's world heritage create high expectations for an exceptional cultural experience	3.10	0.86
	Ad3: Advertisements about Hoi An world heritage provide accurate information that makes me expect the trip to go exactly as I hoped	3.13	0.84
Tourist Expectation (TE)	TE1: I expected the trip to satisfy all my expectations regarding scenic value	3.37	0.86
	TE2: I expected the trip to bring memorable experiences	3.19	0.89
	TE3: I have positive expectations regarding the service quality of the Hoi An destination	3.23	0.83
Tourist Satisfaction (TS)	TS1: I'm completely satisfied with the majestic beauty here	2.81	1.25
	TS2: I'm completely satisfied with the memorable experiences here.	2.87	1.27
	TS3: I'm completely satisfied with the service quality of the Hoi An destination	2.81	1.23
Willingness to stay longer (WTL)	WTL1: If conditions allow, I would like to extend my stay at Hoi An	3.24	0.86
	WTL2: I'm considering staying at the destination for a few more days	3.22	0.88
	WTL3: I have decided to stay at the destination longer than my original plan	3.21	0.83

Measurement Model

SmartPLS 4.0 software was used to assess a measurement theory based on whole-model fit, construct reliability, and validity. The structural association between the constructs was then examined using a structural model. Table 3 indicates that the lowest outer loading was 0.835 (Ad3) (above 0.7), Composite reliability ranged from 0.823 to 0.897 (above 0.6), Cronbach's alpha ranged from 0.813 to 0.894 (above 0.6), and average variance extracted (AVE) ranged from 0.754 to

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0.826 (above 0.5). In this regard, the measures of all required indicators surpassed the minimum acceptable value (Fornell & Larcker, 1981; Hair, 2010)

Table 3: Measurement model of PLS (*n=260*)

Laten variables	Item	Outer loading	AVE	Composite reliability *(rho_a)*	Cronbach's alpha
Heri	Heri1	0.911	0.826	0.895	0.894
	Heri2	0.905			
	Heri3	0.910			
DA	DA1	0.839	0.777	0.860	0.855
	DA2	0.878			
	DA3	0.924			
Ad	Ad1	0.869	0.727	0.823	0.813
	Ad2	0.835			
	Ad3	0.854			
TE	TE1	0.860	0.763	0.845	0.844
	TE2	0.890			
	TE3	0.870			
TS	TS1	0.869	0.754	0.838	0.837
	TS2	0.867			
	TS3	0.869			
WTL	WTL1	0.909	0.812	0.897	0.885
	WTL2	0.867			
	WTL3	0.926			

Note: AVE: Average variance extracted
Source: Table by authors

Table 4 shows the discriminant validity of Heterotrait-Monotrait (HTMT). Discriminant validity in SmartPLS refers to the extent to which a reflective construct is empirically different from other constructs in the model, such that its indicators load more strongly on their intended construct than on others. This validity is mainly evaluated using the HTMT, with recommended thresholds below 0.85 or 0.90, as well as the Fornell–Larcker criterion. In this regard, the indicators in Table 4 range from 0.821 to 0.323, indicating no significant correlation between the discriminant validity of the two independent variables. To summarise, the measurement model in this study has achieved model fit, excellent reliability, and acceptable convergent and discriminant validity.

Table 4: Discriminant validity of heterotrait- monotrait (*n= 260*)

	Ad	DA	Heri	TE	TS	WTL
Ad						
DA	**0.323**					
Heri	0.196	**0.330**				
TE	0.471	0.578	**0.607**			
TS	0.276	0.354	0.548	**0.821**		
WTL	0.069	0.216	0.236	0.349	**0.374**	

Hypothesis testing

The PLS technique was used to evaluate the hypotheses proposed in the conceptual model. The overall results of the hypothesis testing are displayed in Table 5 and Figure 2. Figure 2 illustrates the path coefficients between the latent variables and the β values for each item.

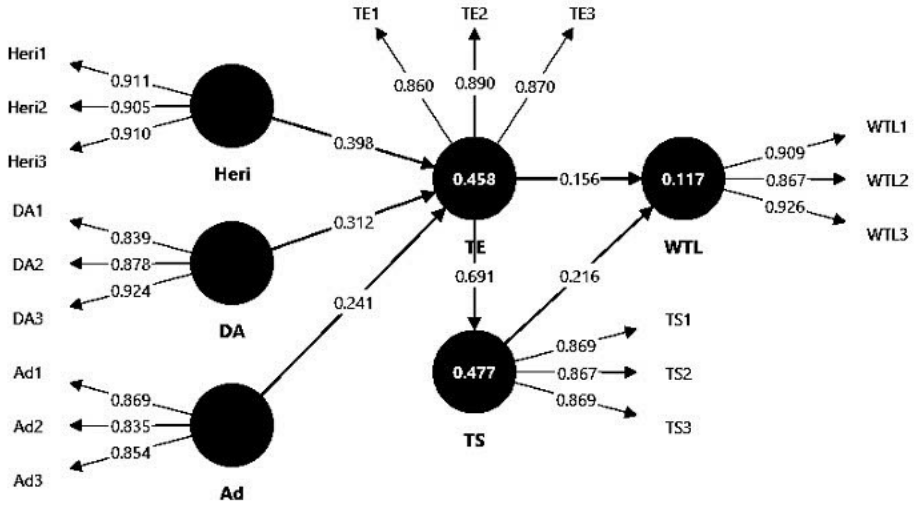


Figure 2: Path analysis result of the structural model
Source: Figure by authors

Table 5 indicates that all the hypotheses (H1, H2, H3, H4, and H6) were supported by their corresponding *p-value,* except for H5. Table 5 indicates that the World Heritage designation has a significant impact on tourists' expectations, with the corresponding coefficient supporting Hypothesis 1 (β = 0.242, p < 0.001). Thus, UNESCO's World Heritage recognition creates high expectations among tourists visiting Hoi An. The result of this study also confirmed supporting Hypothesis 2 (β = 0.312, p < 0.001). In this regard, destination attributes positively impact tourist expectations. Based on this result, it can be concluded that the attractive attributes of the Hoi An destination create positive expectations

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among tourists. The findings also confirmed Hypothesis H3 (β = 0.398, p < 0.001), indicating a positive impact of social media advertising on tourists' expectations. It has been found that advertising on social media is effective in creating positive expectations about Hoi An among tourists.

Table 5: Statistical results of the structural model

Hypo-thesis	Path	*β*-value	SD	*t*-value	*p* -value	Result
H1	World Heritage designation ° Tourist Expectation	0.242	0.054	4.465	0.000	Accepted
H2	Destination attributes ° Tourist Expectation	0.312	0.046	6.749	0.000	Accepted
H3	Social Media Advertising ° Tourist Expectation	0.398	0.043	9.218	0.000	Accepted
H4	Tourist Expectation ° Tourist Satisfaction	0.693	0.024	29.010	0.000	Accepted
H5	Tourist Expectation ° Willingness to stay longer	0.159	0.122	1.284	**0.199**	**Rejected**
H6	Tourist Satisfaction ° Willingness to stay longer	0.217	0.067	3.216	0.001	Accepted

Similarly, tourist expectation has a positive and significant effect on tourist satisfaction, thus supporting Hypothesis H4 ($\beta = 0.693$, $p < 0.001$). In addition, based on the results presented, it can be concluded that tourist satisfaction positively affects willingness to stay longer, thus supporting Hypothesis H6 ($\beta = 0.217$, $p < 0.005$). These results show that tourists are willing to stay longer than originally planned if they are satisfied with the destination. As a consequence, the planner at the destination must ensure the quality of service and the level of tourist satisfaction to convince them to extend their stay. However, the results show that tourist expectation (β = 0.159, p > 0.05) does not affect willingness to stay longer, thus not supporting H5. This finding suggests that having high expectations before or during the visit is not sufficient to motivate tourists to extend their length of stay. Tourist expectations primarily represent tourists' anticipated perceptions of destination performance, but they do not necessarily converse it into actual behaviour intentions. In otherwords, tourists may have positive expectations toward destination based on reputation, attractions, or promotional information; howerver, their decision to stay longer depends more strongly on their actual experience and evaluation afater

consuming tourism services. This result is consistent with the role of satisfactionn as a more proximal determinant of behavioral intention. The significant relationship between tourist expectation and toourist satisfaction indicates that expectation alone may not directly encourage longer stay unless it is confirmed through satisfactory on-site experiences. This finding carries an important implication for destination planners. Attractive of world heritage destination branding and promotion alone are not enough to extend tourist stays. Tourism planners must also ensure high quality on site experiences, since it is satisfaction, not expecttaion alone, that ultimately drives tourists to stay loger.

Regarding the link the three tourism planning stimuli (including world heritage designation, destination attributes, and social media advertising) ° tourist expectation, tourist expectation ° tourists satisfaction and tourist satisfaction ° willing to stay longer, it can be concluded that the tourism planning stimuli significantly influence tourist expectations, which in turn positively affect tourist satisfaction and increase tourists' willingness to extend their length of stay. Finally, tourist expectation and tourist satisfaction play a mediating role in the model, linking tourism planning stimuli to willingness to stay longer.

Following the two-step approach recommended by Hair et al. (2019), after assessing the measurement model, the structural model was evaluated based on the cefficient of determination (R^2), effect size (f^2), collinearity statistics (VIF), and model fit indices.

Table 6 shows the results of coefficient of determinantion (R^2). The R^2 values indicate that World Heritage designation, destination attributes, and social media advertising jointly explain 45.8% of the variance in tourist expectation, which in turn explains 47.7% of the variance in tourist satisfaction. However, tourist expectation and tourist satisfaction together explain only 11.7% of the variance in willingness to stay longer. It suggests that other factors beyond expectation, satisfaction constructs may influence tourists; extended stay decision.

Table 6: Coefficient of Determination (R^2)

Construct	R^2	Adjusted R^2
TE	0.458	0.452
TS	0.477	0.475
WTS	0.117	0.111

Table 7 indicates the results of effect size (f^2). Notably, the effect size of tourist expectation on willingness to stay longer (f^2= 0.014) is negligible, corroborating the non-significant path coefficient (H5) reported in Table 5. This shows that tourist expectation contributes almost nothing to explaning willingness to stay longer once its indirect influence through tourist satisfaction is accounted for.

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Table 7: Effect size (f^2)

Path	*f2*	Effect size
World Heritage designation ° Tourist Expectation	0.265	0.054
Destination attributes ° Tourist Expectation	0.156	0.046
Social Media Advertising ° Tourist Expectation	0.098	0.043
Tourist Expectation ° Tourist Satisfaction	0.912	0.024
Tourist Expectation ° Willingness to stay longer	0.014	0.122
Tourist Satisfaction ° Willingness to stay longer	0.028	0.067

**Threshold: 0.02 = small, 0.15 = medium, 0.35 = large Hair et al., 2019).*

Table 8 illustrates the results of collinearity statistics (inner VIF). All inner VIF values are well below the conservative threshold of 3.3 (Hair et al., 2019), confirming that collinearity among predictor constructs is not concern in the structural model.

Table 8: Collinearity statistics (inner VIF)

Path	VIF
World Heritage designation ° Tourist Expectation	1.090
Destination attributes ° Tourist Expectation	1.154
Social Media Advertising ° Tourist Expectation	1.101
Tourist Expectation ° Tourist Satisfaction	1.000
Tourist Expectation ° Willingness to stay longer	1.912
Tourist Satisfaction ° Willingness to stay longer	1.912

Table 9 show the results of model fit summary. The SRMR value for the estimated model was 0.056, which is below the recommended threshold of 0.08 (Henseler et al., 2016), indicating an acceptable model fit. The NFI value of 0.826 further supports the adequacy of the proposed structural model.

Table 9: Model fit summary

Fix index	Saturated model	Estimated model
SRMR	0.048	0.056
NFI	0.830	0.826

DISCUSSION

The findings from this study are critically examined to highlight their contributions to the existing literature. To begin with, more than half of the respondents stayed in Hoi An for one night, which is an encouraging finding given that previous research showed this proportion was of day-trippers (Minh et al., 2023). This could be considered a result of the extraordinarily low mean scores for tourist satisfaction with the beauty, experiences, and service quality in Hoi An. Over the years, service quality has consistently had a negative impact on tourist satisfaction (Binh, 2019). Vitally, the World Heritage reputation, destination attribute attractiveness, and effective advertising produce favourable expectations. Notwithstanding, the rejection of H5 confirmed that tourist expectations had no significant influence on their willingness to stay longer in Hoi An. In line with Ngoc et al. (2024), Hoi An tourism planners might be successful in attracting tourists to their destination by utilising their reputation for fame, but they still need to work on offering more unforgettable experiences.

From a tourism planning perspective, the finding suggest that extending tourists' length of stay requires more than strengthening destination promotion. Since destination attributes significantly shape tourists' expectations, local authorities should focus on improving the spatial quality and diversity of heritage experiences. Tourism strategy should be implemented to encourage tourists to explore attractions beyond the heavily visited ancient town. This may include developing thematic herittage trails linking tradiational craft villages, reverside landscapes, community-based tourism sites, and cultural attraction in the surrounding areas. Such measure would not only diversify tourist experiences but also reduce cognestion in the central heritage site.

Furthermore, the significant relationship between tourist satisfaction and willingness to stay longer highlights the importance of enriching the overal tourist experience after arrival on sit. Tourism planners should therefore strengthen the night-time economy by expanding cultural performances, traidtional craft demonstration, local culinary activities, and evening heritage events. These activities can increase tourists' engagement, encourage overnight stays, and distribute tourist avtivities throughout the day.

The study also provide implications for transport management and heritage conservation. Improving pedestrian accessibility, cycling infrastructure, public transport connections, and parking management between the ancient town and peripheral attractions would facilitate visitor dispersal while reducing traffic pressure within the heritage zone. At the same time, tourism planners should carefully monitor heritage carrying capacity by regulation visitor flows during peak periods, implementing reservation or timed entry systems where appropriate, and continously assessing the impacts of tourism on cultural

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resources. These planning measures would contribute to balancing tourism development with the long-term conservation of Hoi An World Heritage Site.

CONCLUSION

This study explored the roles of tourism planning stimuli influencing tourists' willingness to stay longer in the Hoi An World Heritage destination. The Stimulus-Organism-Response (S-O-R) model was applied to assess the six hypotheses. The study found that all three factors of tourism planning stimuli, including world heritage designation, destination attributes, and social media advertising, had a significant and positive impact on tourist expectations. Meanwhile, tourists' expectations positively influenced their satisfaction. However, it did not have a significant impact on tourists' willingness to stay longer. Tourist satisfaction was found to have a significant effect on the intention to stay longer.

The findings of this study provide practical implications for destination managers and destination planners from a managerial perspective. In this regard, the planners at the Hoi An World Heritage destination are encouraged to further explore the effects of the three tourism planning stimuli studied in this research on shaping tourists' expectations of on-site experiences and on tourists' satisfaction levels. Meanwhile, destination managers and tourism planners should focus on ensuring service quality in Hoi An, because when tourists are satisfied, they are more likely to stay longer. Moreover, they should enrich the entertainment offerings in ancient towns, as they have recently done with "Hoi An's memories show".

One limitation is that the study was conducted across both international and domestic markets, and these two markets might have different behavioural intentions. For further research, researchers can study market segmentation, focusing on international or domestic markets. To strengthen the strategy and planning for developing sustainable tourism in Hoi An World Heritage and similar destinations, further studies can investigate additional tourism planning stimuli and psychological factors to understand tourists' different responses.

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EVALUATING E-TENDERING READINESS IN MALAYSIAN PUBLIC-PRIVATE PARTNERSHIPS PROCUREMENT: A PLS-SEM APPROACH

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Abstract

The digitalisation of public procurement has accelerated the adoption of electronic tendering (e-tendering), particularly in Public-Private Partnership (PPP) procurement. However, many public organisations remain inadequately prepared for effective implementation. This study examines multidimensional e-tendering readiness in Malaysian PPP procurement by evaluating people, operational, technological, organisational, service provider, and legal-security dimensions. Data were collected from 121 government officers involved in Malaysian PPP procurement and analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The results show that People factors ($\beta = 0.170$, $p = 0.020$) and Operational factors ($\beta = -0.458$, $p < 0.001$) significantly influence readiness, whereas Technology, Work Environment, Service Provider, and Legal and Security factors do not exert statistically significant direct effects. Overall, the findings indicate that human capability and process design are more decisive than technology availability alone. The paper offers a context-specific readiness model based on the perceptions of Malaysian government officers involved in PPP procurement and provides practical implications for public agencies seeking to strengthen digital tendering reform.

***Keywords*:** e-tendering, public-private partnership, PPP procurement, readiness, digital procurement, PLS-SEM

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INTRODUCTION

Public procurement is increasingly recognised as a strategic state function that transforms public resources into infrastructure, services, market opportunities, and public value. Procurement systems are increasingly evaluated by their ability to strengthen transparency, accountability, traceability, and implementation effectiveness rather than cost efficiency alone (Khorana et al., 2024; OECD, 2025). Given its scale and role in service delivery, procurement quality directly influences public trust, governance performance, and project outcomes (OECD, 2025).

In Malaysia, Public-Private Partnerships have become an important route for infrastructure development when governments must balance fiscal discipline with long-term service obligations. PPP arrangements combine private financing, technical expertise, and lifecycle management but involve complex approvals, legal due diligence, lengthy documentation, and intensive public scrutiny over risk allocation and value for money. As a result, the tendering stage is particularly critical because weaknesses at this point can affect competition, confidence, contract quality, and downstream implementation (Al Saadi & Abdou, 2024; Mat Aron et al., 2024; Wang et al., 2018).

Digital procurement and e-tendering address many weaknesses of traditional procurement systems. In Malaysia, e-procurement has been discussed for more than a decade as part of public sector modernisation, with earlier studies already identifying challenges related to organisational adaptation, user readiness, and implementation capability (Aman & Kasimin, 2011; Kaliannan, 2011; Kaliannan & Raman, 2009). Recent studies show that e-tendering improves publication, document access, clarification management, submission control, and audit trails while reducing paper-based documentation and improving consistency in procurement communication (Hochstetter et al., 2023; Khorana et al., 2024). However, implementation still depends on technical capability, user readiness, institutional support, policy consistency, and procedural adaptation, particularly in construction and PPP procurement settings (Inusah et al., 2025; Mat Aron et al., 2024).

The key issue, therefore, is readiness. Organisations may have digital platforms in place but still struggle to use them effectively if staff capability is weak, procedures remain cumbersome, or trust in digital processes is limited. This problem is especially visible in developing procurement systems, where the gap between formal reform and day-to-day practice can be substantial. In the Malaysian PPP context, e-tendering continues to face implementation issues, making it necessary to assess readiness among the public-sector actors responsible for procurement delivery (Mat Aron et al., 2024).

Accordingly, this paper examines six dimensions of e-tendering readiness among government officers involved in PPP procurement in Malaysia:

People, Operational, Technology, Work Environment, Service Provider, and Legal and Security factors. Using questionnaire survey data and PLS-SEM, the paper identifies which dimensions matter most, how they influence readiness, and why some factors that appear important in principle do not emerge as direct predictors in practice. It contributes by offering a multidimensional lens for assessing readiness, providing empirical evidence from Malaysian PPP procurement, and translating the findings into practical implications for agencies seeking to strengthen digital tender implementation.

LITERATURE REVIEW

Recent literature positions digitalisation as a core element of public sector modernisation. E-procurement is increasingly recognised as both an efficiency tool and a governance mechanism that strengthens transparency, accountability, data integration, and decision quality. Mavidis and Folinas (2022) describe this transition as a shift towards intelligent procurement characterised by interoperability, analytics, and strategic technology use, while Bosio et al. (2023) emphasise that its benefits depend on supportive institutional conditions.

Recent studies consistently demonstrate that digital procurement enhances transparency, accountability, auditability, and procurement integrity through improved traceability and electronic documentation (Ahmad et al., 2021; Hochstetter et al., 2023; Khorana et al., 2024; Sanda et al., 2024).

Digital procurement also improves organisational efficiency through faster tender circulation, easier document access, greater standardisation, and stronger process control. However, successful implementation depends on staff capability, managerial support, institutional readiness, and effective process integration (Afolabi et al., 2019; Muhwezi et al., 2023; Waci et al., 2024). Nevertheless, implementation capability, organisational resistance, and process complexity remain major barriers, often outweighing technological limitations (Sakutemba et al., 2024; Inusah et al., 2025; Yevu et al., 2021).

PPP procurement is inherently more complex than conventional procurement because it involves long-term risk allocation, sophisticated financial and legal structures, project-specific technical requirements, and multi-stage evaluations. Studies consistently identify institutional capability, governance, legal continuity, stakeholder commitment, and disciplined monitoring as critical success factors (Osei-Kyei & Chan, 2021; Casady et al., 2023; Alsamarraie et al., 2025; Ojelabi et al., 2025). Emerging technologies, including Industry 4.0, smart contracts, machine learning, and digital contractor prequalification, further strengthen procurement transparency and efficiency (Alaloul et al., 2019; Sava & Dragoș, 2022; Demeter et al., 2025; Abouahmed et al., 2026).

Taken together, the literature shows that e-tendering readiness is multidimensional. It depends not only on the availability of digital tools, but also

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on whether organisations possess the skills, structures, routines, and confidence needed to use those tools effectively. Building on this synthesis, the present study conceptualises six readiness dimensions: People, Operational, Technology, Work Environment, Service Provider, and Legal and Security. People factors represent staff competence, confidence, knowledge, and resource adequacy. Operational factors reflect procurement process complexity, transparency, enforceability, and data integrity. Technology factors encompass system reliability, integration, infrastructure, compatibility, implementation knowledge, and cost considerations. Work Environment factors capture leadership support, organisational culture, strategic clarity, flexibility, awareness, and internal priorities. Service Provider factors represent supplier readiness, interoperability, data sharing, and collaboration. Legal and Security factors include anti-corruption safeguards, electronic signature enforceability, ownership issues, case law, and confidence in digital legal controls. The literature therefore suggests that successful PPP e-tendering depends on alignment across these dimensions rather than technology alone.

Based on the literature, six hypotheses were developed. H1 proposes that People factors positively influence e-tendering readiness, H2 that Operational factors significantly influence readiness, and H3–H6 that Technology, Work Environment, Service Provider, and Legal and Security factors positively influence e-tendering readiness.

RESEARCH METHODOLOGY

This study adopted a quantitative research approach to evaluate the determinants of e-tendering readiness within the context of Malaysian Public-Private Partnership procurement. The research framework comprised seven latent constructs, namely People, Operational, Technology, Work Environment, Service Provider, Legal and Security, and E-Tendering Readiness. These constructs were incorporated into a structured questionnaire designed to capture respondents' background information, involvement in PPP procurement activities, and perceptions of readiness-related factors.

Measurement items were adapted from established literature, refined for the Malaysian PPP procurement context, and reviewed for clarity, content validity, and contextual appropriateness before data collection. All constructs were measured using a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). A five-point Likert scale was adopted because it is widely used in organisational research and is suitable for measuring perceptual constructs in Partial Least Squares Structural Equation Modelling (PLS-SEM) (Hair et al., 2021).

Data were collected through an online questionnaire, providing flexibility, standardisation, and efficient data collection for geographically

dispersed respondents (Evans & Mathur, 2018; Wright, 2005). Data were analysed using IBM SPSS Statistics and SmartPLS 4 for descriptive and PLS-SEM analyses.

Purposive sampling was used because the study required informed respondents who were directly involved in PPP procurement or sufficiently familiar with PPP project processes. Accordingly, the study targeted officers at Grade 41 and above who were involved in procurement planning, tender administration, project coordination, evaluation, or related PPP decision-making functions. The study population comprised officers from PPP-related units across selected Malaysian ministries and agencies. The estimated population of 163 officers was identified from internal organisational directories of the participating ministries and agencies, which were used to identify officers involved in PPP-related procurement and project development functions. Based on this population, the minimum sample size was 113 respondents according to Krejcie and Morgan (1970). Of 150 questionnaires distributed, 124 were returned and 121 were valid for analysis, yielding an 80.6% response rate.

Figure 1 presents the G*Power output used to verify sample adequacy. The analysis indicated a minimum sample size of 107 cases for six predictors. The final sample of 121 responses exceeded this requirement and was therefore adequate for PLS-SEM analysis.

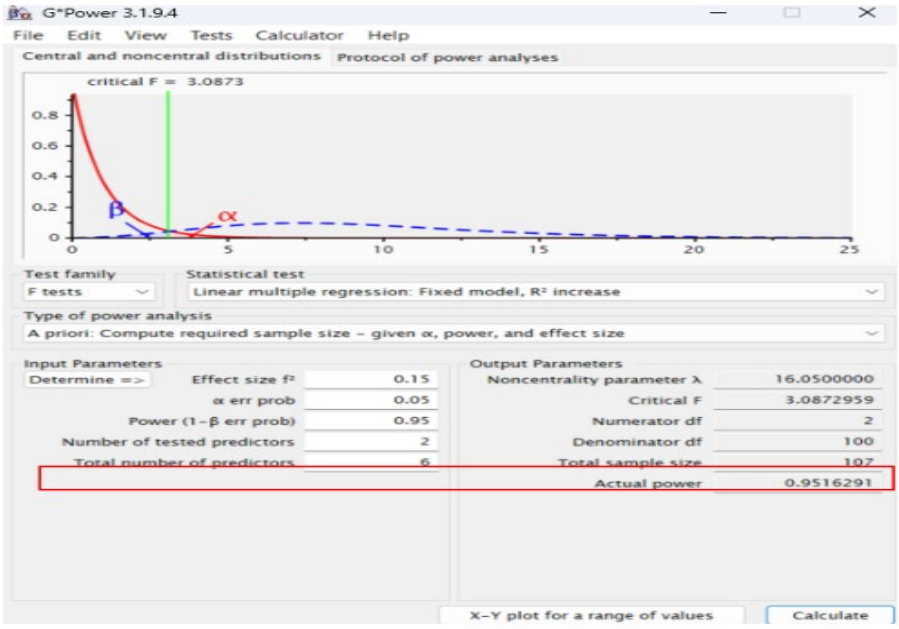


Figure 1: G*Power output for minimum sample size determination

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The questionnaire comprised multi-item indicators representing the seven proposed constructs. Measurement items for each construct were adapted from established literature and refined for the Malaysian PPP context.

Prior to analysis, data were screened for completeness, consistency, and coding accuracy. Measurement items were reviewed to ensure consistent coding direction across the seven latent constructs. Where applicable, negatively worded items were reverse-coded so that higher scores represented higher construct levels. The coding procedure was verified during data screening to ensure alignment with each construct's conceptual definition and minimise coding-related bias during structural model estimation.

Descriptive analysis was conducted using SPSS, while structural relationships were assessed using PLS-SEM in SmartPLS 4. PLS-SEM was selected because it suits complex exploratory models, moderate samples, non-normal data, and prediction-oriented analysis involving multiple latent constructs (Hair et al., 2021, 2019; Henseler et al., 2022; Sarstedt et al., 2022). The analysis assessed indicator reliability, internal consistency, convergent validity, discriminant validity, structural path coefficients, collinearity, and explained variance. The structural model followed the recommended PLS-SEM procedure, covering collinearity (VIF), explanatory power (R^2), effect size (f^2), predictive relevance (Q^2), and bootstrapping-based hypothesis testing (Hair et al., 2021).

ANALYSIS AND DISCUSSION

The respondent profile indicates that the sample was suitable for the study objectives. Most respondents were aged 41–50, had relevant experience, and were directly involved in PPP procurement. Their academic and professional backgrounds suggest that responses reflected informed professional judgment rather than general opinion.

Respondents also reported substantial exposure to PPP-related procurement, including tender processes and different project types. These characteristics support the adequacy of the dataset for analysing e-tendering readiness in PPP procurement. Table 1 summarises the respondent profile.

Table 1: Respondent profile summary

Variable	Key result
Gender	Female 52%; Male 48%
Age	20–30 years 2%; 31–40 years 21%; 41–50 years 51%; 51–60 years 26%
Experience	1–3 years 20%; 4–6 years 30%;

Variable	Key result
	7–9 years 33%; >10 years 17%
Organization type	Government 100%
Procurement involvement	Often 44%; Sometimes 38%; Rarely 18%
Education	Bachelor 61%; Master 37%; PhD 2%

As shown in Table 1, the sample represents a mature and professionally relevant respondent group. The respondents' age, experience, and procurement involvement indicate sufficient familiarity with the procedural, administrative, and strategic aspects of PPP procurement, strengthening the credibility of the analysis.

Prior to evaluating the structural relationships, the measurement model was assessed to establish indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. Following the guidelines of Hair et al. (2021), the assessment included indicator loadings, Cronbach's Alpha, Composite Reliability (CR), Average Variance Extracted (AVE), and the Heterotrait–Monotrait Ratio (HTMT). The results indicate that all constructs satisfied the recommended thresholds, confirming that the measurement model was reliable and valid for subsequent structural model assessment.

Table 2: Reliability and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability	AVE	Assessment
People	0.937	0.935	0.743	Accepted
Operational	0.958	0.956	0.681	Accepted
Technology	0.949	0.948	0.701	Accepted
Work Environment	0.945	0.942	0.673	Accepted
Service Provider	0.881	0.879	0.648	Accepted
Legal & Security	0.933	0.933	0.713	Accepted
Readiness	0.932	0.933	0.706	Accepted

Table 2 shows that all constructs satisfied the recommended thresholds for internal consistency and convergent validity. Cronbach's Alpha and Composite Reliability exceeded 0.70, while AVE values were above 0.50, confirming that the constructs were measured reliably and were suitable for structural model analysis.

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Table 3: Discriminant Validity Assessment using HTMT

Construct	LS	PP	PR	RE	SP	TE	WE
LS	—						
PP	0.454	—					
PR	0.663	0.581	—				
RE	0.626	0.560	0.635	—			
SP	0.278	0.489	0.472	0.353	—		
TE	0.583	0.408	0.772	0.774	0.350	—	
WE	0.589	0.448	0.772	0.693	0.423	0.862	—

Discriminant validity was assessed using the Heterotrait–Monotrait Ratio (HTMT). As shown in Table 3, all values were below the recommended threshold of 0.90 (Hair et al., 2021), confirming that each construct represents a distinct dimension of organisational readiness for e-tendering implementation.

The measurement model demonstrated satisfactory reliability and validity, with most factor loadings exceeding 0.70. Particularly strong loadings were observed for the People construct, especially for staff preparedness, resource adequacy, and e-procurement knowledge. Selected high-loading indicators are presented in Table 4.

Table 4: Selected construct diagnostics from exploratory measurement assessment

Construct	High-loading items	Interpretation
People	PP01 = 0.962; PP05 = 0.850; PP02 = 0.722	Strong human-capability signal
Operational	PR05 = 0.898; PR02 = 0.869; PR07 = 0.868; PR10 = 0.735	Process integrity and transparency are salient
Technology	TE01 = 0.902; TE04 = 0.828; TE08 = 0.785	Infrastructure and integration matter descriptively
Work Environment	WE02, WE03, WE04, WE07, WE11, WE14 all strong	Leadership and culture perceived as important
Service Provider	SP04 = 0.874	Marketplace readiness recognized
Legal and Security	LS11 = 0.934	Corruption and legal clarity remain salient issues

Table 4 shows that several indicators performed strongly across the People, Operational, Technology, Work Environment, Service Provider, and Legal and Security constructs. The People and Operational dimensions recorded the strongest loadings, indicating that staff capability, procedural standards,

document integrity, and transparency are central to e-tendering readiness. These findings support the multidimensional nature of readiness beyond technological capability.

Figure 2 illustrates the factor loading pattern across the study constructs. The figure confirms the multidimensional nature of the model, with particularly strong loadings for the People, Operational, Technology, and Work Environment constructs.

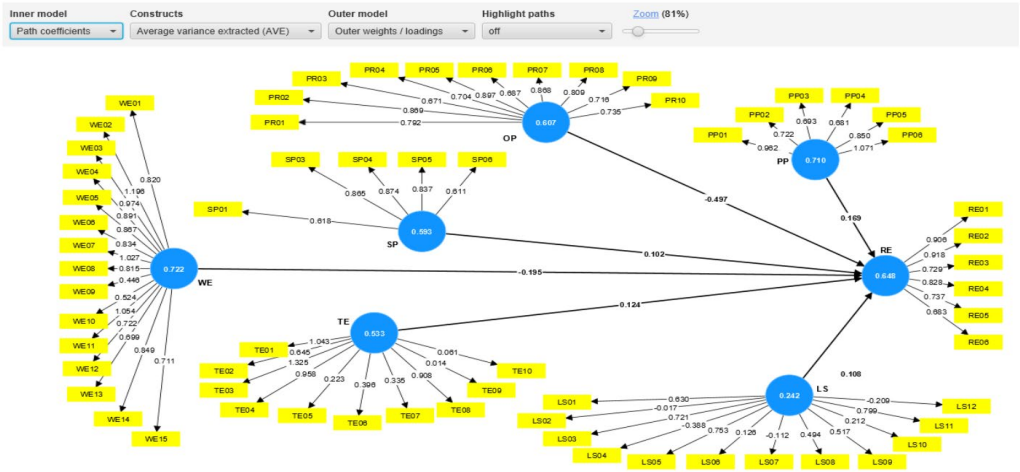


Figure 2: Factor loading and variance distribution across PPP e-tendering readiness constructs

Operational factors showed strong loadings for process standards, document integrity, data transmission, and transparency. Technology also demonstrated satisfactory measurement, particularly for cost implications, system reliability, and integration. The Work Environment, Service Provider, and Legal and Security constructs likewise exhibited acceptable indicator performance, supporting their relevance to organisational readiness.

Following measurement model validation, the structural model was assessed to examine the explanatory capability of the proposed framework. Consistent with Hair et al. (2021), structural model assessment included collinearity (VIF), explanatory power (R^2), effect size (f^2), predictive relevance (Q^2), and bootstrapping. In this study, the analysis focused on VIF, R^2, and bootstrapping using SmartPLS 4.

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Table 5: Structural model assessment

Assessment	Result	Threshold
Maximum VIF	2.44	>0.50
explanatory power (R^2),	0.543	>0
predictive relevance (Q^2)	0.361	<5.0
bootstrapping	5,000	

Table 5 summarises the structural model assessment. The coefficient of determination (R^2 = 0.543) indicates that the six readiness dimensions jointly explained 54.3% of the variance in E-Tendering Readiness, representing a moderate level of explanatory power. Furthermore, all predictor constructs recorded Variance Inflation Factor (VIF) values below the recommended threshold of 5.0, indicating that multicollinearity was not a concern. The value (Q^2) exceeded zero, indicating that the model possesses predictive relevance. The significance of the structural relationships was subsequently evaluated using the bootstrapping procedure in SmartPLS 4 based on the estimated path coefficients and corresponding significance values.

The structural model identified People and Operational factors as the only significant predictors of e-tendering readiness. People factors positively influenced readiness, whereas Operational factors showed a significant negative effect, suggesting that conventional paper-based procedures may hinder end-to-end digital implementation. The structural path estimates are presented in Table 6.

Table 6: Bootstrapping results

Path	Beta	t-value	p-value	Decision
People -> Readiness	0.170	2.34	0.020	Supported
Operational -> Readiness	-0.458	5.11	<0.001	Supported
Technology -> Readiness	0.129	0.73	0.465	Not supported
Work Environment -> Readiness	0.108	1.51	0.132	Not supported
Service Provider -> Readiness	-0.167	1.06	0.292	Not supported
Legal and Security -> Readiness	0.061	0.38	0.702	Not supported

Table 6 shows that People factors are the strongest positive predictor of e-tendering readiness, whereas Operational factors have a significant negative effect. The remaining constructs were not significant direct predictors, although they remain important enabling conditions.

Although Technology, Work Environment, Service Provider, and Legal and Security factors are widely recognised as important determinants of digital

procurement, their non-significant direct effects suggest that they function primarily as enabling conditions rather than immediate drivers of e-tendering readiness. In the Malaysian PPP context, these dimensions are relatively well established across public organisations, resulting in limited variation in respondents' perceptions once People capability and Operational readiness are considered simultaneously. This interpretation is consistent with previous studies showing that organisational resistance and process complexity often exert stronger influences on digital procurement implementation than technology alone (Inusah et al., 2025). Leadership support and supplier readiness may therefore contribute indirectly through staff capability, process improvement, and ecosystem maturity (Duong et al., 2024; Fayos et al., 2022; Herrmann & Cobo Martín, 2025), while legal and security frameworks remain essential for institutional trust and procurement integrity (Sava & Dragoș, 2022; Aboelazm et al., 2025). These dimensions may therefore exert indirect, mediating, or moderating effects that warrant further investigation.

Overall, the six readiness dimensions capture an important part of the factors shaping e-tendering readiness among government officers involved in Malaysian PPP procurement, while the collinearity assessment confirms stable model estimates. People factors emerged as the strongest positive predictor of e-tendering readiness, highlighting the importance of staff capability in digital procurement reform. Officers involved in contract preparation, evaluation, compliance, and clarification management require adequate knowledge, resources, and confidence to support successful implementation, consistent with Afolabi et al. (2019) and Kissi et al. (2025).

Because all measurement items were verified during data preparation, the negative relationship between Operational factors and e-tendering readiness reflects a genuine empirical finding rather than reverse coding or measurement inconsistency. The finding suggests that existing procurement procedures remain insufficiently aligned with digital workflows despite organisational commitment to reform.

PPP procurement processes are often highly formalised to ensure accountability and legal defensibility. However, fragmented approvals, excessive documentation, sequential endorsement processes, and continued reliance on manually signed or hard-copy documents reduce the efficiency of end-to-end digital workflows (Mat Aron et al., 2024; Inusah et al., 2025; World Bank, 2011). These findings suggest that operational procedures should be redesigned to preserve governance while improving digital usability.

The negative effect should therefore not be interpreted as evidence that operational management is inherently detrimental to e-tendering readiness. Instead, it reflects a mismatch between traditional procurement procedures and the operational requirements of digital procurement systems. Although strong

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operational controls remain essential for accountability and transparency, excessive procedural complexity may reduce organisational flexibility and delay digital implementation, consistent with Yevu et al. (2021), Sakutemba et al. (2024), and Inusah et al. (2025).

The insignificance of Technology factors should be interpreted carefully. It does not mean that technology is unimportant; rather, it suggests that technology may already be a background enabling condition in the present sample. Readiness differences therefore appear to depend less on whether systems are available and more on whether people and procedures can use them effectively. Because e-procurement initiatives have been part of Malaysia's public sector modernisation for over a decade, basic technological infrastructure is likely normalised among the experienced Grade 41 and above officers handling these projects. This helps explain why the mere acquisition of platforms does not automatically produce transformation.

Taken together, the findings point to a socio-technical understanding of readiness. E-tendering reform in PPP procurement should not be treated as an isolated technology deployment. Instead, it requires capable people, digitally compatible procedures, and implementation governance that reflects the complexity of PPP transactions. Public agencies can procure systems, but readiness itself must be built through training, process simplification, workflow redesign, and confidence in digital controls.

These findings are also important at the policy level. Ministries and agencies pursuing e-tendering in PPP settings should begin with readiness diagnostics before mandating platform use across complex projects. They should identify where the process architecture is likely to create friction and invest in function-specific training rather than generic awareness programmes. Officers involved in drafting terms, uploading tender packs, managing clarifications, checking compliance, and supporting evaluation committees require different competencies, and a single training module is unlikely to be sufficient.

Overall, the findings indicate that successful digital procurement reform depends on addressing organisational capability and legacy processes rather than technology alone. Public agencies should undertake readiness assessments before implementing new e-tendering systems, procurement officers should strengthen digital competencies through continuous professional development, and system providers should design user-centred platforms that integrate seamlessly with procurement workflows. Accordingly, the proposed readiness model offers a practical diagnostic framework for prioritising improvement initiatives and monitoring digital procurement transformation.

CONCLUSION

This paper examined e-tendering readiness in Public-Private Partnership procurement in Malaysia using questionnaire survey data and PLS-SEM analysis. Readiness was conceptualised as a multidimensional construct comprising People, Operational, Technology, Work Environment, Service Provider, and Legal and Security factors. The findings indicate that People positively and significantly influenced e-tendering readiness, whereas Operational factors had a significant negative effect. Although Technology, Work Environment, Service Provider, and Legal and Security factors are conceptually important, they were not significant direct predictors in the proposed model. The model explained a meaningful proportion of variance in organisational readiness among government officers involved in Malaysian PPP procurement, indicating that the proposed framework provides a useful basis for understanding public-sector readiness for digital procurement reform. The findings should, however, be interpreted within the context of the study population and should not be generalised to private-sector organisations, concessionaires, or other procurement stakeholders without further empirical validation.

Overall, the proposed readiness model provides a practical evidence-based framework that may assist Malaysian public agencies in systematically assessing organisational preparedness before undertaking digital procurement transformation initiatives.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations. First, the respondents were all public-sector officers, so the findings mainly reflect readiness from the government's point of view. The views of other important parties, such as bidders, consultants, concessionaires, and technology providers, were not included directly. Future studies should involve these groups so that e-tendering readiness can be assessed more fully across the entire procurement ecosystem, and not only from an internal government perspective. Accordingly, the findings should be interpreted as reflecting the perceptions of government procurement practitioners and should not be generalised to the wider PPP ecosystem without further empirical evidence from other stakeholder groups.

Second, this study used a cross-sectional design, which means the data were collected at only one point in time. Because of this, the study cannot show how readiness may change before and after new policies, implementation stages, or specific improvement efforts. Future research could use a longitudinal approach to examine whether training, process improvements, or legal and policy changes lead to measurable improvements in readiness over time. Comparative studies across sectors and countries would also be useful to identify which barriers are specific to a particular context and which are more widely shared.

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Future research should also explore the role of emerging technologies in PPP tendering. These may include artificial intelligence to support evaluation, blockchain to strengthen document security, smart contracts to improve enforceability, and advanced analytics to detect procurement risks. In addition, future studies could examine issues such as AI ethics, sustainable procurement measurement, procurement data analysis, and public value. This would help broaden future readiness models so that they address not only adoption, but also integrity, sustainability, resilience, and long-term governance performance.

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DEVELOPING A CONCEPTUAL PROJECT FRAMEWORK FOR BLOCKCHAIN-ENABLED HERITAGE BUILDING INFORMATION MODELLING (HBIM) IN MALAYSIA

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Abstract

The challenges in heritage building documentation and management in Malaysia highlight the need for a more secure and integrated digital framework. Although Heritage Building Information Modelling (HBIM) has improved digital documentation and lifecycle management, current practices remain constrained by data fragmentation, limited transparency, and inefficient stakeholder collaboration. While blockchain technology offers considerable potential to enhance data security and trust, its integration with HBIM in heritage conservation projects remains underexplored. This paper aims to develop a conceptual framework in exploring the interrelated themes influencing the implementation of blockchain integration with HBIM in Malaysian projects. Using a qualitative approach, semi-structured interviews were conducted with industry professionals, and the data were analysed using thematic analysis. The proposed conceptual framework is empirically informed by practitioner interviews, allowing the study to capture both technological possibilities and implementation realities within the Malaysian heritage project context. The findings suggest that blockchain-enabled HBIM has the potential to strengthen data integrity, transparency, traceability, stakeholder accountability, and lifecycle decision-making, although these benefits require further validation through pilot implementation. Future research should further validate the proposed framework through pilot projects, and blockchain governance guidelines tailored to the Malaysia's heritage conservation sector.

Keywords: Heritage Building Information Modelling (HBIM), Blockchain Technology, Blockchain-HBIM framework, Malaysia

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INTRODUCTION

Heritage buildings represent irreplaceable repositories of cultural identity and architectural legacy. In Malaysia, only approximately 183 buildings have been gazetted as national heritage, yet many continue to deteriorate due to poor documentation, insufficient maintenance records, and limited technology adaptation. These systemic deficiencies threaten the country's cultural values and underscore the urgent need for more robust digital frameworks for heritage building management (Ismail et al., 2026). It is further complicated by fragmented documentation, inconsistent maintenance records, limited digital heritage databases, and the absence of integrated systems that can support long-term monitoring and accountability across multiple stakeholders.

Heritage Building Information Modelling (HBIM) has emerged as a promising approach to addressing these challenges. HBIM enables the creation of comprehensive digital representations of heritage assets, facilitating documentation, lifecycle management, condition monitoring, and conservation planning (Baharuddin et al., 2024; Sampaio et al., 2021). It is widely regarded as one of the most reliable tools for the digitisation and management of historical building information (Baharuddin et al., 2023). However, despite its recognised potential, HBIM adoption in Malaysia remains at a nascent stage, constrained by the demand for specialised skills, limited collaboration among stakeholders, high costs of scanning equipment, and the absence of standardised protocols (Ismail et al., 2026; Baharuddin et al., 2024; Yusoff & Brahim, 2021; Ali et al., 2018). Notably, HBIM is not currently required as part of Conservation Permission submissions to the Malaysia National Heritage Department (JWN). This indicates an important institutional gap, as HBIM-based documentation has not yet been acknowledged into conservation procedures, heritage asset monitoring, or formal digital record-keeping practices under Malaysia’s heritage-management framework.

According to Zhou et al., (2024) and Adegoriola et al., (2021), critical limitation of current HBIM practice concerns data security, integrity, and stakeholder trust. Heritage conservation involves multiple stakeholders whose decisions must be transparent and accountable, yet existing systems remain vulnerable to data fragmentation, unauthorised access, and the absence of a single source of truth. On the other hand, blockchain technology, as a decentralised and distributed ledger characterised by immutability and traceability, offers a compelling solution to these challenges transparency (Zhou et al., 2024; Rubino et al., 2024). In the Architecture, Engineering, and Construction (AEC) industry, blockchain has been increasingly explored for enhancing data security, information sharing, and collaborative decision-making. Recent studies have demonstrated its applicability to cultural heritage, including provenance verification, digital rights management, and decentralised collaboration in

restoration projects (Rubino et al., 2024; Zhou et al., 2024; Vacchio & Bifulco, 2022).

Nevertheless, the integration of blockchain with HBIM for heritage conservation remains largely underexplored, particularly in the Malaysian context. Although previous studies have examined HBIM adoption and blockchain applications separately, limited research has explored how blockchain-enabled HBIM can be conceptualised as a project-level framework for heritage conservation, especially in Malaysia. Existing studies also provide limited empirical insight into practitioner perceptions, institutional readiness, data-governance challenges, and stakeholder coordination in the Malaysian heritage sector. While Malaysia has taken initial steps towards blockchain adoption across sectors such as manufacturing, healthcare, and real estate (Salleh et al., 2023; Hira et al., 2022), persistent barriers including limited technical expertise, high implementation costs, and the absence of comprehensive regulatory frameworks suggest that sector-specific investigation is essential. Therefore, this paper aims to develop an empirically informed conceptual project framework for blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysia.

LITERATURE REVIEW

Heritage Building Information Modelling (HBIM): Concept and Development

Heritage Building Information Modelling (HBIM) represents the application of Building Information Modelling (BIM) technology to the documentation, conservation, and management of historic structures. First proposed by Murphy at the Dublin Institute of Technology, HBIM is a system for modelling historic structures from laser scan and photogrammetric data using BIM software, whereby parametric objects representing architectural elements are mapped onto survey data to construct comprehensive digital models (Ismail et al., 2021; Ali et al., 2018). The methodology encompasses three major workflow stages: data acquisition, data processing, and three-dimensional modelling (Baharuddin et al., 2023; Salleh et al., 2023; Ali et al., 2018). Unlike conventional BIM for new construction, HBIM requires a distinct perspective that accounts for historical construction techniques, material degradation, and the complex geometries characteristic of heritage assets (Sampaio et al., 2021). HBIM is widely regarded as one of the most reliable tools for the management and digitisation of documents associated with historical buildings and artefacts, enabling the storage of both graphical and non-graphical information within semantically enriched parametric models (Baharuddin et al., 2023; Ali et al., 2018).

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HBIM facilitates improved documentation, lifecycle management, condition monitoring, and conservation planning by integrating digital representations across the building lifespan (Sampaio et al., 2021). It creates a collection of historical data and different types of design that result in automated documentation for precise preservation and conservation.

Furthermore, HBIM supports interdisciplinary collaboration by providing a centralised platform for data exchange and information management, enabling stakeholders such as architects, engineers, conservators, and project managers to work within a shared digital environment (Adegoriola et al., 2021; Sampaio et al., 2021; Zhou et al., 2024). Studies have also demonstrated the utility of HBIM for facility management, structural analysis, augmented and virtual reality applications, and fire safety design in existing buildings (Adegoriola et al., 2021). The technology has been described as a traceable and sustainable method of lifecycle information management, with a central database that allows easy retrieval, extraction, and use of various types of architectural heritage information (Agwa and Celik, 2025).

HBIM Adoption in Malaysia: Status and Challenges

Despite the global recognition of HBIM's potential, its adoption in Malaysia remains at a nascent stage. Within Malaysia, the value of HBIM should not be limited to three-dimensional modelling but should also be understood in relation to conservation permission, measured drawing records, maintenance documentation, condition assessment, heritage databases, and coordination between heritage agencies, local authorities, managers, consultants, building owners, and conservators. Salleh et al. (2022) attributed this to the demand for new skill sets, including three-dimensional modelling expertise, a thorough understanding of the approach, extensive collaboration requirements, and the psychological challenges of transitioning to new working paradigms. Ismail et al. (2026) confirmed that current facility management practices for heritage buildings in Malaysia do not employ advanced technology for upkeep and maintenance, particularly in producing dilapidation reports and measured drawings (Yusoff and Brahim, 2021). Ismail et al. (2021) found that while awareness of HBIM is increasing among stakeholders, significant challenges persist in terms of data management, collaboration, and system reliability. The challenges restricting BIM implementation in heritage buildings were categorised into three elements: people, process, and technology (Yusoff & Brahim, 2021). Additionally, Malaysia also faces additional barriers, including limited historical datasets, high costs associated with advanced scanning equipment, and the absence of standardised HBIM protocols for heritage assets (Jalaluddin, 2025; Ismail et al., 2021).

Blockchain Technology and Its Potential for Heritage Data Management

In the heritage domain, blockchain has been identified as a potential promising tool for addressing persistent challenges related to data integrity, provenance verification, and collaborative decision-making. It has been explored for cultural heritage preservation, particularly in addressing issues related to data authenticity and long-term digital preservation. Blockchain properties have led to its increasing adoption in the Architecture, Engineering, and Construction (AEC) industry for enhancing data security, information sharing, and trust among stakeholders (Zhou et al., 2024). Zhou et al. (2024) proposed the Architectural Heritage Restoration Distributed Common Data Environment (AHR-DCDE) framework, integrating blockchain and InterPlanetary File System (IPFS) technologies to create a decentralised collaborative design process that achieves data immutability, traceability, and efficient large-scale file processing. The framework was validated through a heritage restoration project in Wuhan, China, demonstrating significant improvements in data security and collaborative efficiency (Zhou et al., 2024). Recent studies have also linked blockchain with Web3 and decentralised digital heritage systems, highlighting its potential to support more open, distributed, and user-centric heritage data ecosystems (Rubino et al., 2024).

However, the integration of blockchain with HBIM remains relatively scarce in the literature. Zhou et al. (2024) noted that while blockchain exhibits considerable promise for mitigating cybersecurity threats in collaborative HBIM projects, its integration into Common Data Environment management for architectural heritage restoration encounters obstacles, including the uniqueness and complexity of historical buildings, which often lead to large and complex HBIM models. The management of architectural heritage using digital technologies, while making the process of saving and updating documents more agile and accessible, also introduces vulnerabilities related to data tampering and the lack of a single source of truth among diverse stakeholders (Sampaio et al., 2021). Adegoriola et al. (2021) highlighted that new research directions are being geared towards leveraging emerging technologies to optimise heritage building maintenance, yet acknowledged that the process is not yet efficient. These findings collectively suggest that while blockchain-enabled HBIM holds significant promise for improving data integrity, transparency, and stakeholder coordination in heritage conservation, substantial barriers, including limited technical expertise, high implementation costs, and the absence of regulatory and standardisation frameworks, must be addressed to achieve effective adoption, particularly in developing contexts such as Malaysia (Jalaluddin, 2025; Zhou et al., 2024; Salleh et al., 2022).

This highlights the need for a framework derived from practitioner insights. Unlike existing blockchain-HBIM studies that primarily focus on

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technical architecture, decentralised data storage, or general digital heritage applications, this study focuses on the Malaysian heritage conservation context and develops a practitioner-informed project framework that links the blockchain potential with HBIM adoption, data-management problems, implementation barriers, and institutional readiness.

RESEARCH METHODOLOGY

This study adopts a qualitative research approach to develop a conceptual framework to captures the interrelated themes influencing the implementation of blockchain integration with HBIM in Malaysia. It is chosen because blockchain-enabled HBIM remains an emerging and underexplored phenomenon in Malaysian heritage conservation. The approach allows the study to examine professional perceptions, constraints, institutional conditions, and implementation requirements that may not be adequately captured through quantitative methods at this exploratory stage. According to Jabareen (2009), in qualitative research, a conceptual framework can be developed from themes identified in the data and organised to explain the key dimensions and relationships underlying the phenomenon being studied.

Data Collection and Analysis

Data were collected through semi-structured interviews. Participants were purposively selected based on their expertise and direct involvement in heritage building projects, BIM implementation, or digital technology adoption within the Malaysian construction and conservation sectors.

The participants consisted of individuals with minimum five years of experience in their respective fields. Participants were selected from Kuala Lumpur and Selangor, as these regions host significant heritage assets and active government or private heritage projects. Participants were contacted through professional networks and social media platforms such as WhatsApp, and email. Detailed notes were also taken to supplement the recordings. To enhance the response rate and broaden the range of perspectives, snowball sampling was employed. At the conclusion of each session, participants were invited to recommend other potential participants with relevant expertise in heritage building conservation or BIM.

Table 1: Details of Interviewees

Interviewee	Position	Year of Professional Experience
P1	Curator	15 years
P2	Conservator	17 years
P3	Assistant Curator	10 years
P4	Government Officer	8 years

Interviewee	Position	Year of Professional Experience
P5	BIM Expert	16 years
P6	Architect	15 years
P7	Project Management Executive	5 years

Although the number of participants was limited, the selected participants represented relevant professional roles in heritage conservation, project management, and BIM practice. This was considered appropriate for an exploratory qualitative study seeking in-depth practitioner insight rather than statistical generalisation.

The interview data were analysed using thematic analysis. The analysis followed the practical guidance provided by Braun and Clarke (2022), informed by the widely adopted six-phase approach to thematic analysis. The process involved data familiarisation, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Data collection was considered sufficient when repeated responses began to emerge, and no substantially new themes were identified from subsequent interviews. This indicator was used to consider that thematic saturation had been reached within the scope of the study.

The analysis began with repeated reading of interview notes and transcripts to gain familiarity with the participants' views. Meaningful statements related to HBIM adoption, blockchain integration, heritage data management, stakeholder coordination, and implementation barriers were then identified and assigned initial codes. The initial codes were compared across participants and grouped into related categories. These categories were then refined into sub-themes, including technological readiness, documentation fragmentation, data security, auditability, collaboration, cost, regulatory support, and resistance to change. Through this process, four overarching themes were developed: current awareness and adoption, data management challenges, perceived potential benefits of blockchain, and barriers to adoption. The proposed framework was developed by linking the four themes to the implementation logic of blockchain-enabled HBIM. Therefore, the framework is conceptual in structure but empirically grounded in the thematic patterns derived from practitioner interviews. To enhance trustworthiness, the coding process was reviewed against the interview data to ensure that the themes accurately reflected participants' responses. The use of purposive sampling, participant role diversity, systematic coding, and theme refinement helped improve the credibility and dependability of the qualitative findings.

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FINDINGS AND DISCUSSION

The thematic analysis of semi-structured interviews revealed four overarching themes shaping the implementation of blockchain integration with HBIM in Malaysia: (i) current awareness and adoption, (ii) data management challenges, (iii) perceived benefits of blockchain, and (iv) barriers to adoption. These themes collectively explain both the need for integration and the conditions influencing its feasibility, as reflected and further discussed in the results shown in Figure 1.

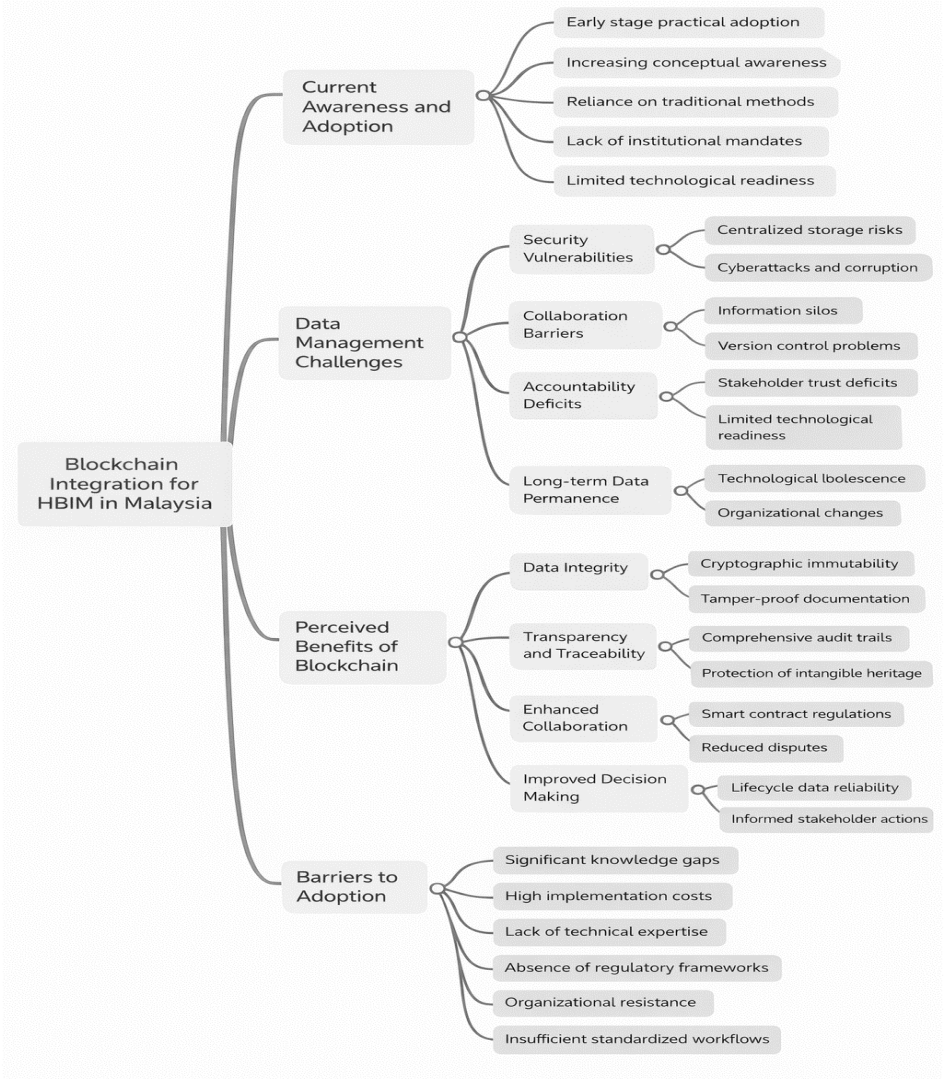


Figure 1: Thematic analysis on blockchain-HBIM integration in Malaysia

Current Awareness and Adoption of HBIM in Malaysia

Participants recognised HBIM as a valuable platform for integrating historical documentation, structural information, and lifecycle data within a unified digital environment. Despite this recognition, implementation remains limited, with most organisations continuing to rely on conventional documentation practices. As participants mentioned, "adoption of HBIM is very limited" and that most agencies still rely on "manual documentation methods such as manual measurements, photography, and manual defect mapping," mainly due to limited budget and technical expertise (P2, P3, P7). The findings indicated that awareness of HBIM among heritage professionals in Malaysia is increasing; however, its practical adoption remains at an early stage.

This gap between awareness and adoption suggests a readiness deficit, where stakeholders acknowledge the benefits of HBIM but lack the institutional and technical capacity to implement it effectively. This finding aligns with previous studies such as Ismail et al. (2021) highlighting the slow adoption of BIM-related technologies in Malaysia due to skill shortages, high costs, and organisational inertia. From a theoretical perspective, this reflects weak facilitating conditions and high effort expectancy, which constrain adoption despite positive perceptions. The absence of regulatory mandates, particularly the lack of HBIM requirements in conservation approval processes, further reinforces this limitation. As such, awareness alone is insufficient to drive adoption; it must be supported by institutional frameworks, policy enforcement, and capacity development. These responses indicate that HBIM awareness is developing among Malaysian heritage practitioners, but awareness has not yet translated into consistent project-level implementation.

Challenges in Heritage Building Data Management and Collaboration

The interview findings reveal that challenges in heritage building data management are deeply systemic and extend beyond isolated technical limitations. One participant explained that heritage projects often face delays because "documents get lost" or different parties work with "different versions," suggesting that fragmented communication and inconsistent records remain major project coordination problems. Heritage projects often involve architects, conservators, engineers, contractors, and public agencies, yet existing HBIM practices frequently lack an integrated data environment. This leads to information silos, inconsistent data sharing, version control conflicts, and communication inefficiencies. As a result, project coordination becomes more difficult, increasing the likelihood of delays, duplication, and inconsistencies in documentation and decision-making.

Another dominant issue is the vulnerability of centralised storage systems, which expose heritage records to risks such as cyberattacks, data

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corruption, and unauthorised modification. These data-management problems are particularly critical in heritage conservation because documentation must remain accurate, traceable, and accessible across long periods of maintenance, repair, restoration, and official review.

The findings also highlight limited transparency and accountability in current systems. Without clear audit trails, it is difficult to verify who made changes, trace decisions, monitor material usage, or confirm compliance with conservation requirements. This lack of traceability reduces trust among project participants and weakens confidence in digital heritage management processes.

A further concern relates to long-term data permanence as highlighted by few of the participants (P1,,P2, P5). Existing systems often do not provide sufficient assurance that heritage information can be preserved and accessed consistently across future technological, organisational, or institutional changes. This raises important concerns for heritage asset management, where continuity of information is essential for long-term conservation planning and intervention.

Participants (P5, P7) also highlighted that current HBIM practices are constrained by broader data governance limitations rather than by technical issues alone. Weaknesses in security, collaboration, transparency, and permanence reduce the effectiveness of HBIM in supporting heritage conservation. These findings indicate that current HBIM practices are constrained by systemic data governance limitations, which undermine their effectiveness in heritage conservation. In Malaysia, such challenges may affect the reliability of conservation records, measured drawings, dilapidation reports, maintenance histories, and documentation submitted to heritage agencies or local authorities. These challenges serve as primary drivers for the need to integrate blockchain technology, as they directly correspond to the capabilities that blockchain is designed to address.

Perceived Benefits of Blockchain Integration with HBIM

The findings indicate that participants perceived blockchain as having potential to improve HBIM-based heritage building management, particularly in relation to data integrity, traceability, transparency, and stakeholder trust (P1, P2, P3, P4, P6). Participants generally linked these benefits to blockchain's core features, particularly decentralisation, immutability, transparency, and security, which they considered highly relevant to the long-term management of heritage information.

One of the most frequently emphasised benefits was data integrity and immutability. Participants viewed blockchain as a secure way to preserve heritage records without the risk of unauthorised alteration (P3, P6). This perception is consistent with the literature, which explains that once validated, blockchain records cannot be changed or removed, thereby improving the reliability of stored

data (Zhou et al., 2024). In the interviews, participants associated this feature with stronger protection of heritage documentation, especially in comparison with centralised storage systems that are more vulnerable to tampering or loss.

A second important benefit identified by participants was transparency and traceability. Several participants (P2, P6) believed that blockchain could provide a clear and verifiable history of actions, updates, and decisions related to heritage assets. This would allow stakeholders to trace who made changes, when they were made, and what information was involved. Such a view aligns with existing research showing that blockchain supports traceability, accountability, and resistance to manipulation in collaborative digital environments (Zhou et al., 2024). Participants considered this especially valuable in heritage projects where documentation accuracy and accountability are essential.

Participants (P2, P4) also highlighted enhanced collaboration and trust as a major benefit. They suggested that blockchain could support a more reliable shared environment for multiple stakeholders, including managers, consultants, and authorities. By improving confidence in the accuracy and ownership of shared data, blockchain was seen as a tool that could reduce disputes and strengthen cooperation. This supports previous work which notes that blockchain can enhance information sharing, trust, and collaborative project delivery in HBIM-related applications (Zhou et al., 2024).

Finally, participants also linked blockchain integration with improved decision-making. They believed that more secure, transparent, and trustworthy data would help stakeholders make better-informed decisions throughout the heritage building lifecycle. Overall, the findings suggest that blockchain is perceived not only as a technical solution, but also as a governance mechanism that can strengthen data reliability, stakeholder trust, and long-term heritage management. However, these benefits should be interpreted as perceived potential rather than confirmed performance outcomes, as this participants of this study did not involve in the development, testing, or piloting of an actual blockchain-HBIM system.

Barriers to Blockchain-Enabled HBIM Adoption

The findings indicate that, despite the recognised benefits of blockchain integration, the adoption of blockchain-enabled HBIM remains constrained by a range of organisational, technical, financial, and institutional barriers. These barriers suggest that implementation is not merely a matter of technological availability, but depends on broader conditions of readiness, capability, and support.

Technical and financial barriers were also strongly evident. This concern was consistent with participants' views (P3, P4, P5, P7) that the main issues are "cost, lack of standardized workflows, and professionals who

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understand both heritage conservation and BIM technology." Participants pointed to the complexity of integrating blockchain with existing digital systems, particularly where organisations already face limitations in software capability, infrastructure, and specialist expertise. High implementation cost further compounds this challenge, making adoption difficult for institutions with constrained financial resources. This reflects previous findings that heritage-focused digital systems are often hindered by the cost of model development, hardware and software limitations, and the need for specialised competencies (Lovell et al., 2023; Lovell et al., 2025). Resistance to change further complicates adoption. Several participants (P3, P4, P5) suggested that established practices and institutional inertia continue to discourage the transition to new digital systems. This indicates that adoption is influenced not only by perceived usefulness, but also by effort expectancy and facilitating conditions.

Across the themes, a broader causal pattern can be observed: existing data management problems create the need for transformation, and the benefits of blockchain justify interest in adoption, yet implementation remains limited by weak organisational readiness, low awareness, and insufficient institutional support. The findings is further illustrated as a conceptual project framework to explain the conditions influencing the adoption of blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysian heritage conservation projects.

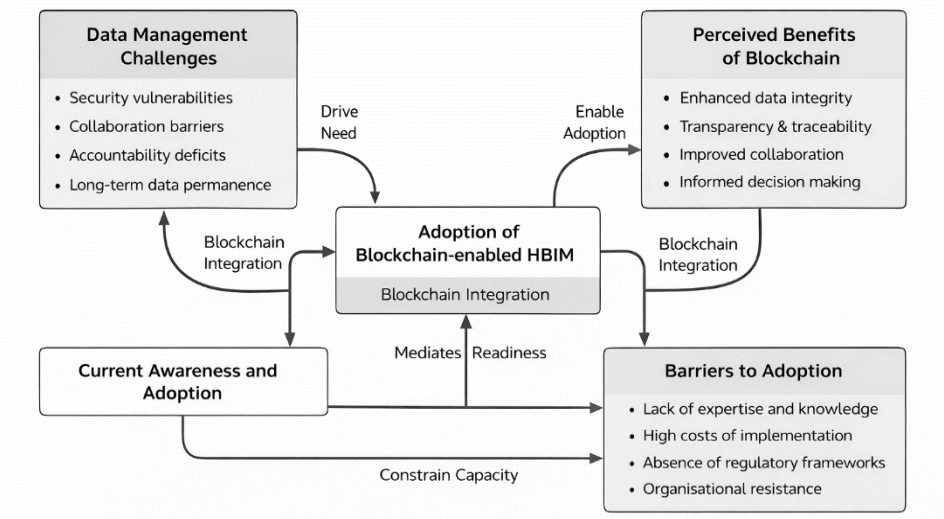


Figure 2: Conceptual project framework for blockchain-enabled HBIM in Malaysia

As illustrated in Figure 2, the framework integrates four interrelated themes: Data Management Challenges, Current Awareness and Adoption, Perceived Benefits of Blockchain, and Barriers to Adoption. At the centre of the framework is the Adoption of Blockchain-Enabled HBIM, representing the proposed integration of blockchain capabilities into HBIM-based information management processes. The conceptual framework explains blockchain-enabled HBIM adoption as the result of interactions among data management challenges, stakeholder readiness, perceived benefits, and implementation barriers. Data management problems, including security vulnerabilities, collaboration difficulties, accountability gaps, and concerns over long-term data permanence, create the initial need for improved heritage information management. These challenges motivate consideration of blockchain integration but do not imply that blockchain will automatically resolve existing weaknesses. Current awareness and adoption influence implementation readiness, as successful integration depends on stakeholders' understanding, acceptance, experience, and organisational preparedness. Limited awareness may restrict the ability to evaluate blockchain applications, build internal capabilities, and integrate the technology into existing HBIM workflows.

At the same time, perceived benefits, such as improved data integrity, transparency, traceability, collaboration, and decision-making, provide the value justification for adoption. However, implementation may be constrained by limited expertise, high costs, inadequate regulatory support, and organisational resistance. The framework therefore presents adoption as a balance between technological need, readiness, perceived value, and constraints. From a project perspective, the framework supports systematic assessment of information-management weaknesses, organisational readiness, expected benefits, and implementation risks. It should be viewed as a conceptual project-level structure that supports further empirical validation and future research on practical, governance, regulatory, and technical implementation pathways.

CONCLUSION

This study developed an empirically informed conceptual project framework for blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysia. Based on semi-structured interviews with heritage project and digital construction practitioners, the study has identified four interrelated themes: current awareness and adoption, data-management challenges, perceived potential benefits of blockchain, and barriers to adoption. The study contributes to the literature by positioning blockchain-enabled HBIM as a socio-technical approach to heritage data governance rather than merely a technological innovation. Practically, the framework provides a structured reference for

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relevant stakeholders seeking to improve documentation, traceability, accountability, and stakeholder coordination in heritage conservation. However, this study is limited by its exploratory qualitative design and relatively small number of participants. The proposed framework has not yet been tested through system development or real-world pilot implementation. Therefore, the findings should be interpreted as practitioner-informed conceptual insights rather than evidence of technical performance.

The findings instead indicate perceived potential, which requires further validation through pilot implementation and technical assessment. It is recommended for further research should also examine integration with national's documentation requirements, HBIM data standards, blockchain governance guidelines, interoperability testing, stakeholder training, and long-term digital preservation protocols.

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PERCEIVED ECONOMIC IMPACTS OF KLUANG RAILWAY STATION: A STAKEHOLDER ANALYSIS

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Abstract

Railway station upgrades are widely promoted as drivers of local economic development, yet stakeholders' perceptions of these impacts remain insufficiently examined in secondary city contexts. This paper investigates whether stakeholders perceive positive economic impacts from the Kluang Railway Station in Johor, Malaysia, and whether perceptions differ between train users and economic operators. Six economic indicators were measured: visitor increase, customer flow, business attraction, employment opportunities, property value increase and local competitiveness. Based on the survey data from respondents within a 400-meter station catchment area, the study employs Binomial tests to show the statistical significance of stakeholder agreement and Chi-Square tests to identify whether perceived benefits differ between train users and economic operators. The results show that positive responses significantly exceed fifty percent for all six indicators, with rates ranging from eighty to ninety percent. The highest rates are observed for visitor increase and business attraction, while property value increase shows the lowest rate at eighty percent. The Chi-Square tests reveal no significant differences between train users and economic operators across any indicator, indicating strong stakeholders' alignment. The paper concludes that the railway station is perceived as generating substantial economic benefits by all stakeholder groups, with no perception gap between business operators and transport users.

Keywords: Economic impacts, railway station, stakeholder perception, secondary city, Kluang

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INTRODUCTION

The modernisation of rail infrastructure in secondary cities is increasingly promoted as a means of fostering regional economic development. In Malaysia, the introduction of the Electric Train Service (ETS) has extended high-quality rail connectivity beyond metropolitan Kuala Lumpur to secondary towns such as Kluang, Johor. The new Kluang Railway Station, which opened in 2025, represents a significant public investment aimed at improving intercity mobility and stimulating local economic activity (KTMB, 2023). Currently, the station is fully operational. Consequently, respondents were asked to evaluate the actual, observable economic impacts currently occurring in the area, rather than expected future outcomes. This station replaces an older colonial-era facility and is part of the larger Electrified Double Tracking Project from Gemas to Johor Bahru, highlighting the critical need to evaluate TOD integration and pedestrian connectivity around early built transit nodes (Abdullah et al., 2023).

The anticipated benefits of such rail upgrades are well documented in transport economics literature. Improved connectivity is expected to reduce travel times, increase service frequency, and enhance passenger comfort, thereby attracting more users to rail transport. For a town like Kluang, which has historically relied on agriculture and small-scale manufacturing, the arrival of the ETS presents an opportunity to diversify the local economy through increased tourism, retail activity, and business investment. However, the realisation of these benefits is not automatic. Studies have shown that rail investments can produce limited or uneven economic outcomes when not integrated with complementary policies such as land-use planning, feeder transport services, and pedestrian infrastructure improvements (World Bank, 2019; Litman, 2015).

While many studies have examined the economic impacts of railway stations in metropolitan contexts such as Kuala Lumpur and Johor Bahru, less attention has been given to stakeholder perceptions in secondary cities (Sharma & Dehalwar, 2025). Understanding whether different stakeholder groups share similar perceptions is critical for transport planning and public acceptance (Litman, 2022). Stakeholders include train users who benefit from mobility, and economic operators such as business owners and employees who rely on customer footfall generated by the station. If these two groups hold divergent views, transport planners may need to adopt differentiated engagement strategies. Conversely, if their perceptions align, a more unified approach to station-area development may be appropriate. By exploring these dynamics, this paper links empirical findings directly to station-area planning and transit-oriented development. Ultimately, it seeks to strengthen the planning contribution regarding pedestrian connectivity, local economic development, and secondary-city regeneration.

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This paper addresses these considerations by analysing survey data collected from 100 respondents within a 400-meter radius of the Kluang Railway Station. The study focuses on six economic indicators: visitor increase, customer flow increase, business and investment attraction, employment opportunities, property value increase, and local competitiveness. These indicators were selected as they capture both immediate and observable effects as well as longer-term indirect effects of transport infrastructure. By examining stakeholder perceptions across these indicators, the paper aims to provide empirical evidence on whether the Kluang Railway Station is viewed as an economic asset by the local community, and whether perceptions differ between train users and business operators.

LITERATURE REVIEW

Railway Stations and Urban Economic Impact

Transport infrastructure is widely recognised as a driver of urban economic development, enhancing productivity, market accessibility, and regional integration (World Bank, 2022). Rail investments, in particular, have been shown to generate productivity gains, expand urban labour markets, and stimulate urban regeneration (Knowles & Ferbrache, 2016). The mechanisms through which these urban economic benefits occur include improved access to jobs and services, increased connectivity between firms and markets, enhanced attractiveness for investment, and the creation of agglomeration economies where businesses cluster near transport nodes (Litman, 2022). Investments in modern rail networks act as a fundamental catalyst for local economic enhancement. By drastically reducing spatial friction, rail infrastructure lowers transaction costs and expands the catchment area for local labour and retail markets. This enhanced accessibility directly contributes to economic vitality by stimulating agglomeration economies, where businesses benefit from proximity to heightened pedestrian flows and improved supply chain linkages (Credit

The theoretical foundation for this study draws on two main frameworks from urban economics and planning (Calthorpe, 1993; Perroux, 1950). The Transit-Oriented Development theory highlights that concentrating commercial, residential, and leisure activities within walking distance of a transit hub creates sustainable urban growth patterns (Calthorpe, 1993). The pedestrian catchment area of 400 to 800 meters represents the zone where this conversion from transport infrastructure to urban economic activity is most likely to occur (Purba et al., 2019). TOD has been shown to generate urban economic benefits including increased property values, enhanced commercial activity, and improved quality of life for urban residents (Sharma & Dehalwar, 2025).

Additionally, the Growth Pole Theory suggests that economic growth originates at distinct poles of intensity within an urban system, with a modernised

railway station acting as a propulsive unit that attracts investment and infrastructure (Perroux, 1950). In the context of urban economics, a railway station can serve as a growth pole around which commercial, residential, and service activities cluster, creating multiplier effects that benefit the broader urban economy. These theories together justify the spatial delimitation of the study to the 400-meter station catchment area and the focus on the station as an urban economic catalyst (Calthorpe, 1993).

The literature on transport infrastructure impacts has identified several moderating factors that influence the magnitude and distribution of benefits (Banister & Berechman, 2001; Litman, 2021). These include the existing level of accessibility in the region, the quality of complementary infrastructure, the regulatory environment, and the capacity of local institutions to plan and implement station-area development (World Bank, 2019). In secondary city contexts, stakeholder perception research is particularly important because urban economic structures, and the resiliency of local economic operators, often differ significantly from metropolitan patterns (Mazlan et al., 2022)

The Transit-Oriented Development (TOD) literature has provided important insights into how rail infrastructure can shape urban economic outcomes (Calthorpe, 1993). The benefits of TOD include reduced car dependence, improved air quality, increased physical activity, enhanced social interaction, and economic benefits such as increased property values and commercial activity (Sharma & Dehalwar, 2025; Bong & Rosdi, 2024).

In the Malaysian context, research on TOD has identified both opportunities and challenges. Studies have shown that TOD can improve accessibility, promote healthier urban lifestyles, and enhance economic prospects, particularly around major transit hubs such as KL Sentral and Bandar Sunway (Zain et al., 2025). However, limitations in stakeholder commitment, urban design frameworks, and community participation are cited as persistent challenges that can weaken the potential benefits of TOD (Yip et al., 2024). These studies emphasise that while TOD can provide social, environmental, and economic benefits, its realisation is contingent upon strong governance frameworks and supportive policy environments.

Stakeholder Perceptions of Urban Economic Benefits

Stakeholder perceptions play a critical role in urban transport infrastructure evaluation (Banister, 2018). Understanding whether different groups share similar perceptions of urban economic benefits is essential for policy legitimacy and public acceptance (Litman, 2022). Disparities between stakeholder groups can indicate information asymmetries, differential benefit distributions, or planning inadequacies (World Bank, 2019). Research on multimodal integration highlights that failures in linking rail to local urban transport networks and

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providing adequate pedestrian infrastructure are common causes of under-utilisation and reduced urban economic benefits (Bhouri et al., 2025).

In secondary city contexts, stakeholder perception research is particularly important because urban economic structures may differ from metropolitan patterns. Business operators and transport users may have different exposure to station impacts and therefore different perceptions of urban economic benefit magnitude (Sharma & Dehalwar, 2025). Within the context of transit development, these stakeholders must be clearly identified to fully understand the distribution of economic benefits. Key stakeholders in this ecosystem primarily include: (1) economic operators, comprising local business owners, retail managers, property investors, and employees whose livelihoods depend on commercial activity; and (2) transport users, encompassing daily commuters, occasional tourists, and local residents who utilize the station for mobility.

Recent literature emphasises that evaluating the perceptions of these specific groups is vital, as their distinct economic priorities such as profitability and footfall for operators, versus affordability and accessibility for users that shape the ultimate success of station-area regeneration. For example, business owners may be more sensitive to changes in customer footfall and urban foot traffic patterns, while train users may prioritise service frequency and fare affordability over broader urban economic considerations (Dell'Olio et al., 2011). Understanding these potential differences is crucial for effective stakeholder engagement in urban planning processes.

Studies of secondary towns such as Kluang emphasise that railway station accessibility affects both train usage and visitation to urban commercial areas (Department of Statistics Malaysia, 2025). The food and beverage sector, in particular, has been identified as highly responsive to station-generated footfall due to short visit durations and impulse spending patterns (Dell'Olio et al., 2011). Retail and tourism sectors also benefit from improved urban accessibility, though potentially with different time profiles and customer segments (Cohen, 2022). These sectoral differences have important implications for urban economic development strategies focused on station-area planning (Sharma & Dehalwar, 2025).

The relationship between transport infrastructure and urban economic development is bidirectional (Banister & Berechman, 2001; Litman, 2022). Improved transport access can stimulate urban economic activity, but urban economic growth also generates demand for transport improvements (Vickerman, 2018). This virtuous cycle suggests that investments in rail infrastructure and complementary urban development policies can reinforce each other, creating sustained urban economic benefits (Sun & Cui, 2018). However, breaking into this cycle requires coordinated planning across transport and urban

development agencies, which is often challenging in secondary city contexts where institutional capacity may be limited (Lee at al., 2024).

RESEARCH METHODOLOGY

The study focuses on the 400-meter radius surrounding Kluang Railway Station, Johor, Malaysia. This boundary was selected based on Transit-Oriented Development theory, which defines the pedestrian catchment area as a radius of approximately 400 to 800 meters, representing a comfortable five-to-ten-minute walk (Calthorpe, 1993). This specific boundary allows the research to isolate the core station precinct where commuter traffic converts into urban economic transactions for local businesses.

The study area comprises a mix of traditional shophouses, food and beverage outlets, retail establishments, and service businesses. This commercial density creates an agglomeration effect where businesses cluster to capitalise on transit user volume. Key commercial clusters within the 400-meter radius include food and beverage outlets along the main thoroughfares, retail shops selling daily necessities and souvenirs, and service establishments such as convenience stores and mobile phone retailers. By focusing on this 400-meter radius illustrated in Figure 1, the research ensures that stakeholder perceptions are specifically tied to the station's immediate urban economic influence rather than broader town-wide trends.

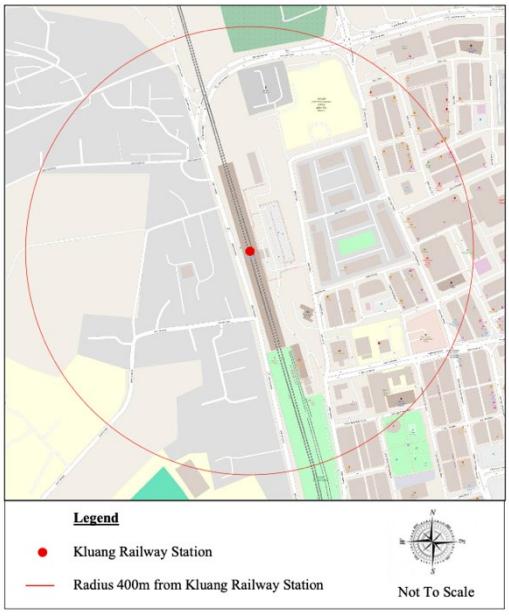


Figure 1: Kluang Railway Station

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Sampling and Data Collection

A structured questionnaire was administered to 100 respondents using purposive sampling. Respondents were directly approached in person within the 400-metre catchment area. Economic operators were surveyed door-to-door at their commercial establishments, while train users were intercepted along the main pedestrian thoroughfares connecting the station to the town center. Purposive sampling was selected because the study requires insights from stakeholders who directly interact with or are economically impacted by the railway station. The sampling frame was divided into two primary strata: train users (including daily commuters and tourists) and economic operators (comprising business owners, managers, and employees within the 400-meter catchment).

A total of 136 questionnaires were initially administered. Following data collection, responses underwent a manual audit for completeness and eligibility. The filtering process involved three criteria: removal of incomplete surveys where key sections were left blank, exclusion of straight-lined responses indicating lack of genuine engagement, and verification of respondent location or usage frequency to ensure they fell within the purposive criteria. Consequently, 36 questionnaires were discarded, resulting in a final sample of 100 valid responses comprising 50 train users and 50 economic operators. This exact even split was intentionally maintained during the final sample selection to ensure equal weighting and a balanced comparative analysis for the subsequent Chi-Square tests.

The questionnaire captured responses for six economic impact indicators: visitor increase, customer flow increase, business and investment attraction, employment opportunities, property value increase, and Kluang competitiveness. The questionnaire development process was grounded in the core economic indicators identified in the Transit-Oriented Developmen. An initial draft of the survey was reviewed to ensure construct validity. Following the feedback, the instrument was pilot-tested with a small subset of local respondents to verify clarity and respondent comprehension before the final data collection. Binary responses were selected because they provide clear, unambiguous measures of stakeholder perception that are suitable for non-parametric statistical tests. While binary (yes/no) questions may oversimplify nuanced perceptions of economic impact, they were utilised to ensure rapid survey completion in a fast-paced transit environment.

Data Analysis

The data analysis employed two non-parametric statistical tests. The Binomial test was conducted for each economic indicator to determine whether the proportion of positive responses significantly exceeds fifty percent. The null hypothesis was that the true proportion equals 0.5, meaning that positive and

negative responses are equally likely. A significant result ($p < 0.05$) indicates that respondents systematically agree on the positive economic impact rather than responding randomly.

The Chi-Square test of independence was conducted to compare responses between economic operators and train users for each economic indicator. The null hypothesis was that respondent group and perception are independent, as that train users and economic operators have the same underlying probability of responding positively. A significant result ($p < 0.05$) would indicate that the two groups differ in their perceptions.

RESULTS AND DISCUSSION

Stakeholder Agreement on Urban Economic Benefits

Binomial tests were conducted to determine whether the proportion of positive responses for each urban economic indicator significantly exceeds fifty percent. The results are presented in Table 1.

Table 1: Binomial Test

Urban Economic Indicator	Percentage Yes (%)	Binomial Significance (p-value)
Visitors Increased	93%	$p < 0.001$
Customer Flow Increased	91%	$p < 0.001$
Business and Investment Attraction	93%	$p < 0.001$
Employment Opportunities	91%	$p < 0.001$
Property Value Increased	89%	$p < 0.001$
Local Competitiveness	91%	$p < 0.001$

**Binomial test comparing proportion to 50 percent; n=100 for all indicators.* *Source: Field Study (2025)*

For all six urban economic indicators, the proportion of positive responses significantly exceeds fifty percent, with all tests showing strong statistical significance at $p < 0.001$. This indicates strong statistical consensus that stakeholders perceive the Kluang Railway Station as generating positive urban economic impacts; however, it is important to note this measures subjective stakeholder perception rather than actual economic performance.

The highest level of agreement was observed for visitor increase and business and investment attraction, each with 93% of respondents agreeing that the railway station has increased the number of visitors and attracted new businesses. This robust consensus empirically validates the Growth Pole Theory (Perroux, 1950) within a secondary city context, demonstrating that the modernised Kluang Railway Station successfully functions as a propulsive unit attracting localized commercial activity. Furthermore, these results align closely with Knowles and

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Ferbrache (2016), who assert that rail investments rapidly stimulate urban regeneration through immediate, consumption-based economic uplifts.

Similarly, the 91% agreement regarding increased customer flow confirms Dell'Olio et al.'s (2011) observation that local retail and food sectors are highly responsive to station-generated footfall. However, the slightly lower agreement on property value increases (89%) provides a critical contrast to metropolitan-focused TOD studies (such as Zain et al., 2025; Sharma & Dehalwar, 2025). In metropolitan hubs, real estate appreciation is often the most immediate and pronounced benefit of transit integration. In contrast, this study reveals that in a secondary town like Kluang, asset-based effects appreciate at a slower, more organic pace than direct retail consumption, likely due to less speculative elasticity in the local property market. Customer flow increase, employment opportunities, and local competitiveness each showed ninety-one percent agreement. The finding that 91% of respondents agreed that customer flow to local urban businesses has increased is particularly important because customer flow represents the direct mechanism through which station-generated footfall translates into urban business revenue. The slightly lower percentage compared to visitor increase indicate that not all visitors become customers, possibly due to the last-mile barrier where unsafe crossings and poor lighting deter walking from the station to urban commercial areas. This barrier highlights a critical gap in station-area design. Without investments in walkability, traffic-calming measures, reliable feeder transport, and safe pedestrian infrastructure, the conversion of transit footfall into actual local economic development will remain constrained. Employment opportunities represent the labour market effects of urban economic growth, while local competitiveness reflects the station's role in positioning Kluang favourably within the regional urban system.

Property value increase showed the lowest agreement at 89%, though this still represents a substantial majority. The slightly lower agreement shows that property values tend to respond more slowly to transport improvements than visitor numbers or business activity, as they depend on sustained demand and market confidence.

Comparing Stakeholder Perceptions of Urban Economic Benefits

Chi-Square tests of independence were conducted to determine whether perceptions of urban economic benefits differ significantly between economic operators and train users. The results are presented in Table 2.

Table 2: Chi-Square Test

Urban Economic Indicator	Economic Operators % Yes	Train Users % Yes	Pearson Chi-Square	Asymptotic Significance
Visitors Increased	88%	98%	0.154	p=0.695
Customer Flow Increased	90%	92%	0.122	p=0.727
Business and Investment Attraction	92%	94%	0.154	p=0.695
Employment Opportunities	90%	92%	0.122	p=0.727
Property Value Increased	84%	94%	0.102	p=0.749
Local Competitiveness	86%	96%	0.122	p=0.727

**Chi-Square test of independence; degrees of freedom = 1 for all tests; critical value at α = 0.05 is 3.84.*

Source: Field Study (2025)

For all six urban economic indicators, the Pearson Chi-Square values range from 0.102 to 0.154. All values are substantially less than the critical value of 3.84 required for statistical significance at the 0.05 level. The asymptotic significance (p-values) range from 0.695 to 0.749, all far exceeding the significance threshold of 0.05.

For visitors increased, economic operators showed 88% agreement while train users showed 98% agreement. While the raw percentages differ by ten percentage points, the Chi-Square test indicates that this difference is not statistically significant, with a p-value of 0.695. For customer flow increased, economic operators showed 90% agreement while train users showed 92% agreement. The difference of two percentage points is even smaller, and the p-value of 0.727 confirms non-significance. For business and investment attraction, economic operators showed 92% agreement while train users showed 94% agreement, with no significant difference (p = 0.695).

For employment opportunities, economic operators showed 90% agreement while train users showed 92% agreement (p = 0.727). For property value increase, economic operators showed 84% agreement while train users showed 94% agreement. This 10-percentage point difference is the largest observed among the six indicators, with a p-value of 0.749 indicating non-significance. The larger difference for property values reflects that several of the property owners which are the economic operators; are more sensitive to urban property market conditions than train users. For local competitiveness, economic operators showed 86% agreement while train users showed 96% agreement (p = 0.727).

Summary of Findings

The analysis yields two principal findings from an urban economic perspective. First, the Binomial tests confirm that stakeholders perceive positive urban economic impacts across all six indicators. The proportion of positive responses ranges from 89% to 93% percent, with visitor increase and business attraction

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showing the highest agreement at 93% percent. All Binomial tests are statistically significant at $p < 0.001$. This demonstrates that stakeholder agreement on urban economic benefits is statistically meaningful rather than random. The pattern of results is logically coherent from an urban economic perspective, with more direct consumption-based effects such as visitors and business activity receiving slightly higher agreement, and the longer-term asset-based effect which is the property values showing slightly lower agreement. These findings strongly align with the Growth Pole Theory (Perroux, 1950), confirming that modernised transport nodes effectively act as propulsive units for localized urban economic activity.

The high agreement regarding visitor increases and business attraction mirrors the findings of Knowles and Ferbrache (2016), who observed similar immediate consumption-based economic uplifts in transit corridors. However, the slightly lower agreement on property value increases (89%) provides a unique contrast to metropolitan-focused studies (such as Zain et al., 2025), which often position real estate appreciation as the most immediate and pronounced benefit of TOD. In the secondary city context of Kluang, this contradiction can be theoretically explained by market dynamics; in which secondary town property markets typically lack the speculative elasticity of metropolitan centres. This shows that asset values appreciate at a slower, more organic pace than direct retail footfall.

The absence of a perception gap between train users and economic operators offers a significant contribution to the literature on transport equity and public acceptance. Previous studies (World Bank, 2019; Sharma & Dehalwar, 2025) often caution that disparities between stakeholder groups can arise due to information asymmetries or differential benefit distributions. For instance, business owners typically prioritize commercial footfall, while commuters prioritize mobility (Dell'Olio et al., 2011). However, the statistical alignment found in Kluang contradicts this expectation of divergence. Instead, it supports Litman's (2022) framework, suggesting that when transit infrastructure effectively integrates into the urban fabric, it achieves high policy legitimacy, with both groups mutually recognizing the station's broader role as a catalyst for urban economic vitality.

CONCLUSION

This stakeholder analysis demonstrates that the Kluang Railway Station is perceived as a significant catalyst for local economic development by both transport users and economic operators. The statistical findings confirm that positive responses significantly exceed chance levels across all six urban economic indicators. The strongest consensus was observed for visitor increases and business attraction, representing the most visible consumption-based

economic effects, while property value increases showed slightly lower, yet still substantial, agreement. These results reinforce the station's successful role as a propulsive gateway to Kluang's urban economy.

Crucially, the analysis revealed strong stakeholder alignment, with no statistically significant perception gap between business operators and transport users regarding these economic benefits. While train users consistently exhibited slightly higher levels of agreement than economic operators, these minor variances highlight a shared, unified recognition of the station's value. This alignment provides strong policy legitimacy, indicating that rail infrastructure upgrades are widely supported by the community as vital contributors to urban economic vitality.

To maximize and sustain these economic benefits, a coordinated approach to station-area planning is essential. It is highly recommended that the Kluang local authority, Keretapi Tanah Melayu Berhad (KTMB), and urban planners collaborate closely with local business operators to urgently address last-mile connectivity. Strategic urban design interventions such as specifically enhancing pedestrian walkways, installing adequate lighting, improving traffic-calming measures, and establishing reliable feeder transit links; are necessary to fully convert transit footfall into tangible secondary-city regeneration.

Finally, it must be acknowledged that this study's reliance on perception-based analysis presents inherent limitations. Subjectively perceived economic benefits may not entirely reflect actual, quantifiable changes in the local economy. To build upon these findings, future research should incorporate quantitative secondary data, such as business turnover records, structured pedestrian counts, rental rate fluctuations, or property transaction data. Integrating these metrics will help empirically validate stakeholder perceptions and provide a more comprehensive measure of the station's true economic impact over time.

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DISCLOSURE STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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A MULTI-CRITERIA QUALITY ASSESSMENT FRAMEWORK FOR AFFORDABLE HOUSING PROJECTS IN KUALA LUMPUR AT DESIGN STAGE USING THE INTEGRATED VALUE MODEL FOR SUSTAINABLE ASSESSMENT (MIVES)

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Abstract

Affordable housing is a policy focus area in Malaysia, with the 13th Malaysia Plan aiming to develop one million affordable housing by 2035. This paper creates a Multi-Criteria Quality Assessment Framework of Affordable Housing Projects in Kuala Lumpur during the Design Phase based on the Integrated Value Model of Sustainable Assessment (MIVES). Development of the framework was based on three steps, with a desktop analysis of twelve Malaysian housing related policies generating 43 policy provisions, which were screened to 25 candidate criteria and reduced to a final 24 through a Modified Delphi Method involving 35 experts. The importance weights were obtained through surveying 450 prospective house buyers. MIVES was chosen because its value functions are defined by the policies and guidelines that set the quality standards for affordable housing, allowing projects to be assessed against these established benchmarks. A Reference Project allows each project to be both classified against a policy-defined benchmark and ranked relative to the others. The most weighted criteria are the area safety level (4.82%), house price (4.79%), and waste management (4.59%). Application of frameworks to five actual Kuala Lumpur projects created consistent rankings, two of the projects being Above Benchmark.

Keywords: Affordable Housing; Multi-Criteria Decision Analysis; MIVES; Housing Quality Assessment; Rank Reversal; Kuala Lumpur

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INTRODUCTION

Housing is widely recognised as a fundamental human right, yet its increasing commodification has progressively undermined access to adequate shelter for millions globally (Mehdipanah et al., 2023; Farha et al., 2022). The global housing affordability crisis has intensified over recent decades, as housing-related expenditures continue to outpace income and wage growth across both developed and developing economies (Wetzstein, 2017; Lee et al., 2022). Globally, approximately 1.6 billion people lack access to adequate housing, with this figure projected to rise to 3 billion by 2030 (UN-Habitat, 2022). In Malaysia, the house price-to-income ratio was recorded at 4.3 in 2022, classified as seriously unaffordable under internationally accepted benchmarks (Bank Negara Malaysia, 2021; Department of Statistics Malaysia, 2022). Average house prices in Kuala Lumpur reached RM780,728 in 2024 (National Property Information Centre, 2024). The 13th Malaysia Plan (RMK13, 2026-2035) formalised a national commitment to build one million affordable homes over ten years (Economic Planning Unit, 2025), making housing quality a central policy priority.

While supply has received policy attention, the quality of what is being built has received comparatively less scrutiny. Affordable housing quality is multi-dimensional, encompassing physical adequacy, safety, access to services, facility provision, and financial sustainability (Wimalasena et al., 2022; Howden-Chapman et al., 2023). Multi-Criteria Decision Analysis (MCDA) is well-suited for structuring such evaluations (Mecca et al., 2023). However, significant gaps persist: most MCDA housing studies derive criteria from academic literature without anchoring them to the regulatory context (Passos Neto et al., 2023); derive weights from housing professionals rather than house buyers (Mulliner et al., 2012); and do not address the rank reversal problem, where rankings change when the evaluation set changes (Belton & Gear, 1983; Triantaphyllou, 2001). This study addresses these gaps by developing a MIVES-based quality assessment framework for affordable housing in Kuala Lumpur at the design stage.

LITERATURE REVIEW

Housing Quality as a Multi-Dimensional Concept

Housing quality encompasses spatial adequacy, safety, environmental quality, access to services, facility provision, and financial sustainability (Wimalasena et al., 2022; Howden-Chapman et al., 2023). Mismatches between affordable housing supply and demand in Malaysia have been linked to product and locational attributes such as unit size, configuration, density, and accessibility (Saleh et al., 2024), underscoring the need to assess these quality dimensions at the design stage. In Malaysia's predominantly Muslim urban context, criteria such

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as proximity to mosques and Islamic mortuary facilities are central to residents' quality experience, underscoring the necessity of context-specific framework development (Brkanić et al., 2023). Most housing quality research adopts a post-occupancy perspective, whereas design-stage assessment supports approval decisions before construction begins.

MCDA in Housing Assessment and the Rank Reversal Problem

MCDA is widely applied in the built environment, with Analytic Hierarchy Process (AHP) (46%), TOPSIS (20%), MIVES (11%), and Complex Proportional Assessment (COPRAS) (9%) the most frequently used methods (Mecca et al., 2023; Villalba et al., 2024). Mulliner et al. (2012) derived criterion weights from interviews and a questionnaire survey of housing and planning professionals across the UK, establishing professional perception as the basis for criterion weighting in housing MCDM. Simpeh et al. (2024) found that community safety, waste management, and education access were most highly prioritised by affordable housing residents. In Greater Kuala Lumpur specifically, Badrudin et al. (2022) found that young households prioritise affordability and proximity to employment in their housing choices, reinforcing the value of grounding criterion weights in buyer priorities. The rank reversal problem, documented by Belton and Gear (1983) and confirmed across TOPSIS and COPRAS (Wang & Luo, 2009; García-Cascales & Lamata, 2012; de Farias Aires & Ferreira, 2019; Shyur & Shih, 2024), is particularly problematic in rolling regulatory contexts where project batches change continuously.

MIVES as a Policy-Aligned MCDA Method

MIVES (Modelo Integrado de Valor para una Evaluación Sostenible) is a value-based MCDA method in which the raw performance of each criterion is converted to a common 0-to-1 value scale through criterion-specific value functions anchored to externally specified reference points (Alarcon et al., 2011; Pons et al., 2016; Biswal et al., 2022). Because these reference points can be set directly from regulatory or policy standards, MIVES lends itself to policy-aligned assessment. In the built environment it has been applied to infrastructure, school buildings, and residential developments to benchmark projects against defined sustainability and quality standards (Cots et al., 2022; Maleki et al., 2024; Tan et al., 2024).

METHODS

Stage 1: Criteria Derivation

A systematic desktop analysis of twelve Malaysian housing policies and planning guidelines including NAHP, PPAM, Residensi Wilayah, PPR, DBKL,

PLANMalaysia, the KL Low Carbon Building Code (LCBC) 2023, and the DOSM Crime Statistics Malaysia 2024 identified 43 candidate quality provisions. Each provision was screened against three inclusion conditions, all of which had to be met for it to be retained: it had to be (i) measurable at the design stage, (ii) relevant to high-rise affordable housing in Kuala Lumpur, and (iii) quantifiable or expressible on an ordinal scale. Provisions failing any condition, such as those assessable only after occupancy, were excluded. This screening reduced the 43 provisions to 25 candidate criteria, which were carried forward to expert validation.

Stage 2: Expert Validation via Modified Delphi

Two rounds of the Modified Delphi Method were conducted with a purposively selected panel of professionals directly involved in the planning, approval, or delivery of affordable housing in Kuala Lumpur, comprising government officers and private-sector developers. Panellists were required to hold at least a bachelor's degree and a minimum of ten years of relevant experience. Of 60 experts invited by email, 35 completed Round 1 and 30 completed Round 2; the Round 1 panel comprised 20 policymakers from agencies including DBKL, JWP, and KPKT and 15 affordable housing developers. For each criterion, responses were analysed using the Interquartile Range (IQR) as the primary measure of consensus, which is appropriate for ordinal Likert-scale data. An item was retained when the IQR was 1.0 or less and at least 60% of respondents rated it at levels 4 or 5, indicating both consistency and positive agreement on relevance. An item was eliminated when the IQR was 1.0 or less but at least 60% of respondents rated it at levels 1 or 2, indicating consistent rejection. Items with IQR exceeding 1.0 were carried forward to the subsequent round regardless of agreement percentage. The process was concluded when all items reached either consensus acceptance or consensus rejection, a condition met at the end of Round 2. In Round 1, the 25 candidate criteria were evaluated, of which 23 achieved consensus for inclusion and two were eliminated on consensus of irrelevance: Distance to Public Health Institution and Land Tenure and Classification. Experts also proposed two additional criteria during Round 1, Maintenance Fees and Level of Furnishing, which were carried into Round 2. In Round 2, Maintenance Fees achieved consensus and was added to the framework, while Level of Furnishing was eliminated on consensus of irrelevance. The process therefore reduced the initial 25 candidates by two eliminations and added one new criterion, yielding a final set of 24 validated quality criteria.

Stage 3: Buyer Survey for Criterion Weighting

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A structured questionnaire survey using a five-point Likert scale (1 = Not Important; 5 = Most Important) was administered to 450 potential house buyers in Kuala Lumpur from May to August 2025. All respondents were Malaysian citizens based or working in KL expressing interest in purchasing affordable housing. The sample of 450 exceeds the Krejcie and Morgan (1970) minimum of 384. All 24 criteria achieved complete responses (n = 450). The Kolmogorov-Smirnov test confirmed non-normal distribution for all criteria ($p < 0.001$). Criterion weights were calculated as each criterion's mean divided by the sum of all means.

MIVES Framework and Value Functions

For each criterion i, a linear value function converts the raw performance x_ij of project j into a value V_i between 0 and 1. The function is defined by two criterion-specific reference points: x_min, the performance scoring 0 (the minimum acceptable level), and x_max, the performance scoring 1 (the target level). For benefit criteria, where higher performance indicates better quality, the value function is:

$$V_i(x_{ij}) = \frac{x_{ij} - x_{min}}{x_{max} - x_{min}}$$

For cost criteria, where lower performance indicates better quality (for example house price, development density, and distance to amenities), the value function is:

$$V_i(x_{ij}) = \frac{x_{min} - x_{ij}}{x_{min} - x_{max}}$$

In both cases the value is bounded to the interval [0, 1]. In Table 1, the "Min." column reports x_min and the "Max." column reports x_max for each criterion. The composite Quality Index I_j for project j aggregates the weighted value scores across all n criteria (Pons et al., 2016):

$$I_j = \sum_{i=1}^{n} w_i \cdot V_i(x_{ij})$$

where w_i is the importance weight of criterion i. The reference points were established through a systematic review of the relevant Malaysian housing policies and planning guidelines identified in Stage 1. The benchmark for each criterion was determined by a consistent selection rule. Where a policy specifies

a value for a criterion, that value was adopted directly as the benchmark. Where several policies specify different values for the same criterion, precedence was given to the principal national instrument, the National Affordable Housing Policy (NAHP), over programme- or agency-specific guidelines. For example, the House Price benchmark of RM300,000 follows the national affordable-housing ceiling; the RM400,000 permitted under the PR1MA programme is not treated as the benchmark but instead defines the minimum-performance (worst) anchor. The Development Density benchmark of 150 units per acre likewise adopts the DBKL planning standard directly. For criteria measured on ordinal scales, such as Aesthetic Design and Waste Management, no policy prescribes a numerical value because the rating scale was developed within this study; for these, the benchmark was set at the midpoint of the scale to represent an acceptable baseline of provision. Table 1 presents the full parameters and policy sources for all 24 criteria. The value functions for all 24 criteria are illustrated in the Appendix (Figures 1 to 24). The benchmark value is a policy-defined threshold used to construct the Reference Project and to classify projects; it does not alter the shape of the value function. The Reference Project is assigned the benchmark value for each criterion simultaneously, yielding I_RP = 0.4747. Projects with I_j >= I_RP are classified as Above Benchmark; those with I_j < I_RP as Below Benchmark. This classification serves as a design guidance tool, not a mandatory planning decision.

Table 1: MIVES Value Function Parameters, Benchmark Values, and Policy Sources for All 24 Criteria

No.	Criteria	Type	Min.	Max.	Benchmark	v(bench)	Policy Source
Unit Characteristics							
1	**House Price**	Cost	RM400k	RM150k	**RM300k**	**0.400**	NAHP; PPAM; PR1MA
2	**Built-Up Area**	Benefit	700 sqft	1,500 sqft	**900 sqft**	**0.250**	NAHP; PPAM
3	**No. of Bedrooms**	Benefit	2	5	**3**	**0.333**	NAHP; PPAM; PPR
4	**No. of Bathrooms**	Benefit	1	3	**2**	**0.500**	PPAM
5	**Car Parking Spaces**	Benefit	0	3 lots	**1 lot**	**0.333**	NAHP; DBKL
6	**Aesthetic Design**	Benefit	Score 1	Score 5	**Score 3**	**0.500**	DBKL
7	**Development Density**	Cost	350 u/ac	120 u/ac	**150 u/ac**	**0.870**	NAHP; DBKL
8	**Maintenance Fees**	Cost	RM0.50	RM0.20	**RM0.30**	**0.667**	JWP
Facilities							
9	**Recreation Facilities**	Benefit	Score 1	Score 4	**Score 2**	**0.333**	DBKL
10	**Multi-Purpose Hall**	Benefit	800 sqft	2,000 sqft	**1,000 sqft**	**0.167**	DBKL; PLANMalaysia
11	**Surau**	Benefit	600 sqft	2,000 sqft	**800 sqft**	**0.143**	DBKL; PLANMalaysia
12	**Islamic Mortuary Room**	Benefit	80 sqft	500 sqft	**323 sqft**	**0.579**	DBKL

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No.	Criteria	Type	Min.	Max.	Benchmark	v(bench)	Policy Source
13	**Management Room**	Benefit	200 sqft	700 sqft	**400 sqft**	**0.400**	DBKL
14	**Kindergarten/Childcare**	Benefit	1,800 sqft	2,324 sqft	**2,000 sqft**	**0.382**	DBKL; PLANMalaysia
15	**Laundry Room**	Benefit	200 sqft	600 sqft	**400 sqft**	**0.500**	DBKL
16	**Waste Management**	Benefit	Score 1	Score 3	**Score 2**	**0.500**	NHP; PLANMalaysia
17	**Energy Efficiency**	Benefit	Score 1	Score 4	**Score 2**	**0.333**	KL LCBC 2023
Location							
18	**Access to Employment**	Cost	20 km	5 km	**10 km**	**0.667**	NHP; Mulliner et al. (2012)
19	**Access to School**	Cost	5.0 km	1.0 km	**2.5 km**	**0.625**	PLANMalaysia; DBKL
20	**Access to Public Transport**	Cost	3.0 km	0.4 km	**1.5 km**	**0.577**	Residensi Madani; JWP
21	**Access to Commercial Area**	Cost	5.0 km	1.0 km	**2.5 km**	**0.625**	PLANMalaysia
22	**Access to Open Space**	Cost	5.0 km	1.0 km	**2.5 km**	**0.625**	PLANMalaysia
23	**Access to Mosque**	Cost	5.0 km	1.0 km	**2.5 km**	**0.625**	DBKL
24	**Area Safety Level**	Cost	409/100k	0/100k	**246/100k**	**0.399**	DOSM (2024)

Note: Min = worst performance (V_i = 0); Max = best performance (V_i = 1); Benchmark = policy standard. v(bench) = value score at benchmark. NAHP = National Affordable Housing Policy; PPAM = Programme Perumahan Awam Malaysia; DBKL = Dewan Bandaraya Kuala Lumpur; PLANMalaysia = Federal Town and Country Planning Dept.; JWP = Jabatan Perumahan Wilayah Persekutuan; NHP = National Housing Policy; LCBC = Low Carbon Building Code KL 2023; DOSM = Department of Statistics Malaysia.

RESULTS

Respondent Profile

Table 2 presents the demographic profile of 450 respondents. The sample is predominantly adults aged 31-50 years (76.2%), married (73.3%), Muslim (93.1%), and educated to at least degree level (75.4%). Government servants represent 60.7%, consistent with the primary PPAM target group, and 64.4% fall within the B40 and M40 income range.

Table 2: Demographic Profile of Survey Respondents (n = 450)

Variable	Category	n	%	Variable	Category	n	%
Age	19-30 years	65	14.4	**Religion**	Islam	419	93.1
	31-40 years	154	34.2		Non-Islam	31	6.9
	41-50 years	189	42.0	**Sector**	Government	273	60.7
	51+ years	42	9.3		Private / Others	177	39.3
Marital status	Married	330	73.3	**Income**	Below RM4,849 (B40)	128	28.4
	Single / Others	120	26.7		RM4,850-RM10,959 (M40)	162	36.0

Variable	Category	n	%	Variable	Category	n	%
Education	SPM/Diploma	111	24.7		Above RM10,960	160	35.6
	Bachelor's degree	224	49.8	**Purchase purpose**	Own occupation	243	54.0
	Postgraduate	115	25.6		Investment / Rental / Others	207	46.0

Criteria Importance Weights

Table 3 presents descriptive statistics and derived weights. All criteria have N = 450. Mean scores range from 3.431 to 4.773. The top five criteria are Area Safety Level (4.82%), House Price (4.79%), Waste Management (4.59%), Access to Employment (4.46%), and Maintenance Fees and Development Density (both 4.43%). Both top-ranked criteria record IQR = 0, indicating universal consensus. Recreation Facilities ranks lowest (3.47%) despite prominent developer marketing, revealing a clear misalignment between supply-side promotion and buyer priorities.

Table 3: Descriptive Statistics and Derived Weights for All 24 Quality Criteria (n = 450)

Rank	Criteria	Category	N	Mean	SD	Weight (%)
1	**Area Safety Level**	Location	450	4.773	0.492	**4.82**
2	**House Price**	Unit Char.	450	4.738	0.591	**4.79**
3	**Waste Management**	Facilities	450	4.547	0.724	**4.59**
4	**Access to Employment**	Location	450	4.413	0.742	**4.46**
5	**Maintenance Fees**	Unit Char.	450	4.389	0.794	**4.43**
6	**Development Density**	Unit Char.	450	4.389	0.774	**4.43**
7	**Access to Public Transport**	Location	450	4.376	0.778	**4.42**
8	**Access to School**	Location	450	4.360	0.803	**4.41**
9	**No. of Bedrooms**	Unit Char.	450	4.320	0.740	**4.37**
10	**Built-Up Area**	Unit Char.	450	4.289	0.799	**4.33**
11	**Car Parking Spaces**	Unit Char.	450	4.271	0.813	**4.32**
12	**Surau**	Facilities	450	4.202	0.947	**4.25**
13	**Access to Mosque**	Location	450	4.200	0.870	**4.24**
14	**Energy Efficiency**	Facilities	450	4.147	0.923	**4.19**
15	**Access to Commercial Area**	Location	450	4.104	0.804	**4.15**
16	**Kindergarten/Childcare**	Facilities	450	4.031	0.985	**4.07**
17	**No. of Bathrooms**	Unit Char.	450	4.000	0.842	**4.04**
18	**Islamic Mortuary Room**	Facilities	450	3.876	1.044	**3.92**
19	**Management Room**	Facilities	450	3.820	0.937	**3.86**

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Rank	Criteria	Category	N	Mean	SD	Weight (%)
20	**Access to Open Space**	Location	450	3.749	0.982	**3.79**
21	**Multi-Purpose Hall**	Facilities	450	3.540	0.994	**3.58**
22	**Aesthetic Design**	Unit Char.	450	3.527	0.942	**3.56**
23	**Laundry Room**	Facilities	450	3.476	1.032	**3.51**
24	**Recreation Facilities**	Facilities	450	3.431	0.930	**3.47**

Project Assessment

Five completed affordable housing projects in Kuala Lumpur were selected from those listed on the official portals of KPKT, PPAM, and JWP. They were chosen purposively to span five different areas of the city and to capture the variation in provision across the 24 quality criteria, ranging from higher- to lower-provision schemes. The raw performance data for each project were extracted from these agency sources and independently cross-checked with the relevant agencies and the respective developers prior to assessment. Table 4a presents the raw performance inputs for all projects. Table 4b presents the corresponding value scores V_i(x_ij), Quality Index I_j, and benchmark classification.

Table 4a: Raw Performance Inputs for All Five Projects and Reference Project (RP)

No.	Criteria	Unit	RP	P1	P2	P3	P4	P5
Unit Characteristics								
1	**House Price**	RM	**300,000**	320,000	295,000	310,000	285,000	280,000
2	**Built-Up Area**	sqft	**900**	800	870	750	820	950
3	**No. of Bedrooms**	count	**3**	3	3	2	3	3
4	**No. of Bathrooms**	count	**2**	2	2	2	2	2
5	**Car Parking Spaces**	lots	**1**	1	2	1	1	2
6	**Aesthetic Design**	score (1-5)	**3**	3	3	2	3	4
7	**Development Density**	u/acre	**150**	160	140	320	180	130
8	**Maintenance Fees**	RM/sqft	**0.30**	0.32	0.25	0.45	0.28	0.22
Facilities								
9	**Recreation Facilities**	score (1-4)	**2**	2	2	1	2	3
10	**Multi-Purpose Hall**	sqft	**1,000**	900	1,100	800	950	1,200
11	**Surau**	sqft	**800**	800	900	650	780	1,000
12	**Islamic Mortuary Room**	sqft	**323**	280	320	100	300	350
13	**Management Room**	sqft	**400**	350	440	220	380	500
14	**Kindergarten/Childcare**	sqft	**2,000**	1,900	2,050	1,850	1,950	2,100

No.	Criteria	Unit	RP	P1	P2	P3	P4	P5
15	**Laundry Room**	sqft	**400**	350	400	250	360	450
16	**Waste Management**	score (1-3)	**2**	2	2	1	2	3
17	**Energy Efficiency**	score (1-4)	**2**	2	3	1	2	3
Location								
18	**Access to Employment**	km	**10.0**	8.0	5.0	12.0	9.0	3.0
19	**Access to School**	km	**2.5**	2.0	1.8	3.5	2.8	1.2
20	**Access to Public Transport**	km	**1.5**	1.8	1.2	2.5	2.0	0.5
21	**Access to Commercial Area**	km	**2.5**	2.0	1.8	3.5	3.0	1.5
22	**Access to Open Space**	km	**2.5**	2.5	2.2	4.0	3.5	2.0
23	**Access to Mosque**	km	**2.5**	2.5	2.0	3.5	2.8	1.0
24	**Area Safety Level**	per 100,000	**246**	200	220	231	210	180

Note: RP = Reference Project assigned exactly the policy benchmark value for each criterion. P1 = Mont Kiara; P2 = Bandar Tun Razak; P3 = Wangsa Maju; P4 = Kepong; P5 = Bukit Bintang. Scores 1-5 for ordinal criteria per Table 1 scale.

Table 4b: Value Scores V_i(x_ij) and Quality Index I_j for All Projects

No.	Criteria	w(%)	V_i(RP)	V_i(P1)	V_i(P2)	V_i(P3)	V_i(P4)	V_i(P5)
Unit Characteristics								
1	**House Price**	4.79	0.400	0.320	0.420	0.360	0.460	0.480
2	**Built-Up Area**	4.33	0.250	0.125	0.212	0.062	0.150	0.312
3	**No. of Bedrooms**	4.37	0.333	0.333	0.333	0.000	0.333	0.333
4	**No. of Bathrooms**	4.04	0.500	0.500	0.500	0.500	0.500	0.500
5	**Car Parking Spaces**	4.32	0.333	0.333	0.667	0.333	0.333	0.667
6	**Aesthetic Design**	3.56	0.500	0.500	0.500	0.250	0.500	0.750
7	**Development Density**	4.43	0.870	0.826	0.913	0.130	0.739	0.957
8	**Maintenance Fees**	4.43	0.667	0.600	0.833	0.167	0.733	0.933
Facilities								
9	**Recreation Facilities**	3.47	0.333	0.333	0.333	0.000	0.333	0.667
10	**Multi-Purpose Hall**	3.58	0.167	0.083	0.250	0.000	0.125	0.333
11	**Surau**	4.25	0.143	0.143	0.214	0.036	0.129	0.286
12	**Islamic Mortuary Room**	3.92	0.579	0.476	0.571	0.048	0.524	0.643
13	**Management Room**	3.86	0.400	0.300	0.440	0.040	0.360	0.600
14	**Kindergarten/Childcare**	4.07	0.382	0.191	0.477	0.095	0.286	0.573
15	**Laundry Room**	3.51	0.500	0.375	0.500	0.125	0.400	0.625
16	**Waste Management**	4.59	0.500	0.500	0.500	0.000	0.500	1.000

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No.	Criteria	w(%)	V_i(RP)	V_i(P1)	V_i(P2)	V_i(P3)	V_i(P4)	V_i(P5)
17	**Energy Efficiency**	4.19	0.333	0.333	0.667	0.000	0.333	0.667
Location								
18	**Access to Employment**	4.46	0.667	0.800	1.000	0.533	0.733	1.000
19	**Access to School**	4.41	0.625	0.750	0.800	0.375	0.550	0.950
20	**Access to Public Transport**	4.42	0.577	0.462	0.692	0.192	0.385	0.962
21	**Access to Commercial Area**	4.15	0.625	0.750	0.800	0.375	0.500	0.875
22	**Access to Open Space**	3.79	0.625	0.625	0.700	0.250	0.375	0.750
23	**Access to Mosque**	4.24	0.625	0.625	0.750	0.375	0.550	1.000
24	**Area Safety Level**	4.82	0.399	0.511	0.462	0.435	0.487	0.560
Quality Index I_j			**0.4747**	**0.4544**	**0.5690**	**0.2002**	**0.4347**	**0.6882**
Rank			RP	3rd	2nd	5th	4th	1st
Classification			Ref.	**Below**	**Above**	**Below**	**Below**	**Above**

Note: Green = Above Benchmark (I_j >= I_RP = 0.4747); Red = Below Benchmark. Classification is a design guidance indicator only, not a mandatory planning decision.

Table 5: Final MIVES Rankings and Benchmark Classification

Rank	Project	Location	Quality Index I_j	vs. I_RP	Classification
1	**P5**	Bukit Bintang	**0.6882**	+0.214	**Above Benchmark**
2	**P2**	Bandar Tun Razak	**0.5690**	+0.094	**Above Benchmark**
RP	**Reference Project**	—	**0.4747**	—	**Reference**
3	**P1**	Mont Kiara	**0.4544**	-0.020	Below Benchmark
4	**P4**	Kepong	**0.4347**	-0.040	Below Benchmark
5	**P3**	Wangsa Maju	**0.2002**	-0.275	Below Benchmark

Note: I_RP = 0.4747. Green shading = Above Benchmark; Red shading = Below Benchmark.

P5 achieves the highest Quality Index (I_5 = 0.6882), driven by outstanding location performance including employment access at 3 km, public transport at 0.5 km, and mosque access at 1.0 km, alongside full waste management provision (V_16 = 1.000). P2 is also Above Benchmark (I_2 = 0.5690). P3 records the lowest index (I_3 = 0.1800), driven by high development density (320 u/acre) and absence of waste management facilities. P4 falls 0.040 below the Reference Project threshold, indicating targeted improvements in development density and transport accessibility could elevate it to Above Benchmark status.

DISCUSSION

The derivation of 24 quality criteria directly from twelve Malaysian housing policies ensures the framework evaluates projects against standards already in regulatory form. The buyer-derived weights from 450 respondents introduce a demand-side perspective largely absent from existing housing assessment frameworks. The narrow weight spread across the top criteria reflects that buyers expect all fundamental dimensions to be addressed simultaneously. The prominence of Islamic-specific facilities (Surau rank 12, Mosque access rank 13, Islamic Mortuary Room rank 18) reflects culturally specific quality dimensions not captured by Western frameworks, and confirms the importance of context-specific criteria derivation in a Muslim-majority urban setting.

The demographic composition of the survey sample, in which 60.7% of respondents are government-sector employees and 93.1% are Muslim, reflects the intended beneficiary population of the programmes that supply affordable housing in Kuala Lumpur. Affordable housing in the city is delivered largely through programmes such as PPAM, Residensi Wilayah, and PR1MA, whose eligibility rules prioritise first-time buyers in the B40 and M40 income groups, with PPAM reserved for civil servants. These target groups are predominantly Bumiputera Malay, who are constitutionally Muslim and who constitute approximately 47% of Kuala Lumpur's population (Department of Statistics Malaysia, 2020). The high shares of government-sector and Muslim respondents are therefore consistent with the demographic profile of the population these programmes are designed to serve. It follows that the weights assigned to religiously specific facilities, namely Surau, Access to Mosque, and Islamic Mortuary Room, reflect the genuine preferences of the intended beneficiaries, underscoring the importance of incorporating the Muslim perspective in affordable housing development in this context. These weights are nonetheless specific to the target-buyer profile examined here; other buyer segments may prioritise criteria differently, and the weight set can be re-derived for different populations, as noted in the future research directions.

The Reference Project mechanism provides a stable, policy-defined quality threshold derived independently of the project dataset. Unlike dataset-dependent methods such as TOPSIS, where adding or removing a project changes the ideal solution and consequently all other scores, MIVES value functions are fixed to policy reference points. This ensures that a project's score remains unchanged regardless of which other projects are evaluated alongside it, a critical requirement for a regulatory instrument applied to rolling project submissions. The borderline case of P4, falling 0.040 below the threshold, demonstrates the framework's practical utility: it enables precise, criterion-level developmental feedback rather than binary rejection, identifying exactly which dimensions require improvement and by how much.

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Although the framework can support all affordable housing stakeholders, it is oriented primarily towards the policymakers and government agencies that manage affordable housing delivery in Kuala Lumpur, such as DBKL, KPKT, and JWP. These agencies select the developers admitted to affordable housing programmes and grant incentives such as subsidies, allocated or discounted land, higher permissible densities, and expedited (green-lane) approval. At the design-approval stage, DBKL, as the local planning authority, can apply the framework when reviewing development proposals, while KPKT and JWP can use it to evaluate projects submitted under the affordable housing programmes they administer, in each case verifying that a design meets the quality standards embedded in national and local policy before approval or programme admission is granted. Developers can use the same tool to self-assess and refine their designs before submission, and housing policymakers can draw on aggregated results across projects to monitor quality and refine benchmark standards.

This framework does not claim MIVES to be superior to other MCDA methods for housing assessment; its contribution lies in configuring MCDA around value functions anchored to the policies and guidelines defining affordable housing quality. MIVES suits this purpose because its bounded value function, scoring 0 at minimum acceptable performance and 1 at maximum, matches the bounded nature of affordable housing standards: a minimum built-up area is mandated, yet oversized units would compromise affordability, and basic facilities such as a surau are required while luxury provisions such as a swimming pool are not. This aligns with the government's emphasis on eliminating components that do not contribute to function and value in publicly funded projects (Economic Planning Unit, 2015); performance beyond the maximum reference point yields no additional score, discouraging over-provision.

CONCLUSION

This study developed a Multi-Criteria Quality Assessment Framework for Affordable Housing Projects in Kuala Lumpur at the Design Stage Using MIVES (Modelo Integrado de Valor para una Evaluación Sostenible). Four principal contributions are made: (1) 24 quality criteria derived from twelve Malaysian housing policies and planning guidelines and validated by an expert stakeholder panel through a Modified Delphi process; (2) buyer-derived weights from 450 respondents (N = 450 for all criteria) revealing area safety, house price, and waste management as top priorities; (3) MIVES value functions anchored to the policies and guidelines that define affordable housing quality, enabling assessment against established benchmarks; and (4) the use of a Reference Project within

MIVES as a methodological mechanism that enables assessment to move beyond binary benchmark classification to the comparative ranking of projects.

Two key limitations are acknowledged. First, the framework assigns a single representative value per criterion per project. Real projects offer multiple unit types with varying specifications such as differing price ranges or built-up areas. Future research should accommodate multiple criterion values per project, for instance through weighted averaging across unit types. Second, some benchmark values are referenced differently across policies: the National Housing Policy specifies RM300,000 as the maximum affordable price while PR1MA allows RM400,000. Future research should conduct stakeholder validation of each benchmark value with policymakers and potential house buyers to resolve such conflicts. Additional directions include extending the framework to landed affordable housing typologies, applying it across other Malaysian states, and stratifying buyer surveys by income group (B40, M40, and civil servants) to examine whether group-specific frameworks produce more precise quality assessments.

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DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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APPENDIX
Figures 1-24. MIVES Linear Value Functions for All 24 Quality Criteria

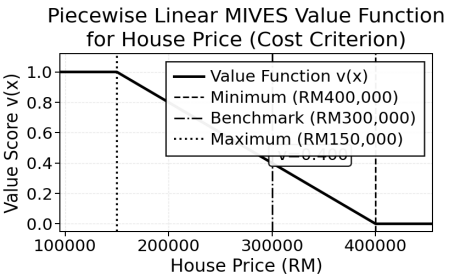


Fig. 1. House Price (Cost, w=4.79%)

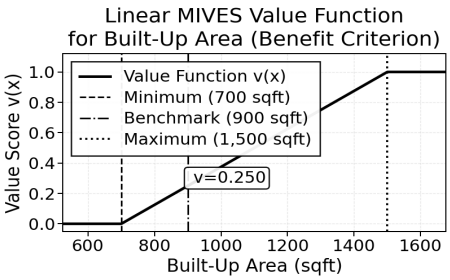


Fig. 2. Built-Up Area (Benefit, w=4.33%)

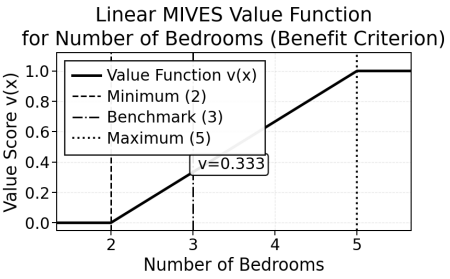


Fig. 3. No. of Bedrooms (Benefit, w=4.37%)

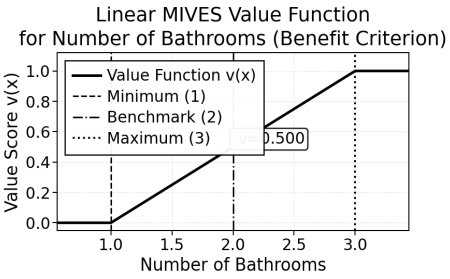


Fig. 4. No. of Bathrooms (Benefit, w=4.04%)

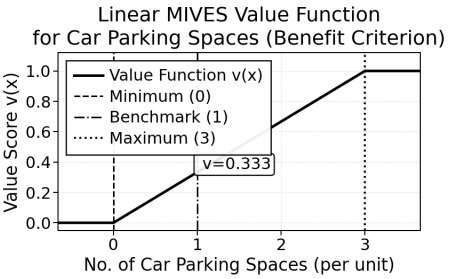


Fig. 5. Car Parking (Benefit, w=4.32%)

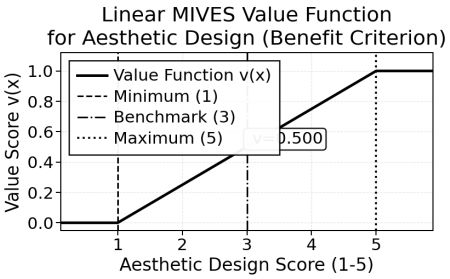


Fig. 6. Aesthetic Design (Benefit, w=3.56%)

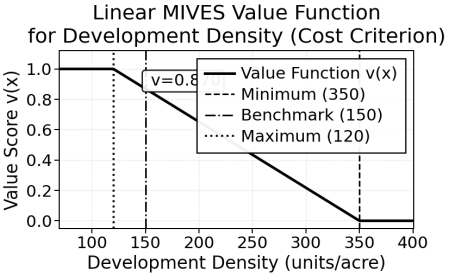


Fig. 7. Development Density (Cost, w=4.43%)

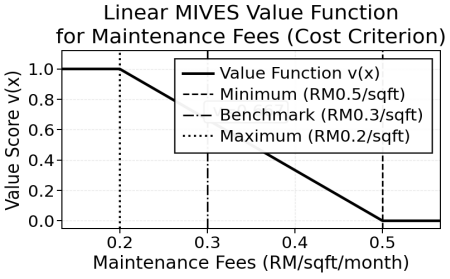


Fig. 8. Maintenance Fees (Cost, w=4.43%)

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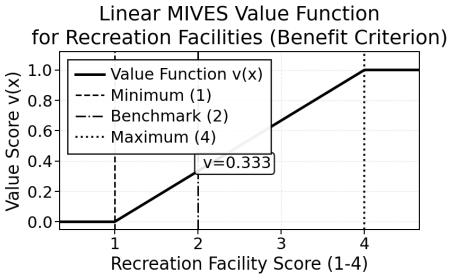


Fig. 9. Recreation Facilities (Benefit, w=3.47%)

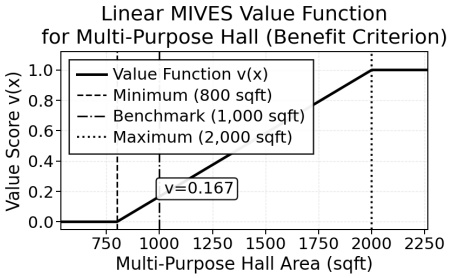


Fig. 10. Multi-Purpose Hall (Benefit, w=3.58%)

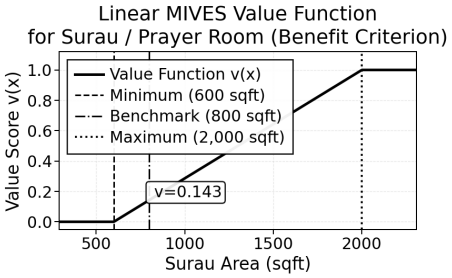


Fig. 11. Surau (Benefit, w=4.25%)

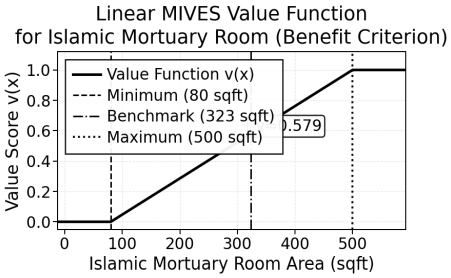


Fig. 12. Islamic Mortuary Room (Benefit, w=3.92%)

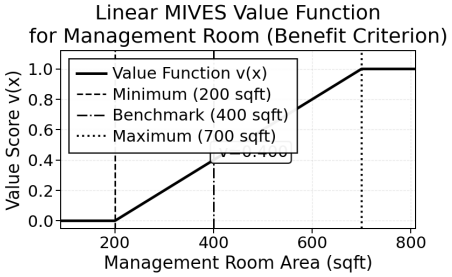


Fig. 13. Management Room (Benefit, w=3.86%)

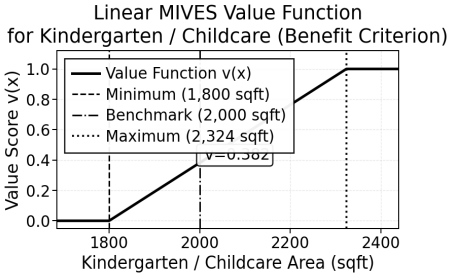


Fig. 14. Kindergarten/Childcare (Benefit, w=4.07%)

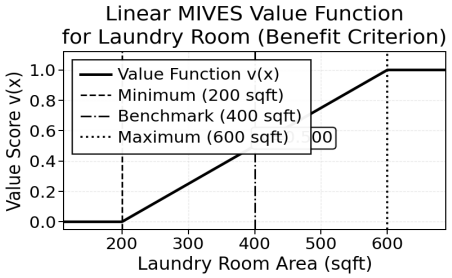


Fig. 15. Laundry Room (Benefit, w=3.51%)

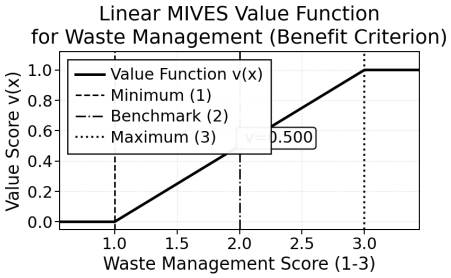


Fig. 16. Waste Management (Benefit, w=4.59%)

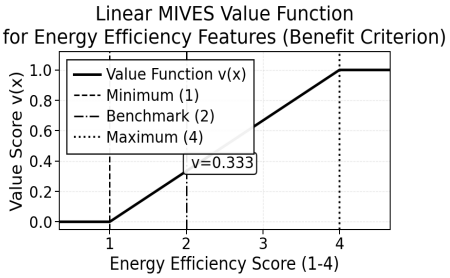


Fig. 17. Energy Efficiency (Benefit, w=4.19%)

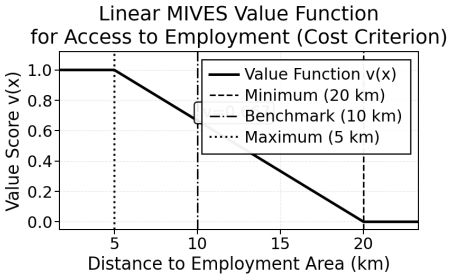


Fig. 18. Access to Employment (Cost, w=4.46%)

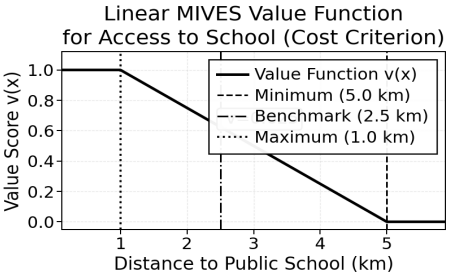


Fig. 19. Access to School (Cost, w=4.41%)

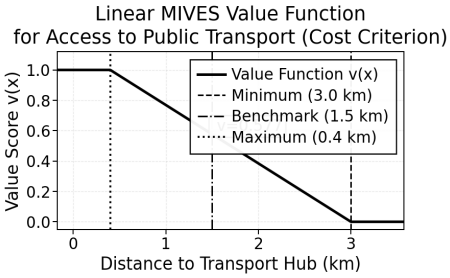


Fig. 20. Access to Public Transport (Cost, w=4.42%)

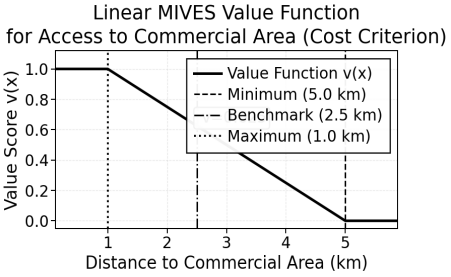


Fig. 21. Access to Commercial Area (Cost, w=4.15%)

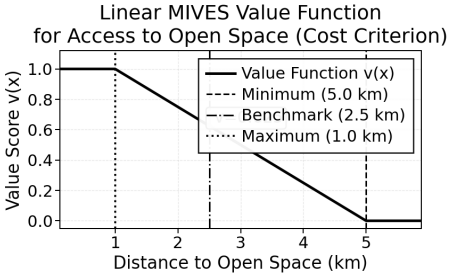


Fig. 22. Access to Open Space (Cost, w=3.79%)

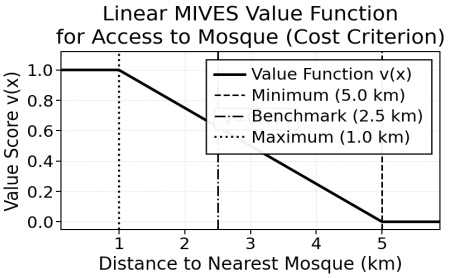


Fig. 23. Access to Mosque (Cost, w=4.24%)

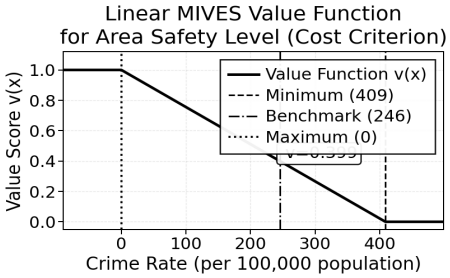


Fig. 24. Area Safety Level (Cost, w=4.82%)

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EXAMINING THE AFFORDANCES OF HABITUAL RANGE IN MALAYSIA'S SOCIAL HOUSING THROUGH MARGINALIZED CHILDREN'S PERSPECTIVES

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Abstract

This study examines how children living in Malaysia's urban social housing, in particular the Projek Perumahan Rakyat (PPR), perceive and envision their neighborhood environments within their habitual range. However, within these high-density settings, the issue arises where children's rights to protection, development, and participation are undermined by spatial constraints that limit their everyday freedoms. To foreground children's perspectives, a child-centered approach was adopted using child-led walks and children's drawings with participants aged 7–12 (N=23). These methods triangulated lived experiences with visualized aspirations to identify key environmental affordances that children valued. Findings reveal that safety, comfort, nature, sensory quality, and accessibility are central to children's priorities. These insights advance child-friendly urbanism by foregrounding the realities of high-density, adult-dominated social housing environments. By evidencing how children navigate current constraints and reimagine improved environments, the study positions them as stakeholders whose perspectives are indispensable for shaping inclusive and context-sensitive environments for children.

Keywords: Social Housing, Children's perspectives, Habitual Range, Neighborhood Environment, Perceived Affordances

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INTRODUCTION

The United Nations Convention on the Rights of the Child (UNCRC) affirms children's three fundamental rights: development, protection, and participation, as integral to their everyday urban lives (United Nations, 1989). However, these rights are increasingly constrained in contexts of rapid urbanization and rising urban poverty. In Malaysia, the government has responded to these challenges by implementing multiple social housing programs to accommodate low-income families (Khazanah Research Institute, 2023). While these developments successfully maximize population density at reduced construction costs (Khazanah Research Institute, 2023), they often do so at the expense of livability, resulting in restricted access to child-friendly outdoor spaces. Such spatial limitations undermine children's everyday freedoms to explore, interact, and develop within their immediate environments.

A growing body of scholarship highlights the importance of environmental affordances, the perceived opportunities within environments that support children's activities and interests (Gibson, 1979; Kyttä, 2002). Understanding how children perceive and utilize these affordances is crucial to identifying the conditions that promote their well-being. Despite increasing international calls for youth participation in planning, children's voices remain marginal within urban policy and design processes, leading to environments that inadequately reflect their lived realities (Bessell, 2019). This persistent exclusion underscores the need for evidence-based frameworks that document children's neighborhood activities, preferences, and priorities.

To address this gap, the present study adopts Moore's (1986) conceptual model of nested neighborhood activity domains to examine how marginalized children in Malaysian social housing navigate and experience their local environments (such as in-between spaces, streets, playgrounds, or gardens). By capturing their perspectives and preferences, the study seeks to foreground children's priorities for planners and policymakers, thereby contributing to the design of more inclusive, supportive, and development-oriented social housing neighborhoods. The findings aim to strengthen the evidence base for child-responsive urban planning, ensuring that the rights articulated in the UNCRC are translated into tangible design practices within high-density, low-income contexts.

LITERATURE REVIEW

Understanding children's interactions within their neighborhoods requires careful attention to the environmental domains in which their daily activities unfold. Moore's (1986) conceptual model of nested neighborhood activity domains provides a useful framework for characterizing children's "activity spaces," highlighting the spatial and temporal patterns that define their engagement with

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local environments. Within this model, a child's habitual range is typically centered around the immediate neighborhood, approximately 400 meters from their residential block, where most out-of-school activities occur (Moore, 1986). These activities are usually undertaken independently, often on foot or by bicycle, and form part of children's routine daily and weekly schedules (Weir, 2023; Moore, 1986; Ning et al., 2025).

Children's perceptions and uses of their neighborhoods are central to understanding how the built and social environment influence developmental outcomes (Chatterjee & Dutta, 2024; Lim et al., 2023). The neighborhood setting has long been recognized as a critical arena for children's holistic development, offering diverse affordances that stimulate cognitive, physical, social, and emotional growth (Kyttä, 2002; Högskolan & Kyttä, 2003; Guo et al., 2023). Such environments provide opportunities for cognitive flexibility, physical fitness, social competence, and emotional resilience, underscoring their multidimensional developmental role (Chetty et al., 2016; Sturges et al., 2023; Antink-Meyer et al., 2024; Weir, 2023).

Importantly, the unstructured nature of neighborhood environments allows children to exercise autonomy, engage in creative expression, and develop problem-solving skills (Weir, 2023). These spaces often serve as the first public arenas where children explore personal interests, experiment with emerging identities, and forge connections with peers and community members (Moore, 1986). Independent exploration and the establishment of meaningful places within these settings represent key processes in the development of self-identity and environmental competence (Chetty et al., 2016; Sturges et al., 2023; Antink-Meyer et al., 2024; Weir, 2023).

Recent scholarship has further emphasized neighborhood-level effects on health and behavior, showing that while individual-level factors remain influential, the broader community context also plays a decisive role (Weir, 2023; Loebach & Gilliland, 2019). Collective attributes, such as socioeconomic conditions, quality and availability of resources, built form, and perceived safety, shape the extent to which neighborhoods support or constrain children's activity, mobility, and wellbeing (Chatterjee & Dutta, 2024; Guo et al., 2023). Neighborhoods enriched with social and physical resources not only encourage active participation and healthy behaviors but also build children's confidence and competencies in ways that extend into adulthood (Zhao et al., 2023; Boardman & Saint-Onge, 2005).

Despite these insights, limited research has examined how children living in high-density social housing environments, particularly in the Malaysian context, perceive and negotiate their neighborhood affordances. This gap is critical, as marginalized children may experience fundamentally different spatial constraints and opportunities compared to their peers in more privileged contexts.

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RESEARCH METHODOLOGY

This study adopted a qualitative, child-centered multiple-case study design to examine children's lived experiences and preferences within Kuala Lumpur's Projek Perumahan Rakyat (PPR) neighborhoods. PPR is a government social housing program intended primarily for low-income households, commonly associated with Malaysia's B40 population, the lowest 40% of households by income. Kuala Lumpur contains 72 PPR neighborhoods across 11 parliamentary constituencies. The sites were initially grouped by constituency, after which the Heads of Village were contacted to facilitate community access and invite participation. Three neighborhoods agreed to participate within the recruitment period (see Figure 1), reflecting the willingness and capacity of local leadership to support access and safeguarding procedures: PPR Gombak Setia (n=6), PPR Pantai Ria (n=13), and PPR Raya Permai (n=7). Their inclusion also supports literal replication across comparable cases, as recommended by Yin (2014). All three sites comprise multiple high-rise residential blocks exceeding five stories.

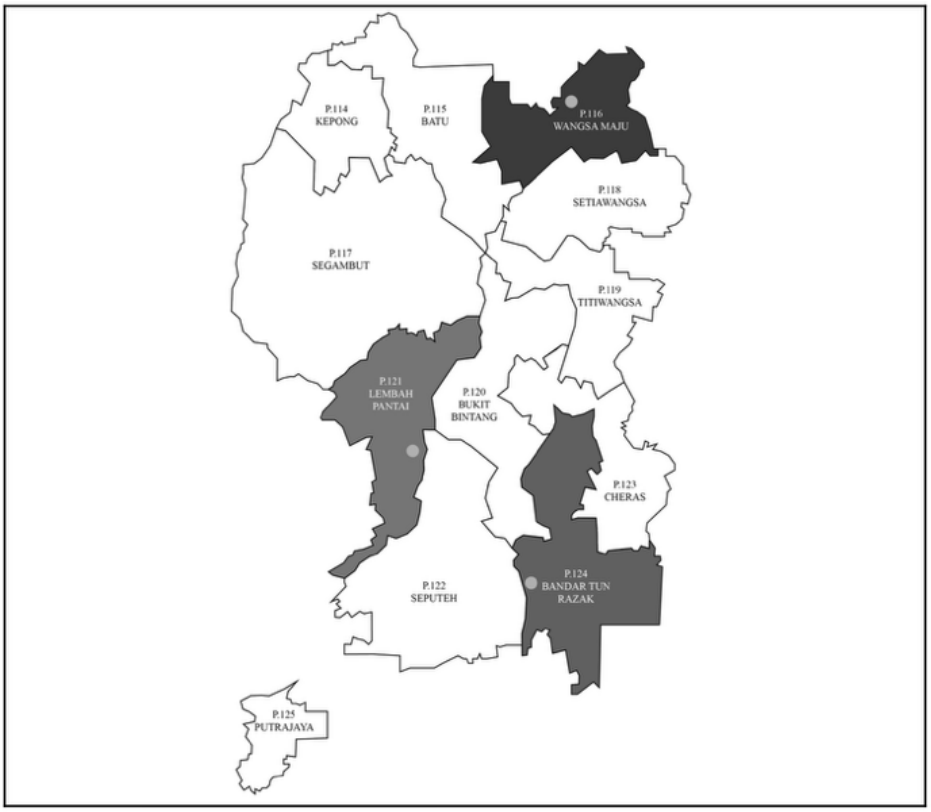


Figure 1: Maps of Participating PPR Neighborhoods in Kuala Lumpur

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Twenty-three children aged 7–12 years participated: 14 girls and nine boys. Thirteen participants were aged 7–9 years, while ten were aged 10–12 years. All participants lived in PPR housing and therefore shared broadly comparable low-income social housing backgrounds.

Ethical approval was obtained. Written parental or guardian consent and children's age-appropriate assent were obtained before participation. Children were informed of their right to decline questions or withdraw without consequence. Participant identities were replaced with codes, and identifying information was removed from transcripts, drawings, and publications. Activities were conducted during daylight in familiar public areas. The researcher, two trained enumerators, a guardian, and a representative of the village committee accompanied each group to ensure safety and respond to any emotional or environmental concerns.

Child-led walks were conducted through go-along conversations to explore children's experiences within their habitual neighborhood range. Children participated in groups of three to four and guided an approximately 400-m route for about 30 minutes. They determined the route, pace, stopping points, and places discussed, while the researcher maintained a facilitative rather than directive role. Prompts included "Where is your favorite place to go?", "What do you like here?", and "What do you dislike along this route?" Data comprised children's verbal accounts, field notes, and route observations.

After the walks, children were given 40 minutes to draw their ideal neighborhood environment. This method allows children to draw what they value in their neighborhood environment, enabling them to express spatial ideas and emotions that may be difficult to communicate verbally (Adam et al., 2025). They were encouraged to depict destinations, activities, people, routes, natural elements, and other features they considered important. Upon completion, children were invited to explain the features they had drawn, including their choices, spatial arrangements, and reasons for including particular elements. These explanations guided the interpretation of the visual data.

Audio-recorded conversations were transcribed and, where necessary, translated into English. Transcripts, field notes, drawings, and children's explanations were managed in NVivo and analyzed inductively through thematic coding. The drawings were examined according to their depicted features, spatial organization, routes, placement of activities, people, vehicles, and natural elements. Triangulation involved comparing each child's lived experiences from the walks with the preferences and spatial solutions represented in the drawings. Convergences and differences were then consolidated into overarching environmental affordance themes. Data collection and preliminary analysis proceeded concurrently. Thematic saturation was considered achieved when

successive walks and drawing explanations across the three neighborhoods repeated established patterns and produced no substantively new codes, environmental attributes, or interpretations.

ANALYSIS

Findings of Child-led Walks

Children consistently identified playgrounds as their preferred outdoor destinations, valuing them as spaces for play, social interaction, and security. Their appeal arose not only from equipment such as swings and seesaws but also from the presence of friends, neighbors, and other residents. Sensory experiences further influenced place preference, as one child explained, "I like the swing because I can feel the wind while using it" (PPRGS02, age8). Thus, children's preferred places combined opportunities for physical activity with social presence and environmental comfort.

However, playgrounds were frequently described as too small, overcrowded, or poorly maintained. When designated facilities could not accommodate them, some children extended their play into nearby streets. Although they recognized the risks, staying close to home provided reassurance through parental proximity. Street play, therefore, represented an adaptive response to insufficient play space rather than an inherently preferred activity. This compromise was captured by one participant: "Sometimes we play on the road. But I don't like cars and motorcycles here. I am afraid to get hit" (PPRPR21, age8).

Children were also attentive to the visual and microclimatic qualities of their surroundings. Well-lit places were perceived as both attractive and secure, while trees offered shade, airflow, and aesthetic relief. As one child noted, "I like trees because they provide fresh air and a cool breeze" (PPRRP12, age11). Frequently mentioned terms, including "near," "friends," "people," "bright," and "trees", show that proximity, sociability, visibility, and environmental quality were closely interconnected in shaping favorite places (Figure 2).

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Figure 2: Word clouds illustrating children's positive and negative experiences from child-led walks across three PPR neighborhoods

Despite these positive associations, children identified substantial spatial constraints. Moving vehicles threatened their safety, while parked cars and motorcycles obstructed pathways, playgrounds, and ground-floor courtyards that might otherwise support informal play. Narrow pedestrian routes also restricted movement: "I don't like small pedestrian lanes; they are very narrow and cause congestion" (PPRGS06, age11). In addition, some playgrounds were located beside waste-disposal or utility areas, while sports courts and gardens were positioned at neighborhood edges, reducing their attractiveness, accessibility, and perceived safety.

Children consistently avoided isolated, confined, or poorly lit locations. The absence of people weakened their sense of security, while limited visibility intensified concerns about strangers, animals, and physical hazards. One child stated, "I don't like quiet places, places with no people, places that are dark, places that are confined" (PPRPR19, age10). Inadequate seating and environmental maintenance further reduced outdoor comfort, as reflected in the observation, "There's nowhere to sit outside, except for the steps" (PPRRP14, age7).

Collectively, the walks demonstrate that children assess neighborhood spaces through interconnected spatial, social, and sensory considerations. Their everyday choices reflect continual negotiation between enjoyment and risk, with proximity to home, social presence, lighting, greenery, cleanliness, and freedom from vehicles determining where they feel able to play and move independently.

Findings of Children's Drawings

The children's drawings depicted neighborhoods that extended beyond the constraints of their existing PPR environments. Across the three sites,

playgrounds, open fields, sports courts, gardens, and gathering spaces appeared as interconnected destinations rather than isolated facilities. This arrangement suggests that children envisioned the neighborhood as an integrated setting for play, movement, relaxation, and social interaction.

A recurring feature was the centralization of communal activities. Many children positioned residential blocks around the outer perimeter, enclosing a shared central core containing playgrounds, sports areas, gardens, and seating. Vehicle parking was generally placed outside this core, creating an interior where children could move and play without competing with traffic. This pattern reflects children's awareness of existing vehicular risks, as the child expressed: "The cars outside, so I can play without having to look around" (PPRPR21, age10). The drawings transformed this concern into a clear spatial response: separating vehicles from everyday play areas.

Children reinforced this vehicle-free core with interconnected pedestrian and cycling paths, crossings, fences, lamp posts, guard points, and human figures. These elements indicated that safe movement depended not only on traffic separation but also on visibility, surveillance, and the presence of other people. Open routes and recognizable signposts further suggested a preference for neighborhoods that children could navigate independently.

The drawings also incorporated shaded shelters, huts, benches, and semi-indoor spaces for resting and gathering. These features show that children did not imagine neighborhoods solely for vigorous activity; they also valued places to pause, converse, and remain outdoors comfortably. The inclusion of trees around pathways and play areas supported this preference for shade and airflow. As one child explained, "I put all the trees, grass and garden here because they provide fresh air, cool breeze, and make the environment pretty" (PPRPR13, age12). Natural and sensory features were prominent. Children drew flowers, gardens, ponds, animals, sand areas, water features, and colorful structures, integrating nature directly into spaces for play and movement. Food stalls and vendors were also positioned near gathering areas, reflecting their role as convenient refreshment and social points. One participant stated, "I like the restaurant because it makes me full, and they have beverages too" (PPRGS03, age9).

Several drawings included exploratory equipment such as climbing structures, play towers, sandpits, and open-ended play zones. These representations conveyed a preference for varied environments that support imagination, challenge, and social play rather than uniform playground equipment alone. Overall, the drawings reconstructed fragmented and vehicle-dominated PPR spaces into centralized, connected, and child-oriented neighborhoods. They demonstrate children's capacity to translate everyday

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constraints into practical spatial proposals that prioritize safe movement, social visibility, comfort, nature, and diverse opportunities for play.

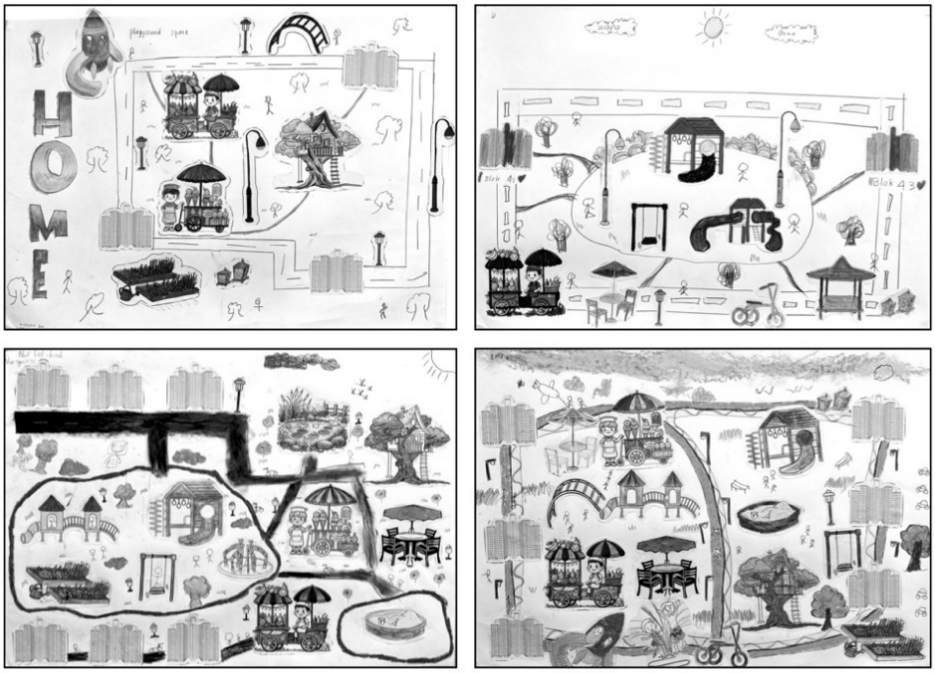


Figure 3: Examples of children's drawings depicting their ideal neighborhood environments

DISCUSSION

Triangulation of the child-led walks and children's drawings revealed how children in Malaysian PPR social housing experience existing neighborhood constraints and envision more supportive environments. The actualized habitual range comprised playgrounds, sports courts, open fields, and streets. The attributes that enabled these spaces to provide affordances were safety, comfort, nature, sensory amenities, and accessibility (Figure 4). Across both methods, children envisioned activities concentrated within a vehicle-free communal core, with residential blocks around the perimeter and parking located outside. This configuration resembles home-zone, superblock, and play-street principles but reflects children's specific responses to the spatial pressures of dense PPR neighborhoods.

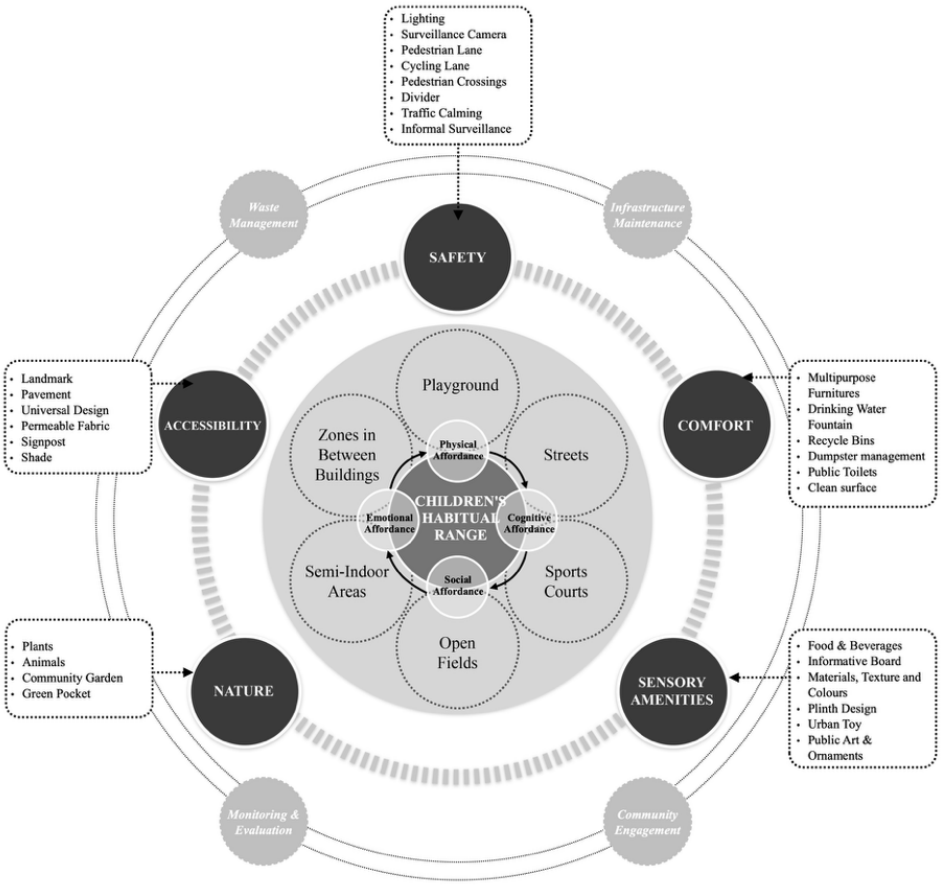


Figure 4: Affordances within the habitual range as perceived by marginalized children

Safety

Safety was the most prominent attribute. Children encountered moving vehicles, motorcycles occupying courtyards, and dark or isolated spaces. One child explained, “Sometimes we play on the road… I am afraid to get hit” (PPRPR21, age 8). Their drawings responded by relocating vehicles to the neighborhood perimeter and adding lighting, fencing, surveillance cameras, and watch points, confirming that safety underpins play and independent mobility.

Safety was also associated with social presence. Neighbors, peers, and adults provided informal surveillance, reflecting Jacobs’ (1961) “eyes on the street” and evidence linking children’s mobility to perceived supervision and reduced traffic exposure (Kyttä, 2002; Högskolan & Kyttä, 2003; Guo et al., 2023).

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Rather than merely proposing traffic calming, children advocated separating vehicles from recreational spaces. This may reflect PPR-specific conditions, including high density, limited parking, and vehicle encroachment. Their street use, therefore, appears less a preference than an adaptation to overcrowded or inadequate play areas.

Comfort

Children sought shade, seating, shelters, and protection from tropical weather. Their drawings included canopies, benches, covered paths, and gathering areas, while the walks revealed dissatisfaction with the limited places available for resting. Comfort therefore encompassed more than physical ease; it enabled children to remain outdoors, interact with friends, and feel socially supported without continuous adult intervention. This aligns with research showing that favorable microclimates and small-scale amenities increase children's use of public spaces and strengthen place attachment (Högskolan & Kyttä, 2003; Zhao et al., 2023; Clark & Moss, 2017).

Comfort was nevertheless weakened when motorcycles occupied ground-floor courtyards and when sports courts or gardens were positioned at neighborhood edges. These conditions indicate that comfort is jointly produced through proximity, safety, maintenance, and spatial management. In high-rise PPR settings, providing benches or shelters alone is insufficient unless communal ground floors are protected from parking and storage encroachment.

Nature

Trees, gardens, flowers, and animals appeared prominently in the drawings, while children valued trees during the walks for shade, airflow, and beauty. As one child explained, "I like trees because they provide shade" (PPRPR24, age7). These findings support evidence that everyday contact with greenery promotes physical activity, restoration, and socio-emotional wellbeing (Högskolan & Kyttä, 2003; Antink-Meyer et al., 2024; Loebach & Gilliland, 2019).

Importantly, children did not depict nature solely as a separate park. Instead, they incorporated trees along paths, vegetation around sports courts, gardens near residential blocks, and shaded play areas. This extends studies that emphasize access to destination greenspaces (Antink-Meyer et al., 2024; Loebach & Gilliland, 2019; Zhao et al., 2023). In dense PPR neighborhoods, distributed greenery may be more valuable than a large peripheral park because it remains visible, nearby, and connected to children's everyday routes. The preference also reflects dissatisfaction with the concrete-dominated character of existing housing environments.

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Sensory Qualities

Lighting, color, sound, movement, and natural materials influenced children's attraction to place. Brightness signaled safety, color encouraged use, and durable materials supported active play (Gibson, 1979; Kyttä, 2002). As one child noted, "I like the mural art because it's very pretty" (PPRRP16, age 10), showing that environmental appeal extended beyond equipment provision and could strengthen place attachment (Weir, 2023).

Unlike studies that associate dim or wild spaces with adventurous play (Antink-Meyer et al., 2024; Dodd et al., 2022), children in PPR settings often interpreted darkness and ambiguity as danger. Sensory quality therefore contributes not only to aesthetics but also to legibility, reassurance, and enjoyment.

Accessibility

Accessibility involves proximity, legibility, and unobstructed movement. Although children generally stayed close to home, their drawings featured continuous walkways, cycling routes, clear signage, and direct connections. Narrow paths, parked motorcycles, poor visibility, and ground-floor clutter restricted mobility even when facilities were nearby.

These findings support Moore's (1986) habitual range and research on children's independent mobility (Kyttä, 2002; Weir, 2023; Loebach & Gilliland, 2019; Ning et al., 2026). Children proposed centralized layouts, shorter routes, clearer sightlines, and activities visible to familiar residents, helping explain why peripheral facilities may remain underused.

Accessibility therefore reflects the difference between potential and actualized affordances: facilities cannot support children when routes are obstructed, unsafe, or difficult to interpret (Gibson, 1979; Kyttä, 2002). In dense social housing, access depends not only on facility provision but on whether children can reach destinations safely, visibly, and independently.

Implications for Child-Friendly Social Housing

The findings indicate that children's perceived and actualized affordances within their habitual range are shaped not only by physical form but also by safety, visibility, accessibility, and social presence. Across the three participating PPR neighborhoods in Kuala Lumpur, children preferred spaces where they could move independently while remaining visible to familiar adults and peers. Their walk narratives and drawings suggest that child-friendly planning does not necessarily require large or specialized facilities; rather, it requires the reorganization and better management of everyday shared spaces.

The five identified affordances can be translated into practical design and policy measures. For safety, parking control should prevent cars and

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motorcycles from occupying courtyards, pedestrian routes, and play areas. Where feasible, parking and vehicle circulation should be relocated towards neighborhood edges, while central communal areas should be prioritized for walking, play, and social interaction. Traffic-calming measures, physical separation between vehicles and pedestrians, improved sightlines, and lighting along frequently used routes would further support children's independent mobility. Lighting should be distributed across paths, courtyards, entrances, and activity nodes rather than concentrated only around parking areas.

For comfort, ground-floor courtyards should be formally designated and managed as shared community spaces rather than treated as residual parking or storage areas. Shaded seating, covered walkways, weather-protected play areas, and well-maintained resting places would enable children to remain outdoors for longer periods in Kuala Lumpur's tropical climate. Clear responsibility for cleaning, maintenance, and the removal of obstructions is therefore as important as the initial provision of facilities.

For nature, planning should incorporate small-scale, continuous green elements throughout children's daily routes. Tree-lined walkways, planted edges, pocket gardens, shaded play areas, and community gardens may be more accessible and usable than a single peripheral green space. Such micro-green infrastructure can improve thermal comfort, visual quality, and opportunities for informal interaction while remaining within children's visible and familiar activity range.

For sensory quality, color, lighting, natural materials, and varied play surfaces should be used to create legible and inviting environments. These elements should not be treated as decoration alone, as they help children recognize safe routes, distinguish activity areas, and develop stronger attachments to place. Durable and easily maintained materials are particularly important in intensively used communal spaces.

For accessibility, facilities should be connected through direct, unobstructed, and shaded pedestrian and cycling routes. Edge-located courts and gardens require improved connections, surveillance, and active frontage if they are to function as usable child-oriented spaces. New facilities should therefore be assessed not only by quantity or distance but also by whether children can reach them safely, independently, and comfortably.

At the policy level, these measures require coordination between housing authorities, local government, resident committees, and facility managers. Parking enforcement, ground-floor management, maintenance responsibilities, lighting audits, and periodic assessments of play-space accessibility should be incorporated into PPR management practices. Children should also be consulted during neighborhood upgrading, as their accounts identify barriers that conventional facility-based planning may overlook.

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These implications should not be generalized to all Malaysian social housing. They arise from three voluntarily participating PPR neighborhoods in Kuala Lumpur. Nevertheless, they provide context-specific directions for improving similar high-density housing environments and a basis for testing child-responsive planning measures across a wider range of PPR settings.

CONCLUSION

This study used child-led walks and children's drawings to examine how children aged 7–12 experience and envision their neighborhood environments across three PPR sites in Kuala Lumpur. Although playgrounds, streets, sports courts, open fields, semi-indoor areas and zones between buildings were valued destinations, children's preferences centered on five interrelated affordances: safety, comfort, nature, sensory quality, and accessibility. Together, these attributes supported a clear spatial preference for centrally located, vehicle-free communal spaces with greenery, shade, lighting, seating, and direct, legible routes.

The findings position marginalized children as critical stakeholders whose experiential knowledge can strengthen social housing planning and management. DBKL should incorporate child-responsive spatial audits and children's participation into PPR upgrading programs and planning approvals. Housing agencies should establish minimum standards and dedicated budgets for play-space provision, shaded connections, lighting, micro-green infrastructure, and long-term maintenance. Architects and planners should prioritize pedestrian–vehicle separation, visible communal cores, unobstructed ground-floor circulation, and facilities located within children's everyday activity range. PPR management bodies and resident committees should enforce parking controls, prevent motorcycles from occupying courtyards and pathways, maintain shared spaces, and periodically consult children regarding neighborhood conditions.

The findings are context-specific and should not be generalized to all Malaysian social housing. The study was limited to 23 children aged 7–12 across three Kuala Lumpur PPR neighborhoods. Future research should include broader age groups, gender-sensitive and intergenerational perspectives, additional housing contexts, and mixed methods such as spatial mapping and mobility tracking.

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MANAGING SCOPE CREEP IN INTEGRATED TOURISM PROJECTS: A GOVERNANCE PERSPECTIVE

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Abstract

Scope creep is traditionally framed as a technical failure in project management; however, in complex urban development projects, it is often shaped by governance and institutional dynamics. This study examines scope evolution in large-scale integrated tourism resort projects through a multi-site qualitative case study of five resorts in China. Data were collected using semi-structured interviews, document analysis and thematic analysis. The findings reveal three distinct scope outcomes: rational scope increase, irrational scope creep, and scope suspension. These outcomes are influenced by governance configurations, power distribution, and competing institutional logics, particularly the interaction between administrative, market, and professional perspectives. The results highlight that scope changes are not merely technical deviations but are embedded within broader governance structures and stakeholder dynamics. This study contributes to the literature on project planning and governance by introducing a governance-based perspective to understand the dynamics of scope changes in complex development projects. It extends scope management theory by introducing a more detailed typology of scope outcomes and by integrating institutional and stakeholder perspectives into project management. Furthermore, empirical evidence from an integrated tourism resort project in China strengthens the understanding of how governance structures and power relations influence scope evolution in large-scale projects involving multiple stakeholders.

***Keywords*:** scope creep, governance, institutional logics, tourism resort development

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INTRODUCTION

Large-scale urban development projects, particularly integrated tourism resorts, are characterised by high complexity, multiple stakeholders, and evolving project requirements. One of the most persistent challenges in such projects is scope creep, defined as the uncontrolled expansion of project scope beyond the original project scope (Kerzner, 2017). Traditionally, scope creep has been attributed to ineffective project management practices, such as poor documentation or inadequate stakeholder control (Project Management Institute, 2021).

However, this perspective is increasingly inadequate for explaining scope dynamics in large-scale developments. In practice, project scope is frequently influenced by wider governance arrangements, institutional demands, and competing stakeholder interests (Flyvbjerg, 2014). This is particularly evident in integrated tourism resort developments, where public authorities, private developers, and consultants operate within a complex governance environment shaped by stakeholder interests, market demands, and regulatory changes. These interactions require ongoing coordination to align strategic objectives with project delivery (Walker, 2010; Bourne & Walker, 2008). Such conditions intensify scope management challenges and frequently trigger scope changes. These changes often result in project delays, cost overruns, and inefficient resource utilisation due to inadequate requirement identification and weak stakeholder communication. While social phenomena are inherently complex, understanding them is essential for assessing stakeholder acceptance, which directly affects tourism management (Mohamad & Mohamed, 2018).

In Malaysia, tourism development operates within a multi-level planning framework involving federal, state, and local authorities. This framework often facing coordination challenges, institutional fragmentation, and evolving regulatory demands (Zulkefli et al., 2022; Marzuki, 2010). Although this study is based on cases in China, the governance-based scope dynamics identified offer relevant insights for Malaysian tourism planning and project delivery. Despite the increasing importance of tourism-led developments, empirical studies on scope creep in this context remain limited, as existing research has predominantly focused on general construction and infrastructure projects, with less attention to the governance complexity and market responsiveness that are specific to tourism developments. Accordingly, this study examines how project scope evolves in large-scale integrated tourism resort developments in China, focusing on the role of governance factors and stakeholder dynamics in shaping scope changes during project implementation.

LITERATURE REVIEW

Causes and Effects of Scope Creep

Scope creep refers to the uncontrolled expansion of project scope without formal approval and is particularly prevalent in large and complex projects involving

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multiple stakeholders and high levels of uncertainty. One of the primary causes is an unclear scope definition**,** where ambiguity at the early project stage increases the likelihood of scope changes during execution (Dumont et al., 1997). Empirical studies confirm that poorly defined scope is a key contributor to project delays and cost overruns (Amoatey & Anson, 2017). Another significant factor is changes in client requirements**,** as evolving customer expectations and diverse user needs increase project complexity, particularly in tourism and resort developments (Faulkner et al., 2003). External stakeholder interventions, including those from government agencies and local communities, may further alter project objectives and expand project scope over time (McAdam, 1999).

In addition, unforeseen risks play a critical role, especially in complex or "soft" projects where uncertainty cannot be adequately managed using traditional approaches (Khan, 2006). Stakeholder conflicts**,** arising from misaligned goals, ineffective communication, and unclear roles, also contribute to uncontrolled scope expansion (Sharma, 2006). The impacts of scope creep are substantial, often resulting in time delays, cost overruns, and reduced quality. Amoatey and Anson (2017) report that scope creep can increase project costs by up to 30%, while negatively affecting overall project performance and stakeholder satisfaction.

Scope Management in Tourism Development Projects

The primary issue in dealing with scope management is the high complexity and varying environmental conditions (Ahmed & Jawad, 2022). In resort and retreat developments, scope management is further complicated by the need to prioritise customer experience and service quality. Tourism is one of the key sectors contributing to Malaysia's economic development, and the Malaysian government has consistently demonstrated its commitment to fostering the industry's growth through strategic planning and policy support (Abdul Latip et. al, 2020). Tourism projects involve multiple stakeholders, including government agencies, developers, local communities, and tourists, whose diverse and often competing interests increase the complexity of scope management and the risk of scope creep (Marnada et al., 2022). Misalignment of stakeholder requirements and frequent interventions, particularly by top management, further contribute to uncontrolled scope changes. To address these challenges, a collaborative team-oriented management approach combined with structured service design methodologies, such as Resort Service Design (RSD), has been recommended to enhance resource allocation and minimise inefficiencies arising from scope changes (Potashova, 2015).

Although existing literature provides valuable insights into the causes and impacts of scope creep, most studies conceptualise it as a technical or managerial issue, focusing on tools, processes, and control mechanisms. Limited attention has been given to the governance and institutional dimensions that

shape scope decisions in complex development projects. Furthermore, there is a lack of empirical research examining scope dynamics specifically within integrated tourism development projects**,** where multiple stakeholders operate under competing priorities. The interaction between administrative, market, and professional interests remains underexplored.

RESEARCH METHODOLOGY

This study adopts a qualitative multiple case study approach**,** which is appropriate for investigating complex and context-dependent phenomena such as scope dynamics in large-scale development projects. A multi-site embedded case study design was employed to allow for cross-case comparison while capturing variations across different project contexts.

Five integrated tourism resort projects in China were selected as case studies based on clear criteria to ensure comparability and contextual diversity. All selected projects are large-scale, mixed-use tourism developments that integrate hospitality, recreation, entertainment, retail, and supporting infrastructure, while also being relatively comparable in terms of investment values, land areas, and stages of development. This uniformity in project type and scale provides a consistent basis for examining scope management practices across cases. The projects were selected from diverse geographical locations in China to capture variations in economic conditions, market demand, and regional planning policies. Differences in governance contexts were also considered by selecting projects operating under distinct administrative and institutional frameworks, including varying levels of local government involvement, approval procedures, regulatory requirements, and stakeholder coordination mechanisms.

The selection of integrated tourism resort projects in China as case studies was informed not only by their scale and complexity, but also by their comparative relevance to other emerging tourism economies such as Malaysia. Both China and Malaysia share similar characteristics in tourism-oriented development, including multi-level governance structures, public-private collaboration, and the involvement of multiple regulatory agencies in planning and implementation (Ministry of Tourism, Arts and Culture Malaysia, 2020). In Malaysia, tourism developments are similarly shaped by overlapping institutional responsibilities and stakeholder coordination challenges, which often influence project scope and delivery (Zulkefli et al., 2022). Accordingly, the Chinese cases provide comparative insights into governance-driven scope evolution that may offer transferable lessons for tourism planning and project governance in the Malaysian context.

Overall, these criteria enable the study to examine how scope management evolves across different contexts while maintaining sufficient comparability for cross-case analysis. To complement the case study selection, a purposive sampling strategy was also employed to identify respondents directly

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involved in project planning, design, and management, ensuring that the data collected reflects perspectives grounded in relevant experience and knowledge regarding scope evolution and project governance practices.

A total of 12 respondents across five case study projects were interviewed, comprising project managers, design consultants, and client representatives. Respondents were selected through purposive sampling, a widely recognised approach in qualitative research that enables the identification of individuals with relevant knowledge, expertise, and direct experience related to the phenomenon being investigated (Patton, 2015). This selection was based on their involvement in scope planning, design coordination, and project implementation, ensuring the data obtained was both in-depth and relevant.

To ensure balanced representation and capture diverse professional perspectives, the distribution of respondents was determined by the project complexity and stakeholder structure. Specifically, each project involved at least two key respondents representing the client and consultant perspectives, while projects with higher complexity or broader stakeholder involvement included an additional project manager. This approach aligns with the principles of multiple-case study research, which emphasises the importance of gathering diverse sources of evidence and perspectives to enhance the validity and reliability of the findings (Yin, 2018). This arrangement enabled a more comprehensive understanding of scope evolution and project governance practices, encompassing both general approaches and those specific to the project context.

The sample size of 12 respondents is considered adequate for qualitative research, as it allows for data saturation**,** where no new themes or insights emerge from additional data collection (Guest, Bunce, & Johnson, 2006). This enhances the depth and reliability of the findings. Data were collected from multiple sources to enable methodological triangulation, including semi-structured interviews on scope management practices, governance structures, and scope creep challenges; document analysis of planning approvals, design revisions, and project reports; and secondary sources, such as policy documents and organisational records, to provide contextual background.

All interviews were audio-recorded and transcribed verbatim, with the transcripts serving as the primary data source for analysis. The collected data, including interview transcripts and supporting documents, were analysed using an interpretative thematic analysis approach to identify recurring patterns and establish relationships between empirical findings and the study's theoretical framework.

The coding process was conducted in three stages. First, open coding was used to identify key ideas and generate initial codes from the data. Second, axial coding was applied to group related codes into broader themes and examine their interrelationships. Finally, selective coding was undertaken to refine and consolidate these themes into higher-order categories for analysis. Theme

development involved repeated reviews of the transcripts and documents to identify recurring issues, contextual variations, and emerging patterns related to scope creep, governance structures, and stakeholder interactions. In addition, a cross-case synthesis was conducted to compare findings across the five cases, enabling the identification of common sources of scope creep as well as context-specific triggers. This comparative approach strengthened the analytical depth and enhanced the transferability of the findings to similar project settings.

ANALYSIS AND DISCUSSION

The empirical findings of this study are based on semi-structured, in-depth interviews with twelve key stakeholders representing the five project sites. In order to capture the divergent points of view and improve the strong interpretative latitude of data, the interviewees were purposefully selected from all the critical functions in the project value chain from beginning to end.

Beyond case-specific differences, the analysis reveals a set of recurring structural drivers shaping scope management across projects. Synthesizing the cross-case findings, distinct configurations of institutional logics are associated with different scope outcomes. In all five cases, scope management presents itself as a result of intricate and deep structural systems, rather than the absence of procedural mechanisms. The absence of governance structural power conflicts is a fundamental risk and remains in the subsurface. Operational logics, in both innovative and disruptive ways, impact growth and contribute to the misalignment of the system. Collectively, these cases illustrate that scope creep in resort projects produces both adaptive successes and costly failures, depending on how governance power, operational logic, and strategic cognition are aligned. These empirical contrasts provide concrete lessons for practitioners regarding when scope flexibility creates value and when it undermines project sustainability.

These findings imply that effective scope management involves understanding and first attending to the structural factors influencing how the project gets governed. *Scope management style* refers to the manner in which project scope is planned, controlled, adjusted, and governed throughout the project lifecycle. It reflects the decision-making approach, level of stakeholder coordination, governance structure, and degree of flexibility applied in responding to emerging project demands and uncertainties. In complex development projects, scope management style influences whether scope changes are strategically integrated, poorly controlled, or partially deferred.

In this study, scope management style is understood through three forms based on decision logic, governance interactions, and scope outcomes. First, an adaptive and strategically aligned style refers to scope decisions that are deliberately introduced through stakeholder coordination and market-oriented considerations. These decisions lead to *rational scope increase,* whereby scope

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expansion is deliberately introduced to enhance project value and competitiveness. Second, a reactive and weakly coordinated style often results in *irrational scope creep*, characterised by unplanned changes, misalignment, and inefficiencies. Third, a constrained or compromised management style may lead to *scope suspension*, where intended project elements are omitted or postponed due to governance conflicts, resource limitations, or institutional barriers. These styles demonstrate that scope management is not merely a technical control function, but a governance-driven process shaped by institutional and stakeholder dynamics. To systematically compare scope governance patterns across the five cases, a cross-case comparison is presented.

Table 1: Cross-Case Comparison of Scope Management and Scope Outcomes

Case	Governance Power Structure	Dominant Logic	Scope Management Style	Scope Outcome
Hangzhou	Fragmented/Weak Integration	Professional	Scope suspension	Scope contraction
Rizhao	Owner dominated	Administrative	Coercive governance	Irrational creep
Wuhan	Diffused fragmented	Operational anxiety	Reactive expansion	Resource-driven creep
Jiaxing	Market-driven	Market	Adaptive informal	Rational expansion
Zhoushan	Constraint-driven	Professional	Conscervative governance	Scope lock-in

Table 1 compares scope management styles and their corresponding scope outcomes across the five cases, illustrating how different governance configurations shape the trajectory of project scope. The comparison shows that scope management practices are closely associated with eventual scope outcomes and are influenced by the underlying governance power structures and dominant institutional logics. Beyond the case-specific variations, the cross-case analysis identifies recurring structural drivers that consistently influence scope decisions across projects. By synthesising these findings, it becomes evident that distinct configurations of institutional logics and governance arrangements tend to produce different scope outcomes, ranging from contraction and lock-in to rational expansion and various forms of scope creep. Drawing from the cross-case patterns identified in Table 1, Figure 1 conceptualises the structural interactions through which governance configurations and institutional logics drive distinct scope management approaches and resulting scope outcomes.

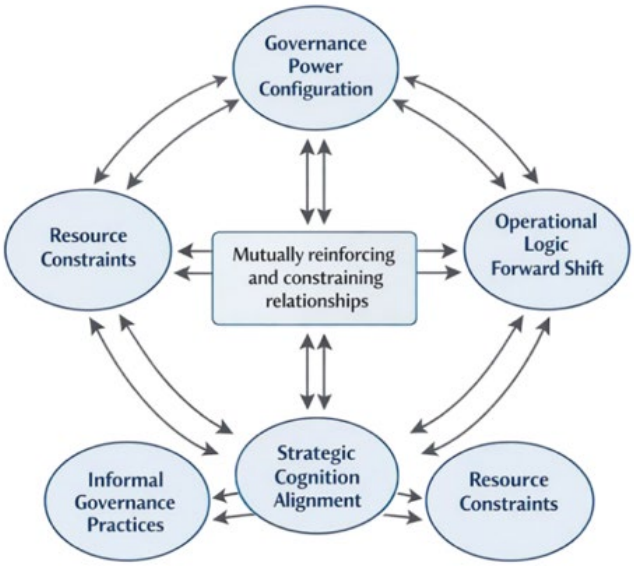


Figure 1: Interaction of Structural Drivers in Scope Governance

Governance, Institutional, and Operational Mechanisms Shaping Scope Decisions and Evolution

In the context of resort tourism projects, scope changes cannot be adequately captured by the single term *scope creep*. The findings indicate that, beyond the conventional notion of scope expansion driven by additional requirements, three distinct forms of scope change are observed.

Forms of Scope Change and Underlying Mechanisms in Resort Tourism Projects

The findings indicate that scope changes in resort tourism projects extend beyond the traditional concept of *scope creep.* Three distinct forms rational scope expansion, irrational scope creep, and scope suspension are identified, each shaped by different governance, institutional, and operational mechanisms.

Rational Scope Expansion and Strategic Governance Alignment

Rational scope expansion is primarily driven by governance mechanisms that emphasise strategic alignment and market responsiveness. The findings show that project steering committees, investor directives, and senior management decisions play a critical role in approving scope enhancements that improve competitiveness and user experience. At the institutional level, tourism development policies and destination branding strategies further legitimise such expansions by encouraging innovation and experiential value creation.

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Operationally, these changes are supported by structured feasibility assessments, stakeholder consultations, and iterative design processes. This suggests that rational scope expansion is not a deviation but an adaptive mechanism, where governance structures enable controlled flexibility in response to dynamic market conditions. This is evident in the operational phase of Jiaxing Senbo Resort, where themed activities and micro-innovations were introduced within feasible resource and professional boundaries. However, when market logic is based on overly optimistic assumptions or lacks governance constraints, it may lead to illogical scope decisions, as seen in the preparation phase of Senbo Wuhan, where workforce expansion exceeded realistic project needs

Irrational Scope Creep and Governance Deficiencies

Irrational scope creep is closely linked to weaknesses in governance and institutional control, where scope changes emerge without clear strategic justification or effective oversight. Unclear approval hierarchies, fragmented decision-making, and weak change-control procedures encourage uncontrolled scope growth, while inconsistent policy interpretation, inadequate resource planning, inaccurate cost estimation, and ineffective stakeholder communication further intensify cumulative and uncoordinated changes. This reflects how unchecked bureaucratic priorities can create conditions for irrational scope creep, as illustrated in the case of Rizhao Senbo Resort, where the decision to enforce an early opening without adequate operational readiness demonstrates how scope decisions became overly driven by administrative priorities rather than professional or operational considerations.

Scope Suspension and Institutional Misalignment

Scope suspension represents the deferment or omission of critical project components due to governance misalignment, shifting strategic priorities, and limited professional input. Unlike scope creep, it reflects a reduction in scope that may diminish project value and functionality. This is illustrated by Hangzhou Senbo Resort, where the brand-building function, originally a key strategic component, was excluded from the organisational structure and resource allocation, demonstrating how the marginalisation of professional judgement can compromise scope integrity and long-term project value.

Reconceptualising Scope Failure: Beyond Expansion to Omission

Collectively, these findings suggest that scope failure in resort tourism projects should be reconceptualised, as supported by existing literature on project governance and megaproject complexity. While traditional studies emphasise excessive scope expansion as the primary concern (Project Management Institute, 2021), emerging research highlights that scope failure also includes the omission or under-specification of critical project elements (Flyvbjerg, 2014). From a

governance perspective, both over-expansion and under-specification can be attributed to misaligned decision-making structures and ineffective governance frameworks (Too & Weaver, 2014). This is consistent with studies indicating that weak governance arrangements often lead to inconsistent scope decisions and reduced project performance. Institutionally, the presence of fragmented policies and inadequate coordination mechanisms further reinforces these challenges, particularly in complex, multi-actor environments such as tourism development projects (World Tourism Organization, 2018).

At the operational level, prior studies have shown that inadequate planning, ineffective communication, and resource constraints significantly contribute to scope instability and project inefficiencies (Kerzner, 2017; Project Management Institute, 2021). These factors can intensify both uncontrolled scope expansion and the unintended omission of critical project components. In line with this, scope failure should be understood as encompassing both excessive expansion (*irrational scope creep*) and insufficient delivery (*scope suspension*), highlighting the need for balanced governance, institutional alignment, and effective operational controls in managing scope evolution (Flyvbjerg, 2014; Too & Weaver, 2014).

The findings of this study indicate that *scope creep* in integrated tourism resort projects exhibits distinct characteristics compared to other project types such as information technology (IT), product development, service-based projects, and conventional construction. While scope changes in these sectors are typically driven by technical requirements, innovation, or service improvements, tourism projects are more strongly influenced by market trends, visitor expectations, branding strategies, regulatory requirements, and multiple stakeholder interests. Scope evolution in tourism developments frequently involves the addition of experiential and commercial elements, including entertainment facilities, retail spaces, and hospitality enhancements, to strengthen destination attractiveness and competitiveness.

Unlike projects with more centralised decision-making structures, tourism developments involve complex interactions among public authorities, private developers, consultants, and local communities. This multi-actor governance environment increases the likelihood of repeated scope adjustments as stakeholder priorities evolve over time, consistent with tourism development literature (Butler, 1980; Getz, 1986). The findings demonstrate that scope change in large-scale tourism resort projects should not be viewed solely as a technical project management failure, but rather as a governance- and institutionally driven process shaped by power relations, stakeholder dynamics, and competing institutional logics. The identification of rational scope increase, irrational scope creep, and scope suspension highlights the multifaceted nature of scope evolution, where adaptive and value-driven decisions coexist with governance weaknesses, misalignment, and ineffective stakeholder coordination. In this

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regard, project control systems in Malaysia may benefit from adopting more adaptive governance mechanisms, including structured stakeholder engagement, clearer approval pathways, and early strategic alignment to better manage scope changes in large-scale tourism developments.

CONCLUSION

This study demonstrates that scope change in large-scale integrated tourism resort projects cannot be adequately explained by the conventional concept of *scope creep* as a purely technical failure. Instead, scope evolution is shown to be a governance- and institutionally driven process shaped by power relations, stakeholder dynamics, and competing institutional logics. The identification of three scope outcomes, namely rational scope increase, irrational scope creep, and scope suspension highlights the multi-dimensional nature of scope change. While rational scope increase reflects adaptive and value-driven decision-making, irrational scope creep and scope suspension reveal the consequences of governance deficiencies, misalignment, and weak coordination among stakeholders. These findings suggest that scope failure should be reconceptualised to include not only excessive expansion but also the omission or deferment of critical project elements.

From a theoretical perspective, this study contributes to project governance and planning literature by extending the understanding of scope dynamics beyond technical control mechanisms to include broader institutional and governance contexts. Practically, the findings underscore the need for stronger governance alignment, clearer decision-making structures, and improved stakeholder coordination to manage scope effectively in complex, multi-actor development environments. Nevertheless, this study is limited by its focus on five resort projects within a single national context. Future research may expand the scope to different geographical settings, employ mixed-methods approaches, or explore the quantitative validation of the identified scope typologies.

Overall, this study highlights that effective scope management in complex development projects requires not only technical competence but also robust governance mechanisms and institutional coherence to balance flexibility with control. Although this study is based on integrated tourism resort projects in China, the findings provide important insights for the Malaysian planning context. Large-scale developments in Malaysia, particularly mixed-use and tourism-oriented projects, are similarly characterised by multi-stakeholder involvement, including local authorities, developers, consultants, and investors. Scope creep in Malaysian projects should not be viewed solely as a technical issue but as a governance challenge shaped by institutional interactions.

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PERCEPTIONS OF TREE SURVIVABILITY AMONG LANDSCAPE ARCHITECTS: A CROSS-SECTIONAL ANALYSIS OF PROFESSIONAL MATURITY

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Abstract

The perception that retained trees are unlikely to survive continues to influence decision-making in urban development, often leading to their removal. This study examines the relationship between professional maturity, measured by years of field experience, and perceptions of tree survivability among landscape architects in Malaysia. A cross-sectional survey was conducted involving 265 practitioners. Data were analyzed using descriptive statistics (mean and standard deviation) and one-way analysis of variance (ANOVA) to compare responses across different experience groups. The results show significant differences in skepticism across years of professional experience ($p < 0.05$). Practitioners with 1–5 years of experience recorded the highest agreement with the statement that retained trees are unable to survive ($M = 4.21$), whereas those with more than 21 years of experience reported lower agreement ($M = 3.04$). The findings indicate that experience is associated with differences in perceptions of tree retention outcomes. This may be attributed to the accumulation of practical knowledge and exposure to varied site conditions over time. The study suggests that differences in perception across experience levels should be addressed through knowledge sharing and continuous professional development to support more informed decision-making in tree retention practice.

Keywords: Urban Tree Retention, Risk Perception, Professional Maturity, Tree Survival, Urban Development.

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INTRODUCTION

A persistent concern in urban development is the perception that retained trees are unlikely to survive following construction activities. This assumption often influences decision-making processes, leading to the removal of trees at the early stages of site development (Suchocka et al., 2023). Generally, urban environments are unfavorable for tree growth due to multiple stressors such as impermeable surfaces, restricted root space, and mechanical damage. Among these, soil compaction acts as a primary driver of decline by reducing aeration and the availability of water and nutrients required for healthy root expansion. Consequently, many trees in cities follow a "live fast and die young" trajectory, often failing to reach their full biological potential (Smith et al., 2019).

In Malaysia, tree protection is supported through regulatory mechanisms such as the Tree Preservation Order under Act 172, although previous studies have highlighted the need to strengthen its implementation and effectiveness (Nik Mohamed Sukri et al., 2017). In planning practice, perceptions of retained tree survivability are relevant because they may influence development control decisions, landscape approval processes, tree preservation requirements, and construction site protection measures. When retained trees are perceived as unlikely to survive, development decisions may favour removal and replacement rather than in situ protection. Therefore, understanding how landscape architects perceive tree survivability is important for strengthening urban greening policy, tree preservation implementation, and evidence based landscape planning practice. Previous research in the Malaysian context has also shown that tree removal in development areas is influenced by differences in professional perception and decision-making among landscape professionals (Hassan et al., 2023). However, empirical evidence examining how professional experience shapes perceptions of retained tree survivability remains limited, particularly among landscape architects in Malaysia.

Therefore, this study aims to examine the relationship between professional maturity, measured by years of field experience, and perceptions of tree survivability among landscape architects in Malaysia. Specifically, the objectives of this study are to examine differences in perceptions of tree survivability across different levels of professional experience among landscape architects and to determine whether professional maturity significantly influences these perceptions. By focusing on professional maturity, this study contributes to urban tree retention research by highlighting practitioner perception as an important dimension alongside biological and technical considerations.

LITERATURE REVIEW

Urban tree survivability is strongly influenced by site conditions before, during, and after construction. Existing literature on urban tree mortality suggests that trees subjected to construction-related disturbances may experience a gradual decline in health due to altered growing conditions. Soil compaction, root disturbance, restricted rooting space, and changes in water availability can weaken tree vitality and reduce long-term survival potential. Suchocka, Błaszczyk, et al. (2019) noted that tree vitality is an important consideration in tree evaluation processes and may influence decisions regarding tree retention or removal when long-term survival is uncertain. Recent studies also show that established urban trees are increasingly exposed to environmental pressures such as urban heat island effects and extensive impervious surfaces, which can restrict oxygen and water movement in the soil (Gaur & Singh, 2024). However, urban tree response is not always straightforward. Cybula et al. (2026) found that impervious surfaces did not necessarily have a detrimental impact on tree crown growth, even when below-ground root morphology showed changes. Their findings suggest that urban trees may respond differently depending on site context, species, and management conditions. This indicates a gap between the perceived failure of retained trees and their actual biological resilience.

Despite the adaptive capacity of some urban trees, soil-related constraints remain a major limitation to long-term sustainability. (Patel et al., 2024) suggested that poor soil quality can contribute to premature tree decline and reduce the environmental returns expected from urban tree planting or retention. Similarly, Malakar et al. (2024) noted that increased root–shoot ratios in urban trees may represent adaptive responses to adverse soil conditions, reflecting the ability of trees to adjust physiologically to stressful environments. Technical interventions have been proposed to improve tree performance in constrained urban settings. Kosno-Jończy et al. (2026) highlighted that engineered soil systems, including structural soils, can help reduce the effects of compaction while supporting root development beneath paved surfaces. Fini et al. (2022) also found that while paved surfaces may alter root function, above-ground growth does not always decline in established trees. Similarly, Ren et al. (2023) observed that urban density and impervious cover do not necessarily reduce canopy development in certain species when early establishment is properly managed.

Successful tree retention is therefore closely linked to how well site limitations are addressed. Jim (2023) emphasized that confined rooting environments can be improved through better soil management practices that enhance aeration and water availability. However, urban stress can still contribute to growth abnormalities and structural issues under certain conditions (Lüttge & Buckeridge, 2023). This suggests that retained tree survivability depends not only

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on environmental stressors but also on the technical knowledge used to interpret and manage those stressors.

Knowledge and perception play an important role in tree retention decisions. Suchocka, Jankowski, et al. (2019) found that general awareness of tree value does not always translate into effective protection on construction sites. This may occur when practitioners lack specific technical understanding of how trees respond to damage, soil disturbance, or environmental stress. In practice, insufficient protection during construction can accelerate decline and later reinforce the belief that retained trees are unlikely to survive.

Professional judgment may also vary according to the individual evaluating tree-related conditions. Koeser and Smiley (2017) demonstrated that assessor background, training, and experience can influence how tree conditions are interpreted. In the context of landscape architectural practice, this suggests that practitioners with different levels of experience may perceive retained tree survivability differently. Less experienced practitioners may be more cautious when construction activities are associated with tree stress and decline, while more experienced practitioners may be more familiar with mitigation approaches such as root protection, soil remediation, monitoring, and post-construction maintenance.

This variation in professional perception can influence decisions related to tree selection, maintenance, retention, and removal (Hassan et al., 2023; Koeser & Smiley, 2017). Infrastructure development may also reduce the perceived environmental value of trees when they are viewed mainly as obstacles to construction rather than as ecological assets (Suchocka, Błaszczyk, et al., 2019). Therefore, professional maturity may be an important factor in shaping how practitioners interpret the survivability of retained trees within development contexts.

Existing studies have largely focused on the biological, physiological, and technical factors affecting urban tree survival. These include construction stress, soil constraints, root disturbance, impervious surfaces, and mitigation strategies. However, less attention has been given to how professional maturity influences practitioners' perceptions of tree survivability. This gap is important because decisions regarding tree retention are not shaped by tree condition alone, but also by how professionals interpret risk, resilience, and the potential for successful mitigation. In the Malaysian context, this relationship remains underexplored, particularly among landscape architects who are involved in planning and design decisions affecting retained trees.

METHODOLOGY

This study employed a cross sectional survey design involving Graduate Members and Corporate Members of the Institute of Landscape Architects Malaysia (ILAM). Participants were selected using a simple random sampling technique from the 2021/2022 ILAM membership registry.

Participants

The target population consisted of 829 eligible Graduate Members and Corporate Members listed in the 2021/2022 ILAM membership registry. Based on the sample size table developed by Krejcie and Morgan (1970), the minimum required sample size for a population of 829 was 262 respondents. A total of 265 valid responses were obtained and included in the final analysis, exceeding the minimum sample size requirement. The data collection process was conducted over a six-month period, and the survey achieved a response rate of 77% based on the number of questionnaires distributed and returned. Although the sampling frame was based on the national ILAM membership registry, the analysis focused on years of professional experience rather than regional distribution, sectoral background, or practice type. Therefore, the findings should be interpreted in relation to professional maturity among ILAM Graduate and Corporate Members, rather than as a comparison across different regional or organisational categories. Respondents were grouped into five experience categories: 1–5 years, 6–10 years, 11–15 years, 16–20 years, and over 21 years. This classification was used to capture variations in professional maturity across different career stages.

Measurement and Analysis

Perceptions of tree survivability were measured using a single-item statement: *"Trees that are retained are unable to survive".* This item was used as a direct indicator of respondents' skepticism toward retained tree survivability, as it specifically reflects the core perception examined in this study. Respondents rated their level of agreement on a five-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Higher scores indicated stronger skepticism toward the survivability of retained trees. Data were analyzed using IBM SPSS Statistics Version 26. Descriptive statistics (mean and standard deviation) were first calculated to summarize response patterns across experience groups. A one-way analysis of variance (ANOVA) was then conducted to examine whether differences in mean responses were statistically significant across the five experience tiers. Where significant differences were identified, a Tukey HSD post hoc test was applied to determine specific group differences. Statistical significance was assessed at the $p < 0.05$ level.

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RESULTS

Descriptive Statistics

The overall mean score for the perception that retained trees are unable to survive was M = 3.89 (SD = 1.02), indicating a general tendency among respondents to agree with the statement. A breakdown by experience level shows variation in perception across professional maturity groups (Table 1). Practitioners with 1–5 years of experience reported the highest level of agreement (M = 4.21, SD = 0.890), suggesting a strong belief that trees are unlikely to survive construction stressors. In contrast, those with more than 21 years of experience reported the lowest agreement (M = 3.04, SD = 1.091), suggesting a more moderate perception of tree retention outcomes. The intermediate groups (6 to 20 years) showed relatively stable mean values ranging from 3.78 to 3.95.

Table 1: Descriptive Statistics of Respondents' Perceptions of Retained Tree Failure by Years of Professional Experience

Professional Experience	N	Mean (M)	Std. Deviation (SD)	95% Confidence Interval
1–5 years	81	4.21	0.890	4.01 – 4.41
6–10 years	82	3.85	1.044	3.62 – 4.08
11–15 years	43	3.95	0.925	3.67 – 4.24
16–20 years	32	3.78	0.941	3.44 – 4.12
21 years and above	27	3.04	1.091	2.61 – 3.47
Total	**265**	**3.89**	**1.020**	**3.76 – 4.01**



Figure 1: Mean Perception Scores by Years of Experience

As illustrated in Figure 1, the mean scores remained relatively high among practitioners with up to 20 years of experience, before declining among those with more than 21 years of experience. This pattern suggests that perceptions of retained tree survivability become less skeptical among the most experienced practitioners. However, the 21-year point should be interpreted as an observed pattern within this dataset rather than a fixed professional threshold.

Inferential Analysis (One-Way ANOVA)

Prior to conducting the one-way ANOVA, the assumptions of independence, normality, and homogeneity of variance were assessed. The independence assumption was addressed through the survey design, as each respondent completed the questionnaire only once. The normality assumption was assessed using the Shapiro-Wilk test. The results indicated significant departures from normality across the experience groups. However, this result was expected due to the use of a five-point Likert scale, and the one-way ANOVA was retained because of the relatively large sample size. Homogeneity of variance was assessed using Levene's test. The result was not significant, F (4, 260) = 1.085, p = .364, indicating that the assumption of homogeneity of variance was met. Therefore, the one-way ANOVA and Tukey HSD post hoc test were considered appropriate for further analysis. A one-way analysis of variance (ANOVA) was conducted to examine whether perceptions of tree survivability differed significantly across the five professional experience groups. Prior to the analysis, the following hypotheses were formulated:

H_0: There is no significant difference in perceptions of tree survivability among landscape architects across different levels of professional experience.

H_1: There is a significant difference in perceptions of tree survivability among landscape architects across different levels of professional experience.

As shown in Table 2, the ANOVA results revealed a statistically significant difference in mean scores across the five professional experience groups, F (4, 260) = 7.554, p < .001. Therefore, the null hypothesis was rejected. This finding indicates that perceptions of tree survivability differ significantly according to years of professional experience. The effect size, calculated using eta squared (η^2), was 0.104, indicating that approximately 10.4% of the variance in perceptions of tree survivability was associated with professional experience. This suggests that professional experience has practical relevance in shaping perceptions, although other factors may also contribute to these differences. Since the ANOVA result only indicates that a significant difference exists among the

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groups, a Tukey HSD post hoc test was conducted to identify the specific experience groups that differed significantly.

Table 2: One-Way ANOVA Results for Perceptions of Tree Survivability Across Professional Experience Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	28.589	4	7.147	7.554	0.000
Within Groups	246.015	260	0.946		
Total	**274.604**	**264**			

Post Hoc Analysis (Tukey HSD)

A Tukey HSD post hoc analysis was performed to isolate specific group variances regarding the perceived failure of retained trees. The analysis identifies practitioners with 21 years of experience and above as a statistically distinct cohort, differing significantly from every other experience category.

Table 3: Tukey HSD Post Hoc Comparison of Perceptions of Tree Survivability by Years of Field Experience

(I) Years of Experience	(J) Years of Experience	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1–5 years	6–10 years	0.356	0.152	0.136	-0.06	0.77
	11–15 years	0.256	0.184	0.630	-0.25	0.76
	16–20 years	0.429	0.203	0.219	-0.13	0.99
	21 years and above	1.173*	0.216	0.000	0.58	1.77
6–10 years	1–5 years	-0.356	0.152	0.136	-0.77	0.06
	11–15 years	-0.100	0.183	0.982	-0.60	0.40
	16–20 years	0.072	0.203	0.997	-0.48	0.63
	21 years and above	0.817*	0.216	0.002	0.22	1.41
11–15 years	1–5 years	-0.256	0.184	0.630	-0.76	0.25
	6–10 years	0.100	0.183	0.982	-0.40	0.60
	16–20 years	0.172	0.227	0.942	-0.45	0.80
	21 years and above	0.916*	0.239	0.001	0.26	1.57
16–20 years	1–5 years	-0.429	0.203	0.219	-0.99	0.13
	6–10 years	-0.072	0.203	0.997	-0.63	0.48
	11–15 years	-0.172	0.227	0.942	-0.80	0.45
	21 years and above	0.744*	0.254	0.030	0.05	1.44
21 years and above	1–5 years	-1.173*	0.216	0.000	-1.77	-0.58
	6–10 years	-0.817*	0.216	0.002	-1.41	-0.22
	11–15 years	-0.916*	0.239	0.001	-1.57	-0.26
	16–20 years	-0.744*	0.254	0.030	-1.44	-0.05

*. The mean difference is significant at the 0.05 level.

As detailed in Table 3, the most substantial divergence was recorded between the most senior practitioners and the 1–5 years cohort (MD = 1.173, $p < 0.001$). Significant differences were also maintained against the 6–10 years group (MD = 0.817, p = 0.002), the 11–15 years group (MD = 0.916, p = .001), and the 16–20 years group (MD = 0.744, p = 0.030). These findings suggest that differences in perception become more pronounced among practitioners with more than two decades of professional experience.

DISCUSSION

The findings indicate that perceptions of tree survivability differ according to practitioners' years of professional experience. Although the descriptive results show a general reduction in skepticism as experience increases, the most noticeable difference was found among practitioners with more than 21 years of experience. This group recorded the lowest agreement with the statement that retained trees are unable to survive (M = 3.04), suggesting that they hold a more moderate view of tree retention compared with less experienced practitioners. The lower agreement among practitioners with more than 21 years of experience may reflect accumulated field exposure. Having observed different tree retention outcomes across various project stages, senior practitioners may assess retained tree survivability more contextually. Therefore, the observed difference should not be interpreted as evidence that experience alone determines perception.

This pattern reflects the role of field experience in shaping practitioners' perceptions of retained tree survivability. More experienced landscape architects have encountered a wider range of site conditions and tree retention outcomes, including cases where retained trees survived through appropriate mitigation, maintenance, and monitoring. This exposure helps explain why they are less likely to assume that retained trees will fail. On the other hand, less experienced practitioners tend to be more cautious, particularly when construction activities are commonly associated with soil disturbance, root damage, compaction, and delayed tree decline. These concerns are consistent with recent discussions on urban tree stress, where limited soil volume, sealed surfaces, construction-related root damage, and poor management continue to affect tree performance in built environments (Egerer et al., 2024). The interpretation also relates to Koeser and Smiley (2017), who noted that professional background, training, and experience can influence how tree-related conditions are interpreted.

The higher agreement among practitioners with 1–5 years of experience (M = 4.21, SD = 0.890) suggests that early-career practitioners may be more likely to view retained trees as vulnerable in development areas. This perception is understandable, as construction activities are often associated with soil

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disturbance, root damage, compaction, and delayed tree decline. Cybula et al. (2026), for example, found that impervious surfaces did not necessarily reduce urban tree crown growth, suggesting that tree response may vary depending on species, site conditions, and management practices. This supports the view that the survival of retained trees is often conditional rather than predetermined.

The findings also show that the most experienced group recorded the highest standard deviation (SD = 1.091). This suggests that senior practitioners do not necessarily share one fixed view of retained tree survivability. Rather, their responses may reflect different project histories, site experiences, and practical knowledge accumulated over time. Experienced practitioners may assess retained trees more contextually by considering site constraints, previous retention outcomes, and available mitigation measures. This is in line with recent urban tree survivorship research, which shows that tree survival can vary across establishment and post-establishment stages depending on site-level and management-related factors (Nelson et al., 2025).

The results also relate to Suchocka, Jankowski, et al. (2019), who found that awareness of tree value does not always lead to effective tree protection on construction sites. In practice, retained trees may still be exposed to inadequate protection, poor soil conditions, and weak post-construction maintenance. These situations can reinforce the perception that retained trees are unlikely to survive. For less experienced practitioners, limited exposure to successful retention cases may further strengthen this cautious perception. In contrast, practitioners with longer experience may have seen how site planning, technical intervention, and aftercare can improve tree survival outcomes.

These findings suggest that differences in perception across experience levels should be addressed through more targeted professional development. General awareness of tree value is useful, but it may not be sufficient. Practitioners also need clearer guidance on tree protection zones, soil remediation, root protection, monitoring, and post-construction care. This is consistent with Zur et al. (2025), who showed that structured criteria and defined protocols can support more consistent tree-related evaluations among non-experts.

From a planning and practice perspective, tree survivability decisions should be supported by clearer professional guidance, continuous professional development, and collaboration with certified arborists. Training should emphasise tree biology, construction-phase protection, root zone management, soil remediation, and post-construction monitoring. Early consultation between landscape architects, arborists, local authorities, and project consultants may help ensure that tree retention decisions are based on site-specific evidence rather than general assumptions about tree failure.

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Overall, the study suggests that professional maturity plays a role in shaping how landscape architects perceive the survivability of retained trees. Experience alone does not guarantee better judgment, but accumulated field exposure may help practitioners develop a more balanced understanding of tree retention. By focusing on professional maturity, this study adds to the discussion on urban tree retention by showing that practitioner perception is also relevant, alongside biological and technical considerations. This finding has practical implications for training, knowledge sharing, and early professional involvement in tree retention decisions.

CONCLUSION

This study examined how professional maturity, measured by years of field experience, influences perceptions of retained tree survivability among landscape architects in Malaysia. The findings show that perceptions differ significantly across experience groups. Practitioners with 1–5 years of experience recorded the highest agreement that retained trees are unable to survive, while those with more than 21 years of experience recorded the lowest agreement. This suggests that longer field experience is associated with a more moderate view of tree retention outcomes.

The study contributes to urban tree retention research by showing that tree survivability is not only interpreted through biological and technical factors, but also through practitioner perception and professional experience. This finding is relevant to planning practice because perceptions of tree survivability may influence development control, landscape approval, tree preservation implementation, and construction site protection decisions. Professional maturity should therefore be considered in practice through mentoring systems, technical review panels, and early involvement of experienced practitioners in projects involving retained trees.

Several limitations should be acknowledged. The study used a cross-sectional survey and measured perception using a single statement, which may not fully capture the complexity of tree retention decisions. The respondents were also limited to ILAM Graduate and Corporate Members and were not stratified by region, sector, or practice type. Future research should include other professionals such as arborists, planners, engineers, local authorities, and developers. Longitudinal studies may also provide deeper understanding of how professional experience, training, project exposure, and arboricultural knowledge shape perceptions of tree survivability over time.

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FROM FRAGMENTATION TO INTEGRATION: DEVELOPING AN INTERDISCIPLINARY DATA SHARING FRAMEWORK FOR SURVEYING PRACTICE IN MALAYSIA'S DIGITAL BUILT ENVIRONMENT

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Abstract

The rapid digital transformation of the built environment has increased the need for effective interdisciplinary data sharing within surveying practice in Malaysia. However, persistent fragmentation across technical systems, organisational structures, and professional workflows continues to hinder seamless integration. This study aims to develop a structured interdisciplinary data sharing framework tailored to Malaysia's digital built environment. A qualitative research design was adopted using semi-structured interviews with 12 experts from multiple surveying disciplines under the Royal Institution of Surveyors Malaysia (RISM). The data were analysed through thematic analysis to identify recurring barriers, opportunities, and governance requirements. The findings reveal that data fragmentation is shaped by three interconnected dimensions: technical interoperability barriers, organisational and contractual constraints, and behavioural and collaborative culture challenges. In response, the study proposes an empirically informed socio technical framework that integrates interoperable digital infrastructure, governance mechanisms, and lifecycle collaborative workflows, based on insights from a purposively selected group of RISM affiliated experts. The study contributes theoretically by advancing understanding of interdisciplinary data sharing challenges in surveying practice and, practically, by offering a framework for policymakers and industry practitioners. Its novelty lies in its context specific focus on surveying data sharing and in the development of an empirically grounded framework that is intended to inform data sharing practices within the Malaysian surveying context. Future research should incorporate broader industry participation and industry based case implementation.

Keywords: Data digital; Digital built environment; Interdisciplinary data sharing; Surveying practice; Malaysia

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INTRODUCTION

The rapid digital transformation of the built environment has fundamentally reshaped the manner in which surveying professionals generate, manage, and exchange spatial and non-spatial data. Within the context of Malaysia's evolving digital construction ecosystem, the increasing adoption of technologies such as Building Information Modelling (BIM), Geographic Information Systems (GIS), remote sensing, cloud-based collaboration platforms, value creation, and digital twins has intensified the need for efficient interdisciplinary data sharing (Abdul Rahman et al., 2026; Nashruddin et al., 2024; Sunandar et al., 2025d).

Surveying practice no longer operates in isolation; rather, it is increasingly embedded within a broader network of architects, engineers, planners, quantity surveyors, contractors, and government agencies (Sayyidqosimov et al., 2025; Wei et al., 2024; Wu et al., 2025). This interconnected professional landscape demands seamless data interoperability to support informed decision-making, project coordination, and life cycle asset management across the digital built environment (Ma et al., 2025; Sun et al., 2025).

Despite these technological advancements, data sharing within surveying practice remains highly fragmented (Berlato et al., 2025; Lai et al., 2025; Parece et al., 2025). Data are often produced and stored in discipline-specific formats, managed through incompatible software environments, and governed by inconsistent organisational protocols (Ebid et al., 2025). Such fragmentation restricts the effective integration of surveying information into multidisciplinary workflows, leading to inefficiencies, duplication of work, communication breakdowns, and reduced data reliability (Ma et al., 2025; Sun et al., 2025).

In Malaysia, these issues are further compounded by variations in institutional readiness, uneven levels of digital maturity, and the absence of standardised cross-disciplinary mechanisms for surveying data governance. As the construction industry moves towards integrated digital delivery, addressing these barriers has become both an academic and a practical imperative (Construction Industry Development Board Malaysia, 2020).

The central problem underpinning this research lies in the persistent disconnect between technological capability and practical implementation. While existing digital tools offer considerable potential for data integration, the actual sharing of surveying data across disciplines remains constrained by technical incompatibility, the lack of common standards, concerns regarding data ownership, inconsistent metadata structures, and limited institutional collaboration (AlMashaan & AlMaian, 2025; Dong & Qin, 2025; Sun et al., 2025; Wang et al., 2023). These challenges hinder the realisation of a fully integrated

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digital built environment and may compromise project performance, decision accuracy, and long-term data sustainability.

A critical review of the literature reveals a significant research gap in the development of interdisciplinary frameworks specifically designed for surveying practice in Malaysia. Although previous studies have examined broader data sharing ecosystems within the built environment, they generally focus on cross sector digital integration, platform architectures, or generic information management. In contrast, this study specifically examines interdisciplinary data sharing within surveying practice, emphasising the unique professional workflows, governance arrangements, and interoperability requirements among surveying disciplines in the Malaysian context.

The novelty of this study lies in its interdisciplinary and context specific approach to framework development. Unlike broader studies that conceptualise data sharing ecosystems at the general built environment level, this research develops a surveying specific framework grounded in empirical evidence from Malaysian surveying professionals. By integrating technical interoperability, governance mechanisms, and collaborative workflows within the context of surveying practice, the proposed framework provides a more profession focused perspective on digital data sharing.

This study contributes to the body of knowledge in three principal ways. First, it advances the theoretical understanding of interdisciplinary data sharing challenges within the surveying profession. Second, it provides an empirically informed framework that may serve as a reference for policymakers, professional bodies, and industry practitioners in Malaysia. Third, it offers practical guidance for improving digital collaboration strategies within the broader built environment ecosystem.

More specifically, the study seeks to develop a structured and contextually relevant framework that addresses the technical, organisational, and procedural challenges associated with data exchange among multiple stakeholders. In doing so, the research aims to support greater interoperability, improve collaborative efficiency, and strengthen the role of surveying data as a strategic asset in digital construction processes. Accordingly, the research is guided by two main objectives (RO). RO1 is to identify the key thematic factors influencing interdisciplinary data sharing in surveying practice within Malaysia's digital built environment. RO2 is to develop an interdisciplinary data sharing framework across surveying and related built environment disciplines.

RESEARCH METHODOLOGY

Data Collection

This study adopted a qualitative research design to explore the complexities of interdisciplinary data sharing within surveying practice in Malaysia's digital built

environment. Given the exploratory nature of the research objectives, semi-structured interviews were employed as the primary method of data collection (Sunandar, Abd Karim, et al., 2026b). Semi-structured interviews offer the flexibility required to investigate complex professional issues while maintaining sufficient consistency across participants (Shakur et al., 2021; Sunandar, Andriyanti, et al., 2026a). The respondents were selected using a purposive sampling strategy. In this study, the selection criteria focused on professionals who were actively involved in surveying practice and held recognised roles within the Royal Institution of Surveyors Malaysia (RISM). The inclusion of RISM members ensured that the participants possessed professional credibility, practical exposure, and disciplinary expertise within Malaysia's surveying ecosystem.

A total of 12 experts were interviewed, at which point data saturation was achieved, as no new themes or insights emerged from the subsequent interviews (Saunders et al., 2018). The participants represented diverse surveying disciplines, including Building Surveying (BS), Geomatics and Land Surveying (GLS), Property Surveying (PS), and Quantity Surveying (QS). They comprised individuals from various professional backgrounds, including academia, government agencies, consultancy, business practice, and directorial roles. In addition, several participants held senior professional positions within RISM, such as fellows, committee members, and ordinary members. This diversity was intentionally sought to capture a broad range of interdisciplinary perspectives and institutional experiences related to data sharing practices. The profile of the participants is presented in Table 1. The interview protocol was organised into three principal parts to ensure alignment with the study objectives. The first part focused on barriers to effective data sharing, exploring the technical, organisational, and procedural constraints experienced by experts when exchanging data across disciplines. The second part addressed opportunities and expectations for data sharing integration. The third part centred on governance and future direction, investigating policy frameworks, institutional responsibilities, professional standards, and strategic recommendations for enhancing long-term interdisciplinary collaboration. All interviews were conducted in a manner that ensured consistency, ethical integrity, and confidentiality (Knott et al., 2022; Sunandar et al., 2025b). The interview responses, obtained through both verbal and written formats, were subsequently transcribed verbatim to facilitate systematic qualitative analysis.

Table 1: Details of Experts

Code	Professional Status	Role in RISM	Discipline
R1	Business Practice, Academic, Consultant	Member	BS
R2	Academic, Consultant	Fellow	BS
R3	Government Officer	Fellow	BS

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Code	Professional Status	Role in RISM	Discipline
R4	Consultant, Director	Graduate	GLS
R5	Academic, Government Officer	Fellow, Committee	PS
R6	Business Practice	Member	PS
R7	Business Practice, Consultant	Fellow, Committee	PS
R8	Consultant, Director	Fellow	PS
R9	Academic	Member	QS
R10	Business Practice	Fellow, Committee	QS
R11	Business Practice, Director	Member	QS
R12	Business Practice	Member	QS

Source: Author's Own Creation (2026)

Data Analysis

The collected interview data were analysed using thematic analysis, a widely accepted qualitative analytical technique for identifying, organising, and interpreting patterns of meaning within textual data (Sunandar, Abd Karim, et al., 2026a; Sunandar et al., 2025c). The analytical process began with data familiarisation, during which all interview transcripts were read repeatedly to develop a comprehensive understanding of the content and contextual nuances of the participants' responses (Braun & Clarke, 2021; Saldana, 2021). The second stage involved open coding, whereby meaningful segments. Similar codes were then compared and merged through constant comparison into higher order categories based on conceptual similarity. Finally, these categories were synthesised into three overarching themes. This iterative process established a transparent analytical pathway from initial codes to categories and themes. To enhance the credibility and consistency of the analysis, the coding process was conducted iteratively and independently reviewed by the research team (Sunandar, Andriyanti, et al., 2026b; Sunandar et al., 2025a). Coding decisions, category definitions, and theme boundaries were discussed until consensus was achieved, thereby reducing individual researcher bias and strengthening analytical reliability. The resulting themes formed the empirical basis for addressing RO1 and subsequently informed the development of the interdisciplinary data sharing framework under RO2.

ANALYSIS AND DISCUSSION

Thematic 1: Barriers to Effective Interdisciplinary Data Sharing

The first major theme emerging from the interview data concerns the barriers that continue to constrain effective interdisciplinary data sharing within surveying practice in Malaysia's digital built environment. Thematic analysis of responses reveals that these barriers extend beyond purely technical issues and are deeply embedded in organisational structures, contractual arrangements, and professional culture. Across participants, three interrelated categories were consistently identified: technical and system interoperability barriers,

organisational and contractual constraints, and behavioural and collaborative culture challenges. Collectively, these categories demonstrate that fragmentation in data sharing is not solely a matter of software incompatibility, but a multidimensional issue involving governance, trust, and professional behaviour. The findings further indicate that the persistence of fragmented data ecosystems is reinforced by both structural and human factors, thereby necessitating an integrated framework that addresses these dimensions simultaneously. The key thematic coding derived from the interviews is summarised in Table 2.

Table 2: Thematic Summary for Barriers to Effective Data Sharing

Category	Coding	Source
Technical and system interoperability barriers	Incompatible software platforms; interoperability gaps; data loss during transfer; legacy systems; inconsistent file formats; manual data re-entry; lack of common standards; version incompatibility; limited automation; security access restrictions	R1, R2, R3, R4, R6, R9, R12
Organisational and contractual constraints	Unclear data ownership; liability concerns; intellectual property protection; confidentiality restrictions; contractual scope limitations; organisational silos; lack of SOPs; accountability ambiguity; absence of data governance	R1, R2, R3, R4, R5, R6, R9, R12
Behavioural and collaborative culture challenges	Silo mentality; low trust; defensive attitudes; knowledge protectionism; reluctance to digitise; weak collaboration culture; compliance driven sharing; fear of blame; selective information disclosure	R1, R2, R3, R4, R6, R7, R9, R10, R12

Source: Author's Own Creation (2026)

The first category, technical and system interoperability barriers, highlights the operational challenges faced by practitioners when exchanging data across multiple digital platforms. Respondents consistently emphasised incompatibility between BIM, CAD, GIS, spreadsheets, and legacy systems as a major obstacle. As R2 explained, "importing a structural engineer's model into our architectural software often results in data loss or geometry errors," illustrating persistent interoperability limitations across digital platforms. Similarly, R3 observed that "different systems are not fully integrated, making data sharing slow and fragmented," while R12 noted that compatibility issues frequently require manual coordination across disciplines. The continued reliance on manual re-entry and platform specific formats increases the risk of duplication, inaccuracy, and delay, ultimately weakening data reliability across project life cycles (R3, R9, R12).

The second category, organisational and contractual constraints, reflects the institutional barriers that restrict effective data exchange. Several respondents emphasised that unclear contractual provisions regarding ownership, liability, and access rights discourage professionals from sharing raw data openly.

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As R2 explained, "we lock data in PDFs" because sharing editable files increases professional liability. Likewise, R4 observed that "the absence of clear Standard Operating Procedures for data handling" creates uncertainty regarding third party data sharing responsibilities. At the organisational level, silo based structures and the lack of formal standard operating procedures further reinforce fragmentation (R3, R4). Confidentiality concerns, particularly in relation to government sensitive and client related information, also emerged as significant constraints (R5, R11, R12). These findings indicate that technical solutions alone are insufficient without clear governance mechanisms and contractual alignment.

The third category, behavioural and collaborative culture challenges, reveals that human and professional attitudes significantly shape data sharing practices. Trust emerged as a central issue influencing data sharing practices. R2 described a persistent "check it yourself" culture in which professionals continue to verify information independently despite receiving digital datasets from other disciplines. Similarly, R6 referred to a historical culture of "data protectionism," whereas R7 succinctly characterised current practice as "all secretive." Conversely, respondents acknowledged that stronger knowledge sharing cultures and clearly mandated collaborative requirements could improve transparency and interdisciplinary coordination (R3, R11). This finding demonstrates that cultural transformation is as critical as technological innovation in achieving effective data integration.

Thematic 2: Opportunities and Framework Design Principles

The second major theme focuses on the opportunities for improving interdisciplinary data integration and the essential design principles required for an effective framework. Responses reveal a strong consensus that the current fragmented environment can be substantially improved through standardisation, shared digital platforms, and lifecycle oriented data governance. Two major categories emerged from the analysis: integration opportunities and framework design principles. The thematic coding is summarised in Table 3.

Table 3: Thematic Summary for Barriers to Effective Data Sharing

Category	Coding	Source
Opportunities for interdisciplinary integration	Standardised data formats; centralised digital platform; API integration; metadata tagging; predictive maintenance; digital twins; lifecycle continuity; real time data access; cross disciplinary visibility	R1, R2, R3, R4, R6, R9, R11, R12
Framework design principles	Interoperability; standard definitions; role clarity; version control; data provenance; tiered access; accountability; vendor neutrality; lifecycle usability	R1, R2, R3, R4, R6, R9, R10, R12

Source: Author's Own Creation (2026)

The first category, opportunities for interdisciplinary integration, highlights the significant potential for improving collaboration across surveying disciplines. Respondents identified centralised digital platforms, open standards, and metadata integration as key opportunities for improving collaboration. R2 highlighted the importance of maintaining a "Golden Thread" of information throughout the building lifecycle, while R6 advocated "API driven market data" and standardised metadata to facilitate real time information exchange. The findings suggest that future integration should move beyond isolated project delivery and instead support continuous information flow throughout planning, construction, operation, and maintenance phases (R2, R3, R9, R12).

The second category, framework design principles, defines the critical features required for a practical and effective interdisciplinary data sharing framework. Participants consistently emphasised interoperability, accountability, and standardisation. As R6 stated, "data must be platform agnostic," while R3 argued that surveyors require "clear roles, ownership and professional accountability" to support reliable interdisciplinary collaboration. Equally important were governance oriented principles such as role clarity, accountability, and version control (R3, R12). These findings indicate that the proposed framework must balance technological functionality with institutional trust and professional accountability, ensuring both usability and legal defensibility.

Thematic 3: Governance and Future Digital Direction

The third theme addresses the strategic governance mechanisms and future digital directions necessary to sustain secure and effective interdisciplinary data sharing. The findings indicate that long-term integration requires strong institutional leadership, nationally aligned standards, and compatibility with emerging digital initiatives. Two categories were identified: governance and institutional support, and alignment with emerging digital initiatives. Table 4 summarises the thematic coding.

Table 4: Thematic Summary for Governance and Future Direction

Category	Coding	Source
Governance and institutional support	National standards; SOPs; cybersecurity; professional mandates; ethical governance; training; regulatory oversight; secure access control; policy alignment	R1, R2, R3, R4, R6, R9, R10, R11, R12
Alignment with emerging digital initiatives	BIM integration; GIS interoperability; digital twins; asset lifecycle support; integrated digital delivery; technology neutrality; national transformation alignment; platform flexibility	R1, R2, R3, R4, R6, R9, R11, R12

Source: Author's Own Creation (2026)

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The first category, governance and institutional support, demonstrates that effective data sharing requires formal regulatory and professional oversight. Respondents consistently pointed to the need for nationally recognised standards and stronger institutional leadership. R2 recommended "professional body mandates" together with "standardised data protocols," whereas R6 advocated a "National Property Data Standard" supported by regulatory oversight. These findings suggest that governance must operate across policy, organisational, and project levels to ensure consistency and accountability.

The second category, alignment with emerging digital initiatives, reflects the necessity of designing a framework that supports BIM, GIS, digital twins, and national digital transformation agendas. Respondents emphasised that future frameworks should support interoperable digital ecosystems rather than isolated technologies. R3 argued that the framework should be "asset centric, not project centric," while R6 emphasised that BIM should evolve into "6D BIM" by integrating valuation and lifecycle costing information. Alignment with national initiatives such as integrated digital delivery and broader digital transformation policies was viewed as essential for long-term relevance and scalability (R4, R6, R12). This finding strongly supports the development of a forward looking framework that can remain adaptable to future technological advancements within Malaysia's digital built environment.

Development of the Interdisciplinary Data Sharing Framework

The proposed interdisciplinary data sharing framework was developed directly from the thematic analysis of the interview data rather than being predetermined from existing theoretical models. The three overarching themes identified through the coding process served as the primary analytical foundation for the framework. Figure 1 presents the resulting framework, which consists of five interrelated components: technical interoperability, organisational governance, access control, lifecycle collaborative workflow, and professional responsibility. Each component corresponds directly to one or more themes generated through the thematic analysis. Rather than representing an abstract conceptual model, the framework constitutes an empirical synthesis of the recurring issues, opportunities, and governance requirements consistently identified across the expert interviews. The framework subsequently underwent an expert review through presentations to the respective RISM surveying divisions and at the RISM Conference 2026, where constructive professional feedback was incorporated to refine the framework presentation and clarify stakeholder responsibilities.

The first component of the framework focuses on technical interoperability and digital infrastructure integration. This layer addresses the operational barriers associated with incompatible software platforms,

inconsistent data formats, and manual data transfer processes identified under Thematic 1. At the core of this component is the establishment of a centralised interoperable digital platform capable of integrating BIM, GIS, remote sensing outputs, cost databases, and asset management systems. The framework advocates the use of standardised data schemas, metadata protocols, and vendor neutral exchange formats. API based connectivity and cloud enabled database architecture are incorporated to support real time data access, version synchronisation, and automated updating of shared datasets. By embedding interoperability as a foundational principle, the framework reduces duplication, minimises data loss during transfer, and enhances the usability of surveying data across planning, design, construction, and operational stages. Nevertheless, successful implementation requires considerable organisational investment in digital infrastructure, system integration, and workforce capability development. Smaller surveying firms may experience financial constraints when upgrading legacy systems and adopting interoperable digital platforms, suggesting that implementation should be undertaken progressively according to organisational readiness.

Figure 1: Interdisciplinary Data Sharing Framework
Source: Author's Own Creation (2026)

The second component addresses organisational governance and institutional control mechanisms. The empirical findings clearly demonstrate that technical solutions alone are insufficient in the absence of robust governance structures. Accordingly, this component introduces a formal governance layer that defines data ownership, access rights, accountability structures, and standard operating procedures for interdisciplinary data exchange. Tiered access control is

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proposed to ensure that data confidentiality, intellectual property protection, and cybersecurity requirements are maintained without undermining collaborative efficiency. Access permissions are assigned according to stakeholder roles and project responsibilities, ensuring that authorised users can create, modify, validate, or retrieve data while maintaining transparency, accountability, and data security throughout the project lifecycle. Ethical governance, legal liability provisions, and data sharing protocols are embedded to strengthen institutional trust and reduce ambiguity regarding information use and ownership. This governance component is essential in creating a defensible and professionally credible structure capable of supporting both public and private sector implementation.

The third component emphasises collaborative workflow integration and lifecycle continuity, which directly responds to the behavioural and cultural barriers identified in the thematic findings. The framework recognises that sustainable data sharing cannot be achieved without strengthening the collaborative culture among professionals. This includes defined procedures for data validation, collaborative review, and cross disciplinary feedback loops to minimise silo based decision making. Professional responsibility is embedded by assigning clear responsibilities for data creation, verification, updating, and approval to each participating discipline, thereby improving data quality, reducing duplication, and strengthening accountability throughout the information lifecycle.

To facilitate practical implementation, the framework operationalises professional responsibility by assigning complementary roles to the principal stakeholders within Malaysia's digital built environment. RISM may serve as the professional coordinator by promoting common data standards, competency development, and interdisciplinary practice guidelines. Government agencies may provide regulatory oversight through standard operating procedures, cybersecurity requirements, and alignment with national digital transformation initiatives. Private surveying firms may operationalise the framework by adopting interoperable BIM and GIS workflows, standardised metadata, and internal data governance procedures. Project teams, including surveyors, architects, engineers, contractors, and asset managers, are responsible for coordinated lifecycle information management, role based data access, interdisciplinary data validation, and timely updating of shared datasets to ensure consistent, reliable, and accountable information exchange across all project phases.

CONCLUSION

This study concludes that interdisciplinary data sharing within surveying practice in Malaysia's digital built environment remains constrained by interconnected technical, organisational, and behavioural barriers. The findings demonstrate that

fragmentation is not merely a technological issue, but is also deeply influenced by ambiguities in governance, contractual limitations, and a weak culture of collaboration across professional disciplines. In response, this research developed a structured interdisciplinary data sharing framework that integrates technical interoperability, governance mechanisms, and lifecycle collaborative workflows to support more effective and sustainable data exchange. The novelty of this study lies in its context specific and socio technical approach to framework development. Unlike previous studies that have primarily focused on isolated technological solutions, this research advances a holistic framework grounded in empirical insights obtained from multidisciplinary surveying experts within the Malaysian context. This offers a more realistic and practice oriented model for addressing local institutional and professional challenges.

The study contributes theoretically by extending the current understanding of data interoperability challenges in surveying practice and contributes practically by offering a reference framework for policymakers, professional bodies, and industry practitioners. To facilitate practical implementation, a staged adoption pathway is recommended. The initial stage should prioritise the establishment of common data standards, governance policies, and stakeholder capacity building. The second stage should focus on implementing interoperable digital platforms, standardised metadata, and role based access control across surveying disciplines. The final stage should promote lifecycle data integration through BIM, GIS, digital twins, and continuous institutional monitoring to support integrated project delivery and long term asset management. Nevertheless, the study is limited by its qualitative scope and the purposive sampling of RISM members. Future research should validate the proposed framework through broader industry participation and case based implementation studies across different built environment projects in Malaysia.

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DISCLOSURE

The authors declare that there is no conflict of interest associated with this research.

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MITIGATING MAINTENANCE COST OVERRUNS IN NON-STRATIFIED GATED AND GUARDED COMMUNITY (GACOS) DEVELOPMENT

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Abstract

Maintenance cost overruns have become a significant challenge in non-stratified Gated and Guarded Community (GACOS) housing scheme in Malaysia, leading to financial strain on property owners and affecting the overall performance and longevity of buildings. In contrast to stratified developments where maintenance costs are managed through a maintenance account fund and a formal management body governed under the Strata Title Act 1985 (Act 318) and Strata Management Act 2013 (Act 757), non-stratified properties including GACOS often lack a structured approach to ensure sufficient financial planning and cost control. In addition to the absence of legal frameworks that govern maintenance and management of the non-stratified properties, a clear strategy to overcome cost overruns in GACOS has also not received adequate attention in existing research. Therefore, this paper attempts to explore key factors contributing to maintenance cost overruns in non-stratified developments and propose practical solutions to mitigate these issues. Two focus group discussions with 13 and 16 participants in each group were conducted to examine stakeholders' perspectives regarding root causes of cost overruns and recommendations to prevent maintenance cost overruns for GACOS. The findings demonstrated that cost overruns in GACOS were exacerbated following to the absence of legislative frameworks, financial management problem, and ineffective maintenance practices. The paper ends with the conclusion that handover the facilities and infrastructure to local authority, long term strategic and saving planning, fund raising, active participation and collaboration, structured in-house teams, and termination of redundant facilities could improve overall cost efficiency. This research contributes to the limited body of knowledge on the long-term management of non-stratified GACOS by foregrounding resident-driven strategies that enable financial resilience and operational sustainability.

Keywords: Cost Overruns, Gated and Guarded Community (GACOS), Maintenance, Non-Stratified, Strategies

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INTRODUCTION

The concept of Gated and Guarded Community Housing Scheme or GACOS is gaining traction globally and is particularly prevalent in urban areas of many countries such as the United States of America, Latin America, Canada, England, China, Hong Kong, and South Africa (Pekelsma, 2024; Tan, 2016). Due to their diverse forms across different countries, there is no universally accepted definition of the concept. Existing interpretations typically reflect the specific socio-cultural and economic contexts in which these developments occur. As spelt out by Grange (2018), the various interpretations of gated communities appear very similar in terms of their common characteristics, yet differ considerably in their institutional conte. Gooblar (2010) for example, defined gated communities as residential areas that are characterized by restricted access and the privatization of spaces that are typically public. For Blakely (2007) and Tahir and Hussin (2012), gated communities are neighbourhood areas with controlled access points and enclaved with physical barriers such as walls, fences or gates to restrict entry solely for its residents and authorized visitors. While many scholars focus on physical gating in the current definition of GACOS, others such as Atkinson and Blandy (2006) and Zainudin and Hussin (2015) referred gated communities as walled housing developments to which the residents are bound to a set of rules that is set up either by the developers or through consensus among homeowners. This is important as gated developments typically involve privatization of spaces, facilities and services including internal infrastructure such as roads and drainage that would otherwise fall under the jurisdiction of public authorities (Fernandez, 2007; Gooblar, 2010). Hence, the privatized model of governance necessitates the establishment of the rules in maintaining functionality, safety, and aesthetic quality of the development, in the absence of direct public oversight.

Jones et al. (2003) stated that the concept of gated communities have originated in the United States prior to the 1960s. Growing concerns over urban crime and safety have been claimed as the main driver of GACOS development (Grant, 2005; Muiga & Rukwaro, 2017; Pekelsma, 2024). As stated by Grange (2018), feelings of threat and insecurity is a well-documented reason for strong demand to live behind the gates. The presence of security guards and installation of boom gates as well as security devices have also been identified as common features for gated estate (Tan, 2016; Zainudin & Hussin, 2015). According to Jones et al. (2003), these features are frequently highlighted by developers as key selling points in their marketing strategies. However, Abdul Mohit and Abdulla (2011) argued that GACOS may create false impression of security. For example, drugs worth about RM145 million were raided in two gated and guarded communities in Kuala Lumpur, Malaysia (Thean, 2020). Wu and Tan (2023) further found that neighbourhood safety is influenced not only by the physical

elements of the development but also by its social qualities particularly residents' interactions and awareness. Nevertheless, individuals' perceptions of what constitutes a safe environment contribute to their sense of peace of mind and remain an important influence on residential choice.

Second motivation for choosing to reside in a gated community is the symbolic value it carries, where such developments are often perceived as indicators of social status and income level. Grange (2018) contends that residents of Hong Kong are willing to pay premium prices for GACOS due to prestige image and lifestyle it offers enabling them to distinguish themselves from lower-income households. Similarly, exclusive amenities contribute to residents' identities of eliteness in Egypt cities (Elyamany, 2024). Although GACOS is increasingly seen as a mechanism that divides society along lines of economic status (Alkurdi, 2017; Roitman & Recio, 2020), cities have traditionally been organized in ways that reflect ethnic and religious segregation. In Malaysia, colonial policies produced spatial and economic segregation, with the Chinese community predominantly concentrated in urban centers engaged in commerce and industry, while the Malay and Indian populations were largely situated in suburban areas, typically involved in agriculture and estate labor (Tedong et al., 2015).

The current trend of gated community scheme in Malaysia has resulted in two distinct forms of residential enclaves (Fernandez, 2007; Tedong et al., 2015). In newly developed areas, private developers construct gated communities under strata titles featuring perimeter walls and appealing shared facilities. Conversely, in more established urban neighborhoods, the residents take the initiative to create guarded communities by installing barriers on public roads and employing security personnel to restrict access to non-residents. According to Town and Country Planning Department (2010), the latter comprised of individually titled properties and often emerge on ad-hoc basis without formal oversight or legal regulation. Legally, it is unlawful to have physical barriers on public roads and enforce any restrictions on entry and exit for residents and the public (Choong, 2023). As stated under Section 46(1) of the Street, Drainage and Building Act 1974 (Act 133), any person can be held liable to a fine not exceeding RM500 and subsequent conviction of fine RM1,000 if builds, erects, sets up or maintains any wall, fence, rail, post or any accumulation of any substance, or other obstruction, in any public place without prior written permission of the local authority. Beyond raising legal concerns, the absence of a specific regulatory framework also creates governance and financial management challenges, particularly in coordinating maintenance responsibilities and funding. As a result, non-stratified GACOS frequently experience maintenance cost overruns (Haroon, 2019; Jia & Morrison, 2025; Nik Yahya et al., 2018). Known for offering exclusive amenities, enhanced security, and a high degree of privacy,

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such communities require substantial financial resources to ensure their ongoing upkeep and sustainability. Although extensive research has examined cost overruns in construction projects and general housing developments (Ammar et al., 2026; Chadee et al., 2023; Lee et al., 2022; Mohd Rahim et al., 2025; Soundarya et al., 2025), limited attention has been given to non-stratified gated community schemes which possess unique management and financial arrangements due to absence of a formal strata governance structure. Therefore, this study fills the gap by identifying factors contributing to maintenance cost overruns in non-stratified GACOS and presents realistic strategies to mitigate them based on the development stakeholders' perspectives.

LITERATURE REVIEW

Factors Affecting Cost Overrun in Maintenance of GACOS

The concept of cost overrun which also termed as cost escalation or budget overrun generally refers to a situation where the actual expenditure of a project surpasses its estimated or approved financial allocation. In the context of building maintenance, the term can be more precisely understood as the circumstance in which maintenance expenditures exceed the forecasted or allocated budget due to unplanned costs required to sustain a building's operational performance. Recognizing and addressing the underlying factors that lead to such overruns is crucial, as maintenance-related expenses typically account for a substantial share of a building's total operating costs, often ranging between 20% and 50% (Ali et al., 2010; Obradovic et al., 2024). As highlighted by Mong et al. (2018), the nature of maintenance work is inherently more complex than building construction as it involves sustaining the building's performance throughout its life cycle. Prior research has identified a wide range of factors that contribute to cost overruns such as inadequate contract planning, weak supervision, ineffective coordination and communication between project teams, schedule delays, frequent design and scope alterations, poor management practices, and market price fluctuations (Abdelalim et al., 2025; Daoud et al., 2023; Sohu et al., 2024). However, Widiaputra and Arumsari (2021) argued that these determinants tend to vary depending on the specific phase of a project particularly during planning, implementation, or after completion. Given that the present discussion focuses on mature gated and guarded residential communities, greater attention is placed on the cost overruns that occur during the post-construction phase, where aging buildings often face distinctive operational and financial challenges that demand higher maintenance expenditure and specialized management responses. Due to limited number of studies examining maintenance cost overruns in non-stratified GACOS, this section synthesizes evidence from the broader literature on building and housing maintenance to establish the theoretical basis for understanding the factors that may also influence GACOS.

As a property ages, the cost of maintenance generally rises due to the progressive deterioration of its structural components and service systems (Kwon et al., 2020; Mahpour, 2023; Yasin et al., 2023). Common age-related problems include weakening structures, subsidence, weather-induced damage, and reduced operational performance (Kazar et al., 2024). The authors further added that older buildings often contain outdated infrastructure such as electrical wiring, plumbing, and mechanical systems that are inefficient, unreliable, or unsafe by contemporary standards. These systems typically require costly upgrades or complete replacements to ensure compliance with modern codes and performance expectations. Within older gated and guarded community developments (GACOS), the issue extends to shared amenities such as swimming pools, gymnasiums, community halls, prayer rooms, ornamental parks, and guardhouses which also deteriorate over time and necessitate continuous maintenance (Xuerui & Gabriel, 2022). Without systematic and preventive upkeep, minor defects may evolve into major structural failures that are far more expensive to repair. Implementing preventive maintenance regimes is therefore essential not only for maintaining safety and comfort but also for extending the service life of building components and reducing the risk of unexpected emergency repairs. Nevertheless, in many older GACOS, maintenance tends to be reactive rather than proactive due to poor budget forecasting and limited financial planning, further contributing to cost inefficiencies and overruns (Twum-Bobie et al., 2025). Che-Ghani et al. (2016) highlighted that maintenance should be carried out only when necessary based on the actual condition and performance of the buildings. As supported by Holmes and Droop (1982), maintenance is budget oriented rather than needs-oriented. Adoption of an optimized maintenance strategy is crucial following to the extensive range of shared facilities and infrastructure under private management.

The issue of maintenance cost overrun is further intensified by the lack of formal governance and financial management mechanisms in non-stratified gated communities. The governance structure determines how maintenance responsibilities, financial contributions, and decision making processes are organized. Consequently, the absence of a formal regulatory framework may affect the ability of communities to plan, finance, and implement maintenance activities effectively. Unlike stratified housing schemes governed under the Strata Title Act 1985 (Act 318), Strata Management Act 2013 (Act 757), and the Building and Common Property (Maintenance and Management) Act 2007 (Act 663), where the management of common property is legally regulated, non-stratified gated and guarded neighbourhoods (GACOS) do not operate under a legally mandated structure such as Joint Management Body (JMB) and Management Corporation (MC). Stratified developments benefit from statutory mechanisms that enable compulsory collection of maintenance charges through

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JMB or MC, and provide legal enforcement against payment defaulters. In contrast, non-stratified GACOS rely on ad hoc arrangements designed by developers, often formalized through a Deed of Mutual Covenant (DMC). While DMCs may include provisions for the collection of maintenance or service fees, this arrangement typically expire once the developer's management period ends, leaving future management uncertain (Zainudin & Hussin, 2015). These arrangements do not provide the same level of statutory authority as JMB or MC structures. After the handover, residents may choose to form a voluntary Residents' Association (RA) unless it has been incorporated earlier in the DMC, but its effectiveness largely depends on community participation and willingness to contribute financially (Khoo, 2020). In the absence of such initiative, the management responsibilities may revert to local authorities, undermining the original intent of private or self-managed gated neighbourhoods. This lack of a consistent legal framework and institutional oversight often results in fragmented management, unclear accountability, and financial mismanagement which exacerbate the problem of maintenance cost overruns in these developments.

Studies on residential building maintenance suggest that increasing resident expectations regarding the standard, comfort, and image of the living environment are important factors influencing maintenance expenditure (Horner & El-Haram, 2002; Johari & Saleh, 2018; Wahedy & Alim, 2022). Residents often expect their shared amenities to be maintained to high standards, reflecting the exclusivity and prestige associated with gated living. Consequently, their elevated expectations frequently translate into demands for more frequent maintenance, aesthetic enhancements, and high-end upgrades that extend beyond essential operational requirements, thereby driving up maintenance expenditure. For Aripin et al. (2024) and Fakhrudin et al. (2011), these expectations are understandable as individuals spend a significant portion of their time within or around their neighbourhood, making building condition and environmental quality integral to overall well-being and lifestyle satisfaction. However, managing these expectations can be financially challenging, particularly when maintenance funds are constrained. The problem is further aggravated by resident behaviour, including vandalism, improper use of facilities, and delays or failure to report defects, which create unanticipated costs and inefficiencies in the maintenance process. To address these challenges, Salleh et al. (2016) suggested that active resident participation and promoting awareness on the cost implications can help balance service quality with financial sustainability. As supported by Au-Yong et al. (2022) and Thakur and Patel (2025), incorporating residents feedback allows facility managers to make evidence-based maintenance decisions, hence ensuring it operates as intended. According to Horner and El-Haram (2002), the heightened expectations of residents may be attributed to the

absence of formal agreements between residents and developers therefore to be incorporated into tenancy or occupancy agreements.

Technical and administrative factors are among the most significant contributors to maintenance cost overruns in gated and guarded housing schemes. From the technical perspective, poor workmanship resulting from the appointment of unqualified contractors often leads to recurring defects and inefficient maintenance. According to Au-Yong et al. (2023) management teams tend to prioritize the lowest tender bids as directed by owners with little consideration given to contractor competency. This practice undermines the quality of maintenance works and increases long-term costs. Another major issue is the unavailability or poor quality of spare parts and materials. Replacement components are often difficult to source locally especially for outdated systems, leading to delays, import costs, and temporary disruption of facilities (Au-Yong et al., 2023). The use of low-quality or second-hand parts further exacerbates maintenance failures and escalates overall expenses. Additionally, limited technological adoption such Building Information Modelling (BIM), Cloud and real time collaboration, Internet of Things (IoT), Blockchain and Artificial Intelligence (AI), within maintenance management contributes to inefficiency (CIDB Malaysia, 2020; Sakhaf & Ayob, 2024). However, Au-Yong et al. (2023) warned that while modern maintenance software can enhance decision-making and budget allocation, its benefits remain unrealized when personnel lack the necessary technical understanding or training.

From an administrative standpoint, weak maintenance management practices, poor budgetary control, and the failure to execute maintenance at the appropriate time are key issues (Che-Ghani et al., 2016; Mong et al., 2018; Wen et al., 2022). Insufficient technical knowledge among staff and inadequate financial planning often result in deferred maintenance and eventually increasing repair costs over time (Wahedy & Alim, 2022). Kazar et al. (2024) further highlighted that maintenance cost overruns can also arise from external factors beyond the control of the management team including unforeseen site conditions, changes in project scope, scheduling delays, inflation, and fluctuations in market prices. Overall, these technical and administrative challenges highlight the need for effective strategies to mitigate maintenance cost overruns, which will be further examined in the following section through the adopted research methodology to identify realistic solutions for gated and guarded communities.

RESEARCH METHODOLOGY

This study adopts a qualitative research approach and conducted in two main phases. The qualitative method was chosen to enable an in-depth exploration of the complex issues surrounding maintenance cost overruns in non-strata gated and guarded community housing schemes (GACOS) where management

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structures and maintenance practices are highly context dependent. The first phase involved an extensive review of relevant literature on the concept of gated and guarded housing schemes and the factors contributing to maintenance cost overruns in such developments. A wide range of materials were reviewed including government publications, documents from Residents' Associations (RAs), books, newspaper articles, and peer-reviewed academic publications. Government documents such as relevant legislation, planning guidelines, and policy documents were reviewed to establish the legal and regulatory context of non-stratified gated communities. Documents obtained from the participating RAs including maintenance records and financial information were used as documentary evidence to support and contextualize the findings from the Focus Group Discussion. Owing to the confidential nature of these documents, only selected information is reported. Academic sources were retrieved primarily from databases such as Google Scholar, ScienceDirect, Emerald, JSTOR Archive, and Taylor & Francis Online. Additionally, reference lists from selected articles were examined to identify further relevant studies considering the limited research available on non-stratified GACOS developments in Malaysia. The literature review established a conceptual foundation and provided insights into key variables influencing maintenance cost escalation in gated communities.

The second phase comprised a Focus Group Discussion (FGD) which served as the primary data collection method for the study. The FGD is an effective qualitative tool for eliciting participants' attitudes, perceptions, knowledge, and experiences through group interaction (Akyildiz & Ahmed, 2021; Eeuwijk & Angehrn, 2017). As argued by Shabina et al. (2024), the method enables participants to express their opinions freely regardless of agreement or disagreement with others thereby producing rich, unbiased, and high-quality data. FGDs were considered particularly appropriate for this study because they facilitated interaction among diverse stakeholders, allowing participants to discuss different perspectives, and collectively identify practical strategies for mitigating maintenance cost overruns in non-stratified gated and guarded housing. This approach is especially relevant given the scarcity of empirical studies on maintenance management strategies for such communities. Four FGDs were conducted over a period of six (6) months involving members of Management Committee from two (2) non-stratified gated and guarded neighborhoods (hereafter referred to as A and B) with 13 and 16 participants respectively. Multiple case studies are considered to yield more robust results compared to single case study (Kass et al., 2024). Each discussion lasted approximately 60 to 90 minutes and was moderated by the principal researcher, and all discussions were audio-recorded and subsequently transcribed verbatism for analysis with participants' consent. The selection of the two communities was purposive, as both were established in the early 2000s and share similar

characteristics in terms of age, size, location, and common challenges related to aging facilities. This allowed for meaningful comparison of their maintenance strategies under comparable environmental and operational conditions. Despite these similarities, both communities exhibit distinct financial and management practices. Due to the confidential nature of RA financial records, detailed annual expenditure breakdowns could not be disclosed. However, available financial indicators were used to demonstrate differences in maintenance management approaches between the case studies.

Case study A, for instance, has maintained its maintenance fee at RM0.07 per square foot since 2011, yet continues to provide high-quality services and facilities, including landscape upkeep, security, and communal amenities. In contrast, Case study B imposes a higher maintenance fee of RM0.17 per square foot, but has demonstrated robust financial management, accumulating over RM4 million in sinking fund reserves while maintaining service quality and operational efficiency. A comparative summary of both neighborhoods is presented in Table 1.

Table 1: Summary of case study background

	Case study	
	A	**B**
Age (years)	23	20
Area (acre)	40	53
Maintenance fee rate (RM per square foot)	0.07	0.17
Development	136 units bungalows	53 units bungalows 62 units semi-detached house 170 units link houses
Facilities	Playground, swimming pool, jogging tracks, clubhouse, 3 ponds	Playground, swimming pool, jogging tracks, wading pool, gymnasium, barbecue area

Unlike stratified developments, , both case studies are individual-title gated and guarded communities. While their management structures and practices often emulate those of stratified developments, they are not legally bound by the same regulations hence providing greater flexibility in establishing site-specific management arrangements. In most cases, GACOS developments voluntarily adopt Act 318 to manage their RAs, particularly in the absence of dedicated legislation for non-strata schemes. However, certain statutory provisions such as Section 2(6) of the Act 318 which limits committee members to three consecutive terms may be applied at the discretion of each community. Accordingly, FGD participants were purposively selected from the RA management committees. Participants were at least 21 years of age, eligible to serve on the committee based on property ownership requirements, had served on the committee for a minimum of three (3) years, and were directly involved in management and maintenance

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decision making. In Case study A, committee members are permitted to serve beyond three terms with the approval of the residents, resulting in long-serving members. Many of them with over five (5) years of continuous service, and some for as long as nine (9) years. These individuals possess deep institutional knowledge and firsthand experience managing maintenance issues since the RA's inception, making them valuable informants for this study. In Case study B, while committee terms are limited to one (1) year, many members have served multiple consecutive terms often rotating roles. This practice ensures a comprehensive understanding of various management aspects, including finance, maintenance, security, and legal matters, while maintaining continuity through mentoring and guidance from senior members.

FINDINGS AND DISCUSSION

The findings of the FGD focused on factors contributing to cost overruns and mitigation strategies and were analysed using thematic analysis. The credibility of the findings was enhanced through data triangulation by comparing the FGD results with relevant literature and previous empirical studies. Results from the FGD in Table 2 showed several interrelated factors contributing to cost overruns in the maintenance of non-stratified gated and guarded housing communities (GACOS). Legislative and governance gaps emerged as an important theme where participants highlighted the absence of legally mandated legislation or formal regulatory frameworks for non-stratified GACOS. Unlike strata developments that operate under established management structures, non stratified GACOS depend on voluntary agreements and informal arrangements among residents, resulting in ambiguity regarding authority, responsibility, and accountability for maintenance decisions. As supported by Khoo (2020), management of non-stratified GACOS is uncertain as it rely only on ad hoc arrangements designed by developers. This finding extends previous research by demonstrating that the regulatory gap does not merely create administrative challenges but also directly influences the financial sustainability of these communities. The problem is further exacerbated in managing ageing GACOS as compliance with modern safety standards and performance requirements has become increasingly complex, particularly in meeting rising expectations of the residents. As argued by Kazar et al. (2024), older buildings often have outdated infrastructure and services that are inefficient, unreliable or unsafe by today's standards. These systems usually require costly upgrades or full replacement to meet current codes and performance needs. Therefore, the findings suggest that legislative and governance gaps represent a critical factor contributing to maintenance cost overruns particularly when ageing GACOS face increasing technical requirements and rising expectations from residents.

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Table 2: Factors contributing to cost overrun in maintenance of GACOS

Concepts	Emergent themes	Constructs
Factors of maintenance cost overruns	Legislative and governance gaps	Absence of legally mandated legislation for non-stratified gated and guarded communities
		Complexity in ensuring compliance with modern requirements
	Maintenance planning and strategic management	Short term and inconsistent maintenance planning
		Plans changing every management team
		Focus on daily operations and handling arising matters
	Stakeholder engagement	Low levels of awareness, motivation, and participation among residents

The analysis also identified ineffective maintenance planning and strategic management as another significant contributor to cost overruns. Participants reported that maintenance plans were often short-term and subject to change with each management term, with greater emphasis placed on daily operational issues and immediate problem solving rather than systematic preventive maintenance. As one participant explained:

'Repair and maintenance work is usually carried out only after a complaint has been received. The work…is often intended to resolve immediate issue without considering its long-term sustainability…but the practice tend to change whenever there is a change in the committee'.

(AS02)

This finding suggests that maintenance decisions in non-stratified GACOS are frequently driven by short-term priorities rather than long-term asset management objectives. This finding is consistent with previous studies (Kwon et al., 2020; Yasin et al., 2023) highlighting that ineffective maintenance planning can accelerate deterioration and increase lifecycle cost. Another contributing factor found related to low levels of awareness, motivation, and participation among residents. For example, stringent standard practices limiting capital expenditure in Case study B were intended to control spending, however inadequate member engagement often hindered consensus building for necessary capital investments and eventually leading to higher corrective maintenance costs in the long term. This finding highlights the complex relationship between cost control and asset sustainability, where excessive emphasis on immediate expenditure reduction may unintentionally increase future financial liabilities. Following the identification of cost overruns factors, the FGD further examined participants' views on strategies to address these issues as demonstrated in Table 3.

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Table 3. Strategies to mitigate cost overruns in GACOS

Concepts	Emergent themes	Constructs
Strategies to mitigate maintenance cost overruns	Strategic transfer to local authorities	Selective handover of infrastructure and facilities
		Cost savings from utility and service transfer
		Trade-offs between cost reduction and community identity
	Long term maintenance and financial planning	Multi year maintenance planning
		Budget forecasting and fee increment planning
		Continuity of management decision making
	Financial governance	Stringent approval procedures for expenditure
		Balancing cost control with lifecycle replacement needs
	Alternative financing	Fundraising for non-essential or enhancement projects
		Participation in government and community schemes
	Optimization of existing resources	Leveraging residents' professional expertise
		In-kind contributions and cost-price services
		Elimination of redundant facilities

Table 3 illustrated that both case studies adopt a combination of institutional, financial, social, and operational strategies to mitigate long-term maintenance cost overruns in the absence of formal regulatory frameworks. One of the most prominent strategies identified involves the selective handover of infrastructure and services such as roads, drainage systems, street lighting, waste collection, and landscaping to local authorities. Participants emphasized that such decisions are community driven and contingent upon cost-benefit considerations. For example, Case study A reported immediate savings in electricity expenditure following the handover of street lighting, while both case studies highlighted waste collection as a costly recurring service better managed by local authorities. However, the handover process was not without complications. As one participant highlighted:

'Of course…we can certainly hand over some infrastructure or facilities back to the local authority…but it can create other issues that need to be carefully considered'.

(DI08)

Case study A experienced disputes regarding public access regarding the reclassification of internal roads as public infrastructure. These challenges were mitigated through legal clarification, drawing on precedent from Au Kean Hoe v. Persatuan Penduduk D'Villa Equestrian (2015) which affirmed the right

of gated communities to restrict access for security reasons under valid grounds. Furthermore, resistance to handing over landscape areas reflected concerns over the erosion of community identity and exclusivity, underscoring the trade-off between cost reduction and place branding. Previous study by Guiheng et al. (2025) warned that the implementation of such strategies require careful consideration as the immediate consequences for residents particularly in terms of mental well-being and sense of belonging should not be overlooked. Although transferring certain facilities or infrastructure to local authorities may reduce maintenance burdens on residents, such approach requires careful consideration.

Participants further identified the absence of structured long-term planning as a key contributor to cost overruns (Table 2). In response, both case studies advocated for five-year strategic maintenance plans supported by financial projections. Such plans function as operational blueprints, guiding committees in preventive maintenance, refurbishment cycles, and incremental fee adjustments. More importantly, these plans were perceived as institutional memory tools that support continuity across changing committee memberships. For Twum-Bobie et al. (2025), this strategy is crucial in enhancing the life cycle of the assets. Furthermore, strong internal financial governance also emerged as a critical mitigating factor. In particular, Case study B demonstrated a stringent approval system whereby all expenditures require committee consent and AGM endorsement. This approach was perceived to enhance transparency and minimize corruption risks. Nevertheless, participants acknowledged unintended consequences including delayed replacement of ageing facilities due to conservative spending practices, which highlighting the tension between fiscal prudence and asset lifecycle management.

In addition, fundraising was also primarily utilized for enhancement projects beyond essential maintenance such as the proposed construction of an indoor gymnasium in Case study A. While this strategy reduces pressure on maintenance and sinking funds, it introduces challenges related to equity and participation. Participants noted that unequal contributions and free-rider behaviour can undermine collective moral and slow project implementation, and eventually suggesting limitations to voluntary financing mechanisms in residential settings. Following this, the participants further added that active engagement with external organizations and government programmes such as security initiatives and community partnerships served as another alternative for GACOS to secure grants and sponsorships for maintaining and upgrading their communities. Beyond financial gains, these collaborations also enhance resident participation, awareness of maintenance issues, and volunteerism. This finding highlights the role of social capital and institutional networking as indirect yet impactful cost mitigation strategy.

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Both case studies further leveraged residents' professional expertise to reduce operational costs. Legal advice, architectural and engineering services, financial planning, insurance brokerage, and landscaping supplies were provided at nominal or cost prices by residents. For instance, supplier of different fertilizers for turfing, trees, and shrubs were provided at cost price from a resident in Case study A who is a manufacturer himself. In Case study B, residents with construction backgrounds provide building maintenance advises and recommend trusted contractors with reasonable pricing. Additionally, communities in both case studies shared that they undertook systematic reviews of existing facilities, leading to the consolidation or termination of underutilized and aesthetic driven amenities. These include the removal of redundant water features, consolidation of playgrounds, and replacement of outdated intercom and CCTV systems with cost-effective technological alternatives. Overall, these findings demonstrate that cost overrun mitigation in non—stratified GACOS relies heavily on self-governance, social capital, and adaptive management strategies rather than formal regulatory compliance. This highlights the importance of strengthening governance arrangements throughout the neighbourhood lifecycle particularly during the transition from developer-led management to resident-led administration. Clearer roles for RAs supported by local authorities through appropriate policy guidance could contribute to the long term sustainability and resilience of non-stratified gated communities.

CONCLUSION

This study examined realistic strategies for mitigating maintenance cost overruns in non-stratified gated and guarded community neighbourhoods (GACOS) through focus group discussions with resident associations members managing mature developments. By drawing on case studies that have remained operational for more than two decades, the research provides rare empirical insights into how long-established communities sustain their physical assets and financial viability in the absence of prescriptive regulatory frameworks. The findings demonstrated that cost overrun mitigation in non-stratified GACOS is not driven by formal statutory mechanisms but by adaptive and resident-led governance practices. Strategies such as selective handover of facilities to local authorities, long-term maintenance and financial planning, stringent internal financial controls, optimization of residents' professional expertise, external collaborations, and rationalization of redundant facilities reflect context-sensitive approach to neighbourhood management. The proposed strategies may not be equally applicable across all non-stratified GACOS as they depends on contextual factors such as residents' willingness to contribute, and availability of institutional support. These strategies are shaped by lived experience, accumulated institutional knowledge, and continuous negotiation between cost efficiency,

security, and community identity. The significance of incorporating ground level input from resident associations lies in its ability to capture decision making processes that are often undocumented yet critical to long term sustainability. Furthermore, the use of mature case studies highlights the importance of social capital, collective action, and institutional continuity in sustaining neighbourhood maintenance. Most importantly, the study illustrated how human and social resources can compensate for financial limitations and regulatory gaps. The findings have practical implications for resident associations, policymakers, and local governments by providing evidence to strengthen existing governance frameworks for neighbourhood maintenance and improve the financial sustainability of non-stratified gated communities.

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CRITICAL SUCCESS FACTOR FRAMEWORK FOR PUBLIC HOUSING MAINTENANCE IN MALAYSIA: THE MODERATING ROLE OF MAINTENANCE BUDGET

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Abstract

Effective building maintenance is crucial for the sustainability of public housing, but it frequently faces challenges due to budgetary and operational constraints. This study identifies and analyses Critical Success Factors to develop a contextualised framework for optimising maintenance performance (MP) within the People's Housing Programme (PHP). This research redefines the Maintenance Budget (MB) as a dynamic moderating variable rather than a conventional, static input. Following `a systematic literature review, factors were validated through a three-round Delphi study involving 15 highly experienced industry experts and ranked using the Relative Importance Index (RII). The structural relationships were subsequently tested using Partial Least Squares Structural Equation Modelling (PLS-SEM) with cross-sectional survey data from 156 practitioners across Peninsular Malaysia. The findings revealed that technology-related factors ($\beta = 0.328$, $p < 0.01$) and operations and management-related factors ($\beta = 0.233$, $p < 0.01$) exert the strongest direct impacts on MP. Furthermore, the empirical data confirm that MB significantly moderates the relationships between organisational, technical, human resource, building user, and operational factors and MP. The framework provides evidence-based guidance for policymakers to prioritise funding allocations within Outcome-Based Budgeting mechanisms.

Keywords: Critical Success Factors, Maintenance Performance, Maintenance Budget, Public Housing, Partial Least Squares Structural Equation Modelling

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INTRODUCTION

Ensuring adequate, safe, and affordable housing remains a cornerstone of Malaysia's social welfare and urban planning agenda. The People's Housing Programme (PHP) serves as the principal vehicle for delivering housing to the nation's low-income urban population. Despite these efforts, public housing in Malaysia is beset by persistent operational challenges, including progressive deterioration linked to age and material quality, limited stakeholder awareness, vandalism, and chronically low maintenance fee collection rates (Abas et al., 2021; Rabe et al., 2021). Although the National Housing Policy (Dasar Perumahan Negara 2018-2025) provides a comprehensive strategic direction, the maintenance of public housing is critically hampered by financial constraints (Ministry of Housing and Local Government, 2018). Rental rates and maintenance fees have been heavily subsidised and capped at RM124 per month since 1998, whereas actual maintenance expenditures currently average RM450 per unit each month (Fischer, 2006; Shuid, 2016). This substantial deficit dependence necessitates heavy reliance on federal subsidies, which are primarily administered through the Outcome-Based Budgeting (OBB) system (Tuan Mat et al., 2023). However, this mechanism often fails to address the actual operational needs of public housing maintenance.

While a considerable body of research has explored maintenance success factors in commercial and private high-rise settings, there remains a conspicuous gap in empirically validated frameworks that address the statutory, financial, and operational realities unique to Malaysian public housing (Khalid et al., 2017). In response, this study seeks to validate a comprehensive set of Critical Success Factors for Building Maintenance (CSFBM) specifically for the PHP context through the Delphi method, empirically evaluate their direct impact on maintenance performance (MP), and investigate the moderating effect of the maintenance budget (MB) using partial least squares structural equation modelling (PLS-SEM). The primary objective is to develop a CSFBM framework that integrates budgetary moderation to facilitate the effective implementation of national housing policies and local authority mandates

LITERATURE SYNTHESIS AND CONCEPTUAL FRAMEWORK

The theoretical framework underpinning this study integrates the Input-Output Model (Ogunbayo et al., 2022). Within this context, CSFBMs are conceptualised as essential resource inputs to the maintenance management system. It is posited that public housing management is highly dependent on external federal subsidies and statutory fee collections; thus, budget availability dynamically changes the strength of relationships between technical, human, and operational inputs and final performance outcomes.

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Maintenance Performance (MP) is operationalised through measurable reductions in work backlogs, user complaints, and facility breakdowns. While these indicators represent core operational outcomes, they are highly critical in public housing environments where resource scarcity dictates that functionality (She et al., 2022), cost-effectiveness, and service continuity take precedence. Anchored in strategic objectives, Critical Success Factors (CSFs) provide direction for managerial decision-making, supporting the optimisation of time, cost, and resource allocation to deliver sustainable, high-quality results (Dahal & Dahal, 2020; Zawawi et al., 2011).

A Systematic Literature Review (SLR) was conducted following the PRISMA protocol (Page et al., 2021) to establish a theoretical foundation which justifies the initial pool of CSFs. The initial review identified 32 relevant factors. Foundational models in the literature, notably the widely cited five-factor framework by Hauashdh et al. (2021), were utilised as comparative baselines. This study extends existing models by establishing seven independent CSFBM constructs specifically tailored to the public housing context: Organisational-Related Factors (ORF), Human Resource-Related Factors (HRRF), Technical-Related Factors (TRF), Building User-Related Factors (BURF), Statutory Requirement-Related Factors (SRRF), Operation and Management-Related Factors (OMRF), and Physical Building-Related Factors (PBRF). Historically, building maintenance frameworks have categorised Financial-Related Factors (FRF) as standard independent variables. However, this perspective fails to adequately capture the constraints inherent in public sector building maintenance management. In practice, public building maintenance budgets are rarely determined by actual physical requirements or comprehensive condition surveys; instead, they frequently rely on arbitrary allocations and outdated legacy practices. Consequently, financial constraints act as a rigid boundary that governs and limits the implementation of all other maintenance strategies (Mohd Noor, 2018; Noor & Hamid, 2011). Recent literature corroborates this, demonstrating that even robust organisational policies and technical systems are rendered ineffective without adequate financial resources (Amos et al., 2021).

To resolve this conceptual ambiguity, the present study diverges from conventional models by reconceptualising FRF entirely as a dynamic moderating variable, as the Maintenance Budget (MB). Because public housing management relies heavily on external federal subsidies and statutory fee collections, it is posited that budget availability dynamically amplifies or constrains the effectiveness of the core technical, human, and operational drivers of maintenance performance.

Grounded in this conceptual framework, the following hypotheses are proposed:

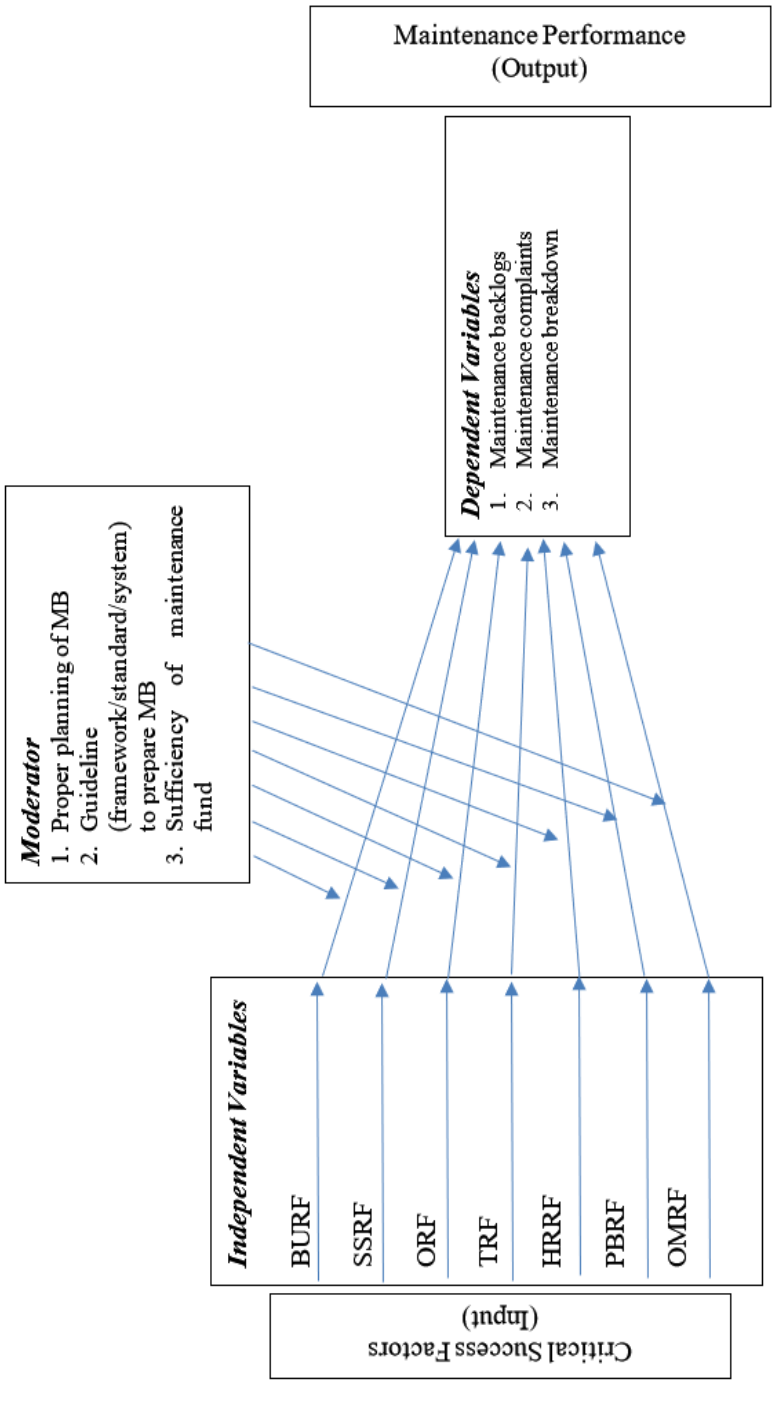
- **H1–H7:** ORF, HRRF, TRF, BURF, SRRF, OMRF, and PBRF have a significant positive direct effect on Maintenance Performance (MP).
- **H8–H14:** MB significantly moderates the relationships between the seven CSFBM constructs and MP.

METHODOLOGY

A quantitative research design was implemented, comprising three primary phases: systematic literature review (SLR), the Delphi technique, and empirical validation using PLS-SEM. The CSFBM identified through the SLR was validated using a three-round Delphi technique. A purposive panel of 15 subject matter experts was engaged. The selection criteria required experts to possess over ten years of professional experience specifically within property management, budgeting, and public housing operations. A rigorous 70% consensus threshold was established to determine indicator retention across the three rounds, achieving a 100% participant retention rate. Indicators deemed overly generic or incompatible with the socio-legal realities of PHP (e.g., highly advanced but impractical software integration) were removed, while context-specific indicators (e.g., strategies for managing hardcore defaulters) were incorporated. This culminated in a finalised framework comprising 36 CSFs distributed across the seven constructs. Data were analysed using Smart-PLS 4. Contemporary reporting standards were adhered to by evaluating the measurement model's reliability and validity. Internal consistency was confirmed with Cronbach's Alpha and Composite Reliability (CR) values exceeding the 0.70 threshold across all constructs. Convergent validity was established, as the Average Variance Extracted (AVE) values for all constructs surpassed 0.50, and indicator outer loadings exceeded 0.70. Discriminant validity was rigorously verified using the Heterotrait-Monotrait Ratio (HTMT), with all values falling below the conservative threshold of 0.85, ensuring that the constructs are empirically distinct.

Structural model diagnostics indicated an absence of multicollinearity (Inner VIF values < 3.0) and confirmed the model's predictive relevance ($Q^2 > 0$) alongside a robust coefficient of determination (R^2). The significance of the path coefficients (β) was assessed using a 5,000-subsample bootstrapping procedure.

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Source :Adapted from Ogunbayo, Ohis Aigbavboa, et al. (2022) Input-Output Model

Figure 1: The Conceptual Framework of CSFBM of PHP

ANALYSIS AND RESULTS

Delphi Validation for CSFBM

In the three rounds of the Delphi technique, experts systematically excluded concepts that, while academically endorsed, were deemed impractical for real-world implementation (e.g., BIM integration). Conversely, the panel incorporated socio-legal complexities with direct operational relevance, such as strategies for managing persistent defaulters. This iterative process culminated in a finalised measurement framework comprising 36 CSFs distributed across seven constructs. The indicators are shown in Table 1.

Table 1: List of CSFBM indicators

Organisational-related Factor (ORF)		
1	ORF1	Clear organisation structure and job description
2	ORF2	Collaboration among maintenance stakeholders
3	ORF3	Verification and assessment of maintenance work quality
4	ORF4	Implementing preventive maintenance
Human Resources-related Factor (HRRF)		
5	HRRF1	Employ skilled and experienced manpower
6	HRRF2	Job training for maintenance staffs
7	HRRF3	Courses and workshops to improve staffs' skills
8	HRRF4	Employ experts of building maintenance professionals
9	HRRF5	Monitoring of maintenance staff performance
Technical-related Factor (TRF)		
10	TRF1	Proper maintenance planning at the building design stage and design of building maintenance work accessibility
11	TRF2	Record of accurate data and information about the maintenance work
12	TRF3	Application of advanced technology to detect or evaluate building defects - Adopting building information modelling (BIM)
13	TRF4	Usage of Information and Communications Technology (ICT) - system, software in maintenance work
14	TRF5	Prioritise maintenance activities based on criticality, risk assessment, and the impact on operations.
Financial-related Factor (FRF)		
15	FRF1	Proper planning of maintenance budget
16	FRF2	Sufficiency of maintenance fund
17	FRF3	Guideline (framework/standard/system) to prepare maintenance budget
Building User-related Factor (BURF)		
18	BURF1	Awareness to maintain the building and facility among the building users

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19	BURF2	Understanding the usage of building facilities
20	BURF4	Commitment to report building defects by the building users
Statutory requirements-related Factor (SRRF)		
21	SRRF1	Application of prescribed method in the procurement of maintenance contractors
22	SRRF 2	Compliance to Strata Management Act
23	SRRF 4	Inspection of building safety and health – lift and building
24	SRRF 5	Guideline to deal with hardcore defaulters
25	SRRF 6	Property management company with proper standard operating procedures (SOPs) and good headquarters (HQ) support
26	SRRF 7	Active involvement and surveillance by the authorities on the service performance carried out by the Property Management (PM) team (appointed)
Operation and Management-related Factor (OMRF)		
27	OMRF1	The quality of spare parts, components and materials being used
28	OMRF2	Performance of the maintenance group
29	OMRF 3	Availability of operation and maintenance manuals
30	OMRF 4	Response to maintenance request
31	OMRF 5	Outsourcing maintenance work
Physical Building-related Factor (PBRF)		
32	PBRF1	Existing building condition
33	PBRF2	Building age
34	PBRF3	Facilities services - lift systems, water supply systems, power supply systems; security system and fire protection system
35	PBRF4	Design of the building
36	PBRF5	Number of units in the development

PLS-SEM: Measurement Model Assessment

Following the validation of CSFBM, the structural model was evaluated using PLS-SEM to test the hypothesised direct relationships (H1–H7) and the moderating effects of the MB (H8–H14) on MP. The significance of the path coefficients (β) was assessed using a bootstrapping procedure.

Direct Effects of CSFs on Maintenance Performance (H1–H7)

The path analysis produced compelling empirical evidence for the structural influence of five key operational and tactical constructs on maintenance performance in public housing. Table 2 shows the results of the direct effects on MP.

Table 2: Result of Direct Effects on Maintenance Performance (MP)

Factor	Path Coefficient (β)	t-value	p-value
Technical-Related Factors (TRF)	0.328	5.912	< 0.001
Operation and Management-Related Factors (OMRF)	0.233	3.265	0.001
Organisational-Related Factors (ORF)	0.209	3.520	< 0.001
Human Resource-Related Factors (HRRF)	0.182	3.140	0.002
Building User-Related Factors (BURF)	0.174	2.898	0.004

TRF emerged as the most substantial direct predictor of maintenance performance, highlighting the importance of technical systems and rigorous risk assessment protocols. OMRF also contributed significantly, demonstrating the value of effective tactical execution. The results confirm the necessity of robust strategic governance, as ORF had a meaningful impact on maintenance outcomes. The analysis further underscores the critical role of human capital, with HRRF exerting a significant direct effect, and BURF illustrating the influence of tenant engagement and defect reporting on sustained performance. Collectively, these findings support hypotheses H1 through H4 and H6, underscoring the multifaceted drivers of maintenance success in the public sector. In contrast, the empirical analysis did not reveal statistically significant direct effects of SRRF ($\beta = -0.016$, $p = 0.811$) or PBRF ($\beta = 0.069$, $p = 0.185$) on daily maintenance metrics. Consequently, hypotheses H5 and H7 were not supported, indicating that these constructs do not exert a direct structural influence within the tested model.

Moderating Effects of the Maintenance Budget (H8–H14)

An interaction-moderation analysis examined the moderating effect of Maintenance Budget (MB) on relationships between key operational constructs and Maintenance Performance (MP) in public housing. Findings confirmed MB is a highly significant and positive moderator across all five tested pathways. The strongest moderating effect was between MB and Organisational-Related Factors (ORF), with a notable effect size ($\beta = 0.303$, $f^2 = 0.294$, $p < 0.001$). Significant moderating effects were also found for Building User-Related Factors (BURF), Technical-Related Factors (TRF), Operation and Management-Related Factors (OMRF), and Human Resource-Related Factors (HRRF), each showing statistically robust coefficients and p-values.

These findings offer strong empirical support for the hypothesis that the influence of strategic and operational drivers on maintenance performance is significantly enhanced when adequate budgetary resources are available. This underscores the importance of aligning financial planning with operational priorities to achieve effective and sustainable maintenance outcomes in public housing. Table 3 presents the results of the test of the moderation hypothesis.

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Table 3: Results of Moderation Hypothesis Testing

Hypothesis	Interaction Path	Path Coefficient (β)	t-value	p-value	Effect size (f^2)	Decision
H8	MB X ORF →MP	0.303	5.457	0.000***	0.294	Supported
H11	MB X BURF→MP	0.280	4.643	0.000***	0.227	Supported
H10	MB X TRF →MP	0.244	4.133	0.000***	0.147	Supported
H13	MB X OMRF →MP	0.201	2.917	0.004**	0.129	Supported
H9	MB X HRRF →MP	0.136	2.496	0.013*	0.055	Supported
H12	MB × SRRF → MP	0.034	0.561	0.575	0.003	Not Supported
H14	MB × PBRF → MP	0.034	0.613	0.540	0.003	Not Supported

DISCUSSION

The PLS-SEM analysis reveals that the maintenance budget (MB) serves as a critical multiplier, significantly enhancing the influence of Organisational-Related (ORF), Operation and Management-Related (OMRF), Technical-Related (TRF), Human Resource-Related (HRRF), and Building User-Related Factors (BURF) on maintenance performance. Robust organisational frameworks, such as scheduled preventive maintenance and rigorous contractor coordination, are foundational but remain insufficient without adequate financial backing. Specifically, implementing advanced technical solutions, including Building Information Modelling (BIM) and ICT-based defect tracking systems, requires substantial initial and ongoing capital. Similarly, continuous professional development for the maintenance workforce relies heavily on consistent financial support. When adequately funded, these technical and human resource investments can drastically reduce lifecycle costs and system downtime. Furthermore, the budget directly shapes the efficacy of building user engagement; translating tenant awareness into tangible outcomes through clear signage, educational initiatives, and responsive defect-reporting systems fundamentally depends on the management body's financial capacity to execute prompt repairs. A key finding of this study is the lack of significant direct and moderating effects for Statutory Requirement-Related Factors (SRRF) and Physical Building-Related Factors (PBRF). The analysis indicates that legal compliance mandates (e.g., the Strata Management Act and occupational safety inspections) and physical building characteristics (e.g., structural age and mechanical complexity) establish a consistent baseline across all public housing schemes. Because these institutional and physical characteristics are fixed and uniformly mandated, they do not function as daily, fluctuating drivers that alleviate immediate maintenance backlogs or complaints. Furthermore, the budgets analysed in this context are

primarily allocated for routine Operation and Maintenance (O&M). Consequently, augmenting routine O&M budgets does not alter a building's inherent physical age, nor does it affect the efficacy of statutory compliance, which is more closely tied to procurement integrity, contract duration, and regulatory enforcement than to routine financial allocations.

In the context of Malaysia's People's Housing Programme (PHP), these findings expose a significant vulnerability in current building maintenance management models: robust technical and organisational frameworks cannot offset the detrimental effects of persistent underfunding. To enhance maintenance performance and preserve the liveability of public housing, policymakers must transition away from flat-rate or historically constrained subsidy models. Rather than broadly advocating for increased funding, this study recommends that the Ministry of Housing and Local Government (KPKT) and local authorities integrate risk-based budgeting within the federal Outcome-Based Budgeting (OBB) framework. Financial allocations must be strategically aligned with active operational drivers, linking funding directly to performance metrics. Priority should be given to preventive maintenance reserves and digital management systems over reactive interventions. Concurrently, local authorities must strengthen the statutory enforcement of maintenance fee collections to curb operational deficits and secure long-term financial sustainability.

While this study provides valuable empirical insights, it acknowledges several methodological limitations. The reliance on a cross-sectional design and self-reported survey data captures perceptions at a single point in time, thereby limiting the ability to establish strict causal relationships. Additionally, the sample was geographically confined to Peninsular Malaysia, which may restrict the generalisability of the CSFBM framework to other regional contexts or distinct housing systems. Future research should prioritise longitudinal studies to evaluate maintenance performance over time, ideally incorporating objective maintenance logs and cost-effectiveness analyses to complement perceptual data. Cross-country comparative studies within Southeast Asia, as well as comparative analyses across different housing typologies (e.g., public versus private strata developments), are also recommended to broaden the framework's applicability and refine its contextual nuances.

CONCLUSION AND POLICY IMPLICATIONS

Achieving long-term sustainability and functional efficiency in Malaysia's Public Housing Programmes (PHP) requires a shift from reactive maintenance to a proactive, performance-oriented framework. To support this transition, the present research systematically identified 36 Critical Success Factors of Building Maintenance (CSFBM) tailored to the public housing sector. Empirical analysis using Partial Least Squares Structural Equation Modelling (PLS-SEM) indicates

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that Technical-Related Factors (TRF) and Operation and Management-Related Factors (OMRF) have the most significant direct effects on maintenance performance. These operational drivers are underpinned by strong organisational governance, skilled human resources, and active tenant engagement. Notably, this study advances maintenance management models by conceptualising the Maintenance Budget (MB) as a dynamic moderator rather than a static input, challenging the traditional view that financial resources function independently of managerial strategies. Additionally, by incorporating context-specific dimensions such as Statutory Requirement, Operation and Management, and Physical Building-Related Factors, this research disputes the assumption that public-sector facilities are exempt from the rigorous physical and statutory scrutiny applied to private developments.

Practically, the contextualised CSFBM framework serves as a critical decision-support tool, bridging the gap between federal funding allocations and local, real-time operational requirements. By empirically demonstrating that the effective implementation of organisational and technical frameworks depends on sufficient financial resources, this study supports a move away from uniform, flat-rate budget distributions. The framework provides housing authorities and budgeting officers with evidence to direct funds toward validated, high-impact initiatives. This strategic approach aligns local maintenance practices with the Federal Government's Outcome-Based Budgeting (OBB) system, thereby optimising the allocation of public funds to foster safer and more sustainable public housing environments.

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FACILITIES OF GREEN RESIDENTIAL BUILDING ELEMENTS AND THEIR IMPACT ON LIFE CYCLE COSTS IN HOUSING PROJECT DESIGN

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Abstract

Green buildings are designed to promote environmental stewardship and resource conservation throughout their life cycle, from construction to demolition. In response to global warming and growing urban populations, the adoption of green features in residential buildings has become an essential practice to conserve the natural environment, reduce resource consumption, and protect human health. This study investigates the utilisation of green features in certified green residential buildings and examines their impact on life cycle costs. A qualitative research design was adopted, involving multiple case studies of five GBI-awarded green residential projects. Data were collected through semi-structured interviews with developers and document analysis of project records to capture real descriptive perspectives and prevailing cost trends in the industry. The analysis reveals that, from a cost-effectiveness perspective, building orientation, window design, and rainwater harvesting systems are the most commonly applied green features across all projects, contributing to improved energy and water efficiency. The findings also indicate that the highest cost implications occur during the design and construction phase of the life cycle, while reduced operational costs over time help offset the higher initial investment. This study contributes to the body of knowledge by providing empirical insights into how specific green residential building features influence life cycle cost components in the Malaysian context, thereby informing developers and policymakers on cost-effective strategies for sustainable housing. Future research should further explore the constraints in implementing green building features and assess the level of awareness of life cycle costing among construction stakeholders to support more effective sustainable construction practices.

Keywords: Residential Building Facilities, Green Building, Green Features, Life Cycle Cost, Life Cycle Cost Analysis

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INTRODUCTION

Green building implementation has emerged as an important strategy to minimise environmental degradation caused by human activities while promoting sustainable development. Green buildings are recognised for balancing the three pillars of sustainability—environmental, social and economic sustainability (Ha et al., 2023). Although green buildings generally require higher initial investment, numerous studies have demonstrated that this additional cost can be offset through lower operational and maintenance expenses over the building's life cycle, resulting in improved long-term economic performance (Weerasinghe et al., 2022).

In Malaysia, the promotion of green buildings has gained increasing attention in support of the United Nations 2030 Agenda for Sustainable Development. The introduction of the Green Building Index (GBI) in 2009 as the national green building rating tool reflects the country's commitment to sustainable construction and environmentally responsible development (Zakaria et al., 2024). Within the residential sector, the adoption of green features has become increasingly important due to growing concerns over climate change and carbon emissions. The building sector is a major consumer of energy and contributor to greenhouse gas emissions, making residential buildings a key area for sustainable intervention (Min et al., 2022). Green features, including passive and active building systems, are therefore introduced to improve energy efficiency, conserve resources and enhance indoor environmental quality (Mazli & Fauzi, 2022; Simpeh et al., 2024).

Despite these benefits, the implementation of green residential buildings in Malaysia remains relatively limited. One of the major barriers is the perception of higher construction costs, with green buildings reported to cost approximately 10.77% more than conventional buildings (Husin et al., 2024). This additional cost discourages developers and contractors from adopting green features due to concerns over project profitability (Ahmad et al., 2024). Therefore, this paper reviews the utilisation of green features in residential buildings and examines their implications on life cycle cost, focusing on design and construction cost, operational and maintenance cost, and end-of-life cost.

LITERATURE REVIEW

Green Features and Life Cycle Cost

Green features refer to building characteristics and technologies incorporated to minimise environmental impacts while improving resource efficiency, occupant well-being and overall building performance (Goh et al., 2022; Mazli & Fauzi, 2022). These features include both passive and active design strategies that contribute to sustainable building development. In contrast, life cycle cost (LCC) refers to the total cost incurred throughout a building's life cycle, encompassing

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design and construction, operation and maintenance, and end-of-life activities such as demolition, recycling and disposal (Dwaikat & Ali, 2018). Since green buildings require additional initial investment, evaluating their economic performance using LCC provides a more comprehensive assessment than considering construction cost alone.

Malaysia Green Building Index

The Green Building Index (GBI), introduced in 2009 by the Pertubuhan Akitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM), is Malaysia's primary green building rating system. GBI evaluates building sustainability based on six criteria: energy efficiency (EE), indoor environmental quality (EQ), sustainable site planning and management (SM), materials and resources (MR), water efficiency (WE), and innovation (IN). These criteria provide guidance for integrating sustainable practices throughout the design, construction and operational stages of buildings.

Building Life Cycle Cost Analysis

Life cycle cost analysis (LCCA) is widely recognised as an effective decision-making tool for evaluating the long-term economic performance of buildings. In line with ISO 15686-5:2017, LCC consists of design and construction cost, operational cost, maintenance cost and end-of-life cost, together with considerations of service life, analysis period and discount rate (Dwaikat & Ali, 2018; Zakaria et al., 2024; Ayob et al., 2026). Rather than focusing solely on initial construction expenditure, LCCA enables decision-makers to assess future cost savings arising from improved building performance, making it particularly suitable for evaluating green building investments.

Utilization of Green Features in Green Residential Buildings

The incorporation of green features into residential buildings has become an important strategy for achieving sustainable development through reduced energy consumption, efficient resource utilisation and improved indoor environmental quality (GBI, 2013). Based on previous studies, this research focuses on six commonly adopted green features in Malaysian residential buildings, namely building orientation, window, ventilation and daylight design, green and cool roofs, low volatile organic compound (VOC) materials, rainwater harvesting systems and renewable energy systems. These features represent a combination of passive and active design strategies that enhance environmental performance while supporting long-term economic sustainability.

Building orientation is a passive design strategy that minimises solar heat gain and maximises natural daylight, thereby reducing cooling and lighting energy demand (Sivadasan & Basiruddin, 2019; Ha et al., 2023). Similarly,

appropriate window design, natural ventilation and daylight optimisation improve thermal comfort and indoor environmental quality while reducing dependence on artificial lighting and mechanical ventilation (Goh et al., 2022). Green roofs and cool roofs improve thermal performance by reducing heat transfer through the building envelope. Green roofs absorb solar radiation through vegetation, whereas cool roofs utilise reflective materials to reduce roof surface temperature and mitigate the urban heat island effect (Goh et al., 2022; Lawin & Zakaria, 2023).

Low VOC materials are increasingly adopted to improve indoor air quality by reducing harmful emissions from construction materials. Products such as low VOC paints, adhesives and sustainable materials, including bamboo, contribute to healthier indoor environments while promoting the use of renewable resources (Ha et al., 2023; Isukuru et al., 2023).

Rainwater harvesting systems improve water efficiency by collecting and reusing rainwater for non-potable purposes such as toilet flushing and landscape irrigation. The system consists of storage tanks, pumps and distribution pipes that reduce dependence on treated water supplies (Goh et al., 2022). Renewable energy systems, particularly solar photovoltaic (PV) technology, further improve building sustainability by generating clean electricity from renewable resources and reducing reliance on conventional energy sources (Goh et al., 2022).

Overall, the selected green features are expected to influence the life cycle cost performance of residential buildings differently. While some features primarily reduce energy and water consumption during the operational stage, others contribute to improved building durability, lower maintenance requirements or higher residual value at the end of the building's service life. Therefore, understanding the utilisation of these green features provides an important basis for evaluating their implications on life cycle cost in green residential buildings.

Implications of Green Features on Life Cycle Cost of Residential Buildings

Green features are widely recognised as important determinants of the life cycle cost (LCC) performance of green residential buildings. Although the incorporation of green features may require additional investment during the design and construction stage, previous studies have shown that these features can generate long-term economic benefits through lower operational expenditure, reduced maintenance requirements and higher residual value at the end of the building's service life (Dwaikat & Ali, 2018; Weerasinghe et al., 2022). Therefore, the economic performance of green buildings should be evaluated based on the entire building life cycle rather than the initial construction cost alone.

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In this study, green features represent the independent variable, while life cycle cost is the dependent variable. The selected green features comprise building orientation, window, ventilation and daylight design, green and cool roof, low VOC materials, rainwater harvesting system and renewable energy system. These features are expected to influence the three main LCC components, namely design and construction cost, operational and maintenance cost, and end-of-life cost. Since each green feature contributes differently throughout the building life cycle, a comprehensive investigation is required to understand their individual impacts on the overall life cycle cost performance of green residential buildings.

Implications of Green Features on Design and Construction Cost

According to Dwaikat and Ali (2016), they revealed that the green building construction cost is higher as compared to the conventional building and range between 0% to 21%, depending on the type of residential buildings such as terraced house, bungalow and apartment buildings. According to Husin et al. (2024), they explained that passive design strategies such as building orientation, walls insulation and low-emissivity windows will result in relatively lower cost implications in terms of design and construction.

Different green features contribute differently to the initial project cost. Passive design features such as building orientation and natural daylight optimisation generally require greater design consideration with minimal additional construction cost, whereas active systems such as rainwater harvesting and renewable energy installations involve higher expenditure due to additional equipment, materials and installation works. Likewise, the use of low VOC materials and green roofing systems may increase material procurement costs but are expected to provide long-term economic benefits through improved durability and resource efficiency. Therefore, the impact of each green feature on design and construction cost should be evaluated individually rather than generalising the cost implication of green buildings.

Implications of Green Features on Operational and Maintenance Cost

A comparative study between three green buildings and one conventional building by Weerasinghe et al. (2022) shown that the ratio of the overall operational to maintenance cost is approximately 80:20 in both green and conventional buildings. Based on the research outcomes from Weerasinghe et al. (2022), the utilities cost is the main contributor to the operational costs. Nevertheless, there was a significant savings in utilities cost for green buildings over conventional buildings due to the integrated green building features. Similarly, the maintenance cost for internal services is significantly contribute to the total maintenance cost. However, there was also showing a huge savings in

maintenance cost for green buildings over conventional buildings due to the availability of green technologies to control the building environment quality.

The operational and maintenance cost savings also vary according to the type of green feature implemented. Passive features, including building orientation, window design and green roofs, primarily reduce electricity consumption by lowering cooling and lighting demands. Meanwhile, active systems such as rainwater harvesting and renewable energy systems directly reduce water and electricity utility costs. Material-related features, including low VOC materials, may also reduce maintenance frequency due to improved durability and building performance. Hence, understanding the contribution of each green feature provides a more comprehensive evaluation of operational and maintenance cost throughout the building life cycle.

Implications of Green Features on End-of-Life Cost

In the pursue of sustainable practices, the industry is expected to apply deconstruction technique as the option to carefully demolish, dismantle and recycle the building materials (Dwaikat & Ali, 2018). Due to the application of material recycling, the residual value of the green building would be higher than the building that applying mechanical technique for demolition (Weerasinghe et al., 2022). Also, some of the green building features such as photovoltaic panels or the bamboo-made materials could be removed from the building for recycle operations to enhance more residual value**.**

The influence of green features extends beyond the operational stage to the end-of-life phase of the building. Green materials and building systems that are designed for reuse, recycling or deconstruction can reduce demolition waste and disposal costs while increasing the residual value of recoverable materials and components. For example, photovoltaic panels, recyclable roofing materials and certain sustainable building products may retain salvage value after the building reaches the end of its service life. Therefore, evaluating the contribution of individual green features to end-of-life cost is essential to capture their overall economic benefits within the life cycle cost assessment.

RESEARCH METHODOLOGY

This study used a qualitative multiple-case study approach to explore how green features are used in residential buildings and how they affect life cycle costs (LCC). Data came from semi-structured interviews and document analysis, providing detailed insights from industry practitioners (Creswell & Creswell, 2018). Five residential projects certified by the Green Building Index (GBI) were chosen as case studies. Selection was based on their certification, project completion, available documents, and the willingness of developers or property managers to take part. Respondents included property developers, property

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managers, and facilities managers, each with at least five years of experience in green building implementation, operation, or maintenance. The interview questions were developed from a literature review and checked by experts before data collection to make sure they were clear and relevant.

Document analysis was used to support and check the interview results. The documents reviewed included GBI assessment reports, project specifications, cost plans, Bills of Quantities, and records of operation and maintenance. The analysis looked at six main green building features found in the literature: building orientation, window, ventilation and daylighting design, green and cool roofs, low VOC materials, rainwater harvesting systems, and renewable energy systems. The study examined how these features affected four parts of life cycle cost: design and construction, operation, maintenance, and end-of-life costs. Data from interviews and documents were analysed using qualitative content analysis and cross-case comparison to find common patterns and differences among the five case studies.

FINDINGS AND DISCUSSION

Data analysis is carried out through content analysis method to identify the utilization of green features and to analyse the implications of green features on life cycle cost of the green residential buildings.

Green Residential Projects

In this research, there are five GBI-awarded green residential projects being studied. Table 1.0 shows the list of GBI-awarded green residential projects that have involved in this study. The projects are named as Project A, B, C, D and E respectively.

Table 1.0: List of Projects

Project	Project Name
A	Construction and Completion of 37-Storey Luxury Apartment at Jalan Molek 1/27, Taman Molek, 81100 Mukim Plentong, Daerah Johor Bahru, Johor Darul Takzim
B	Construction and Completion of 28-Storey and 6-Storey Luxury Apartment at Jalan Molek 1/27, Taman Molek, 81100 Mukim Plentong, Daerah Johor Bahru, Johor Darul Takzim
C	Construction and Completion of 16-Storey Luxury Apartment at Persiaran Ponderosa Utama, Zon 2A, Taman Ponderosa, 81100 Mukim Plentong, Daerah Johor Bahru, Johor Darul Takzim
D	Construction and Completion of 35-Storey Condominium at Jalan Laksamana 1, Persiaran Puteri Selatan, Puteri Harbour, Iskandar Puteri, 79100 Mukim Pulai, Daerah Johor Bahru, Johor Darul Takzim

Project	Project Name
E	Construction and Completion of 44-Storey and 43-Storey Condominium at Jalan Jalil Perkasa 1, Bukit Jalil, 57000 Mukim Petaling, Daerah Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur.

Utilization of Green Features in Green Residential Buildings

Based on the data from five GBI-awarded projects, the current prevalent green features that have applied in the green residential buildings are identified. Table 2.0 shows the summary of green features that are utilized in five GBI-awarded green residential projects. These green features are divided into two different design approaches, namely passive design and active design. Based on the summary, passive design approach results in higher rate of utilization as compared to active design approach.

Passive design approach such as building orientation as well as window, ventilation and daylighting design are applied in all of the five projects. These green features typically involve lower initial and operational cost as well as minimal maintenance requirements. Thus, developers of all projects tend to apply passive green features from the perspective of cost effectiveness. However, green and cool roof are the least preferred passive green features due to their higher initial cost and maintenance challenges. There are three projects only to apply green and cool roof. Whereas, the remaining two projects are choosing other passive green features like landscaped garden or green vertical wall as the alternatives to prevent heat.

Table 2.0: Utilization of Green Features in Green Residential Projects

Green Features		**Project A**	**Project B**	**Project C**	**Project D**	**Project E**	**Total Project Applied**
Passive Design	Building Orientation	√	√	√	√	√	5
	Window, Ventilation & Daylight	√	√	√	√	√	5
	Green & Cool Roof	√	√	√	X	X	3
Active Design	Low VOC Materials	√	√	√	X	X	3
	Rainwater Harvesting System	√	√	√	√	√	5
	Renewable Energy System	√	√	X	X	X	2

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Among the six green features, the rainwater harvesting system was implemented in all five projects, making it the most widely adopted active design strategy. Developers considered it particularly suitable for high-rise residential buildings due to its ability to collect and reuse rainwater for non-potable purposes such as landscape irrigation and cleaning of common areas, thereby improving water efficiency. In contrast, low VOC materials and renewable energy systems were less frequently adopted. Only three projects utilised low VOC paints, adhesives, sealants and finishes, as these materials generally incur higher costs while offering limited direct energy-saving benefits. One project instead prioritised reducing transportation emissions during material procurement. Renewable energy systems, particularly solar photovoltaic panels, were the least adopted green feature, with only two projects incorporating them. Their limited implementation was mainly attributed to high initial investment costs and licensing requirements despite their potential to promote cleaner energy use.

Implications of Green Features on Life Cycle Cost of Residential Buildings

Based on the cost data obtained from the five case study projects, the implications of green features on the life cycle cost (LCC) of green residential buildings were analysed. Table 3.0 summarises the LCC breakdown into four components: design and construction cost, operational cost, maintenance cost and end-of-life cost. This classification provides a comprehensive understanding of cost allocation throughout the building life cycle and identifies the key sources of cost implications associated with green building implementation.

The findings show that the life cycle cost per square metre (LCC/m²) ranges from RM3,369.21/m² to RM4,280.77/m², with an average of RM3,789.68/m². The variation reflects differences in building size, design complexity, selection of green features, construction practices, long-term maintenance strategies and occupancy rates. These factors demonstrate that the economic performance of green residential buildings is influenced not only by the adoption of green features but also by project-specific characteristics.

Among the four cost components, design and construction cost accounts for the largest proportion of the total LCC, averaging 65.05%. This reflects the substantial upfront investment required to integrate green features during the development stage. Projects A and E recorded the highest design and construction costs due to extensive green feature adoption and greater structural complexity, while Projects B, C and D incurred relatively lower costs because of their smaller development scale.

Maintenance cost represents the second largest component, contributing an average of 19.22% of the LCC. The findings indicate that projects with greater utilisation of green technologies, such as rainwater harvesting and renewable energy systems, require more regular maintenance to sustain building

performance. Projects B, C and D recorded higher maintenance costs, mainly due to higher occupancy rates and greater utilisation of green systems. In contrast, Projects A and E incurred relatively lower maintenance costs, partly because lower occupancy resulted in reduced system usage and maintenance demand.

Operational cost contributes an average of 15.42% of the LCC, demonstrating the long-term economic benefits of green building implementation. The lower operational expenditure is largely attributed to reduced energy and water consumption achieved through the integration of green features. Projects B, C and D recorded relatively higher operational costs due to higher occupancy rates, whereas Projects A and E achieved lower operational costs through more effective integration of green features and lower building occupancy.

End-of-life cost constitutes only 0.31% of the total LCC, indicating minimal expenditure for deconstruction and disposal activities. Larger developments, including Projects A, B, D and E, incurred relatively higher deconstruction costs due to their building size, while Project C recorded the lowest end-of-life cost. In addition, Projects A and B demonstrated higher residual values through the recovery of recyclable materials, particularly solar photovoltaic systems, highlighting the potential economic benefits of sustainable material recovery at the end of the building life cycle.

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Table 3.0: Life Cycle Cost Breakdown for Green Residential Projects

	Components	Project A		Project B		Project C		Project D		Project E		Average	
		Cost (RM)	%	Cost (RM)	%	Cost (RM)	%	Cost (RM)	%	Cost (RM)	%	Cost (RM)	%
DESIGN & CONSTRUCTION COST	Building Works	150,000,000.00	59.68	102,000,000.00	53.75	31,400,000.00	56.05	100,000,000.00	55.17	140,000,000.00	60.85	104,680,000.00	57.10
	GBI Certification	100,000.00	0.04	100,000.00	0.05	50,000.00	0.09	100,000.00	0.06	100,000.00	0.04	90,000.00	0.06
	Other Costs (Site & Soft Costs)	10,500,000.00	4.18	7,140,000.00	3.76	1,884,000.00	3.36	8,000,000.00	4.41	11,200,000.00	4.87	7,744,800.00	4.12
	Professional Fees	10,500,000.00	4.18	7,140,000.00	3.76	1,570,000.00	2.80	7,000,000.00	3.86	9,800,000.00	4.26	7,202,000.00	3.77
	Subtotal	**171,100,000.00**	**68.08**	**116,380,000.00**	**61.32**	**34,904,000.00**	**62.30**	**115,100,000.00**	**63.50**	**161,100,000.00**	**70.02**	**119,716,800.00**	**65.05**
OPERATIONAL COST	Utilities Cost	13,711,163.20	5.45	11,415,902.40	6.02	4,004,626.08	7.15	9,362,248.00	5.16	11,748,111.20	5.11	10,048,410.18	5.77
	- Energy Cost	9,966,264.00	3.96	10,570,280.00	5.57	3,741,879.12	6.69	7,248,192.00	3.99	9,060,240.00	3.94	8,117,371.02	4.83
	- Water Cost	3,442,891.20	1.37	604,016.00	0.32	187,244.96	0.33	1,812,048.00	1.00	2,416,064.00	1.05	1,692,452.83	0.81
	- Sewerage Cost	302,008.00	0.12	241,606.40	0.13	75,502.00	0.13	302,008.00	0.17	271,807.20	0.12	238,586.32	0.13
	Administrative Cost	16,006,424.00	6.37	15,100,400.00	7.96	4,644,883.04	8.29	14,496,384.00	8.00	15,493,010.40	6.73	13,148,220.29	7.47
	Other Costs (Ins. &Taxes)	4,530,120.00	1.80	4,107,308.80	2.16	1,268,433.60	2.26	5,405,943.20	2.98	3,926,104.00	1.71	3,847,581.92	2.18
	Subtotal	**34,247,707.20**	**13.62**	**30,623,611.20**	**16.14**	**9,917,942.72**	**17.70**	**29,264,575.20**	**16.14**	**31,167,225.60**	**13.55**	**27,044,212.38**	**15.42**
MAINTENANCE COST	Services	13,590,360.00	5.41	13,590,360.00	7.16	4,530,120.00	8.09	9,060,240.00	5.00	13,590,360.00	5.91	10,872,288.00	6.31
	Fabric & Decoration	9,060,240.00	3.60	7,550,200.00	3.98	1,661,044.00	2.96	9,060,240.00	5.00	5,436,144.00	2.36	6,553,573.60	3.58
	Cleaning & Ext. Works	13,590,360.00	5.41	13,590,360.00	7.16	1,812,048.00	3.23	9,060,240.00	5.00	6,040,160.00	2.63	8,818,633.60	4.69
	Repairs & Replacement	9,060,240.00	3.60	7,550,200.00	3.98	3,020,080.00	5.39	9,060,240.00	5.00	12,080,320.00	5.25	8,154,216.00	4.64
	Subtotal	**45,301,200.00**	**18.02**	**42,281,120.00**	**22.28**	**11,023,292.00**	**19.67**	**36,240,960.00**	**20.00**	**37,146,984.00**	**16.15**	**34,398,711.20**	**19.22**
END OF LIFE COST	Deconstructing Cost	1,410,000.00	0.56	958,800.00	0.51	236,128.00	0.42	940,000.00	0.52	1,316,000.00	0.57	972,185.60	0.52
	Residual Value	(705,000.00)	-0.28	(479,400.00)	-0.25	(59,032.00)	-0.09	(282,000.00)	-0.16	(658,000.00)	-0.29	(436,686.40)	-0.21
	Subtotal	**705,000.00**	**0.28**	**479,400.00**	**0.26**	**177,096.00**	**0.33**	**658,000.00**	**0.36**	**658,000.00**	**0.28**	**535,499.20**	**0.31**
	Total LCC (RM)	**251,353,907.20**	**100**	**189,764,131.20**	**100**	**56,022,330.72**	**100**	**181,263,535.20**	**100**	**230,072,209.60**	**100**	**181,695,222.78**	**100**
	Gross Floor Area (m2)	**58,717**		**52,800**		**15,465**		**53,800**		**56,364**		-	
	Total LCC/m2 (RM)	**4,280.77**		**3,594.02**		**3,622.52**		**3,369.21**		**4,081.90**		**3,789.68**	

CONCLUSION

This study successfully accomplished two primary research objectives. Regarding the utilization of green features, data from the five GBI-awarded residential projects revealed that developers strongly prefer passive design approaches over active ones. Specifically, building orientation, optimized window design, and rainwater harvesting systems were universally implemented across all five projects. In contrast, only three projects utilized green or cool roofs and low-VOC materials, while just two integrated renewable energy systems.

In terms of life cycle cost (LCC) implications, the findings indicated that the financial impact is heavily concentrated in the initial phases. The design and construction stage carried the highest cost implication at 65.05%, followed by maintenance costs at 19.22%, operational costs at 15.42%, and end-of-life costs at a negligible 0.31%. A closer look at the individual projects revealed that two projects incurred higher cost implications during the design and construction phase, while the remaining three experienced lower impacts. Conversely, for both the operational and maintenance phases, three projects faced higher cost implications compared to two with lower impacts. In the final deconstruction phase, four projects saw higher cost implications, leaving only one with a lower financial impact.

Several limitations were encountered during the research process, most notably the difficulty of recruiting qualified interviewees and accessing sensitive cost data due to strict privacy and confidentiality constraints. To build upon these insights, future studies should pursue more rigorous research into the broader scope of green building features and life cycle costing, ultimately producing more comprehensive benchmarks to guide future sustainable construction.

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HOME ENVIRONMENT SAFETY RISKS AND PERCEIVED SAFETY AMONG EMPTY-NESTER ELDERLY IN NANCHANG, CHINA: A MIXED-METHODS STUDY

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Abstract

China's rapid population ageing and urbanisation have resulted in a growing number of empty-nester elderly living in housing environments not designed to support ageing in place. Despite policy initiatives such as Healthy China 2030, a critical gap persists between age-friendly policy ambitions and the actual safety conditions of domestic environments. This study adopts a mixed-methods approach to examine home safety risks and the adoption of smart elderly care among 384 empty-nester adults (aged ≥60) across six urban districts in Nanchang, Jiangxi Province. A structured survey was complemented by in-situ observations of ten purposively selected households to capture lived spatial practices and environmental conditions. The findings demonstrate that home environmental factors significantly influence perceived safety, explaining 89.7% of the variance ($R^2 = 0.897$, $p < 0.001$). Key determinants include mobility safety ($\beta = 0.409$), non-slip surfaces ($\beta = 0.326$), and adequate lighting ($\beta = 0.191$). Qualitative insights reveal the normalisation of unsafe adaptive practices, such as reliance on handheld lighting for night-time mobility and the use of temporary floor coverings to mitigate uneven surfaces. Spatial disparities across districts further highlight uneven implementation of age-friendly planning principles, with newer developments exhibiting barrier-free features, while older neighbourhoods remain inadequately retrofitted. The study contributes to urban planning discourse by exposing the disconnect between age-friendly policy frameworks and micro-scale residential realities. It calls for a more integrated planning approach that combines housing retrofitting strategies, inclusive design standards, and smart care technologies within local governance systems.

Keywords: Home safety, empty-nester elderly, smart elderly care, ageing in place and elderly housing retrofitting

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INTRODUCTION

China faces rapid demographic aging, with 297 million elderly (21.1% of population) by end-2023, exceeding 15.4% for those aged 65 and above (Cho & Yoon, 2024; Lu et al., 2023). This deep aging phase (14% 65 and above since 2021) is projected to reach 430 million (34.69%) by 2057 (South China Morning Post, 2024), straining traditional family care as seniors live independently. Home environments remain hazardous: 46.4% lack handrails, 46.3% have slippery floors, and 42.8% lack age-appropriate facilities (Chen, Lin, & Li, 2019), making falls the leading injury cause. Health challenges persist, with healthy life expectancy lagging; seniors comprise 40.01% of discharged patients, 79.7% reporting poor health (Fang, Chen, & Zhou, 2019), driving demand for emergency calls (67.74%) and location services (60.74%) (Hu & Zhu, 2025). While the 14th Five-Year Plan (2022) prioritizes home-based tech-integrated care (Hu & Zhu, 2025), implementation gaps persist due to uneven urban-rural resources (Li, Gao, & Yan, 2019) and institutional inefficiencies (Wang & An, 2020), notably lacking incentives to merge age-friendly modifications with smart technologies. Current research fragments physical and smart interventions, overlooking their synergy and underrepresenting older residents' views, especially in cities like Nanchang. Addressing this, the study asks: i) What home attributes risk empty-nester safety in Nanchang? ii) How do perceptions/well-being shape perceived safety? iii) How do smart-home features enhance it?

LITERATURE REVIEW

Physical Environment Deficiencies in Age-Friendly Housing Design

Existing literature highlights that many urban housing environments in China lack alignment with age-friendly principles. Common shortcomings include suboptimal layouts, inadequate lighting, and missing safety features like handrails and non-slip flooring (Ma & Wang, 2021). These deficiencies increase fall risks and reduce mobility confidence, acting as key barriers to safe ageing-in-place.

Health Monitoring Gaps and Emergency Response in Ageing-in-Place Systems

Existing smart ageing-in-place systems show critical gaps in integrating health monitoring and emergency response. Ma & Wang (2021) rank emergency rescue as seniors' top priority, followed by fall detection. Yet, as Wang & Zuo (2024) note, prevalent shortcomings in real-time surveillance of vital signs (e.g., heart rate) and environmental hazards (e.g., gas leaks) delay risk detection, allowing health declines and dangers to escalate before intervention.

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Barriers to Smart Technology Adoption Among Older Adults: Digital Divide and Usability Challenges

Literature identifies persistent barriers to smart ageing technology adoption despite promotional efforts. Wang & Zuo (2024) attribute this to a widening digital divide, citing age-related physical/cognitive declines, low digital literacy, and non-age-friendly interfaces. The same authors further note that privacy risks—including data breaches, unauthorized access, and financial exploitation—undermine older adults' trust and willingness to adopt these systems, underscoring that uptake hinges on accessibility, trust, and inclusive design, not mere availability.

Theoretical Foundation: The Competence–Press Model and Person–Environment Fit in Ageing

Lawton and Nahemow's (1973) Competence–Press Model frames late-life well-being and safety as a dynamic balance between personal competence (health, sensory, and cognitive capacity) and environmental press (physical demands). Excess press undermines outcomes (e.g., falls, anxiety), while aligned environments bolster safety and autonomy. Smart home technologies serve as adaptive tools that enhance person–environment fit by mitigating press via responsive design and real-time support.

Global Perspective

Positioned within global aging-in-place planning, this study offers critical insights for Malaysia while drawing on local scholarship. Abdullah and Salleh (2023) advocate shifting from macro-policy to micro-level retrofits in dense housing, a view reinforced by Ismail and Othman (2022), who stress aligning technological solutions with local socioeconomic realities and support mechanisms. Further enriching this evidence base, Hafiszah et al. (2024) and Ismail et al. (2023)—published in the Journal of Malaysian Planning—highlight intergenerational variations in senior housing needs, cautioning against sole reliance on physical modifications. Collectively, these perspectives mirror the implementation gaps facing Nanchang City in actualizing national age-friendly guidelines.

METHODOLOGY

An explanatory sequential mixed-methods design was employed, initiating with a quantitative survey before transitioning to qualitative participant observation to statistically identify and then contextually interpret key relationships. The study spanned six purposefully selected districts in Nanchang, Jiangxi: Donghu and Xihu (aging, high-density urban core); Qingyunpu (transitional, mixed-use industrial); Honggutan (new development with smart-city integration);

Qingshanhu (industrial-tech corridor with varied housing); and Xinjian (peri-urban fringe with limited infrastructure) (see Figure 1). (refer to Figure 1).

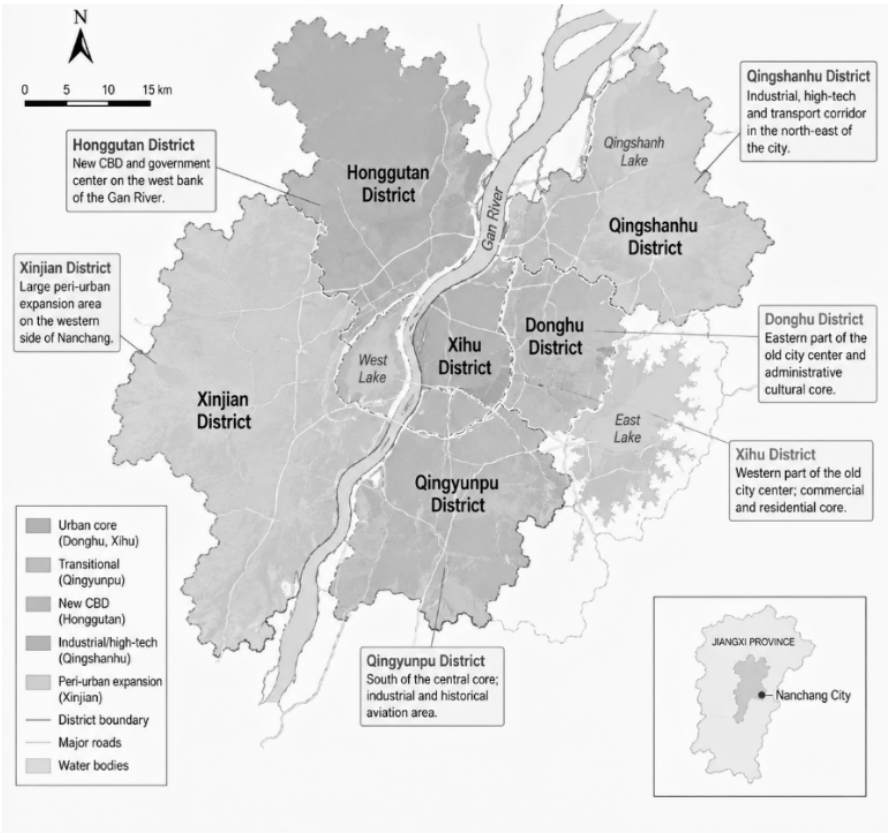


Figure 1: The conceptual map of six urban districts of Nanchang, Jiangxi Province.
Source: Author

Stage 1: Quantitative Data using Survey

The target population comprised empty-nester older adults aged 60 years and above residing in urban Nanchang. A stratified random sampling strategy, based on district, residential type, and age group, was employed. A total of 400 questionnaires were distributed, of which 384 were deemed valid, yielding a usable response rate of 96.0%. Data were collected through face-to-face structured interviews to ensure accuracy and completeness. The overall 31-item scale demonstrated excellent internal consistency, with a Cronbach's alpha coefficient of 0.962.

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Measurement and Reliability

The instrument comprised 31 items: five constructs of five items each (25 attitudinal items) and six demographic items. All attitudinal items used a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The constructs are defined as follows (refer Table 1):

Table 1: Construct Measurement and Reliability Statistics

Construct	Items	Source	Reliability (α)
Home-Environment Safety (HES)	5	Environmental-gerontology	0.962 (Overall)
Well-Being Outcomes (WBO)	5	Established well-being measures	0.89
Perceptions & Usability (PUE)	5	Davis (1989) TAM	0.91
Smart-Home Systems (SHS)	5	Smart-home safety literature	0.88
Elderly Safety (ES) - DV	5	Safety-appraisal literature	0.90

The instrument was validated through a pilot study (n = 40) using item-total analysis (KMO = .712; Bartlett's test significant), which refined it from 35 to 25 attitudinal items; the main-study instrument achieved an overall Cronbach's α of 0.962, and the principal component analysis confirmed the expected five-factor structure. Subscale Cronbach's α coefficients are reported alongside the overall scale reliability to evidence reliability at both levels.

Stage 2: Qualitative Data using Participant Observation

Ten purposively selected empty-nester households from the quantitative sample underwent 3–4 hour in-situ participant observations across three contrasting districts: Donghu (aging high-density), West Lake (notable safety deficits), and Honggutan (modern barrier-free). This design facilitated cross-case comparisons of environmental impacts on elderly safety and mobility. The protocol encompassed a structured safety checklist, contextual inquiry via integrated semi-structured questions on daily routines, and photographic documentation of non-identifiable home features.

RESULT AND FINDINGS

Findings from the Questionnaire Survey

Demographic Characteristics

Table 2 reveals a balanced gender split (47.4% male, 49.0% female) and a predominantly younger-old cohort (68.2% aged 60–69). While 65.9% held a

Bachelor's degree or higher, 53.6% reported annual incomes below ¥5,000, highlighting severe socioeconomic constraints affecting tech affordability. Crucially, the reported "monthly personal income" reflects China's tiered pension system. Generous state-funded pensions for public institution employees contrast sharply with lower benefits for enterprise and urban/rural residents. Consequently, even highly educated retirees often face a "high-income, low-pension" paradox due to low replacement rates in enterprise schemes.

Table 2: Summarises the demographic characteristics of the 384 respondents.

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	182	47.4
	Female	188	49.0
	Rather not say	14	3.6
Age (years)	60–64	151	39.3
	65–69	111	28.9
	70–74	61	15.9
	75–79	35	9.1
	85 and above	26	6.8
Marital Status	Single	117	30.5
	Married	202	52.6
	Divorced	39	10.2
	Widowed	13	3.4
	Separated	13	3.4
Annual Income	Below ¥3,000	75	19.5
	¥3,000–5,000	131	34.1
	¥5,001–8,000	85	22.1
	¥8,001–12,000	63	16.4
	Above ¥12,000	30	7.8
Education	Primary school	26	6.8
	Secondary school	57	14.8
	Vocational training	48	12.5
	Bachelor's degree	149	38.8
	Master's degree	83	21.6
	Doctoral degree	21	5.5

Descriptive Analysis of Safety Risks in the Home Environment of Older Adults

The descriptive statistics on home-environment safety risks revealed key findings shown in Table 2. Flooring safety recorded the lowest mean score (HES2: M = 2.30, SD = 1.49), indicating the most critical safety concern, followed by lighting adequacy (HES1: M = 2.40). In contrast, confidence in movement showed the highest mean (HES5: M = 2.86), suggesting adaptive behavioural responses to environmental risks. Positive skewness values (0.13–0.77) further indicate responses were clustered toward lower safety ratings, reflecting a general

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perception of unsafe home conditions. Table 3 presents descriptive statistics for the five items measuring safety risks in the home environment. The items are on a 5-point Likert scale, where lower scores mean higher perceived risk.

Table 3: Descriptive Statistics of Home-Environment Safety Risks (N=384)

Item	Mean	Std. Deviation	Skewness
HES1: Adequate lighting	2.40	1.19	0.151
HES2: Safe flooring (even, trip-free)	2.30	1.49	0.770
HES3: Non-slip surfaces (bathroom/kitchen)	2.68	1.23	0.131
HES4: Mobility safety (move without obstacles)	2.70	1.20	0.140
HES5: Confidence in movement	2.86	1.35	0.130

Inferential Analysis: Regression Model

A multiple linear regression analysis was performed to examine the predictive effects of home-environment safety factors on perceived elderly safety (dependent variable). The model identified four significant predictors ($p < 0.001$) as presented in Table 4. Mobility safety (HES4) was the strongest predictor ($\beta = 0.409$), followed by non-slip surfaces (HES3) ($\beta = 0.326$), adequate lighting (HES1) ($\beta = 0.191$), and confidence in movement (HES5) ($\beta = 0.111$). In contrast, safe flooring (HES2) was not a significant predictor ($\beta = -0.036$, $p = 0.130$), indicating that flooring evenness and trip-free conditions did not independently influence perceived safety when other factors were controlled (refer to Table 5).

Table 4: Summary of the regression model

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	0.947	0.897	0.896	0.352

The regression model was highly significant ($F=660.229$, $p<0.001$).

Table 5: Regression Coefficients Results

Predictor	Unstandardised B	Std. Error	Standardised β	t	Sig.
(Constant)	0.282	0.047	–	5.959	<0.001
HES1: Adequate lighting	0.176	0.030	0.191	5.762	<0.001

Predictor	Unstandardised B	Std. Error	Standardised β	t	Sig.
HES2: Safe flooring	-0.026	0.017	-0.036	-1.517	0.130
HES3: Non-slip surfaces	0.290	0.069	0.326	4.210	<0.001
HES4: Mobility safety	0.372	0.069	0.409	5.396	<0.001
HES5: Confidence in movement	0.090	0.017	0.111	5.166	<0.001

Prior to interpretation, diagnostic tests confirmed all regression assumptions: VIF values (1.18–2.37) indicated no multicollinearity, while residual normality, homoscedasticity, and independence were also satisfied. A Pearson correlation revealed a very strong positive link between home-environment safety and perceived safety ($r= 0.914$, $p< 0.001$, $N= 384$). Consistently, the regression model was significant ($F= 660.229$, $p< 0.001$) with substantial variance explained ($R^2= 0.897$), confirming a robust positive effect and rejecting the null hypothesis.

Findings from the Participant Observation

Observation Procedure and Protocol

Following an explanatory sequential design, household observations were conducted after the questionnaire survey to provide an in-depth explanation of the statistical findings. Using purposive maximum-variation sampling, 10 households (coded H1–H10) were selected across three districts with significant disparities and covering the full spectrum of smart-home adoption: Honggutan District (high income, high adoption rate; n = 3), Donghu District (moderate level; n = 4), and Xihu District (low income, zero adoption rate; n = 3). Each home visit lasted 3 to 4 hours, utilizing a structured observation checklist organized around four core constructs: home-environment safety, well-being, perceptions and usability, and smart-home systems. The researcher walked through the homes with the residents to record the presence, condition, and functionality of safety-related facilities. Concurrent contextual interviews were conducted using open-ended questions to understand residents' daily safety practices, experiences with existing technologies, device usability, and views on privacy. Throughout the visits, photographic evidence was collected, and reflexive field notes were documented.

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Coding Method

Data analysis followed Braun and Clarke's (2006) six-phase thematic analysis using NVivo. A hybrid abductive approach was adopted, using four conceptual constructs as a deductive framework while inductively coding resident accounts and observations through the standard six phases. Ultimately, all themes were mapped to the study's constructs. Analytical rigor was ensured through supervisory peer debriefing, member checking, audit trails, and reflexive journaling.

Ethical Considerations and Safeguards

The study was approved by the University of Malaya Ethics Committee (UMREC/2025/SS-073). Written informed consent was obtained following cognitive screening, with data anonymized and securely stored. Participants could withdraw anytime, and visits were scheduled at their convenience to minimize disruption. Photographs required explicit consent and excluded identifiable facial features.

Integration with Survey Data

Using an explanatory sequential design, observational and survey data were integrated via "joint displays" to link quantitative findings with qualitative explanations, revealing four core mechanisms; i) A risk awareness effect where high physical mobility correlated with greater risk-taking and fewer safety installations; ii) An integration effect where isolated devices (e.g., automated lighting, standalone alarms) offered negligible security versus valued integrated systems with family notifications; iii) A cognitive association between continuous, integrated monitoring and perceived security, driving sensor dominance; iv) Structural inequality and an awareness gap, wherein stratified services revealed fall-detection devices were exclusive to low-income households as passive post-incident measures which is absent in tech-rich homes highlighting disparities rooted in awareness, not capability.

Theme 1: Perceived Safety as a Product of Personal Adaptation. Across the observations, perceived safety was not primarily derived from the original design quality of the home but from residents' ongoing, self-initiated adaptations to mitigate environmental risks. Participants described safety as an outcome of accumulated experience, where behavioural adjustments and incremental modifications, rather than inherently safe housing conditions, played a central role in maintaining everyday security. The participants responded as;

"*On the whole, my home is comfortable, but there are minor threats. The shower makes the bathroom floor slippery, so I fitted a mat. The hallway lighting was*

previously very low, but sensors come in handy. Nevertheless, I am still very careful, more so at night." (East Lake's Participant P1)

"*I am very sure that my home is very safe now, but it took effort to make it so. I got my son to install grab bars in the bathroom and near the stairs. Before this, I had nearly fallen on both occasions*." (West Lake's Participant P2)

Observational evidence corroborated these accounts: homes in East Lake commonly exhibited deliberate safety modifications such as grab bars, additional lighting, and non-slip mats, whereas West Lake homes showed limited evidence of such interventions.

Theme 2: Lighting and Visibility as Determinants of Safety

Adequate lighting and clear visibility emerged as fundamental determinants of perceived and actual safety within the home environment. Participants' accounts revealed that safety is highly contingent on the ability to visually navigate spaces, particularly during nighttime or low-light conditions. The absence of reliable lighting was associated with disorientation, loss of spatial awareness, and increased risk of collision or falls, underscoring the critical role of illumination as both a preventive and enabling environmental factor.

"*The time when the power went off at night was a time when I felt insecure. I did not know where to go in the kitchen due to the dark conditions and hit a chair. After that, I installed emergency lighting, which comes on automatically*." Participant P2

Inadequate lighting compromises safety and triggers reactive adaptations, such as emergency lighting. Observations confirmed this: 70% of homes had adequate lighting, but disparities existed. Honggutan featured proactive, built-in motion sensors, while East Lake residents independently installed battery-operated sensors. Conversely, West Lake relied on minimal lighting; some residents used handheld torches, a functional but risky coping strategy due to limited illumination.

Theme 3: Flooring and Surface Risks.

Flooring conditions were identified as a key contributor to slip-and-fall risks, particularly in wet areas such as bathrooms and kitchens. Participants' accounts highlighted how smooth or wet surfaces directly increase the likelihood of accidents, often leading to safety modifications after minor falls or near-miss events. This reflects how flooring safety is experienced in daily life as an ongoing risk requiring adaptation.

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"*Approximately one year ago, I fell slightly, leaving the shower due to the floor being wet and smooth. It frightened me, though I was not seriously injured. I then fitted an anti-slip mat and grab handle*." (Participant P1)

This statement shows how even minor incidents prompt immediate behavioural and environmental adjustments to reduce future risk. Observations confirmed these findings. Six of ten (60%) homes had adequate flooring safety. All Honggutan homes used uniform anti-slip matte flooring, while some East Lake homes had partial anti-slip mats. In contrast, all West Lake homes had polished tiles in wet areas without anti-slip measures, indicating a higher persistent slip risk. Slippery and uneven flooring was a major concern.

Theme 4: Structural Inequalities in Home-Environment Safety Across Districts

A cross-case and comparative analysis finding of this study is that home safety conditions are not evenly distributed, but are shaped by broader structural and spatial inequalities. Differences in housing age, urban development policies, and access to retrofit support have produced distinct levels of safety and technology adoption across districts, beyond individual household control or awareness.

This pattern highlights that safety outcomes are strongly influenced by structural conditions such as construction era, municipal investment in inclusive infrastructure, household income levels, and access to retrofit or ageing-in-place programmes. Rather than reflecting differences in personal safety awareness or motivation, the findings indicate that inequality in the built environment significantly shapes the level of protection available to older adults across districts (refer to Table 6).

Table 6: District Safety Features & Smart Home Adoption Levels

District	Housing Type	Safety Features	Smart Home Adoption
Honggutan	Modern high-rise, barrier-free	Built-in motion lighting, anti-slip floors, grab bars	High (integrated systems)
East Lake	Older mixed	Self-initiated adaptations (grab bars, mats, sensor lights)	Partial (standalone devices)
West Lake	Oldest stock, unmodified	Polished ceramic tiles, no grab bars, no anti-slip	None (cost and support barriers)

Theme 5: Normalised Hazards Uncovered by Observation

Participant observation uncovered unreported home hazards—including rugs masking uneven tiles (Donghu), bedside torches (Xihu), poor drainage causing shower stagnation (Xihu), and walkway obstructions (both districts)—underscoring observation's value. These risks, normalized through long-term exposure, were invisible to residents yet clearly visible during visits, explaining critical underreporting in self-reported data.

DISCUSSION

This study establishes home-environment safety as the predominant determinant of perceived elderly safety, accounting for 89.7% of variance, corroborating Xu et al. (2026) on lighting and physical design in Jiangxi. Extending Lawton and Nahemow's (1973) Competence–Press Model, mobility safety emerged as the strongest predictor, indicating perceived safety is driven more by navigational ease than static features. While safe flooring lacked statistical significance (contra Cho & Yoo, 2024), qualitative data revealed persistent slip hazards in West Lake, suggesting non-significance stemmed from low flooring-type variability in standardized Nanchang housing rather than risk absence. Notably, psychological confidence ($\beta = 0.111$) proved an independent predictor, augmenting the Ecological Theory of Aging by foregrounding subjective adaptation alongside functional competence (Zhou & Wu, 2022). Integrating mixed methods thus elucidates how perceived safety synthesizes physical conditions and subjective experience, exposing limitations in survey-only assessments.

Policy and practical implications follow accordingly: i) prioritizing mobility through retrofits that ensure clear, widened circulation pathways (Zhang & Liu, 2024); ii) deploying low-cost, high-impact interventions such as motion-sensitive lighting and anti-slip surfaces to mitigate prevalent hazards; iii) directing structural subsidies toward aging, low-income housing particularly in high-risk, underserved districts such as West Lake in redress systemic inequities; and iv) integrating wireless or voice-activated emergency systems within high-risk zones (e.g., bathrooms and bedrooms) to enhance responsiveness and safety (Zhang & Li, 2023).

CONCLUSION

This study examined the relationship between home-environment safety and perceived safety among empty-nester elderly in Nanchang, China. Findings show that home-environment safety explains 89.7% of the variance in perceived safety, with mobility safety, non-slip surfaces, adequate lighting, and confidence in movement as significant predictors, leading to the rejection of the null hypothesis. Complementary qualitative findings revealed normalized hazards, district-level structural inequalities, and adaptive coping strategies that surveys alone missed.

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The study contributes theoretically by extending the Ecological Theory of Aging to show psychological confidence as an independent determinant of safety; methodologically by highlighting participant observation to identify hidden risks; and practically by guiding age-friendly housing interventions that prioritize mobility, lighting, anti-slip surfaces, and equitable retrofits.

Despite limitations of its cross-sectional, single-city design and small qualitative sample, future research should adopt longitudinal approaches and comparative studies. Furthermore, integrated frameworks linking housing design, smart technology, and community governance are needed. Notably, while the quantitative model highlights physical factors as primary predictors, the qualitative phase revealed that smart technologies act as a complementary layer of security, particularly in high-income districts.

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PROFESSIONAL SUSTAINABILITY AND REGULATORY MISALIGNMENT IN MALAYSIAN REAL ESTATE AGENCY PRACTICE: INSIGHTS FROM ELITE PRACTITIONERS

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Abstract

The Malaysian real estate agency sector is governed by a formal regulatory framework intended to uphold professionalism, protect consumers, and preserve market integrity. Despite this, persistent concerns regarding illegal brokerage, weak enforcement, inadequate negotiator oversight, uneven technological adaptation, and declining professional standards continue to affect the sector. This study examines how regulatory and governance challenges shape the sustainability of professional real estate agency practice in Malaysia. Using a qualitative exploratory design, semi-structured interviews were conducted with five experienced registered estate agents in Malaysia and analysed thematically. The analysis identifies four interrelated challenges: outdated legislation, enforcement asymmetry, uneven oversight of real estate negotiators, and business and digital pressures affecting sustainable compliance. Together, these challenges point to a broader condition of regulatory misalignment in which formal professional expectations are insufficiently aligned with operational realities. The study argues that the sustainability of professional real estate agency practice depends not only on formal compliance structures but also on the degree to which regulation, supervision, market conditions, and institutional capacity are mutually aligned. By reframing familiar industry problems as a governance issue affecting professional sustainability, the paper offers an integrated and analytically grounded interpretation of reform needs in Malaysian real estate agency practice.

Keywords: Real Estate Agency Practice, Professional Sustainability, Regulatory Misalignment, Governance, Real Estate Negotiators

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INTRODUCTION

The real estate agency sector plays an important intermediary role in property markets by facilitating transactions, reducing information asymmetry, and supporting consumer decision-making in complex, high-value exchanges. Because of this role, estate agency practice is commonly regulated to ensure competence, ethical conduct, accountability, and consumer protection. In Malaysia, it is formally governed by the Valuers, Appraisers, Estate Agents and Property Managers Act 1981 (Act 242) together with related professional standards and regulatory guidance intended to preserve public confidence and market integrity (BOVAEP, 2020).

Despite this framework, the industry continues to face recurring challenges: illegal brokerage, weak enforcement, inadequate negotiator oversight, non-compliance with professional norms, and uneven adaptation to digital change (Ahmad et al., 2024; Baharum et al., 2025; Johaimi Ling et al., 2025; Ting & Baharum, 2024). Often treated as separate operational or ethical problems, these may reflect a broader structural concern: a growing disconnect between formal regulatory expectations and the realities of contemporary practice. The professions literature suggests that where formal standards detach from changing organisational and market realities, professional legitimacy and regulatory credibility come under strain (Muzio & Kirkpatrick, 2011; Noordegraaf, 2020).

This concern is especially relevant in Malaysia, where the profession is formally expected to uphold competence, fiduciary responsibility, and the public interest, yet practice is increasingly shaped by commission dependence, large negotiator workforces, intense competition, and digital transformation (Low et al., 2020; Ting & Baharum, 2024). Where these conditions are not adequately reflected in regulatory design and enforcement, professionalism becomes harder to sustain, even where it remains formally mandated. Familiar sectoral problems may therefore be better understood not as failures of conduct alone, but as signs of regulatory misalignment.

Recent Malaysian literature documents ethical concerns, regulatory shortcomings, and ambiguities in negotiator practice, alongside calls for reform (Ahmad et al., 2024; Baharum et al., 2025; Johaimi Ling et al., 2025; Ting & Baharum, 2024), yet less attention has been paid to how these issues collectively affect the longer-term sustainability of professional practice. Drawing on qualitative interviews with experienced registered estate agents, this study examines how regulatory and governance challenges shape professionalism and compliance in everyday practice. It argues that the profession's sustainability depends not only on formal rules, but on whether they remain aligned with workforce structure, supervisory capacity, technological change, and market pressures.

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LITERATURE REVIEW

Professionalism in Real Estate Agency Practice

Real estate agency occupies a hybrid position between commercial intermediation and professional service. Agents work in competitive, commission-driven markets yet are also expected to demonstrate specialised knowledge, ethical conduct, accountability, and fiduciary responsibility. The legitimacy of the profession therefore rests not on sales performance alone, but on trust, transparency, and the quality of client representation (Markoc & Cizmeci, 2021).

In Malaysia, these expectations are institutionalised through Act 242 and related standards administered by the Board of Valuers, Appraisers, Estate Agents and Property Managers (BOVAEP, 2020). This reflects a conventional model of professional governance in which registration, supervision, ethical rules, and disciplinary processes are intended to uphold public confidence. Recent studies suggest, however, that the challenge is no longer simply defining professionalism but sustaining it under changing market and organisational conditions, with Malaysian research highlighting persistent ethical concerns, weak transparency, uneven professional behaviour, and continuing calls for reform (Ahmad et al., 2024; Baharum et al., 2025; Johaimi Ling et al., 2025).

Governance Gaps, REN Oversight, and Market Integrity

Regulation in real estate agency serves both protective and legitimising functions, shielding consumers from poor practice and distinguishing licensed, accountable intermediation from informal or unethical activity. Yet several signs suggest the current Malaysian framework is under strain: weak enforcement against illegal brokers, uneven accountability, and limitations in the supervisory relationship between registered estate agents (REAs) and real estate negotiators (RENs) (Baharum et al., 2025; Ting & Baharum, 2024).

The role of RENs is especially significant because negotiators now form a large and operationally important segment of the workforce. Although required to operate under the supervision of registered principals, they raise concerns in recent studies regarding ambiguous role boundaries, ethical lapses, and the practical difficulty of meaningful oversight at scale (Johaimi Ling et al., 2025; Ting & Baharum, 2024). The issue is thus not only individual misconduct but institutional design and workforce organisation.

These concerns are not unique to Malaysia. Comparative research on property markets in emerging and middle-income economies shows similar tensions wherever formal systems operate alongside less organised, less transparent practices. In Zambian cities, for example, formal and informal real estate markets coexist and interact, with informal activity continuing to shape property transactions despite the formal regulatory framework (Munshifwa et al.,

2018). In the South African real estate industry, the sector is likewise challenged by unregistered and non-compliant practitioners operating alongside licensed firms, and by persistent difficulties in enforcing ethical standards in practice (Moropane et al., 2023). Read against this literature, the Malaysian case reinforces the view that the core challenges are ones of governance and enforcement capacity rather than gaps in formal legislation alone.

Professional Sustainability and Regulatory Alignment

The analysis is organised around two related concepts: professional sustainability and regulatory misalignment. Professional sustainability is defined here as the capacity of a profession to maintain its competence, legitimacy, and public trust over time as economic, organisational, and technological conditions change, extending the term beyond its environmental meaning to the long-term resilience and social legitimacy of an institutionalised occupation. Regulatory alignment refers to how far formal rules, governance mechanisms, and supervisory arrangements remain compatible with how professional work is organised and performed; regulatory misalignment describes the converse a disconnect between formal expectations and the legal design, enforcement capacity, workforce structure, and market conditions through which professional practice is enacted.

Framed this way, regulatory misalignment is closely related to institutional decoupling, in which the formal structures of an organisation or field become detached from its operational practices (Bromley & Powell, 2012; Meyer & Rowan, 1977). Where professional standards persist as symbolic commitments but lack the conditions required to enact them, the result is a policy-practice decoupling that weakens the credibility of the rules. This connects to the professions literature, which holds that legitimacy depends not only on credentials and codified standards, but on the institutional framework's continued capacity to align them with changing organisational and market realities (Muzio & Kirkpatrick, 2011; Noordegraaf, 2015; Suddaby et al., 2007). Professional sustainability is thus undermined less by isolated misconduct than by the cumulative effect of this decoupling.

This lens is relevant because technological change and business-model shifts are altering how intermediation is practised. Digital transformation can support efficiency and value creation, but its benefits depend on institutional support, adaptive capability, and governance coherence (Guandalini, 2022; Low et al., 2020); broader work shows organisational adaptation is uneven and often constrained by cost, capability, and structural barriers (Nadkarni & Prügl, 2021). Professional sustainability in estate agency therefore depends not only on ethical norms and formal compliance, but on whether the regulatory system remains aligned with market realities, workforce structure, and digital change.

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Against this background, the present study interprets widely reported industry problems not as disconnected deficiencies but as indicators of whether the conditions necessary to sustain professionalism remain intact. This offers a governance-oriented perspective on reform and positions estate agency practice within a wider institutional concern relevant to planning, regulation, and property market integrity.

RESEARCH METHODOLOGY

This study adopts a qualitative exploratory design to examine how regulatory and governance challenges affect the sustainability of professional real estate agency practice in Malaysia. A qualitative approach suits the issues under investigation: professionalism, compliance, regulatory fit, and institutional constraints, shaped by practitioner experience and organisational context rather than by purely measurable variables. The study therefore seeks analytical depth rather than statistical generalisation.

Data Collection

Primary data were collected through semi-structured interviews with five experienced registered estate agents in Malaysia, most based in the Klang Valley. A purposive elite-sampling strategy recruited information-rich participants with substantial professional experience and direct familiarity with the regulatory, operational, and professional dimensions of estate agency practice. They were selected because they occupied senior positions and were well placed to reflect on governance, enforcement, supervision, and sectoral change. Elite interviewing is particularly useful where the aim is to access perspectives grounded in authority, specialised knowledge, and institutional experience rather than broad population coverage (Solarino & Aguinis, 2021).

Participants were identified through purposive elite sampling and recruited via professional association networks and the authors' contacts. They were approached by email and telephone, briefed, and invited to take part voluntarily. Interviews were conducted both face-to-face and online, according to availability, and each lasted approximately 60 to 90 minutes. They followed a semi-structured protocol developed from the study objectives and the literature, covering legislative fit, enforcement and illegal brokerage, negotiator supervision, professionalism, and business and digital change. Interviews were held in a mix of English and Malay, with quotations translated where relevant. All were conducted with informed consent, audio-recorded, transcribed, and anonymised using participant codes (P1-P5).

Basing the study on five elite participants was guided by the principle of information power rather than a predetermined target sample size (Malterud et al., 2016): the number required depends on the richness each case contributes

relative to the aim, so the denser the information, the fewer participants are needed. Several features indicate high information power here. The aim is narrow and clearly bounded; the participants are highly specific to it, each a senior practitioner with direct involvement in professional governance, enforcement, supervision, or training; and the analysis is theoretically informed, drawing on established concepts from the professions and regulation literature. The extended interviews supported detailed accounts, and the strategy was case-oriented and interpretive rather than aimed at cross-sectional comparison. Together these conditions raise information power and lower the number required. Table 1 summarises the participant profile.

Table 1: Profile of Interview Participants.

Participant	Role	Experience (years)	Industry involvement
P1	Agency Principal / senior practitioner	26	Office bearer in professional association. Continuous Professional Development trainer
P2	Agency Principal / senior practitioner	28	Office bearer in professional association. Continuous Professional Development trainer
P3	Agency Principal / senior practitioner	26	Former office bearer in professional association. BOVAEP committee member
P4	Agency Principal / senior practitioner	22	Office bearer in professional association. BOVAEP committee member
P5	Agency Principal / senior practitioner	16	Office bearer in professional association. Continuous Professional Development trainer

Source: Developed by the author (2026)

It is important to acknowledge the standpoint from which these findings are generated. All five participants were senior registered estate agents and agency principals, several holding or having held positions in professional associations or on regulatory committees. As established, licensed members of the profession, their accounts reflect the perspective of incumbents whose standing is tied to the existing licensing regime. This is analytically valuable, since they hold authoritative knowledge of how regulation, enforcement, and supervision work in practice. Yet the actors they identify as sources of difficulty: illegal brokers and inadequately supervised negotiators are those who compete with, or operate beneath, licensed principals. Their characterisation is therefore best read as the situated perspective of the established profession, and the analysis is framed accordingly.

Data Analysis

The interview data were analysed using Braun and Clarke's (2021a) six-phase approach to thematic analysis, a systematic yet flexible method for identifying patterns of meaning across a qualitative dataset. Analysis began with repeated reading of the transcripts for familiarisation, followed by initial coding applied

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manually across all transcripts. Related codes were clustered into candidate themes, reviewed against the coded extracts and the dataset, refined, and defined in relation to the study objectives. Coding and theme development were led by the lead author and reviewed by the wider author team, with differences resolved through discussion. This produced four interrelated themes: (i) outdated regulation and the declining fit with contemporary practice; (ii) enforcement asymmetry, illegal brokerage, and weakened regulatory legitimacy; (iii) uneven REN oversight, workforce structure, and the erosion of professionalism; and (iv) business fragility, digital unevenness, and sustainable compliance.

Sample adequacy was assessed in terms of thematic sufficiency within a narrowly defined, elite, and relatively homogeneous group. By the later interviews the same core issues were recurring and no substantially new categories relevant to the study's focus were emerging. Consistent with guidance cautioning against treating data saturation as a fixed threshold in reflexive thematic analysis (Braun & Clarke, 2021b), the study does not claim industry-wide saturation or statistical representativeness. Rather, it offers analytically relevant insights from information-rich elite informants whose authority and institutional experience are directly pertinent to the governance issues investigated (Rahimi & Khatooni, 2024). The thematic analysis generated four interrelated themes that structure the analysis and discussion presented in the following section, as summarised in Table 2.

Table 2: Themes, Indicative Issues, and Analytical Implications.

Theme	Indicative issues raised by participants	Analytical implication
Outdated regulation and the declining fit with contemporary practice	Outdated Act 242; limited recognition of digital transactions, e-signatures, online marketing, and platform-based practice; regulatory lag behind industry change	Indicates weakening alignment between formal regulation and contemporary operational realities
Enforcement asymmetry, illegal brokerage, and weakened regulatory legitimacy	Persistent presence of illegal brokers; limited enforcement reach; unfair competition for licensed practitioners; weak deterrence; erosion of consumer trust	Suggests that regulatory legitimacy is weakened when the system cannot maintain a credible boundary between legal and illegal practice
Uneven REN oversight, workforce structure, and the erosion of professionalism	Weak or uneven REN supervision; limited training depth; fake advertisements; misleading conduct; inconsistent service quality; difficulty enforcing standards across large negotiator workforces	Highlights a structural tension between formal professional accountability and the operational reality of negotiator-led practice
Business fragility, digital unevenness, and the challenge of sustainable compliance	Competitive pressure; fragile business models; smaller firms struggling with technology adoption; uneven digital capacity; difficulty maintaining supervision, training, and ethical standards under financial strain	Shows that sustainable professionalism depends not only on regulation, but also on organisational capacity and the viability of compliance under market pressure

Source: Developed by the author from thematic analysis (2026).

Several steps supported the trustworthiness of the findings, following the criteria of credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). Credibility was supported through information-rich elite participants, verbatim transcription, and peer debriefing among the author team. Transferability is supported by clear description of the participants, context, and analytical reasoning, enabling readers to assess relevance to other settings. Dependability and confirmability were supported by grounding each theme in participants' own accounts through illustrative quotations. Where coding was conducted primarily by one researcher, themes were reviewed collectively by the author team to guard against idiosyncratic interpretation.

ANALYSIS AND DISCUSSION

Theme 1: Outdated Regulation and the Declining Fit with Contemporary Practice

A central concern was that the legal and regulatory framework has not kept pace with the industry's transformation. Participants repeatedly described Act 242 as an old framework that no longer fits contemporary practice, particularly regarding digital transactions, e-commerce, digital signatures, and platform-based services. While the legislation still provides the formal basis for regulation, they saw it as increasingly disconnected from how agency work is currently conducted. As one participant stated:

> *"The Act 242 and Standards should be updated to include provisions for digital transactions, e-signatures, and online platforms to reflect current industry practices."*

This matters because regulation is not only a legal instrument; it also structures the expectations and accountability mechanisms through which a profession maintains legitimacy. When practitioners regard the system as outdated, formal rules risk being treated as procedural hurdles rather than meaningful guides to practice. Their accounts convey not a rejection of regulation, but concern that the framework has not kept pace with technological change and shifting business models; a challenge the professions literature also identifies, where formal systems struggle to remain aligned with rapidly changing organisational and technological environments (Muzio & Kirkpatrick, 2011; Susskind & Susskind, 2015).

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Theme 2: Enforcement Asymmetry, Illegal Brokerage, and Weakened Regulatory Legitimacy

A second theme concerned the persistent presence of illegal brokers and the limits of enforcement. Participants emphasised that although regulation governs licensed practitioners, the system is far less effective against unlicensed actors operating outside the formal structure. This creates enforcement asymmetry: registered practitioners remain bound by compliance obligations while illegal brokers operate with fewer constraints and limited fear of sanction.

For participants, this was not merely a legal problem but a structural threat to market integrity and professional morale. Illegal brokers were seen as undermining consumer trust, distorting competition, and weakening the credibility of the licensed profession. One participant observed that:

> *"The industry faces significant challenges with unethical behaviour, including fake advertisements, illegal brokers, and unscrupulous agents who mislead clients."*

Several participants suggested that the regulator's inability to act decisively against such actors has left compliant practitioners professionally and commercially disadvantaged. This is reinforced by the limited reach of Act 242, which does not directly extend to illegal brokers operating outside the formal system (Mahaletchumi, 2020). The issue is thus not only enforcement weakness but also weakened regulatory legitimacy and trust in the profession's capacity to maintain credible market boundaries (Noordegraaf, 2020; Suddaby et al., 2007).

This has wider implications for professional sustainability. A profession depends not only on internal standards but on its institutional framework's ability to distinguish legitimate from illegitimate practice in visible, enforceable ways; where that boundary weakens, the value of professional registration erodes. Illegal brokerage is therefore not a peripheral enforcement issue but a governance problem that weakens institutional credibility and confidence in the regulatory system. This extends recent Malaysian work on unethical conduct and stricter enforcement (Baharum et al., 2025; Johaimi Ling et al., 2025), reframing it as a question of regulatory legitimacy rather than discipline alone (Noordegraaf, 2020; Suddaby et al., 2007).

Theme 3: Uneven REN Oversight, Workforce Structure, and the Erosion of Professionalism

The third theme concerns real estate negotiators and the limits of current supervisory arrangements. Participants acknowledged negotiator's importance but doubted that the existing framework provides sufficiently robust oversight, training, or accountability for this segment of the workforce. Although

negotiators must formally work under the supervision of registered agents, participants questioned whether this can be meaningfully sustained, particularly in firms managing large teams or under intense commercial pressure.

This was closely linked to perceptions of declining professionalism. Participants cited fake advertisements, misleading conduct, inconsistent service standards, and varying competency among negotiators, suggesting the current oversight model often fails to ensure consistent adherence to professional expectations. The issue is therefore not simply that individual negotiators behave improperly, but that the supervisory structure may be poorly aligned with workforce scale, recruitment intensity, and competitive pressure. As one participant put it:

> *"Act and rules only apply to REA, PEA, PV & RV, not to REN. Negotiators running wild, tarnishing reputation of the profession."*

Participants also highlighted the limitations of current training pathways. The comparatively light requirements for negotiators were seen as inadequate for roles that are increasingly visible and client-facing. This has direct implications for professional sustainability, since a profession's credibility depends not only on the conduct of formally registered principals, but also on the competency and behaviour of the wider workforce through which the profession is enacted.

This suggests the issue is not only training or discipline, but whether the profession's organisational structure still allows professional standards to be enacted consistently (Muzio & Faulconbridge, 2013; Muzio & Kirkpatrick, 2011). Recent work in *Planning Malaysia* has similarly highlighted ambiguities in REN roles and the need for tighter oversight and stronger disciplinary measures (Johaimi Ling et al., 2025; Ting & Baharum, 2024). The present study reinforces those concerns but recasts REN governance as a workforce-structure issue: the question is not only whether negotiators behave professionally, but whether the current regulatory design makes sustained supervision realistically achievable.

Theme 4: Business Fragility, Digital Unevenness, and the Challenge of Sustainable Compliance

The fourth theme highlights how professional compliance is shaped by business conditions and differential organisational capacity. Participants described a sector strained by competition, business-model fragility, pressure to recruit and retain negotiators, and the need to adapt to digital technologies. Smaller firms were seen as especially vulnerable, facing higher relative costs, weaker capital, and fewer capabilities for investing in technology, training, and operational systems.

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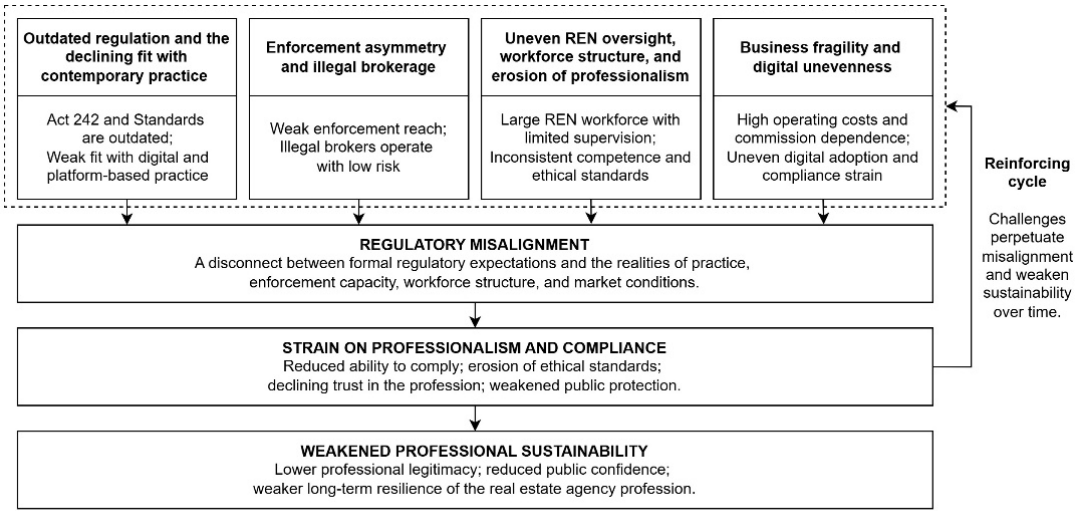
These pressures affect professionalism through the organisational conditions under which compliance must be sustained. Under severe financial pressure, participants suggested, maintaining high standards of supervision, training, and ethical discipline becomes more difficult. Digital transformation was seen as both necessary and uneven: larger firms were generally better able to adopt digital platforms and data-driven systems, while smaller firms struggled to keep pace because of resource limitations, as one participant described:

> *"Larger firms with more resources are increasingly leveraging technology to streamline operations, while smaller firms struggle with technology adoption due to limited capital. Many small companies are struggling, so more and more of them are having to merge with or join bigger companies."*

This uneven capability raises the prospect of a widening divide between firms that can modernise and those dependent on more fragile, reactive practices. Sustainable professionalism therefore requires not only rules and enforcement, but an institutional environment in which ethical and competent practice remains organisationally viable.

This is consistent with scholarship showing that digital transformation and sustainability are positively linked only where firms possess sufficient adaptive capacity (Guandalini, 2022; Low et al., 2020), and with research positioning regulation, innovation, and sustainable growth as interconnected rather than separate (Islam & Wahab, 2021). Governance reform should therefore not be conceived only as tighter control, but as enabling firms, especially smaller ones, to sustain professionalism under uneven conditions. In technology-mediated markets, intermediary professions must continue to demonstrate functional value to clients, not merely compliance or symbolic status (Muzio & Faulconbridge, 2013; Susskind & Susskind, 2015).

Taken together, the four themes indicate that the central issue is not a simple decline in ethics or discipline, but a deeper governance condition in which formal expectations of professionalism are increasingly misaligned with legal design, enforcement capacity, workforce organisation, and business reality. Figure 1 interprets how these interrelated pressures collectively weaken professional sustainability in Malaysian real estate agency practice.



Note: REN = Real Estate Negotiator; Act 242 = Valuers, Appraisers, Estate Agents and Property Managers Act 1981 (Act 242)

Figure 1: Conceptual Interpretation of Regulatory Misalignment and Professional Sustainability in Malaysian Real Estate Agency Practice.
Source: Developed by the author from thematic analysis (2026)

As Figure 1 shows, the challenges are best understood as interacting rather than isolated. Their cumulative effect is regulatory misalignment, which in turn places sustained pressure on professionalism, compliance, and institutional legitimacy. This helps explain why familiar sectoral problems persist despite a formal regulatory framework.

CONCLUSION

This study examined how experienced practitioners perceive the relationship between regulation, governance, and everyday professional practice. The findings show that outdated legislation, weak enforcement, uneven REN oversight, and business and digital pressures are not isolated deficiencies but interconnected symptoms of regulatory misalignment, leaving the current governance framework increasingly out of step with the organisational and market realities of contemporary estate agency practice.

The paper argues that professional sustainability rests not on the existence of formal regulation alone, but on whether that regulation remains relevant, enforceable, and institutionally compatible with how practice is organised. This is consistent with the findings of Lai & Stacchezzini (2021). Where this alignment weakens, professionalism becomes harder to sustain, public trust may erode, and the profession's legitimacy may be undermined. Reframing familiar sectoral problems through the lens of regulatory misalignment offers a

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more integrated interpretation of reform needs than one treating them as discrete failures of individual conduct.

These findings carry implications for the principal actors in estate agency governance. For *regulators*, and BOVAEP in particular, two priorities stand out: amending Act 242 and its standards to recognise digital transactions, electronic signatures, and platform-based practice; and extending enforcement and sanctions to unlicensed actors beyond the registered system. For *professional bodies* such as the Malaysian Institute of Estate Agents, there is scope to strengthen continuing professional development and ethics requirements and to provide shared compliance, training, and technology resources smaller firms cannot easily develop alone. For *registered estate agents*, the findings underline the need for realistic supervision ratios and internal compliance processes so that accountability for negotiators remains meaningful as teams grow. For *real estate negotiator supervision* specifically, negotiators should be brought within the profession's disciplinary framework, minimum training raised, and the negotiator-to-principal ratio limited so that oversight remains achievable. Together these measures address not only the content of regulation but the institutional conditions on which sustained professionalism depends.

As with all qualitative research of this kind, these findings support analytical rather than statistical generalisation. The study does not claim to represent all Malaysian estate agents; it reflects the situated perspective of senior, licensed practitioners rather than a comprehensive view of the sector. What it offers is transferable insight into the governance dynamics shaping professional sustainability in regulated intermediary professions facing technological change and workforce expansion. The interacting pressures identified here: outdated regulation, enforcement asymmetry, workforce structure, and organisational capacity, are likely to be analytically relevant to comparable regulated professions and property markets. The resilience of Malaysian real estate agency practice will depend on moving beyond static compliance toward a more responsive, institutionally aligned model of regulation. Future research could extend this study by including regulators, real estate negotiators, consumers, and firms beyond the Klang Valley to examine whether similar patterns of regulatory misalignment occur across the wider Malaysian real estate agency sector.

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DISCLOSURE

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IS GREEN A PREMIUM? AN INVESTIGATION ON THE IMPACT OF URBAN PARK ON HOUSING PRICE

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Abstract

Urban green spaces are increasing recognised as an important element of residential development. In line with this, this study aims to quantify the extent to which urban park landscape features contribute to housing prices. This study utilized residential transaction data spanning from 2016 to 2023 across three major housing areas, incorporating both conventional and modern landscape designs. This study employs hedonic price modelling to estimate the green premium via Ordinary Least Squares regressions. The findings suggest a positive correlation between housing prices and the presence of urban parks, indicating the existence of a "green premium". The research contributes to the literature by providing empirical evidence of the urban park landscape's economic value in the housing market. It underscores the critical role of urban park landscape in shaping the economic dynamics of the housing market. It provides valuable insights for urban planners, valuers, financial institution and policymakers in advocating for a holistic approach to urban development that harmonizes economic objectives with environmental and aesthetic considerations.

Keywords: Housing Price, Landscape, Green Premium, Urban Park, Hedonic Pricing Modelling

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INTRODUCTION

Urban landscapes, particularly urban green spaces such as parks, gardens and tree-lined streets, play an important role in shaping the aesthetic quality and environmental performance of residential areas (Chen et al., 2022), enhancing the liveability of urban environments (Zambrano-Monserrate et al., 2021). These green elements provide ecological and well-being benefits, including recreation, psychological restoration and urban environmental regulation which are often perceived as valuable by residents and therefore may be reflected in property values (Chen et al., 2022). Essentially, a sustainable urban park will ensure accessibility, safety, social interaction, aesthetic quality, resilience and economic viability (Nik Hashim et al., 2025). The capitalization of green amenities into housing prices is commonly explained through the idea that households reveal willingness-to-pay for desirable locational and neighbourhood attributes in the housing market (Chen et al., 2022; Liu et al., 2024). In our case, willingness to pay more for residing nearby to the urban park (Zhou et al., 2021).

Evidently, while we are entering the recovering the post-COVID 19 period, recent research suggests renewed attention to parks and open spaces as daily-life infrastructure, particularly for outdoor activities (Yang et al., 2024; Zhao et al., 2023). Evidence also indicates that the relationship between proximity to parks and housing values can change over time and context. For instance, during the pandemic's early stages, properties closer to parks could experience weaker or even negative effects due to concerns such as noise or perceived health risks, whereas during recovery periods the preference for outdoor access may strengthen the positive capitalization of park proximity (Yang et al., 2024). Such findings imply that green premiums may not be fully stable and can depend on social conditions and park usage patterns (Yang et al., 2024; Zhao et al., 2023).

Empirical studies investigating the impacts of urban green environments on housing prices have frequently applied hedonic pricing methods, using distance to parks or surrounding greenery as a central measure of accessibility and amenity value (Chen et al., 2022; Chen et al., 2023; Saleh et al., 2025). Many studies report a distance-decay relationship in which the effect of green space tends to be stronger for residences located closer to green spaces and weaker as distance increases (Bottero et al., 2022; Chen et al., 2023; Liu et al., 2024). Recent methodological work further suggests that green-space capitalization often operates within identifiable spatial thresholds (e.g., within about 1 km in certain contexts), encouraging the use of ring-based measures and improved identification strategies (Liu et al., 2024). Beyond proximity, research also shows that green space characteristics such as spatial configuration and distribution strategies (e.g., dispersed neighborhood greenery versus centralized large parks) can influence housing value outcomes (Li et al., 2024).

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Nevertheless, a key limitation in the existing literature is the relative lack of studies examining how urban greenery affects housing prices within gated and guarded housing schemes. As defined by Blakely & Snyder (1997), a gated and guarded housing scheme is a residential area that has restricted access in which normal public spaces are privatized. Gated communities typically restrict access through physical barriers and controlled entrances, and they often include internally managed shared amenities (Levin et al., 2026). Because gated communities may offer privately maintained landscapes and facilities, the marginal value of external public greenery may differ from that in non-gated neighbourhoods (Levin et al., 2026). This further suggests that internal landscaping and shared facilities may partially substitute for external parks, while large public parks may still provide unique benefits not replicated inside gated schemes (Levin et al., 2026; Yang et al., 2024). Hence, the urban landscape influences housing prices for this gated and guarded housing scheme is unique and is worth investigating, alongside contributing to the existing literature.

Accordingly, this study contributes to the discussion on the impact of urban greeneries on housing prices by estimating the green premium via a hedonic pricing model. The green premium is examined through (i) neighbourhood park which located within the respective gated and guarded housing scheme, (ii) central park whereby the park facilities and amenities will be enjoyed by not only residents but also opened to public and (iii) football field which is an open space field primarily used for football or other similar recreation activities. Following the established practice as adopted in previous studies, the distance between residential units and parks is adopted as a proxy for green amenity capitalization, with the expectation that units closer to parks exhibit higher prices. On top of that, this study captures greenness intensity by estimating "green catchment" exposure within a near-field buffer of the residence, consistent with recent attention to improving greenness measurement beyond single proximity indicators (Liu et al., 2024; An et al., 2023).

Overall, the study is among early contributions explicitly considering gated and guarded schemes when examining how green amenities are capitalized into housing prices, thereby extending existing evidence on green premiums into a distinctive residential governance setting (Levin et al., 2026). The remainder of the article is organized as follows: a literature review session to acknowledge the recent trend of empirical studies while highlighting the literature gap, then, the study area and methodology are described in the Research Method section, followed by findings and discussion, before concluding remarks.

URBAN LANDSCAPE AND HOUSING PRICES

Urban landscape can be defined as the integrated physical and experiential character of the built and natural environment in cities. In terms of physical characteristics, it refers to built-up areas, including size, density, configuration

and network structure where these features summarize how cities are spatially organized (Rezaei & Millard-Ball, 2023). Meanwhile, the term landscape is not only at its material form but also what is being seen, interpreted and evaluated by people as visual characteristics of the built environment shape how people perceive and experience cities (Ito et al., 2024). Essentially, urban visual perceptions vary across demographics and personalities, implying that urban landscape is partly constituted through human evaluation of urban scenes rather than physical attributes alone (Quintana et al., 2025). This idea is operationalized by treating urban landscape quality as a multidimensional construct that can be assessed via user perception across spatial and aesthetic attributes, alongside the cultural and service dimensions (Huang et al., 2025).

In assessing the impacts of urban landscape on housing prices, urban landscape is generally being categorised into five categories that reflect distinct channels through which urban environments may be capitalized into property values. Firstly, is the category of morphological and structural landscape. This category of landscape includes street-network structure, density and built landscape configuration that widely used in urban measurement and comparative analyses (Rezaei & Millard-Ball, 2023). Secondly, the functional and land-use landscape which predominantly refer to the land-use mix and intensity that define the urban character. While landscape is a unique and identifiable pattern of elements that recurs across areas, the urban character descriptions often incorporate function and transportation alongside other attributes like social features (Mou et al., 2023). The third category is ecological (green and blue) landscape, referring to greenery and water elements that structure urban environmental amenity. The greenery and water landscape constitute a major, recurring physical aspect that being studied in relation to how cities are experienced (Ito et al., 2024). Another category is the visual-perceptual landscape, focusing on streetscape appearance and scenic view that shape individual's subjective evaluations. Yet, visual features of built environment are a central driver of perceived urban experience (Ito et al., 2024) and that such perception is vary systematically across population groups (Quintana et al., 2025). Finally, the fifth category is cultural and identity related landscape. This type of landscape instils cultural meaning, place identity and heritage-related qualities to the citizens. Evidently, the cultural perception from spatial and aesthetic perception are different when assessing urban landscape quality (Huang et al., 2025). In this study, we are focusing only on the urban park in understanding how urban landscape may influence housing price.

In terms of its influence on housing price, urban landscape affects residential property values generally via amenity capitalization, whereby households' willingness to pay for a house reflects not only the structure itself but also the bundle of nearby environmental and design attributes (Bishop et al.,

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2020). Essentially, how environmental amenity being perceived and used by public will influence its impact on property value (An et al., 2023). In hedonic pricing modelling, proximity to parks, open space and other urban green or blue features is repeatedly associated with price premium because these landscapes provide recreational access, aesthetic enjoyment and environmental functions that assumed to foster the housing demand (Brander & Koetse, 2011). The interpretation of amenity benefits can be localized and mediated by accessibility and neighbourhood context (Liu et al., 2024). Empirical evidence indicates that housing prices increase as distance to urban open space decreases, and that the magnitude of capitalization varies with contextual factors such as population density and open space type (Brander & Koetse, 2011; Chen et al., 2023). Nevertheless, it is worth acknowledged that the influence of urban parks on housing price is limited by its effective range (Daams et al., 2019).

Importantly, the premium is also depending on landscape condition and management in which well-maintained, safe and accessible green spaces tend to generate stronger price effects than neglected or nuisance generating spaces, consistent with review evidence that park impacts vary by park type and use intensity (Brander & Koetse, 2011). This further implies that urban green landscape is valued as a functional amenity rather than a general land cover (Chen et al., 2022). Recent study by Russell and Kweon (2025) acknowledged a price premium of 8.69% to 8.96% for a community managed park. By considering gated guarded housing scheme in the analysis, this study is in line with the literature in which it is generally being assumed that urban park will be in better condition and management within the gated guarded community as management fees paid by residents are covering the maintenance of the park.

RESEARCH METHODOLOGY

This study uses manageable randomized samples to generalize the findings to larger populations. The range of secondary market transacted data are collected starting from 2016 – 2023 which sited in Puncak Alam, it consists of Eco-Grandeur Project, Maple Hillpark Project and Saujana Utama Project. There are three rational for us to select these housing schemes. Firstly, all three housing schemes are located within the newly emerging township of Puncak Alam in which this allows comparison within a relatively similar local housing market. Secondly, all these housing schemes are offering landed properties, making them suitable for examining the potential influence of urban green park on housing prices based on proximity distance as compared to high-rise residential. Thirdly, these three housing schemes represent a different in green spaces provision. The Eco-Grandeur project represents a newer master planned housing scheme with the provision of dedicated landscape and central park amenities; on the other hand, Mapple Hillpark project featuring eco-themed development with a relatively smaller central park but well planned jogging paths and cycling tracks

on its neighbourhood park; lastly, Saujana Utama project is a more established and mature housing scheme with open spaces as the greenery space rather than dedicated planned green space in Eco-Grandeur project and Maple Hillpark project. As these three housing schemes are located within the same suburban growth corridor, these three housing schemes provide a suitable comparative basis for examining how proximity and green catchment area varies across these housing schemes may influence the housing prices while maintaining reasonable similarity in location and local housing context.

The location of each housing scheme is presented using QGIS together with the transaction data. The green spaces were identified and digitalised as a polygon layer in the application of GIS. Figure 1 to Figure 4 illustrates the distribution of transaction data and green spaces.



Figure 1 Proximity to Green Space in Eco-Grandeur



Figure 2 Proximity to Green Space in Maple Hillpark



Figure 3 Proximity to Green Space in Saujana Utama

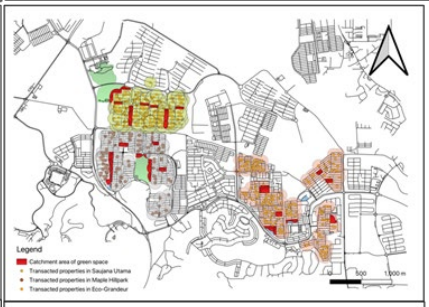


Figure 4 Catchment Area of Green Space

This study explored the relationship between the urban greeneries landscape and housing prices for estimating the "green premium" which exert in a housing project. There are two aspects that are used to measure the green premium. Firstly, the proximity to green space such as central park, neighborhood park and football field. It is hypothesized that the proximity to green space has an inverse relationship with the property prices. In other words, the property

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prices are expected to decrease if they are located further away from the green space. Secondly, the catchment area of green space for 100m buffer of residential property is computed. This factor expects the property prices to increase based on the size of catchment area for the green space. Residents are willing to pay a premium for gaining more green space in the surroundings. This is another unique consideration for green density of the landscape within the study area. Hypothetically, having more green space is beneficial to the residents in terms of better view, meanwhile, it contributes to residents' psychological needs satisfaction and attachment to the natural landscape (Landon *et al*., 2021). The 100m distance was selected as this distance is a close and direct exposure zone of housing to the green spaces. Importantly, this is a common practice (Liu et al., 2025) and being empirical proven in similar studies setting such as Bräuniger et al. (2010) and Shen et al. (2015).

This study employs four models to validate the proposed hypothesis. The green premium is first estimated using baseline OLS hedonic models for diagnostic purposes, while the final reported estimates adopt spatial econometric models where spatial dependence is detected. This method has frequently been used to estimate static versions of the model, in which property values are the dependent variable and the independent variables are a collection of qualities or traits expected to affect property prices (Garay et al., 2022). There are various types of properties traded at various times, making it difficult to establish the green premium solely based on the price change of properties without considering their quality. There are four hedonic price models established in this study.

Model 1: Basic Hedonic Price Model for Saujana Utama

$$\ln\text{Price}_{it} = \beta_0 + \delta_1 Football\_field\_catchment_{it} + \delta_2 Football\_field\_proximity_{it} + \delta_3 Neighbourhood\_park\_catchment_{it} + \delta_4 Neighbourhood\_park\_proximity_{it} + \beta_k Z_{it} + \theta_k Year_{it} + \varepsilon_{it} \quad (1)$$

Model 2: Basic Hedonic Price Model for Maple Hillpark

$$\ln\text{Price}_{it} = \beta_0 + \delta_1 Central\_park\_catchment_{it} + \delta_2 Central\_park\_proximity_{it} + \delta_3 Neighbourhood\_park\_catchment_{it} + \delta_4 Neighbourhood\_park\_proximity_{it} + \beta_k Z_{it} + \theta_k Year_{it} + \varepsilon_{it} \quad (2)$$

Model 3: Basic Hedonic Price Model for Eco-Grandeur

$$\ln\text{Price}_{it} = \beta_0 + \delta_1 Central\_park\_catchment_{it} + \delta_2 Central\_park\_proximity_{it} + \delta_3 Neighbourhood\_park\_catchment_{it} + \delta_4 Neighbourhood\_park\_proximity_{it} + \beta_k Z_{it} + \theta_k Year_{it} + \varepsilon_{it} \quad (3)$$

Model 4: Basic Hedonic Price Model for Quality of Green Space

$$\ln\text{Price}_{it} = \beta_0 + \delta_1 Central\_park\_catchment_{it} + \delta_2 Neighbourhood\_park\_catchment_{it} + \delta_3 Football\_field\_catchment_{it} + \beta_k Z_{it} + \theta_k Year_{it} + \varepsilon_{it} \quad (4)$$

Table 1: List of Variables

$\ln Price_{it}$	= Transacted Price in logarithm form (RM) for i property at period t
$Central\_park\_catchment_{it}$	= Catchment area of central park (m^2) for i property at period t
$Neighbourhood\_park\_catchment_{it}$	= Catchment area of neighbourhood park (m) for i property at period t
$Football\_field\_catchment_{it}$	= Catchment area of football field for i property at period t
$Central\_park\_proximity_{it}$	= Proximity to central park for i property at period t
$Neighbourhood\_park\_proximity_{it}$	= Proximity to neighbourhood park for i property at period t
$Football\_field\_proximity_{it}$	= Proximity to football field for for i property at period t
Z_{it}	= Property attributes for i property at period t
$Year_{it}$	= Transacted period for i property at period t
δ_k	= Regression coefficient for k number of green elements
β_k	=Regression coefficient for k number of property attributes
θ_k	= Time effect of transacted period

Source: Authors' Compilation

Table 2: Results for Diagnostic Tests

Diagnostic Test	Model 1 (Maple Hillpark)	Model 2 (Saujana Utama)	Model 3 (Eco-Grandeur)	Model 4 (Combined Model)	Interpretation
Maximum VIF	2.62	2.65	2.50	2.74	All VIF values are below 5, indicating no multicollinearity.
Breusch–Pagan Test	p = 0.272	p = 0.365	p = 0.017	p < 0.001	Models 1 and 2 satisfy homoscedasticity, whereas Models 3 and 4 exhibit heteroscedasticities. Robust standard errors were therefore reported for the OLS estimates.
White Test	p = 0.079	p = 0.298	p = 0.032	p < 0.001	Consistent with the Breusch–Pagan results. Heteroscedasticity is only evident in Models 3 and 4.
Jarque–Bera Test	p = 0.197	p = 0.835	p = 0.399	p = 0.038	Residuals are approximately normally distributed in Models 1–3. Model 4 shows a slight departure from normality, which is acceptable given the large sample size (N = 534).
OLS Residual Moran's I	p < 0.001	p = 0.0016	p = 0.644	p < 0.001	Significant spatial autocorrelation remains in Models 1, 2 and 4, indicating that OLS is inadequate. Model 3 shows no significant global residual spatial autocorrelation.
Robust Rao's Score Error	p < 0.001	p = 0.031	p = 0.017	p < 0.001	Supports the Spatial Error Model (SEM) for Models 1, 2 and 4.
Robust Rao's Score Lag	p < 0.001	p = 0.819	p < 0.001	p = 0.751	Supports the Spatial Lag Model (SLM) only for Model 3.
Selected Spatial Model	**SEM**	**SEM**	**SLM**	**SEM**	Selected based on robust Rao's Score tests, AIC, log-likelihood and residual Moran's I.

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Residual Moran's I (Final Model)	p = 0.620	p = 0.463	p = 0.955	p = 0.714	Residual spatial autocorrelation is successfully removed in all final models.
Best AIC	SEM	SEM	SLM	SEM	The selected model achieves the lowest AIC among competing specifications.

Source: Authors' Computation

Model 1 – 3 are the individual hedonic price models for three housing schemes with different levels of landscape design: Model 1 for Maple Hillpark, Model 2 for Saujana Utama and Model 3 for Eco-Grandeur. Saujana Utama is the oldest residential area where minimal landscape was built. Then follow by the Maple Hillpark which has included a lifestyle concept in the development such as neighbourhood park and central park. However, these amenities are not extensive compared to the housing scheme in Eco-Grandeur. A quality neighbourhood park and central park is important in promoting interactive activities and providing psychological support within the community. The green premium will be assessed based on the proximity to the amenities and also the catchment area of green space. Additionally, this study will also examine the quality of green space through Model 4. This model comprises all three housing schemes and the quality of green space is evaluated based on the catchment area of neighbourhood park, central park and football field. These three variables are the interactive terms that are associated with the quality of landscape in the respective housing schemes.

FINDINGS AND DISCUSSION

Prior to further data analysis, 54 data had been removed due to extreme values, missing address information, non-arm's length transaction and only transaction of shares instead of whole unit transactions. Table 3 depicts the comparison of hedonic price models for green premium in Puncak Alam were covering three main housing schemes, Model 1- Maple Hillpark, Model 2 - Saujana Utama, Model 3 - Eco-Grandeur, respectively. Subsequently. the quality of green premium is assessed through Model 4. Saujana Utama is the oldest housing scheme among the three examined housing scheme, and it serves as a comparable in this model. These models have examined the urban greenery elements that could contribute to the housing prices.

The green premium is measured from two perspectives. First, consider the proximity to neighbourhood park, central park and football field, then proceed to assess the area covered by green spaces within a 100-meter radius distance around residential properties. For catchment result interpretation, the measure is with every 1000m^2 density. As shown in Table 3, the catchment area of central park appears to be significant in Model 4. Based on the coefficient of 0.00000216, every additional 1000m^2 of central park catchment area is associated with an

approximate 0.216% uplift in housing price, assuming the variable is measured in square metres, and the dependent variable is in logarithmic form.

The results presented in Table 3 demonstrate that the influence of green space attributes on housing prices across the three residential developments. Across all four models, land area consistently exhibits a positive and statistically significant effect on housing prices, indicating that larger lot sizes command higher market values. Built-up area is also positively associated with property prices in Saujana Utama, Eco-Grandeur, and the combined model, although it is insignificant in Maple Hillpark. Regarding the green space variables, the findings indicate that their effects are development specific. In Maple Hillpark, only the distance to neighbourhood park is positively and significantly associated with property prices, while the central park area, neighbourhood park area, and distance to the central park are not statistically significant. This positive coefficient runs counter to the hypothesised inverse proximity relationship and suggests that, in this case, being farther from the neighbourhood park is associated with higher prices, potentially reflecting development specific factors such as privacy, traffic, noise or lot-position effects. In Saujana Utama, none of the green space variables, including neighbourhood park area, football field area, and the associated proximity measures, significantly influence property prices. Similarly, in Eco-Grandeur, neither the green space areas nor the proximity variables are statistically significant after accounting for spatial dependence.

Table 3: Comparison of Hedonic Price Models for Green Premium

Variables	Model 1 (Maple Hillpark)	Model 2 (Saujana Utama)	Model 3 (Eco-Grandeur)	Model 4 (Quality of Green Space)
Dependent Variable: ln(Price)				
Independent Variables				
Constant	12.777***	12.1550 ***	10.2820***	12.7060***
Land_Area	0.002622***	0.001674***	0.002799***	0.002590***
Built_up_Area	0.000334	0.003654 ***	0.000747**	0.002214***
Saujana	-	-	-	-0.44934***
Maple_Hill	-	-	-	-0.18090***
Year Effects				
2017	0.1031***	0.01617	–	–
2018	0.0336***	0.02004	–	–
2019	0.0165	0.05351	-0.00709	0.02723**
2020	-0.0622***	0.09908***	-0.11073***	-0.02380**
2021	-0.0486***	0.10527 ***	-0.10389***	-0.03941***
2022	0.0021	0.16227***	-0.06407**	0.02056
Green Space Variables				
Central_Park (m^2)	-0.0000017	–	0.00000493	0.00000216*
Neighbourhood_Park (m^2)	-0.0000020	-0.00000758	0.00000330	-0.00000086
Football_Field (m^2)	–	-0.00000453	–	-0.00000745
Proximity Variables				
Distance to Central_Park	-0.000126	–	-0.000028	–

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Distance to Neighbourhood_Park	0.000219***	-0.00000972	0.000041	–
Distance to Football_Field	–	0.00001702	–	–
Model Fit				
Spatial lag coefficient	-	-	0.19835***	-
Spatial Error Coefficient	0.6402***	0.38781***	-	0.41548***
MSE	0.002593344	0.004462564	0.003730762	0.006384
Sample Size (N)	155	185	228	534

Remarks: * Significant at 10% level, ** significant at 5% level, *** significant at 1% level.
Source: Authors' Computation

The combined Spatial Error Model, which integrates all three housing developments, indicates that only the central park area has a marginal positive effect on housing prices ($p < 0.10$), whereas neighbourhood park area and football field area are not statistically significant. This finding further strengthens the impacts from the associated activities and use of urban park in determining housing price premium is essential (Brander & Koetse, 2011; Chen et al., 2022; Chen et al., 2023). These findings suggest that the contribution of green space attributes is not consistent across different housing developments. The township dummy variables in the combined model further reveal significant price differentials among the developments. Relative to Eco-Grandeur, properties located in Saujana Utama and Maple Hillpark exhibit significantly lower housing prices after controlling for structural housing characteristics, temporal effects, and green space attributes.

From the spatial econometric perspective, the preferred model differs across the case studies. The Spatial Error Model (SEM) provides the best model fit for Maple Hillpark, Saujana Utama, and the combined dataset, whereas the Spatial Lag Model (SLM) is preferred for Eco-Grandeur. This indicates that spatial dependence is present in all housing developments but is characterised by different spatial processes. Overall, the results demonstrate that structural housing characteristics exert a more consistent influence on housing prices than green space variables, while the pricing effects of green spaces vary according to the characteristics of individual residential developments. This provides alternative facet of the impact of the size of urban greeneries landscape on housing prices whereby larger natural made greeneries (such as forest and national park) will likely to be appreciated by the residents (Tyrväinen and Miettinen, 2000; and Trojanek et al., 2018).

CONCLUSION

By considering the characteristic of gated and guarded housing scheme arrangement, this study examines the impact of urban greeneries landscape on the housing prices and examine its green premium via two perspectives. Firstly, this study demonstrates that the impact of urban green spaces on housing prices is development-specific rather than universal. The significance of proximity and

catchment area variables differs across the three residential developments after controlling for spatial dependence. Secondly, the combined spatial model indicates that structural housing characteristics exert a more consistent influence on housing prices than green space attributes. Among the green space variables, only the central park area exhibits a marginal positive effect, suggesting that the economic value of urban green spaces depends more on their quality and contextual characteristics than on their size alone. In line with this, we claim that our findings have contributed to the planning policy and valuation practices. In terms of planning contribution, while open space is recognised as an integral part of residential development where there is a requirement of 10% open space mandatory requirement for residential development, our findings further indicate that there is a need to carefully design and provide landscape that cater for noise and privacy in mitigating the potential negative externalities of urban greeneries landscape rather than just comply to the allocation. Furthermore, our findings further indicate that green spaces should not be treated as residual land or merely for the planning compliance, in fact, green spaces are contributing to the housing value. We provide an empirical finding via a GIS-based proximity measurement and catchment green area analysis for assessing the nearby green spaces contribution to residential value variation. This is consistent with valuation practises whereby neighbourhood characteristics are relevant in property valuation considerations.

However, this study is not without limitation. First, the type of facilities offered by the urban park is not considered whereby future studies may consider including these as a service quality of urban park to the neighbourhood residents. Secondly, this study overlooks residents' visit to urban park in which the frequency of visit may influence the price premium for those frequently visited parks may perceive conveniency in residing nearby the park, thus, willing to pay more for the premium. Thirdly, we shall acknowledge the possibility of endogeneity of our findings in which a better planned housing scheme may have both higher quality green spaces and higher housing prices. Nevertheless, to address this, we had selected three housing schemes represent different quality level of green spaces. Additionally, selecting the housing scheme within the same suburban area minimise the bias due to different locality features. During the analysis, we had also control for the housing attribute in reducing the bias. Nevertheless, we acknowledge that the findings shall be interpreted carefully as an association between green space and housing price rather than a purely causal effect finding.

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BEYOND WILLINGNESS: COMMUNITY READINESS FOR PARTICIPATION IN COMMUNITY-BASED ECOTOURISM IN KAMPUNG ROSOB, SABAH

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Abstract

Community-based ecotourism (CBET) is widely promoted for sustainable development, yet participation remains uneven in rural contexts. This study addresses this gap by distinguishing between willingness and readiness in explaining community participation. Focusing on Kampung Rosob, Sabah, it adopts an explanatory sequential mixed-methods design. The quantitative phase (n = 153) applies an integrated Theory of Planned Behaviour–Norm Activation Model (TPB–NAM). It is analysed using PLS-SEM, followed by qualitative interviews to contextualise the statistical findings. Results show that perceived behavioural control, reconceptualised as community readiness, is the only significant direct predictor of willingness to participate. Readiness serves as a mediator between attitudes and moral norms, increasing willingness to participate. In contrast, subjective norms are not significant. Qualitative findings highlight the role of structural and institutional constraints in shaping readiness. The study contributes to rural tourism planning by demonstrating that community readiness enables willingness to participate in CBET.

Keywords: Community-based Ecotourism; Community Participation; Community Readiness; Community Willingness; TPB–NAM

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INTRODUCTION

Community-based ecotourism (CBET) is widely promoted as a sustainable approach that integrates biodiversity conservation with local socio-economic development through community participation (Guerrero-Moreno & Oliveira-Junior, 2024). It aims to empower communities by involving them in decision-making, strengthening local capacities, and creating sustainable livelihoods (Zanudin et al., 2024). CBET's success depends not only on the potential of natural resources but also on effective community participation in tourism planning and implementation (Kunjuraman, 2021; Zanudin et al., 2024).

In Malaysia, ecotourism is central to national development strategies, as reflected in the National Tourism Policy (2020–2030) and the National Ecotourism Plan (2016–2025) (MOTAC, 2016, 2020). Sabah, known for its rich biodiversity and indigenous heritage, is a key area for CBET development. In 2023, the state contributed RM13.1 billion to the tourism sector and continues to receive investment in rural tourism and diversification (DOSM, 2024; Sabah State Government, 2019), making it an important context for examining community-based initiatives.

Despite strong policy support, many CBET initiatives face implementation challenges. While communities often show willingness to participate, actual involvement is frequently constrained by financial limitations, inadequate training, weak governance, and bureaucratic barriers (Chan et al., 2021; Kunjuraman, 2021). This gap highlights a critical issue in community-based tourism planning and implementation, where willingness to participate does not necessarily translate into actual participation. Participation in the community should be distinguished from the preceding behavioural processes. Willingness reflects motivation to engage, whereas actual participation refers to observable involvement in CBET activities (Kurniati et al., 2024; Lucrezi & Cilliers, 2023). Between these two stages lies community readiness, which reflects the capacity, resources, and institutional support required for effective participation (Kurniati et al., 2024; Oetting et al., 2014). Existing studies often examine these factors independently, with limited attention to their interactions. Understanding these relationships is crucial for explaining why willingness does not always translate into meaningful community participation in CBET.

To address this gap, this study examines how community readiness influences willingness to participate in CBET in Kampung Rosob, Sabah. It applies an integrated framework based on the Theory of Planned Behaviour (TPB) and the Norm Activation Model (NAM) to investigate how cognitive, social, and moral factors interact with community readiness to shape willingness to participate. The study is guided by three research questions: (i) What motivates community willingness to participate in CBET? (ii) What barriers affect

community readiness? (iii) How does readiness influence the translation of willingness into participation?

This study contributes to rural tourism planning by highlighting the role of readiness as a prerequisite in enabling participation in CBET. It provides planners with a context-based understanding of how capacity, resources, and governance conditions shape community involvement before implementing community-based ecotourism initiatives. The findings further support community-based resource management and protected-area governance by highlighting community readiness as an essential planning consideration for strengthening community engagement in conservation-oriented CBET.

LITERATURE REVIEW

Community Participation as a Behavioural Outcome

Community participation has long been recognised as essential to the success of CBET, particularly where local livelihoods depend on environmental stewardship (Lijun & Ahmed, 2024). Traditionally, the literature has conceptualised community participation in terms of stakeholder involvement, institutional arrangements, and collaborative decision-making (Dangi & Petrick, 2021; Oedl-Wieser et al., 2020). However, participation can also be understood as a behavioural outcome influenced by individual motivations, moral values, and perceived capability (Tao et al., 2021).

This behavioural perspective complements structural explanations by recognising that participation may depend not only on opportunities created through planning and governance, but also on individuals' willingness and readiness to participate. Accordingly, behavioural frameworks such as the Theory of Planned Behaviour (TPB) and the Norm Activation Model (NAM) provide useful insights into how motivation, moral obligation, and perceived control influence participation in CBET. Therefore, this study distinguishes between willingness (behavioural intention), readiness (an enabling condition for participation), and community participation (behavioural outcome).

Theoretical Foundation: TPB–NAM

The Theory of Planned Behaviour (TPB) explains behavioural intention in terms of attitude (ATT), subjective norms (SN), and perceived behavioural control (PBC) (Ajzen, 1988). In CBET, these factors reflect how individuals evaluate participation, perceive social expectations, and assess their ability to engage.

While PBC often reflects an individual’s perceived capability to perform a behaviour (Ajzen, 2002; Ajzen, 2019b), CBET participation in a complex rural setting depends on broader factors beyond self-confidence. These include skills and knowledge, access and facilities, opportunities for participation, time availability, and financial capacity (Tao et al., 2021). To

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capture both perceived ability and the enabling variables that determine whether participation is viable, this study conceptualises PBC as an indicator of community readiness within the CBET context.

However, TPB gives limited attention to moral obligation (Tao et al., 2021). The Norm Activation Model (NAM) addresses this by introducing personal moral norms as a key driver of pro-social and pro-environmental behaviour (Schwartz, 1977). Integrating TPB and NAM provides a more comprehensive framework by combining cognitive, social, and moral factors with readiness to explain, thereby improving understanding of willingness to participate in CBET (Tao et al., 2021).

Conceptual Framework and Hypotheses Development

Figure 1 presents a conceptual framework that integrates ATT, SN, PMN, and PBC to explain willingness to participate (WTP) in CBET. In this study, community readiness is operationalised as a formative construct through PBC, as its indicators collectively define the construct rather than reflecting a single underlying characteristic (Tao et al., 2021).

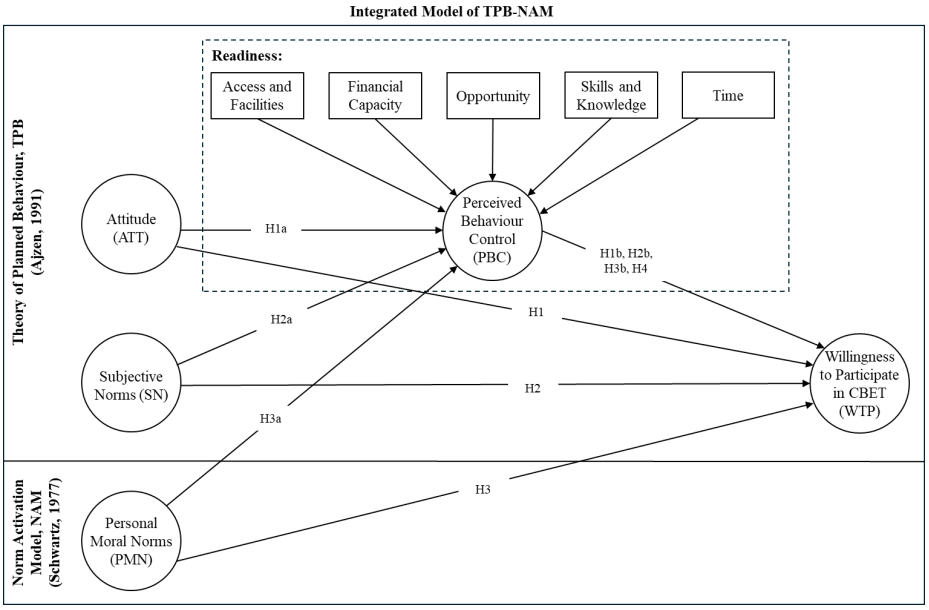


Figure 1: Conceptual Framework
Adapted from Ajzen (2019b) and Schwartz (1977)

The framework proposes that ATT, SN, and PMN influence WTP both directly and indirectly through PBC. This reflects the idea that willingness depends not only on favourable perceptions, social influence, and moral

commitment, but also on whether individuals feel capable of participating under existing conditions. PBC is therefore positioned as both a direct predictor of willingness and a mediator linking cognitive, social, and moral factors to WTP. Accordingly, the following hypotheses are proposed:

H1: ATT positively influences WTP in CBET.
H1a: ATT positively influences PBC.
H1b: ATT positively influences WTP via PBC.
H2: SN positively influences WTP in CBET.
H2a: SN positively influences PBC.
H2b: SN positively influences WTP via PBC.
H3: PMN positively influences WTP in CBET.
H3a: PMN positively influences PBC.
H3b: PMN positively influences WTP via PBC.
H4: PBC positively influences WTP in CBET.

RESEARCH METHODOLOGY

This study adopted an explanatory sequential mixed-methods design comprising a quantitative phase followed by a qualitative phase. The integrated TPB–NAM framework guided the quantitative analysis, while follow-up interviews explored perceptions of readiness and contextual factors influencing participation. This approach enables deeper interpretation of statistical findings through qualitative insights (Creswell & Plano Clark, 2018).

Study Area: Kampung Rosob, Sabah

The study was conducted in Kampung Rosob, Pitas, Sabah, located within Tun Mustapha Park (TMP), a protected marine area and lies within Class I Protection Forest Reserve (Sabah Forestry Department, 2024), highlighting its conservation and ecotourism potential.

Kampung Rosob has 548 residents across 143 households, with livelihoods spanning government service, private sector employment, fishing, agriculture, small businesses, and village-based services (Ministry of Rural and Regional Development Sabah, 2023). This reflects both a traditional resource base and emerging income diversification. The Rosob Mangrove Pitas Boardwalk, developed in 2020 as a tourism initiative, was later discontinued due to limited institutional coordination. Figure 2 shows the comparison of the ecotourism site in 2020 and 2024. Despite this, the *Kawasan Rukun Tetangga* (KRT) has expressed interest in future management. This provides a relevant context for examining community readiness and governance challenges.

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(a) (b)

Figure 2: Comparison of Rosob Mangrove Pitas in 2020 and 2024
Source: (a) Sabah Malaysian Borneo Travel Blog (2020); (b) Fieldwork, 2024

Quantitative Phase

A structured questionnaire based on standard TPB/NAM guidelines (Ajzen, 2019a; Schwartz, 1977) was distributed door-to-door to residents of Kampung Rosob, along with a consent form. Items were adapted from validated studies on community-based tourism, pro-environmental behaviour, and rural participation. Responses were measured using a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

Sampling and Analysis

To ensure relevance, purposive sampling was applied. Respondents were residents aged 18 and above who had lived in Kampung Rosob for at least 10 years and were familiar with the CBET initiative. The questionnaire data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS4. PLS-SEM was selected due to its ability to analyse complex models involving reflective and formative measurement specifications and is appropriate for prediction-oriented research (Hair et al., 2022). The analysis comprised two stages. Firstly, the PLS algorithm assessed the measurement and structural models. Subsequently, hypothesis testing utilised a bootstrapping procedure with 5,000 resamples, a two-tailed test, and a significance level of 0.05 to evaluate the significance of path coefficients, outer weights, and indirect effects (Hair et al., 2022). Sample size was calculated based on Cohen (1988) and Westland (2010), as presented in Table 1 below:

Table 1: Sample Size Calculation

SEM Sample Size Parameter	Value
Kampung Rosob population	548
Anticipated effect size	0.3
Desired statistical power level	0.8
Number of latent variables	5

SEM Sample Size Parameter	Value
Number of observed variables	32
Probability level	0.05
Minimum sample size to detect effect	150
Minimum sample size for model structure	269
Recommended minimum sample size	269
Sample size obtained	**153**

Source: Author's Calculation

Although the sample size obtained (n = 153) exceeded the minimum required to detect the anticipated effect, it did not reach the recommended sample size of 269 for estimating the full structural model. This limitation reflects the relatively small population of Kampung Rosob and the limited number of eligible respondents who met the study's sampling criteria. Nevertheless, PLS-SEM remained appropriate because it is well-suited to prediction-oriented research involving complex structural models and formative constructs, particularly when sample sizes are constrained (Hair et al., 2022). As a result, the findings should be viewed as context-specific to Kampung Rosob instead of statistically generalisable to other rural communities. Future research should use larger samples from several CBET sites to validate the proposed framework.

Qualitative Phase

Semi-structured interviews were conducted after the quantitative analysis to explain and contextualise the statistical findings. The interview guide was developed based on significant statistical results to help participants share their experiences and views on community participation in CBET. Interviews lasted 30–40 minutes, were audio-recorded with consent, transcribed verbatim, and analysed thematically to support the interpretation of the quantitative results.

Participant and Sampling

Five participants were purposely selected from the quantitative phase to provide insights into experiences and perceptions of community participation in CBET. Rather than aiming for statistical representativeness, qualitative participants in explanatory sequential mixed-methods designs are chosen to contextualise and comment on statistical findings. The sample included the village head, a village committee representative, and three community members to capture perspectives from both governance and community levels.

RESULTS

Respondent Profile

With a total of 153 valid responses, the respondents have a balanced gender distribution (49.7% male; 50.3% female). Most respondents (approximately 75%) had resided in Kampung Rosob for more than 20 years, reflecting extensive

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familiarity with the local community. Household income levels were generally low, with 33.3% of respondents reporting a monthly household income of RM1 to RM1000. Only 3.3% reported previous involvement in CBET, indicating that ecotourism remains a relatively new activity within the village.

Measurement Model Assessment

Reflective Constructs

As shown in Table 2, the measurement model results demonstrated acceptable reliability and validity. Composite reliabilities for reflective constructions ranged from 0.877 to 0.952, indicating strong internal consistency. Meanwhile, convergent validity was demonstrated because average variance extracted (AVE) values exceeded the suggested criterion of 0.50, ranging from 0.643 to 0.792. Although two indicators (SN_4 and PMN_4) exhibited outer loadings below 0.70, they were retained because the corresponding constructs satisfied the recommended thresholds for composite reliability and AVE, and their removal was not theoretically justified (Hair et al., 2022; Tao et al., 2021).

Table 2: Results of Convergent Validity and Cronbach's Alpha Coefficients (α)

Latent Variable	Observed Indicators	Outer Loading	CR	AVE	α
ATT	ATT_1	0.720	0.952	0.690	0.943
	ATT_2	0.746			
	ATT_3	0.892			
	ATT_4	0.836			
	ATT_5	0.750			
	ATT_6	0.890			
	ATT_7	0.885			
	ATT_8	0.863			
	ATT_9	0.868			
SN	SN_1	0.899	0.886	0.665	0.823
	SN_2	0.841			
	SN_3	0.894			
	SN_4	0.587			
PMN	PMN_1	0.809	0.877	0.643	0.811
	PMN_2	0.902			
	PMN_3	0.834			
	PMN_4	0.639			
WTP	WTP_1	0.891	0.920	0.792	0.868
	WTP_2	0.924			
	WTP_3	0.854			

Source: Author's Calculation

Heterotrait–monotrait ratio (HTMT) was used to assess discriminant validity. As shown in Table 3, two construct pairs (ATT–PMN and SN–PMN) slightly exceeded the recommended threshold of 0.90, indicating a degree of conceptual overlap. However, slight HTMT exceedances do not necessarily

indicate a lack of discriminant validity and should be interpreted alongside theoretical justification rather than as a definitive criterion for construct removal (Franke & Sarstedt, 2018). In this study, the constructs were retained because they represent theoretically distinct concepts derived from the TPB–NAM. Given the nature of CBET, moderate conceptual overlap among these constructs is theoretically reasonable while they remain conceptually distinct.

Table 3: HTMT Values for Each Construct

	ATT	PMN	SN	WTP
ATT	-			
PMN	0.926	-		
SN	0.796	0.971	-	
WTP	0.712	0.761	0.740	-

Source: Author's Calculation

Formative Construct

As shown in Table 4, the significant indicators of the formative construct PBC are only from the opportunity and time availability to participate. The remaining indicators were retained because formative indicators should not be removed solely on the basis of non-significant outer weights when they represent theoretically essential dimensions of the construct (Hair et al., 2022). Furthermore, all indicators demonstrated acceptable collinearity (VIF < 5), indicating no multicollinearity issues and preserving the content validity of community readiness as a multidimensional construct.

Table 4: Results of Outer Weights, Significance Thresholds, and VIF Value

Indicator	Outer Weight (β)	t-value	p-value	VIF
PBC_AF_1	0.038	0.523	0.601	2.014
PBC_AF_2	-0.098	1.516	0.130	1.753
PBC_FC_1	-0.035	0.535	0.593	1.989
PBC_FC_2	0.034	0.487	0.626	2.257
PBC_FC_3	-0.023	0.443	0.658	1.169
PBC_O_1	0.243	3.211	0.001*	3.161
PBC_O_2	0.077	0.848	0.396	3.904
PBC_O_3	0.445	4.524	0.000*	4.106
PBC_SK_1	-0.071	0.951	0.342	1.987
PBC_SK_2	0.124	1.865	0.062	1.571
PBC_T_1	0.225	2.431	0.015*	2.514
PBC_T_2	0.294	4.246	0.000*	2.280

Notes: * in p-values indicate significant indicator at $p < 0.05$, VIF stand for variance inflation factor
Source: Author's Calculation

Structural Model Assessment and Hypothesis Testing

Figure 4 illustrates the structural model obtained from SmartPLS 4 bootstrapping. The model comprises exogenous constructs (ATT, SN, and PMN) and

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endogenous constructs (PBC and WTP). The structural model showed satisfactory explanatory power, with R^2 values of 0.665 for PBC and 0.662 for WTP, indicating that approximately 66% of the variance in both endogenous constructs was explained by the proposed model.

As shown in Table 5, all VIF values within the inner matrix were below the recommended threshold of 5, indicating no multicollinearity concerns (Hair et al., 2022). Effect size (f^2) analysis showed that PBC produced a significant influence on WTP ($f^2 = 0.512$), while PMN had a small effect on PBC ($f^2 = 0.129$). The remaining predictors exhibited negligible to minor effect sizes. Blindfolding further yielded Q^2 values of 0.232 (PBC) and 0.496 (WTP), indicating satisfactory predictive relevance, as both exceeded zero (Hair et al., 2022).

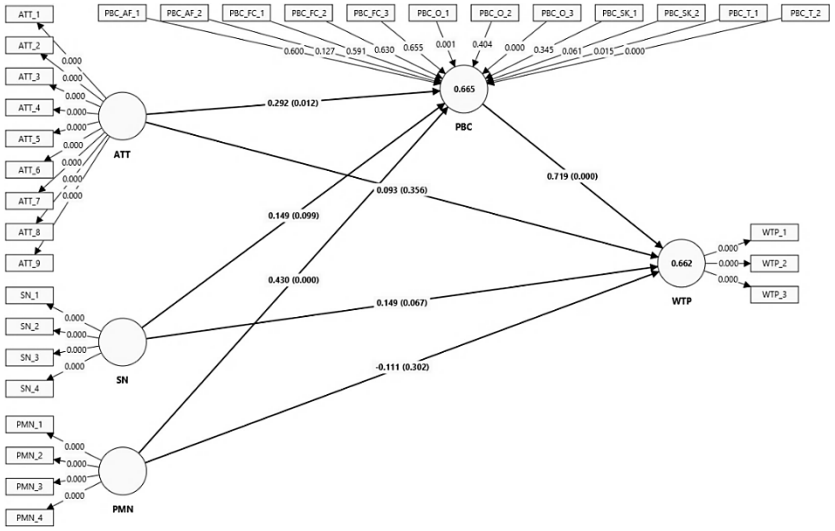


Figure 3: Structural model with path coefficients
Source: Author's Computation

Table 5: VIF and f^2 Values for Endogenous Constructs

Predictor	VIF		f^2	
	PBC	**WTP**	**PBC**	**WTP**
ATT	3.312	3.567	0.007	0.007
SN	2.779	2.845	0.024	0.023
PMN	4.288	4.842	0.129	0.008
PBC	-	2.989	-	0.512

Source: Author's Calculation

The structural relationships were subsequently examined through hypothesis testing. As presented in Table 6, H1a, H1b, H3a, H3b, and H4, were supported, whereas H1, H2, H2a, H2b, and H3 were not. PBC exerted a strong and significant direct effect on WTP ($\beta = 0.719$, $p < 0.001$), making it the

strongest predictor of WTP. ATT and PMN influenced WTP indirectly through PBC, indicating full mediation. Specifically, favourable attitudes and stronger personal moral norms enhanced community readiness, thereby increasing willingness to participate. In contrast, SN ex3hibited neither a significant direct nor an indirect effect on WTP, suggesting that social expectations played a limited role in influencing participation in the Kampung Rosob context.

Table 6: Results of Path Coefficients and Hypothesis Testing

Hypothesis		Effect type	β	t-value	p-value	Decision
H1	ATT → WTP	Direct	0.093	0.924	0.356	Not Supported
H1a	ATT → PBC	Direct	0.292	2.515	0.012*	**Supported**
H1b	ATT → PBC → WTP	Indirect	0.214	2.325	0.020*	**Supported**
H2	SN → WTP	Direct	0.149	1.833	0.067	Not Supported
H2a	SN → PBC	Direct	0.149	1.650	0.099	Not Supported
H2b	SN → PBC → WTP	Indirect	0.113	1.564	0.118	Not Supported
H3	PMN → WTP	Direct	−0.111	1.032	0.302	Not Supported
H3a	PMN → PBC	Direct	0.430	4.079	0.000*	**Supported**
H3b	PMN → PBC → WTP	Indirect	0.319	3.339	0.001*	**Supported**
H4	PBC → WTP	Direct	0.719	7.811	0.000*	**Supported**

Notes: * in p-values indicate significant indicator at $p < 0.05$
Source: Author's Calculation

DISCUSSION

Community Readiness as the Enabling Condition

The quantitative findings highlight community readiness, as measured by PBC, as the primary determinant of participation. Participants in the qualitative phase constantly confirm that readiness is shaped by access to resources, skills, infrastructure, time availability, and institutional support, as well as constraints such as bureaucratic complexity and unclear governance structures. This finding corroborates previous research in Sabah, indicating that infrastructure, financial support, and training are crucial for ecotourism participation (Chan et al., 2024). Cooperative models like KOPEL and KOPSTAY improve readiness by enhancing governance and benefit-sharing (Walai Tokou Kundasang Berhad, 2020). The main barrier is not a lack of interest but a lack of practical readiness. Strengthening capacity, coordination, and support is crucial. KRT and community leaders should organise local participation and identify locals willing to participate, who may need assistance. Local authorities and Sabah tourism agencies can increase readiness by offering training, small-scale funding, and technical assistance. At the same time, conservation agencies should integrate CBET capacity-building into protected-area governance and community-based resource management.

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Motivation Without Capacity

Although residents have positive attitudes toward ecotourism and strong environmental values, these factors influence willingness only indirectly through readiness. Qualitative findings reveal that while community members recognise the benefits of CBET, participation remains limited due to perceived constraints, including insufficient skills, unclear opportunities, weak institutional support, and project discontinuity. This supports prior research showing that motivation alone does not lead to action without enabling conditions (Han, 2021; Savari et al., 2023). The main challenge is not awareness, but a lack of mechanisms to turn motivation into action. These findings suggest that local authorities and tourism organisations should prioritise developing readiness by providing entrepreneurship training, mentorship, financial support, and structured participation pathways to translate willingness into active involvement.

Limited Role of Subjective Norms

Subjective norms did not significantly predict participation, suggesting that decisions are based on feasibility rather than social expectations. One explanation is that CBET in Kampung Rosob is not yet socially institutionalised. Although community members support ecotourism, participation is viewed as voluntary rather than expected. The discontinuation of the mangrove boardwalk project likely weakened the development of shared participation norms. In contrast, stronger social influence happens where participation is part of the community. For example, Latifinia et al. (2025) found that local norms affected conservation behaviour in Iran, whereas in Kampung Rosob, they did not. This comparison shows that Kampung Rosob lacks an established culture of participation. To foster meaningful change, participation must be boosted through stronger governance, effective leadership, and consistent engagement opportunities. Collaboration among KRT, community leaders, and conservation agencies should be tailored to foster inclusive participation and benefit-sharing, thereby enhancing collective ownership of CBET initiatives.

CONCLUSION

This study indicates that the community's willingness to participate in CBET in resource-constrained rural areas is primarily shaped by perceived readiness. Attitudes, moral commitment, or social influence play a lesser role. Using an integrated TPB-NAM framework, the research shows that individuals are willing to participate only when resources, skills, time, support, and governance are available. In Kampung Rosob, the key barrier is insufficient readiness, rather than a lack of awareness or support. Consequently, CBET planning should focus on enhancing community readiness through capacity-building, technical training, accessible funding, governance support, infrastructure enhancements, equitable

benefit-sharing arrangements, and effective management of community-based tourism. These interventions can better enable local communities to participate effectively in conservation-oriented tourism initiatives.

The findings should be interpreted within the context of Kampung Rosob, as this single-village case study limits the generalisability of the results to other CBET settings. Future studies should examine multiple rural communities to validate the proposed framework across different planning and governance contexts. Additionally, the minor role of subjective norms may indicate that informal social dynamics were not fully captured. Future studies could use social network analysis to clarify how informal social structures affect engagement.

In conclusion, by positioning community readiness as the enabling mechanism linking motivation to willingness to participate, this study provides a planning-oriented framework for designing more inclusive and sustainable community-based ecotourism initiatives in rural conservation landscapes.

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ETHICAL CONSIDERATIONS

This study obtained Universiti Malaya Research Ethics Committee approval under project ID #IF052-2024 (Reference No.: UM.TNC2/UMREC_3958).

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CHALLENGES AND STRATEGIES FOR LASER SCANNING ADOPTION IN HBIM FOR HERITAGE ASSET AND PROJECT MANAGEMENT IN MALAYSIA

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Abstract

This study examines the adoption of laser scanning technology within Historic Building Information Modelling (HBIM) workflows for heritage asset management in Malaysia. Although laser scanning and HBIM have the potential to improve documentation accuracy, information integration, and lifecycle-oriented management, their practical application in Malaysian heritage projects remains limited and fragmented. A qualitative research approach was adopted through semi-structured interviews with seven stakeholders involved in heritage asset management, including conservators, architects, HBIM specialists, laser scanning practitioners, quantity surveyors, and government representatives. The interview data were analysed using thematic analysis to identify key adoption challenges and strategic responses. The findings reveal that adoption is constrained by high implementation costs, limited technical expertise, fragmented organisational workflows, weak stakeholder coordination, and insufficient policy or contractual support. In response, the study highlights the need for financial support mechanisms, capacity-building programmes, standardised scan-to-HBIM workflows, clearer project requirements, and stronger institutional support. The study contributes to planning and heritage-management practice by demonstrating how laser scanning and HBIM can support conservation documentation, maintenance planning, condition monitoring, adaptive reuse assessment, and more evidence-based decision-making for heritage assets. The findings provide practical insights for planners, policymakers, local authorities, and industry practitioners seeking to strengthen digital adoption in Malaysian heritage asset management.

Keywords: Heritage asset management, Historic Building Information Modelling (HBIM), Laser scanning technology, Digital adoption, Malaysia

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INTRODUCTION

Heritage buildings represent an essential component of a nation's cultural identity, reflecting historical, architectural, and socio-cultural values that shape the character of cities and communities. In Malaysia, the management of heritage assets has become increasingly important in the context of rapid urbanisation and development pressures, which place heritage assets at risk of deterioration or redevelopment (Baharuddin et al., 2022; Ismail et al., 2021). From a heritage asset management perspective, these buildings should be treated as long-term assets that require systematic documentation, monitoring, and maintenance throughout their lifecycle.

Effective heritage asset management relies heavily on accurate and reliable documentation to support decision-making, maintenance planning, and long-term monitoring. However, current practices in Malaysia remain largely dependent on conventional documentation methods, such as manual measurements, photographic records, and written reports, which are often time-consuming, fragmented, and prone to inconsistencies (Ismail et al., 2026; López et al., 2018). These limitations restrict the ability of stakeholders to manage heritage assets efficiently and to implement data-driven asset management strategies.

To address these limitations, digital technologies have been increasingly introduced into the built environment. Building Information Modelling (BIM) enables the integration of geometric and non-geometric data within a unified digital environment, supporting improved information management and lifecycle coordination (Abugu, 2025; López et al., 2018; Lovell et al., 2023). In the context of heritage assets, Historic Building Information Modelling (HBIM) extends BIM capabilities by incorporating historical, material, and condition-related information into structured digital models (López et al., 2018; Godinho et al., 2019). A key enabler of HBIM is laser scanning technology, particularly Terrestrial Laser Scanning (TLS), which allows accurate capture of complex geometries and supports the development of high-quality digital representations (Alshawabkeh et al., 2021).

Beyond documentation accuracy, the integration of laser scanning and HBIM can support heritage planning and asset management decisions. Laser scanning provides reliable geometric and spatial data for assessing existing building conditions, proposed interventions, and conservation requirements (Alshawabkeh et al., 2021). When integrated into HBIM models, this information can be linked with material, defect, and maintenance records to support lifecycle asset management, preventive maintenance, condition monitoring, and conservation planning (Lovell et al., 2023; Rocha et al., 2020). Such scan-to-HBIM workflows can also assist adaptive reuse assessment and local authority decision-making by enabling stakeholders to evaluate physical constraints and

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potential intervention impacts before implementation (Salleh et al., 2022; Ismail et al., 2021).

Despite the recognised potential of these technologies, their adoption within the Malaysian context remains limited and uncoordinated (Ismail et al., 2021; Mustafa et al., 2020; Ali et al., 2018). Existing studies have largely focused on technological development and international applications, with limited attention given to the practical realities faced by stakeholders in Malaysia (Lovell et al., 2023; López et al., 2018; Dore & Murphy, 2017). In particular, there is insufficient empirical understanding of stakeholder perceptions, implementation challenges, and the strategies required to support wider adoption. This gap is critical, as successful digital integration depends not only on technological capabilities but also on organisational readiness, institutional capacity, and policy alignment (Ismail et al., 2026; Pärn & Edwards, 2019). The lack of systematic digital adoption further constrains lifecycle-oriented asset management practices, including maintenance planning and long-term monitoring.

This study focuses specifically on the adoption of laser scanning technology within scan-to-HBIM workflows, rather than examining HBIM adoption or digital heritage management as broad standalone concepts. Laser scanning is treated as the data acquisition method used to capture accurate geometric and spatial information, while HBIM is viewed as the digital platform through which this information can be organised, interpreted, and used for heritage asset management. The discussion mainly refers to terrestrial laser scanning and scan-to-HBIM workflows, while acknowledging that other digital documentation methods such as photogrammetry may complement laser scanning in heritage projects.

Therefore, this study aims to explore the adoption of laser scanning technology within HBIM workflows for heritage asset management in Malaysia by examining stakeholder perceptions, identifying key challenges, and proposing strategic recommendations. Using a qualitative approach based on semi-structured interviews, this study provides empirical insights into the current state of digital adoption. The findings contribute to a more structured and coordinated approach to integrating digital technologies into heritage asset management, supporting more effective, data-driven, and sustainable management of heritage assets.

LITERATURE REVIEW

Heritage Asset Management and Documentation Practices in Malaysia

Heritage asset management in Malaysia plays a critical role in preserving cultural identity while ensuring the long-term functionality and value of historic buildings. The management of heritage assets is guided by legislative frameworks such as the National Heritage Act 2005 (Act 645), which emphasises systematic

documentation and conservation planning to support sustainable management (Baharuddin et al., 2024).

Despite these frameworks, current practices remain largely dependent on conventional documentation methods, including manual measurements, photographic records, and written reports. While these approaches provide essential baseline information, they are often time-consuming, fragmented, and prone to inconsistencies, limiting their effectiveness in supporting integrated asset management processes (Baharuddin et al., 2024; Ali et al., 2018). In particular, traditional documentation methods are inadequate in capturing complex geometries and detailed architectural features, which are critical for the accurate representation and management of heritage assets.

From a heritage asset management perspective, these limitations restrict the ability to support lifecycle-oriented activities such as maintenance planning, condition monitoring, and data-driven decision-making. The lack of structured and integrated information systems further hinders coordination among stakeholders and reduces the efficiency of managing heritage assets over time (Salleh et al., 2022; López et al., 2018). These challenges highlight the need for more advanced digital approaches to enhance documentation, integration, and long-term management of heritage assets in Malaysia.

Digital Technologies in Heritage Asset Management: BIM and HBIM

The advancement of digital technologies has significantly transformed information management practices in the built environment, particularly through the adoption of Building Information Modelling (BIM). BIM enables the integration of geometric and non-geometric data within a unified digital platform, supporting improved collaboration, information sharing, and lifecycle management of built assets (Lovell et al., 2023; López et al., 2018).

In the context of heritage assets, BIM has evolved into Historic Building Information Modelling (HBIM), which adapts BIM principles to accommodate the unique characteristics of historic structures. HBIM facilitates the development of information-rich digital models that incorporate historical, material, and condition-related data, enabling more systematic documentation and management of heritage assets (Lovell et al., 2023; Dore & Murphy, 2017). This capability is particularly important for supporting long-term asset management processes, including maintenance planning, condition assessment, and data-driven decision-making.

Despite its potential, the adoption of HBIM in Malaysia remains limited. Existing Malaysian HBIM studies have also proposed BIM-based processes for heritage documentation and data management, but wider implementation remains constrained by technical, organisational, and expertise-related challenges (Agwa & Celik, 2025; Mustafa et al., 2020). As a result, the

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benefits of HBIM in enhancing coordinated and lifecycle-oriented heritage asset management have yet to be fully realised within the Malaysian context.

Laser Scanning Technology in HBIM Workflows

Laser scanning technology plays a critical role in HBIM workflows, particularly in the data acquisition stage where accurate geometric information is required. Technologies such as Terrestrial Laser Scanning (TLS) enable the rapid capture of high-density point cloud data, allowing precise three-dimensional representation of heritage assets (Alshawabkeh & Baik, 2023). Compared to conventional survey methods, laser scanning offers significant advantages in terms of accuracy, efficiency, and the ability to capture complex and irregular geometries.

The integration of laser scanning with HBIM, commonly referred to as Scan-to-BIM, enables point cloud data to be processed into structured digital models that contain both geometric and semantic information (Rocha et al., 2020). This integration enhances the quality and reliability of documentation, supporting key asset management functions such as condition assessment, maintenance planning, and long-term monitoring of heritage assets.

Despite these advantages, the application of laser scanning in heritage asset management remains limited in practice. Challenges related to data processing complexity, large data volumes, and interoperability issues continue to affect the efficiency of integrating point cloud data into HBIM platforms (Rocha et al., 2020). These limitations highlight the need for improved workflows and technical capabilities to support the effective use of laser scanning within asset management processes.

Challenges in Adopting Laser Scanning and HBIM

Despite the recognised benefits of laser scanning and HBIM, their adoption in practice remains constrained by several challenges. One of the primary barriers is the high initial cost associated with equipment, software, and training, which limits accessibility, particularly for small and medium-sized organisations (Agwa & Celik, 2025). In cost-driven environments, such investments are often difficult to justify without clear short-term returns.

In addition to financial constraints, the lack of technical expertise has been widely identified as a significant challenge. The operation of laser scanning equipment and the processing of point cloud data require specialised skills that are not commonly available among industry practitioners, thereby limiting effective implementation (Ismail et al., 2021; Ali et al., 2018).

Organisational and institutional factors further affect adoption. The absence of standardised workflows, guidelines, and best practices contributes to inconsistencies in implementation and reduces stakeholder confidence in

adopting these technologies (Ismail et al., 2026; López et al., 2018). Moreover, limited coordination among stakeholders hinders effective data sharing and integration within digital environments.

Technical challenges related to data processing, interoperability, and model accuracy also persist. Issues such as large data volumes, processing complexity, and software limitations continue to affect the usability of HBIM models (Rocha et al., 2020). These challenges indicate that the adoption of laser scanning and HBIM is not solely a technological issue but involves broader organisational and institutional considerations.

To guide the interpretation of these adoption barriers, this study draws on the Technology–Organisation–Environment (TOE) perspective. The TOE perspective explains technology adoption through three interrelated contexts: technological conditions, organisational readiness, and external environmental factors. In this study, technical and data-related challenges are interpreted under the technological context, skill-related and organisational challenges under the organisational context, and financial, regulatory, and policy-related challenges under the environmental context.

RESEARCH METHODOLOGY

This study adopts a qualitative research approach to explore the adoption of laser scanning technology within Historic Building Information Modelling (HBIM) workflows for heritage asset management in Malaysia. A qualitative approach is appropriate as the study seeks to obtain in-depth insights into stakeholders' perceptions, experiences, and challenges that cannot be effectively captured through quantitative methods (Creswell, 2014).

Data were collected through semi-structured interviews with key stakeholders involved in heritage-related projects. This method allows flexibility in exploring participants' perspectives while maintaining consistency across interviews, ensuring comparability of responses (Bryman, 2016).

A purposive sampling strategy was employed to select participants with relevant expertise in heritage conservation, laser scanning, HBIM, or heritage asset management. Participants were required to have at least five years of professional experience and prior involvement in heritage-related projects. Seven participants were interviewed, representing conservators, conservation architects, HBIM specialists, laser scanning practitioners, quantity surveyors, and government representatives. Although the sample size was small, it was considered suitable for this qualitative study due to the specialised nature of the topic, the focused research scope, and the recurrence of similar themes across the interviews, indicating thematic saturation (Hennink & Kaiser, 2022).

The interviews were conducted between 10 November and 16 December 2025. The participants represented key professional roles related to

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heritage conservation, laser scanning, HBIM, quantity surveying, and public-sector heritage management. Their profiles, including professional role, organisation or sector, years of experience, and relevance to heritage or digital documentation projects, are summarised in Table 1.

Table 1: Profile of Interview Participants.

Interviewee	Professional Role	Organisation / Sector	Years of Experience	Relevant Expertise / Heritage Project Involvement
R1	Laser scanning specialist	Digital surveying / geospatial service provider	7	Laser scanning and digital documentation of existing buildings; involved in 3D data capture and point cloud processing for building documentation projects
R2	HBIM expert	BIM / digital construction consultancy	8	HBIM modelling and scan-to-HBIM workflow integration; involved in converting survey data into structured digital models for existing and heritage-related buildings
R3	Quantity surveyor	Construction cost consultancy / project management	5	Cost, procurement, and project implementation considerations; involved in assessing project cost implications and digital technology adoption in building projects
R4	Conservation architect	Architectural / heritage conservation practice	14	Heritage conservation planning and design coordination; involved in conservation design, documentation review, and coordination with project stakeholders
R5	Conservator	Heritage conservation practice	15	Conservation practice and heritage documentation; involved in site documentation, condition observation, and conservation-related recording of heritage assets
R6	Government heritage officer	Public-sector heritage administration / local authority	10	Heritage administration, approval procedures, and policy implementation; involved in reviewing heritage-related

Interviewee	Professional Role	Organisation / Sector	Years of Experience	Relevant Expertise / Heritage Project Involvement
				submissions and coordinating conservation requirements
R7	Conservator	Heritage conservation practice	17	Conservation practice, site issues, and long-term maintenance considerations; involved in heritage building conservation, maintenance observation, and post-conservation monitoring
				Source: Author's own work

Source: Author's own work

The interviews were conducted face-to-face or online, depending on participant availability, and each session lasted between 30 and 60 minutes. All interviews were recorded with consent. The interview guide was developed based on the research objectives and covered three main areas: current adoption of laser scanning in HBIM workflows, implementation challenges, and strategies to enhance its application in heritage asset management. Ethical considerations were observed through voluntary participation, informed consent, and anonymisation of participant identities.

The interview data were analysed using thematic analysis based on Braun and Clarke's (2006) procedure. The process involved familiarisation with the data, initial coding, theme generation, theme review, theme definition, and reporting. Codes were first generated from recurring ideas in the interview data and then grouped into broader themes such as financial constraints, technical and data-related challenges, skill-related gaps, organisational challenges, and regulatory or policy-related issues. To improve credibility, the themes were reviewed against the interview data and discussed among the research team before being finalised.

RESULTS AND DISCUSSION

Challenges in Implementing Laser Scanning Technology in HBIM

The findings indicate that the adoption of laser scanning technology in HBIM is constrained by multiple interrelated factors, including financial, technical, skill-related, organisational, and regulatory challenges.

Financial constraints remain a primary barrier, as the high cost of equipment, software, and training limits adoption, particularly in cost-sensitive projects (Ismail et al., 2021; Pärn & Edwards, 2019). In addition, the lack of

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technical expertise further restricts implementation, as specialised skills are required for operating laser scanning systems and processing point cloud data (Baharuddin et al., 2024; Ismail et al., 2021).

Organisational challenges, including fragmented workflows and limited stakeholder coordination, hinder effective data integration and reduce the efficiency of digital implementation (López et al., 2018). At the institutional level, the absence of clear policies and regulatory requirements reduces the urgency for adoption and limits the integration of digital technologies into heritage asset management practices. Technical issues related to data processing complexity, large data volumes, and interoperability further complicate implementation (Rocha et al., 2020).

Table 2: Thematic Analysis of Challenges in Implementing Laser Scanning Technology in HBIM.

Themes	Codes	Interviewees
Financial Constraints	High implementation cost	All respondents
	Lack of dedicated funding or incentives for digital heritage documentation	R5, R6
Technical and Data-Related Challenges	Difficulty integrating point cloud data into HBIM models	R1, R2, R4
	Large data size and complexity of point cloud processing	R1, R2
Skill-Related Gaps	Shortage of professionals skilled in both heritage conservation and HBIM	R2, R3, R4, R5, R6
	Low digital literacy among conservators and site personnel	R4, R7
	Limited hands-on training opportunities in laser scanning and HBIM	R5, R7
Organisational Challenges	Fragmented workflows between consultants, contractors, and conservators	R2, R3, R4, R6
	Resistance to change and reliance on conventional documentation methods	R3, R4, R6
Regulatory and Policy-Related Challenges	Lack of contractual requirements mandating laser scanning or HBIM usage	R3, R7
	Unclear approval requirements for digital documentation submissions	R1, R2, R5

Source: Author's own work

Table 2 presents the key challenges identified from the thematic analysis. The findings indicate that the adoption of laser scanning in HBIM workflows is constrained by financial, technical, skill-related, organisational, and regulatory barriers. These findings are consistent with previous studies that highlighted high implementation cost, technical complexity, limited expertise, and weak institutional support as common barriers to digital adoption in heritage and construction contexts (Agwa & Celik, 2025; Baharuddin et al., 2024; Rocha

et al., 2020). However, the interview findings further show that, in Malaysian heritage projects, these barriers are closely connected to project delivery and heritage-management practice.

For financial constraints, R3 noted that "the initial cost of laser scanning equipment and specialised services is relatively high, especially for heritage projects with limited budgets." This reflects the difficulty of justifying laser scanning investment in projects where conservation budgets are already limited. For technical and data-related challenges, R1 and R2 indicated that point cloud data can be difficult to process and integrate into HBIM models when clear workflows, software compatibility, and technical expertise are lacking. For skill-related gaps, R4, R5, and R7 highlighted that many heritage practitioners are still more familiar with conventional documentation methods, such as photographs, manual measurements, and written reports, than with laser scanning and HBIM-based workflows. Organisationally, R2, R3, R4, and R6 indicated that fragmented coordination between consultants, conservators, contractors, and government agencies can reduce the continuity of digital information across documentation, conservation planning, implementation, and maintenance stages. At the regulatory level, R6 highlighted that "the approval process for digital documentation is not clearly defined," creating uncertainty when laser scanning or HBIM outputs are submitted for project use.

From a planning and heritage-management perspective, these challenges suggest that laser scanning adoption should not be treated as a purely technical issue. Financial constraints affect the willingness of asset owners and project teams to invest in accurate digital documentation, while skill gaps limit the conversion of point cloud data into useful HBIM information. Organisational fragmentation also weakens continuity between documentation, conservation planning, implementation, and post-conservation maintenance. Therefore, effective adoption requires not only access to technology, but also clearer project requirements, professional capacity, coordinated workflows, and institutional recognition of digital documentation within heritage conservation processes.

Strategies to Enhance the Adoption of Laser Scanning Technology in HBIM

In response to the identified challenges, several strategies are proposed to support the adoption of laser scanning technology within HBIM workflows for heritage asset management.

Financial support mechanisms are essential to reduce cost barriers and encourage initial adoption. The provision of government incentives, subsidies, or cost-sharing schemes can help organisations manage the high upfront investment associated with laser scanning technologies. Such measures enable a shift from short-term cost-driven practices towards long-term value-oriented asset management (Alshawabkeh & Baik, 2023).

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Capacity development is equally critical in addressing the lack of technical expertise. Training programmes, professional workshops, and academic integration can enhance stakeholders' competencies in operating laser scanning systems and processing point cloud data. Strengthening human capital not only improves implementation efficiency but also increases confidence in adopting digital technologies.

At the organisational level, the development of standardised workflows and guidelines can improve consistency and reduce uncertainties in implementation. Clear procedures for data acquisition, processing, and integration within HBIM platforms are essential to ensure reliable and structured information management. These standardisation efforts support better interoperability and facilitate more effective asset management practices.

From an institutional perspective, stronger policy frameworks and regulatory support are necessary to drive large-scale adoption. The integration of digital requirements into national heritage guidelines can formalise the use of laser scanning and HBIM, encouraging broader industry uptake (Alshawabkeh & Baik, 2023). Policy intervention plays a key role in institutionalising digital practices within heritage asset management systems.

Table 3: Thematic Analysis of Strategies to Enhance the Adoption of Laser Scanning Technology in HBIM.

Themes	Codes	Interviewees
Financial Support and Cost Mitigation Strategies	Government grants or subsidies to offset high initial cost of laser scanning services	R3, R4, R5, R7
	Cost-sharing arrangement among project stakeholders for laser scanning and HBIM	R1, R2
	Phased adoption strategy instead of directly full integration	R3, R6
Technical Strategies	Clear definition of expected deliverables for laser scanning and HBIM outputs	R1, R2, R3
	Improved integration of laser scanning data beyond 2D drawings into HBIM models	R1, R2, R4
Skill and Knowledge Enhancement	Structured training programmes on laser scanning and HBIM for industry practitioners	R1, R2, R4, R6, R7
	Integration of HBIM and laser scanning modules into higher education curricula	R5, R6, R7
	Continuous professional development programmes on laser scanning and HBIM	R5
Organisational Coordination and Collaboration	Improved collaboration on data-sharing among stakeholders	R2, R3, R6
	Early involvement of digital specialists in conservation project planning	R1, R4, R5
	Establishment of clear roles and responsibilities managing digital heritage data	R1, R4

Themes	Codes	Interviewees
Regulatory and Policy Enhancement	Development of national guidelines or standards for laser scanning in heritage conservation	R1, R2, R4, R6, R7
	Inclusion of laser scanning or HBIM requirements in conservation project contracts	R3, R7

Source: Author's own work

Table 3 summarises the strategies proposed by interview participants to enhance laser scanning adoption in HBIM workflows. The findings suggest that adoption should be supported through a staged and coordinated approach rather than isolated technology investment. Financial support, including grants, subsidies, cost-sharing arrangements, and phased implementation, can reduce the initial cost burden and allow project teams to demonstrate value before wider adoption. At the technical level, respondents emphasised the need to define expected deliverables, including point cloud accuracy, HBIM model outputs, data formats, ownership, and update responsibilities, so that laser scanning data can be used beyond 2D documentation.

The findings also highlight the importance of capacity building and institutional support. Structured training, continuous professional development, and the integration of laser scanning and HBIM modules into higher education can help address the shortage of professionals with combined conservation and digital expertise. Organisationally, early involvement of digital specialists and clearer roles for managing digital heritage data can improve coordination between consultants, contractors, conservators, and public agencies. From a planning perspective, the inclusion of laser scanning or HBIM requirements in conservation project contracts and national guidelines can help formalise adoption and support more consistent use of digital documentation for conservation approval, maintenance planning, adaptive reuse assessment, and long-term monitoring.

Based on the identified challenges and proposed strategies, the staged roadmap in Table 4 is developed as a practical adoption readiness framework for laser scanning and HBIM in Malaysian heritage projects. The roadmap reflects the Technology–Organisation–Environment (TOE) perspective by linking technological readiness, organisational capacity, and institutional support to progressive stages of implementation. Technological readiness is addressed through digital documentation and scan-to-HBIM modelling, organisational readiness is addressed through asset management integration and coordinated information use, while environmental and institutional readiness is addressed through long-term monitoring, data ownership, and alignment with local authority or heritage-agency requirements.

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Table 4: TOE-Based Staged Adoption Readiness Roadmap for Laser Scanning and HBIM in Malaysian Heritage Projects.

Stage	Focus	Key Actions	Expected Planning and Heritage-Management Outcome
Stage 1	Digital documentation	Conduct laser scanning of selected heritage buildings or critical building elements; prepare point cloud records and measured documentation.	More accurate baseline information for conservation planning and approval.
Stage 2	Scan-to-HBIM modelling	Convert point cloud data into HBIM models with geometric, material, defect, and condition-related information.	Improved information integration for consultants, conservators, and asset owners.
Stage 3	Asset management integration	Link HBIM outputs with maintenance schedules, repair records, facility information, and conservation project requirements.	Stronger support for maintenance planning, facility management, and adaptive reuse assessment.
Stage 4	Long-term monitoring and governance	Update HBIM records through periodic scanning, define data ownership, and align digital outputs with local authority or heritage-agency requirements.	More consistent condition monitoring, decision-making, and lifecycle-based heritage asset management.

Source: Author's own work

This staged roadmap suggests that laser scanning and HBIM adoption should begin with focused documentation before progressing towards modelling, asset management integration, and long-term monitoring. Such a phased approach is more suitable for Malaysian heritage projects because it allows stakeholders to manage cost, build technical capacity, and gradually formalise digital documentation within conservation and planning processes.

CONCLUSION

This study examined the adoption of laser scanning technology within Historic Building Information Modelling (HBIM) workflows for heritage asset management in Malaysia, focusing on stakeholder perspectives, implementation challenges, and strategic implications. The findings indicate that adoption remains limited despite increasing awareness, with current practices still relying heavily on conventional documentation methods that are inefficient in managing complex heritage assets.

The study identifies that the adoption of digital technologies is constrained by multiple interrelated factors, including high costs, limited technical expertise, organisational challenges, weak stakeholder coordination, and insufficient policy support. These findings suggest that the barriers are not

solely technological but are embedded within broader institutional and operational contexts.

From a heritage asset management perspective, the integration of laser scanning and HBIM offers significant potential to enhance documentation accuracy, support lifecycle management, and enable more informed decision-making. However, realising these benefits requires coordinated efforts, including financial support, capacity development, standardised workflows, and stronger policy frameworks.

As this study is based on qualitative interviews with seven participants, the findings should be interpreted as stakeholder-based insights rather than statistically generalisable conclusions for all Malaysian heritage projects. Nevertheless, the diversity of professional backgrounds among the participants provides useful indicative evidence on the practical challenges and strategic needs associated with laser scanning and HBIM adoption in heritage asset management. Future research may expand the sample size, include additional heritage agencies and local authorities, and examine specific pilot projects to further validate the proposed strategies.

Overall, this study contributes empirical insights into digital adoption within the Malaysian heritage asset management context. It highlights the need for a structured and strategic approach that links laser scanning and HBIM with conservation documentation, maintenance planning, adaptive reuse assessment, local authority decision-making, and long-term monitoring.

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FIRE EVACUATION PREPAREDNESS AMONG OLDER RESIDENTS IN AN INDEPENDENT LIVING FACILITY

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Abstract

This study examines fire evacuation preparedness among older residents in an independent living facility, with particular attention to self-reported fire safety knowledge, perceived evacuation cues, and egress-related preparedness. Using the Protective Action Decision Model (PADM) as a guiding framework, a structured survey questionnaire was administered to 137 residents aged 50 years and above at an Independent Living Complex, Temerloh, Pahang of whom 75 provided complete responses for analysis, immediately after an inaugural fire drill conducted at the facility. The questionnaire comprised four sections addressing respondent background, environmental and social cues, protective action decision-making, and fire safety knowledge. Findings indicate that respondents placed strong importance on route-related orientation, place of assembly, and alarm-related cues, while mobility-related considerations remained relevant to perceived evacuation readiness. Given that the survey relied on self-reported responses from a single site immediately after a drill, findings are interpreted as exploratory post-drill perceptions rather than definitive evidence of evacuation performance. Nonetheless, the study offers practical insight for planning and facility design, highlighting the need for clearer wayfinding signage, accessible and redundant alarm communication systems, and structured assisted-evacuation arrangements to strengthen fire preparedness among older residents in independent living settings.

Keywords: Fire safety, Independent Living, Older Residents, Evacuation, Human Behaviour

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INTRODUCTION

Fire safety for independently living older residents is critical due to their heightened vulnerability during emergencies. Physical limitations, cognitive impairments, and comorbidities can hinder swift and safe evacuation (Shah et al., 2023; Taylor et al., 2023; Halbouni et al., 2025), while age-related physiological changes increase the risk of severe injury outcomes (Akashah et al., 2017). Many older residents remain inadequately prepared for emergencies, particularly those living alone or lacking prior emergency experience (Thompson et al., 2024; Khalaf et al., 2023). Personal barriers such as mobility limitations and complex building layouts impede evacuation, whereas facilitators such as family discussion of evacuation plans improve preparedness (Thériault et al., 2024; Thompson et al., 2024). Existing evacuation strategies in senior residences may not adequately address this population's needs, reinforcing calls for tailored, inclusive planning that respects older residents' autonomy (Thériault et al., 2024).

In Malaysia, research on older residents' evacuation preparedness remains limited and largely disconnected from local housing and ageing-in-place policy discourse. Most available evidence originates from simulation studies, general evacuation theory, or institutional care contexts, offering little insight into how older residents in independent living arrangements (Quan & Ahn, 2024; Ahmad Khalid et al., 2020), an increasingly emphasised model under Malaysia's ageing-in-place and housing policy agenda, perceive and respond to real fire drill scenarios. This gap is significant given Malaysia's rapidly ageing population and growing policy interest in enabling older residents to remain in community-based, non-institutional housing. This study addresses this gap by examining post-drill fire evacuation preparedness among residents aged 50 and above (reflecting Malaysia's inclusion of the pre-elderly cohort in ageing-related planning frameworks) at Independent Living Complex, Temerloh, Pahang, guided by the Protective Action Decision Model (PADM).

LITERATURE REVIEW

Evacuation Timeline and Its Relation to Fire Safety

Evacuation timeline directly shapes emergency response effectiveness and occupant survival (Liu et al., 2026). Pre-evacuation time, comprising recognition and response time, is shaped by alarm clarity, environmental conditions, and behavioural response (Liu et al., 2026). Darkness can extend evacuation time by 28.1%, and older residents require roughly 30.4% longer than younger occupants due to age-related limitations (Kinkel et al., 2024). Alarm familiarity and prior training shorten recognition time, while social cues also influence response (Menzemer et al., 2024; Balboa et al., 2023). Reduced visibility can lower walking speed by 43.9% (Yan et al., 2024), and regular drills improve evacuation efficiency by up to 12.87% (Ding et al., 2024). Figure 1 illustrates these phases,

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highlighting the critical nature of pre-evacuation time in ensuring occupant safety during a fire.

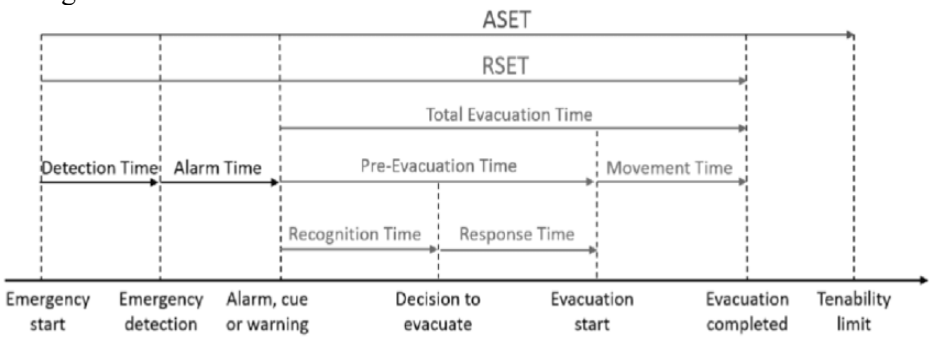


Figure 1: Evacuation timeline
Source: Satir & Toprakli (2020)

Pre-evacuation Behaviours

Pre-evacuation behaviour encompasses the cognitive and behavioural processes that determine how individuals interpret risk and decide to evacuate (Liu et al., 2026). Fire alarms are frequently perceived as false alerts, delaying protective action, although prior training increases perceived urgency and encourages earlier evacuation (Menzemer et al., 2024). Decision-making is also influenced by environmental familiarity, social conformity, and route-selection preferences (Wang et al., 2024). Emerging technologies, including multi-sensory alarms, mobile applications, and virtual reality training, have demonstrated potential to improve evacuation preparedness (Mao et al., 2024; Yan et al., 2024; Salleh & Mohtar, 2020). These findings reinforce the importance of combining effective warning systems with regular fire drills to strengthen evacuation preparedness among older residents.

Fire Safety among Older Residents

Fire safety presents particular challenges for older residents because age-related changes in mobility, vision, hearing, cognition, and chronic health conditions can delay evacuation and increase vulnerability during emergencies (Priastana et al., 2023; Jia et al., 2023; Ahmad Khalid et al., 2020; Shah et al., 2023). Previous studies have highlighted the importance of individualised evacuation planning, accessible building design, caregiver support, and assistive technologies, such as visual and vibrating alarms, to improve preparedness and support independent evacuation (Thompson et al., 2024; Lian, 2024; Babu et al., 2023; Bhalotia et al., 2023).

Despite these advances, most existing evidence is derived from institutional or residential care settings where evacuation is largely supported by staff, such as healthcare facilities (Lim et al., 2023; Choi et al., 2019; Liu et al.,

2024). Comparatively, independent living facilities have received far less attention, even though residents are expected to rely more on their own decision-making and familiarity with evacuation routes during emergencies. This distinction is particularly relevant in Malaysia, where housing and ageing policies increasingly promote ageing-in-place by enabling older residents to remain in community-based housing rather than institutional care. However, Malaysian fire safety research has yet to generate sufficient empirical evidence to support evacuation planning within these independent living environments. Most local studies continue to emphasise evacuation simulations, building performance, or theoretical modelling (Ahmad et al., 2018; Noumeur et al., 2024; Tan et al., 2014), with limited investigation of residents' post-drill perceptions of evacuation preparedness.

Accordingly, this study addresses this gap by examining post-drill perceptions of fire evacuation preparedness among residents aged 50 years and above in an independent living facility in Temerloh, Pahang. The age threshold was adopted to capture individuals entering later adulthood, when changes in mobility, sensory function, and emergency response may begin to emerge, while reflecting Malaysia's recognition of the pre-elderly population in ageing-related planning. The findings provide context-specific evidence to inform fire safety planning, independent living facility management, and ageing-in-place housing policy in Malaysia.

RESEARCH METHODOLOGY

This study employed a quantitative cross-sectional survey design to examine post-drill fire evacuation preparedness among older residents in an independent living facility. It is important to clarify that the study measured self-reported post-drill perceptions of preparedness, evacuation cues, and egress-related awareness, rather than observed or measured actual evacuation behaviour (e.g., evacuation time, route choice, or physical performance). This distinction is central to interpreting the findings as exploratory perceptual data rather than behavioural or performance evidence.

Independent Living Complex, Temerloh, Pahang, is a five-storey residential facility comprising 100 residential units and accommodating 137 older residents. The building is equipped with four emergency staircases (two located on each side of every floor), one lift, and a designated assembly point located at the ground-floor car park near the building. Fire safety provisions include portable fire extinguishers, emergency lighting, and six loud hailer sirens used as a makeshift fire alarm system. The facility was selected because evacuation depends largely on residents' personal awareness and route familiarity rather than continuous staff-led assistance, distinguishing it from institutional care settings.

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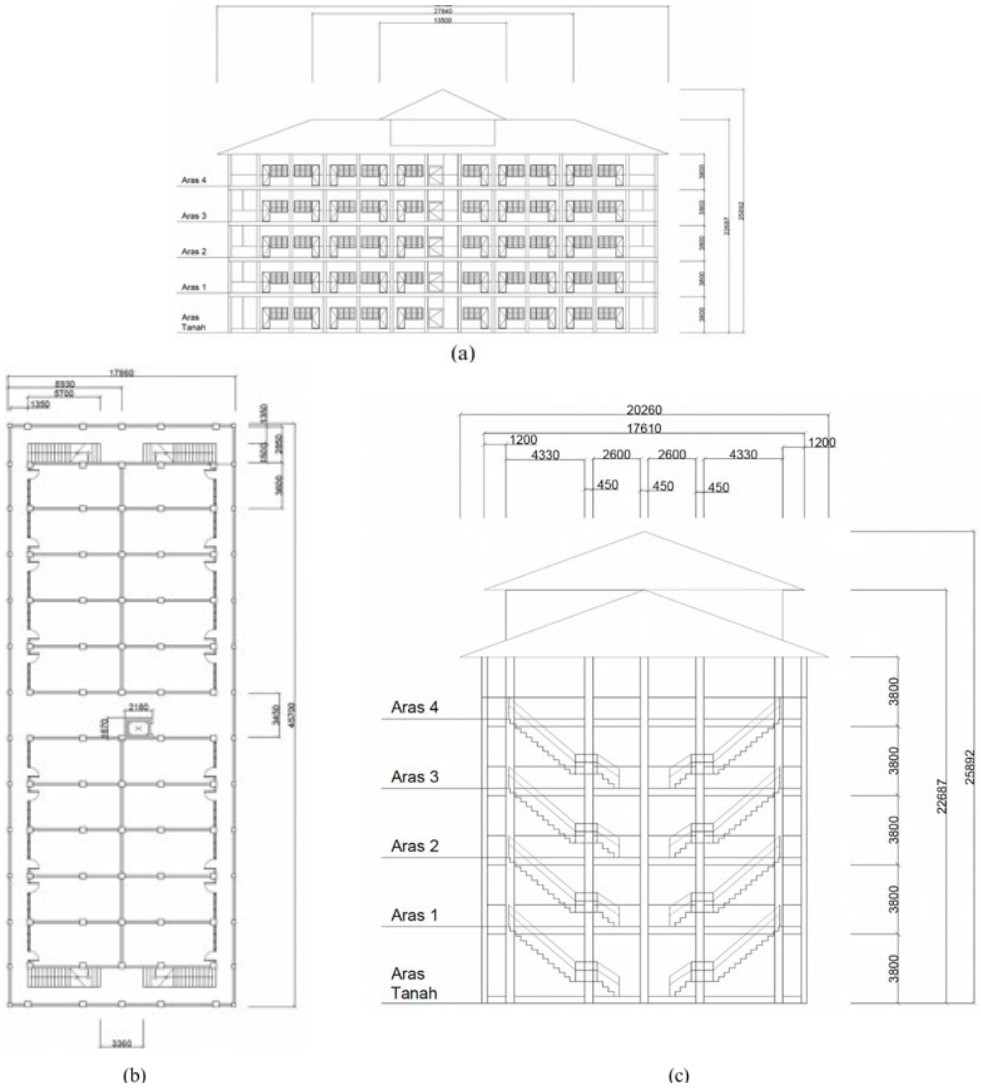


Figure 2: Floor plans and views of Independent Living Complex: (a) Front view, (b) Plan view, (c) Side views (left and right)
Source: Author's work

In addition, its structural layout provides a suitable context for examining residential evacuation challenges among older occupants. Figure 2 presents the floor plan and elevation of the facility to illustrate the evacuation routes, exits, and egress components referenced in the questionnaire.

The survey was administered immediately following the facility's inaugural unannounced fire drill. The drill involved 100% of the residents, with the evacuation coordinated by the building management staff and observed by the Fire and Rescue Department of Malaysia . As described in the Methodology, the evacuation alarm was initiated using the loud hailer sirens, with residents proceeding to the designated assembly point. Questionnaires were distributed to and returned by all 137 residents present during the drill. However, 75 responses (54.7%) were sufficiently complete for inclusion in the analysis. Incomplete responses reflected the limited on-site assistance available relative to the number of residents requiring support, given the physical and sensory needs common among this population. Fire safety awareness activities, including a fire extinguisher demonstration, and a post-drill feedback session led by the Chief of the local Fire and Rescue Department Station and his team, were also conducted. Although evacuation performance data (e.g., evacuation time and observations) were recorded during the drill, these data are beyond the scope of the present study, which focuses on residents' post-drill perceptions of evacuation preparedness. The questionnaire was therefore administered immediately after the drill to capture responses while evacuation cues, route familiarity, and alarm-related awareness remained fresh.

This study adopted a total population (census) sampling approach, targeting all residents aged 50 years and above residing in the facility, rather than a sample drawn from a larger population. This age threshold is consistent with studies that recognise this age group as entering later adulthood, when age-related changes in mobility, sensory perception, and emergency response may begin to emerge, enabling the study to capture early variations in evacuation preparedness before the conventional definition of older age (≥60 years)

The questionnaire was developed based on the Protective Action Decision Model (PADM; Lindell, 2017), which explains how individuals perceive risk information, personalise threat, and select protective actions. PADM constructs were operationalised across four sections. Section A captured respondent background (age, gender, tenancy, floor level, prior drill experience). Section B captured environmental and social cues and threat perception (how residents were alerted, and their assumption of the situation). Section C captured protective action decision-making and implementation, including the sequence of pre-evacuation actions, the trigger for beginning evacuation, physical/mobility constraints, and a 13-item scale of perceived evacuation efficacy. Section D captured fire safety knowledge and enabling factors, including awareness of building layout, routes, and equipment, prior training received, and experience with stairs, lifts, and mobility assistance.

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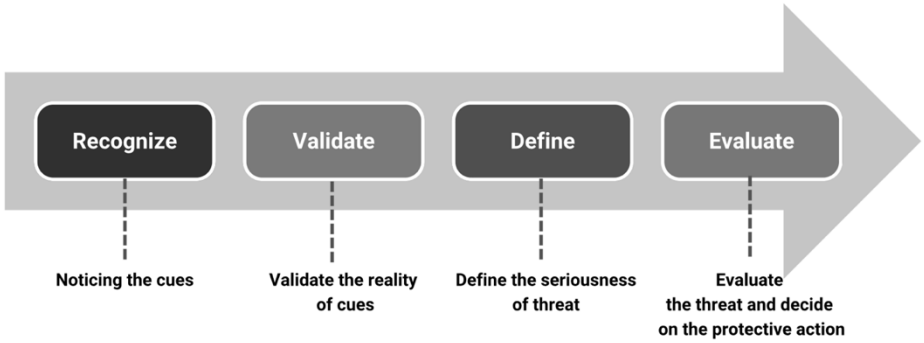


Figure 3: Decision-making stages according to the Protective Action Decision Model (PADM)
Source: Adapted from Lindell (2017)

Internal consistency was assessed for the multi-item evacuation preparedness scale using Cronbach's alpha. The scale demonstrated good internal consistency ($\alpha = 0.873$), indicating that the items reliably measured the underlying construct of evacuation preparedness. Content validity was established through expert review to ensure the questionnaire items were relevant and appropriate for assessing fire evacuation preparedness among older residents.

Data were imported into SPSS and screened for accuracy prior to analysis. Spearman rank correlation was selected because several study variables were measured on ordinal Likert scales and were not normally distributed, making this non-parametric test appropriate for assessing the strength and direction of association between ranked variables. One-tailed significance tests ($p < 0.05$) were applied based on the directional hypotheses. The Relative Importance Index (RII) was used to rank preparedness factors by perceived importance, as it is well suited to converting ordinal survey responses into a standardised index for comparative prioritisation, calculated using the below formula, which facilitated the prioritization of key safety factors based on the residents' responses.

$$Relative\ Importance\ Index\ (RII) = \frac{\sum W}{A \times N}$$

Where:

- WW is the weighting given to each factor by the respondents,
- A is the highest weight (e.g., 5 for a Likert scale of 1-5),
- N is the total number of respondents.

These analyses provide insights into preparedness-related factors, evacuation perceptions, and perceived priorities among older residents, and

helped identify practical areas for improving fire safety planning and support in similar residential settings.

RESULTS AND DISCUSSION

Demographic, Preparedness and Evacuation Preferences

Based on Table 1, older residents in the higher age brackets (66–80 and 81+) and who have lived longer in the building (37–72 months) show stronger and more consistent participation in fire drills than younger and newer residents, suggesting greater familiarity with and commitment to fire safety procedures. The majority prefer emergency stairs (78.7%) and individual evacuation (69.3%), indicating a strong emphasis on autonomy and accepted stair use, while a small group rely on lifts or group evacuation, highlighting mobility constraints and the need for supportive measures such as designated helpers, evacuation chairs, or protected evacuation lifts. These patterns imply that evacuation planning should simultaneously strengthen routine drill engagement for newer residents and incorporate assisted-evacuation provisions for those with reduced mobility.

An important strength of the study is that the survey was administered immediately after an inaugural fire drill conducted at the facility. This provided a more grounded basis for respondents to reflect on evacuation cues, route familiarity, assemble procedures, and egress-related concerns than would have been possible in a purely hypothetical survey setting. In this sense, the findings reflect preparedness perceptions formed in close temporal relation to an actual evacuation exercise.

At the same time, the post-drill timing may have influenced respondents' answers. Participation in the drill could have heightened immediate awareness of fire safety issues, increased the prominence of evacuation routes and alarm cues, and shaped responses in socially desirable ways. The findings should therefore be interpreted as post-drill perceptions rather than a baseline preparedness entirely unaffected by recent intervention.

Fire Safety Knowledge

Table 1 summarises respondents' self-reported fire safety knowledge captured immediately after the drill. Most respondents (73%) reported awareness of the building's evacuation procedures, and the general alarm was overwhelmingly identified as both the primary informing cue (83.6%) and the dominant trigger for action (89%), consistent with PADM's emphasis on environmental cues as the starting point of protective decision-making (Lindell, 2017). However, only 52% assumed the cue signalled a real fire, while nearly a third either interpreted it as a scheduled drill or remained uncertain, a pattern that echoes findings elsewhere that fire alarms are frequently first read as false alerts or tests rather than genuine threats, delaying recognition (Menzemer et al., 2024). This is reinforced by the

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reported first action: most respondents looked around to assess the situation before moving towards exits, mirroring the social-cue-seeking behaviour documented in prior evacuation research (Balboa et al., 2023). Together, these results suggest that while procedural awareness is reasonably strong, the recognition stage of the PADM process, distinguishing a genuine emergency from routine or ambiguous cues, remains a bottleneck, pointing to a need for alarm systems and drills that shorten this appraisal delay rather than only reinforcing route familiarity.

Table 1: Summary of Respondents' Self-Reported Fire Safety Knowledge (Post-Drill)

Indicator	Finding
Awareness of building evacuation procedures	73% aware
Medium informing need to evacuate	Fire alarm 83.6%; voice announcement 30.1%; management instruction 9.6%
Assumed nature of the evacuation cue	Real fire 52%; scheduled drill 21.7%; uncertain 11%
Main cue prompting evacuation action	General alarm 89%; management/warden instruction 25%; neighbour/friend prompt 19%
First action taken after the cue	Looked around; moved to stairs/exits; followed instructions; alerted others

Source: Author's work

Fire Cues for Evacuation

The predominance of the general alarm as the primary evacuation cue highlights the importance of clear warning systems in initiating protective action among older residents, consistent with previous studies that identify alarms as the main trigger for evacuation. However, the reliance on instructions from building management or wardens suggests that many residents seek confirmation from trusted authorities before acting, reflecting the decision-making process described in the PADM. While this may increase confidence, it could also prolong pre-evacuation time if communication is delayed. The limited influence of social cues indicates that evacuation decisions in this setting are driven more by formal warning systems than by observing others. These findings suggest that effective evacuation planning should integrate reliable alarm systems with timely staff communication, supported by visual and voice alarms, particularly for residents with hearing impairments. Regular fire drills should also reinforce prompt evacuation behaviour and reduce dependence on management instructions during emergencies.

Mobility, Correlation, and Preparedness (RII)

Spearman's rho analysis (Table 2) revealed statistically significant but weak positive correlations between physical mobility problems and fire alarm audibility ($\rho = 0.285$, $p = 0.007$), ease of movement ($\rho = 0.233$, $p = 0.022$), and

movement speed ($\rho = 0.221$, $p = 0.029$). Correlation strength was classified using Evans's (1996) guideline, in which coefficients of 0.20–0.39 denote a weak association. As the effect sizes are weak, these results are interpreted with caution: significance suggests a detectable association, though it does not confirm that mobility limitations directly influence evacuation readiness. Other factors, such as evacuation knowledge, procedural familiarity, and decision-making confidence, may also play a role and merit further examination. In terms of fire safety knowledge, most respondents were able to identify evacuation routes and alarm cues, reflecting a reasonable level of procedural awareness, while continued training may help reinforce practical readiness.

Table 2: Spearman's Rho Correlations Between Physical Mobility Problems and Evacuation-Related Factors

Variable	Spearman's rho	p-value	Interpretation
Fire alarm audibility	0.285	0.007	Significant
Ease of evacuation	0.078	0.253	Not significant
Speed of evacuation	0.04	0.368	Not significant
Ease of movement under good physical condition	0.233	0.022	Significant
Movement speed under good physical condition	0.221	0.029	Significant
Fatigue during evacuation	-0.004	0.486	Not significant
Fatigue after evacuation	0.002	0.493	Not significant
Need for assistance	0.126	0.14	Not significant
Need for mobility aids	0.171	0.071	Not significant
Confidence in evacuation decision-making	0.07	0.275	Not significant
Familiarity with evacuation procedures	0.127	0.138	Not significant
Awareness of evacuation routes	0.053	0.324	Not significant
Overall evacuation preparedness	-0.015	0.448	Not significant

Source: Author's work

Table 3 shows that respondents ranked location of assembly (RII = 0.808), building layout (0.800), and emergency route (0.773) highest, while fire extinguishers (0.616) and emergency assistance (0.621) ranked lowest. This pattern suggests that older residents' preparedness is anchored more in spatial and procedural awareness than in equipment operation or active help-seeking, consistent with the broader evacuation literature indicating that wayfinding confidence, rather than technical competence, drives perceived readiness among older populations (Liao & Hu, 2025; Lim et al., 2023). The comparatively low ranking of emergency assistance is notable, as it may reflect reliance on management-led instructions and public address systems during drills rather than independent decision-making, a pattern documented in studies of building-dependent evacuation behaviour among older residents (Choi et al., 2019; Lim et al., 2023). This reliance carries implications for redundancy: if verbal or centralised instructions fail during an actual emergency, residents lacking

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confidence in self-directed evacuation routes may be disproportionately disadvantaged, underscoring the need for multi-modal, redundant communication systems such as visual signage, tactile cues, and haptic alerts.

Table 3: Older Residents' Knowledge of Core Factors in Fire Evacuation Preparedness

No.	Factor	RII means	Rank
1	Building layout	0.80000	2
2	Location/place of assembly	0.80800	1
3	Emergency route	0.77333	3
4	Fire alarm location	0.67467	6
5	Fire extinguishers	0.61600	9
6	Emergency assistance	0.62133	8
7	Awareness in aspects of fire safety	0.72800	5
8	Fire drills	0.75733	4
9	Written evacuation procedures	0.65867	7

Source: Author's work

Several limitations should be acknowledged. The study was limited to one independent living facility, restricting generalisability to other settings and populations. Future studies could extend this evacuation-preparedness framework to other vulnerable populations in institutional settings, such as healthcare facilities (Liu et al., 2024). Results relied on self-reported responses, reflecting perceived preparedness and stated readiness rather than directly observed evacuation performance. The survey was also administered immediately after an inaugural drill, which likely heightened awareness of cues and procedures. Findings should therefore be interpreted as exploratory post-drill perceptions rather than baseline preparedness unaffected by recent intervention.

Overall, the findings indicate that older and longer-term residents were more engaged in fire drills, most preferred autonomous stair-based evacuation, and alarms together with management instructions served as the primary evacuation cues. Mobility limitations were associated with greater emphasis on spatial orientation than on independent use of fire safety equipment. These findings suggest that evacuation planning should prioritise age-friendly wayfinding, clearly marked assembly areas, visual and auditory alarm systems, evacuation chairs, protected refuge areas, buddy systems, and staff-assisted evacuation procedures. Regular fire drills tailored to residents with different mobility needs should also be incorporated to strengthen preparedness and support safer emergency evacuation in independent living facilities.

CONCLUSION

In conclusion, this study examined post-drill perceptions of fire evacuation preparedness among older residents in an independent living facility. The

findings indicate that respondents considered route orientation, assembly-point familiarity, and alarm-related cues as the most important factors influencing perceived evacuation preparedness, while mobility-related considerations also remained relevant. As the questionnaire was administered immediately after a fire drill and relied on self-reported responses from a single facility, the findings should be interpreted as exploratory evidence of post-drill perceptions rather than direct measures of actual evacuation performance.

From a theoretical perspective, this study demonstrates the applicability of the PADM in examining post-drill perceptions of evacuation preparedness among older adults. It contributes to the limited literature on post-drill behavioural assessment within independent living facilities in the Malaysian context and provides evidence on how environmental cues and perceived mobility constraints influence evacuation decision-making.

From a planning and design perspective, the findings have practical implications for planners, housing managers, and building designers. The identified preparedness factors support the need for age-friendly evacuation planning through intuitive wayfinding, clearly designated assembly areas, accessible escape routes, effective visual and auditory alarm systems, and evacuation strategies that accommodate residents with mobility limitations. The recommendations presented in the Results and Discussion section further emphasise the importance of regular fire drills, staff-assisted evacuation procedures, buddy systems, and inclusive emergency management practices. Collectively, these findings provide practical evidence to inform the design, management, and fire safety planning of independent living facilities, thereby supporting safer and more resilient environments for ageing populations.

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Consent to Participate

This study was conducted with the informed consent of all participants. Prior to data collection, participants were provided with detailed information about the study's purpose, procedures, and their rights, including the assurance of confidentiality and voluntary participation. Written consent was obtained from all participants, and the study adhered to ethical guidelines throughout the research process.

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Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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SPATIAL ASSESSMENT OF FLOOD-PRONE AREAS IN MELAKA TENGAH, MALAYSIA, USING THE ANALYTIC HIERARCHY PROCESS AND GIS

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Abstract

Driven by population growth and tourism, urban expansion in Melaka Tengah has converted natural landscapes into built-up areas, escalating regional flood risks. This study evaluates flood susceptibility using a Geographic Information System (GIS) -based Analytic Hierarchy Process (AHP), assessing five core factors: land-use change, rainfall, drainage density, slope, and elevation. Results indicate a 6% increase in built-up areas from 2014 to 2023, with rainfall identified as the primary risk driver (31% weight). Cross-referenced with local 2035 planning blueprints, this spatial framework offers empirical insights for sustainable risk mitigation and municipal urban governance.

Keywords: Land Use Changes, Flood-Prone Areas, Analytic Hierarchy Process (AHP), Geographic Information System (GIS)

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INTRODUCTION

Melaka City, a UNESCO World Heritage Site and popular tourist destination, is vulnerable to heavy rainfall and flash floods in dense built-up regions (Bahari et al., 2023; Khairi, 2021). The Smart Melaka Blueprint 2035 predicts an 86.5% urbanisation rate and a 40% population increase to 1.54 million by 2035 (State Government of Melaka & Malaysian Industry Government Group for High Technology, 2024). This progressive expansion of impervious surfaces alters catchment hydrology by reducing soil infiltration, disrupting natural runoff pathways, accelerating peak discharge, and overwhelming existing drainage networks (Abdulkareem et al., 2018; Ahmed et al., 2024). The Department of Irrigation and Drainage (JPS) empirical records show that past flood hotspots are in low-lying, intensively developed metropolitan areas. GIS-based multi-criteria flood susceptibility mapping is widely used worldwide, but existing frameworks categorise land use broadly and rarely bridge the empirical gap between tourism-driven land dynamics and watershed-scale hydrological models. (Giofandi et al., 2024; Widaningrum et al., 2020). Tourism-driven urban growth and GIS-AHP flood mapping have been reported in Melaka Tengah, but no integrated spatial tool has been developed to predict how this land conversion will interact with monsoonal rainfall regimes to change flood limits and influence local spatial planning (Giofandi et al., 2024).

LITERATURE REVIEW

Characteristics and Causative Factors of Flooding

In Malaysia, flooding reflects the interaction of seasonal monsoon rainfall, catchment characteristics, land-use change, and drainage capacity. Monsoon floods are prolonged and predictable during the Northeast Monsoon, while flash floods occur rapidly in heavily developed areas and are associated with sharp water-level rise, high flow velocity, and substantial debris loads (Rosmadi et al., 2024, 2023). In urban settings, flood behaviour is further intensified by rapid urbanisation, poor drainage, land clearance, and climate-linked increases in rainfall intensity, which tend to increase both flood frequency and inundation extent (Ibrahim et al., 2024a; Mahmoud & Gan, 2018; Saad et al., 2024). Malaysian flood-susceptibility studies therefore commonly use variables such as rainfall, slope, drainage network or density, land use, soil type, elevation, TWI, and flow accumulation because these capture the main hydrological and terrain controls on where flooding occurs (Elsheikh et al., 2015a; Ibrahim et al., 2024b).

Methodological Framework: GIS and the Analytic Hierarchy Process (AHP)

In practice, GIS is widely used to delineate flood-prone areas using factors such as Land Use and Land Cover (LULC), drainage density, geology,

geomorphology, soil, normalised difference vegetation index (NDVI), slope and topography witness index (TWI) (Blakime et al., 2024; Bokhari et al., 2024; Subraelu et al., 2023). In flood studies, AHP is frequently combined with GIS because it enables the transparent, replicable weighting and integration of multiple spatial factors into composite flood susceptibility maps (Zhran et al., 2024). In Malaysia, GIS-AHP approaches have proven effective in different settings: for example, Rasu et al., (2023) mapped flood risk in Maran, Pahang, using a limited set of parameters (digital elevation model, soil type, land use, topography and rainfall) and showed that low slopes, clay-rich soils, sparse vegetation and high rainfall substantially increase flood susceptibility.

Research Significance and Objectives

Multi-criteria, GIS-based flood susceptibility models incorporating expert-derived weights are widely utilised to synthesise rainfall, drainage density, slope, elevation, and land use into composite risk maps across diverse physical and urban landscapes (Dano et al., 2019a; Lin et al., 2019; Sahraei et al., 2023). Many modern economic or environmental assessments of localised flood impacts use descriptive statistics or micro-scale hydrodynamic simulations instead of integrating multiple physical and anthropogenic drivers into a spatial decision-making matrix (Ibrahim et al., 2024c; Ouma & Omai, 2023). Despite the development of expert-weighted multi-criteria GIS models, tourism-driven built-up expansion and watershed-based flood susceptibility in Melaka Tengah have not been explicitly linked, despite similar approaches being used in other regions for land-use planning and risk zoning (Dano et al., 2019b; Ibrahim et al., 2024b; Mariappan et al., 2019). Five factors were selected because they capture Malaysia's main flood controls, while other variables were omitted because the literature treats them as secondary, context-specific, or data-dependent refinements rather than core drivers, with rainfall repeatedly identified as the main trigger, drainage density as a runoff concentrator, slope and elevation as controls on flow and ponding, and land use as a proxy for urbanisation and infiltration loss (Ashfaq et al., 2025; Elsheikh et al., 2015b; Imani et al., 2025a). Thus, this research identify, evaluate, and map flood-prone areas in Melaka Tengah, Malaysia, by integrating the AHP and GIS based on selected flood-conditioning factors.

RESEARCH METHODOLOGY

Study area and description

The study was conducted in Melaka Tengah District on the southwest coast of Peninsular Malaysia, one of three districts in the state alongside Alor Gajah and Jasin. The district comprises a heterogeneous mix of dense urban fabric,

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residential suburbs, industrial zones, tourism facilities and remnant agricultural and vegetated areas.

Materials and data sources

This work examines five flood-conditioning parameters, LULC change, monsoonal rainfall, drainage density, topographic slope, and elevation, to maintain model parsimony and eliminate multicollinearity. The homogenous soil structure in Melaka Tengah's coastal plain precluded secondary factors like lithology and soil capacity. Instead, the chosen elements capture the crucial connections between monsoonal weather cycles, topography restrictions, and rapid, tourism-driven urban surface alterations. **Table 1** summarises the datasets, processing steps and roles of each component in the flood susceptibility analysis.

Table 1: Materials and data sources for flood-conditioning factors in Melaka Tengah

Component	Description
Flood-conditioning framework	Five factors were used: land use and land cover, elevation, slope, rainfall and drainage density, combining geospatial, hydrometeorological and planning data for Melaka Tengah.
Terrain and drainage	A 30 m United States Geological Survey (USGS) DEM was processed (reprojected, clipped, sink-filled) to derive elevation (five classes, −14 to 181 m), slope (very gentle to very steep) and drainage density (total stream length per unit area).
Rainfall	Station data in and around Melaka were converted to multi-year average monthly values and interpolated with Inverse Distance Weighting (IDW) to produce a 30 m rainfall surface.
Land use and land cover	Landsat 8 imagery (2014, 2018, 2023) was classified (maximum likelihood) into water, barren land, vegetation, and built-up, resampled to 30 m, clipped to Melaka Tengah, and validated against plans and high-resolution imagery.
Contextual documents	Strategic plans and national statistics informed the selection of factors and the interpretation of flood-susceptibility results.

Data Processing and Accuracy Assessment of the Flood Susceptibility Model

All values were resampled to 30 m resolution and reprojected to the Kertau Rectified Skew Orthomorphic (RSO) Malaya Meter system (EPSG: 3168) for GIS modelling in ArcGIS Pro using the Spatial Analyst extension. Line Density was used to compute drainage density from Department of Irrigation and Drainage stream vectors, while slope (degrees) was derived from a pre-processed 30 m DEM. Inverse Distance Weighting was used to create continuous precipitation surfaces from point data. Human effect was captured by classifying Landsat 8 data (2014, 2018, 2023) into built-up, vegetation, water, and barren land inputs. Using a confusion (error) matrix, stratified random reference points for each land-cover class were validated against high-resolution reference imagery and ground-truth data to calculate the overall accuracy, Kappa coefficient, and producer and user accuracy. The classification accuracy of 87.5%

and Kappa coefficient of 0.83 supported the reliability of the land-use inputs for flood susceptibility modelling.

The resulting flood susceptibility map was then validated against two independent reference datasets: historical flood records from the DID and official evacuation records for the study area. Using a spatial overlay procedure in ArcGIS Pro, documented past flood events from the DID registers were converted into point features, overlaid onto the classified susceptibility map, and intersected with the underlying risk classes. The majority of these points fell within the "High" and "Very High" risk corridors, confirming that the model correctly identified genuinely flood-prone locations. The same procedure was applied to the official evacuation records. Because evacuations occur only during severe flooding, these locations serve as on-the-ground indicators of significant flood impact, and they, too, aligned predominantly with the high-risk zones. This strong spatial agreement confirms that the map reliably reflects the actual pattern of chronic inundation within the study area.

Analytic Hierarchy Process

To establish objective priority weights for the five flood-conditioning factors, the Analytic Hierarchy Process (AHP) was utilised, drawing on input from a panel of seven local experts in urban planning, hydrology, and municipal infrastructure management. Their pairwise comparisons were grounded in historical municipal flood records and extensive professional field experience across Melaka, ensuring contextually accurate and robust model weighting. The AHP was introduced by Saaty (1987) and was used to derive weights for the five flood-conditioning factors, land use and land cover, rainfall, elevation, slope, and drainage density, based on their relative influence on flood susceptibility in Melaka Tengah. In AHP, expert judgements on the importance of each factor are expressed through pairwise comparisons and assembled in a square comparison matrix $A = [a_{ij}]$, where a_{ij}denotes the importance of factor $i$relative to factor $j$on Saaty's 1–9 scale (1 = equal importance, 9 = extreme importance; Saaty, 1980, 2008). The consolidated pairwise comparison matrix derived from the expert panel is presented below:

Table 2: Pairwise Comparison Matrix ($\boldsymbol{A}$)

Criteria	Rainfall	Drainage Density	LULC	Slope	Elevation
Rainfall	1	1	3	2	2
Drainage Density	1	1	2	1	1
LULC	1/3	1/2	1	1	1
Slope	1/2	1	1	1	1
Elevation	1/2	1	1	1	1

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The priority weight vector $w = (w_1, \dots, w_n)^T$ is obtained as the normalised principal eigenvector of A, satisfying $Aw = \lambda_{max} w$, where λ_{max} is the maximum eigenvalue. This yielded the following weights: rainfall (0.31), drainage density (0.22), elevation (0.17), slope (0.17), and land use/land cover (0.13). Consistency of the judgements was evaluated using the Consistency Index $CI = (\lambda_{max} - n)/(n - 1)$ and the Consistency Ratio $CR = CI/RI$, where n is the number of factors and RI is the Random Index. For $n = 5 (RI = 1.12)$, the analysis produced $\lambda_{max} = 5.25$, $CI = 0.063$, and $CR = 0.056$. As $CR < 0.10$, the criterion for acceptable consistency was satisfied in the present study. Each factor was represented as a 30 m raster layer in a common projection and reclassified into ordered susceptibility classes. The final AHP-derived weights were integrated into a Geographic Information System using a weighted linear combination $S = \sum_{i=1}^{5} w_i F_i$, where F_i are the standardised factor maps, to produce a continuous flood susceptibility index that was subsequently classified into five classes (very low, low, moderate, high, and very high) for mapping and interpretation.

ANALYSIS AND DISCUSSION

Land Use Change

Between 2014 and 2023, built-up areas in Melaka Tengah expanded from 64.33% to 70.33% (199.81–218.48 km²). This growth displaced water bodies (declining from 2.45% to 1.21%), barren land (3.40% to 1.06%), and vegetation (29.64% to 27.41%). Concentrated around rapidly urbanizing mukims like Bandar Melaka, Batu Berendam, and Bukit Katil, these transitions mirror trends in growing global cities where population growth drives green space loss and heightened flood exposure (Handayani et al., 2020; Rendana et al., 2025a; Weday et al., 2023).

Flood Causative Factors

Between 2014 and 2023, built-up areas in Melaka Tengah expanded from 64.33% to 70.33% (199.81–218.48 km²), displacing water bodies (2.45% to 1.21%), barren land (3.40% to 1.06%), and vegetation (29.64% to 27.41%). Concentrated in rapidly developing mukims such as Bandar Melaka, Batu Berendam, and Bukit Katil, these infrastructure and residential conversions mirror broader global trends in which urban population growth drives green space degradation and heightened flood exposure (Kafi & Ponrahono, 2026). The selection of causative factors is justified by the region's physical and developmental characteristics, where intense monsoonal rainfall, low-lying terrain, gentle slopes, expanding built-up areas, and modified drainage systems collectively drive localised flooding. Integrating these parameters effectively captures the hydrological, topographic, and human-induced dynamics essential for comprehensive risk assessment (see Figure 1 to Figure 4), as they determine spatial risk patterns and

improve identification accuracy (Kafi et al., 2025). This approach helps identify and delineate risk-prone zones in Melaka.

Causative Factors Influencing Flood Risk

Figure 5 presents the AHP weights derived from expert consensus, which prioritize rainfall (31%) as the primary driver of flood risk in Melaka, followed by drainage density (22%) due to its control over runoff concentration. Reflecting Melaka's flat terrain, elevation (17%) and slope (17%) exert moderate influence, while land use (13%) contributes the least through impervious surfaces. Compared to regional GIS-AHP benchmarks, such as Kota Setar and Padang Terap (land use: 21%) or Batu Pahat (land cover: 11%), Melaka's land-use weight occupies the lower end of the regional literature spectrum, emphasizing regional precipitation and drainage networks over surface characteristics (Imani et al., 2025b; Zainudin et al., 2026).

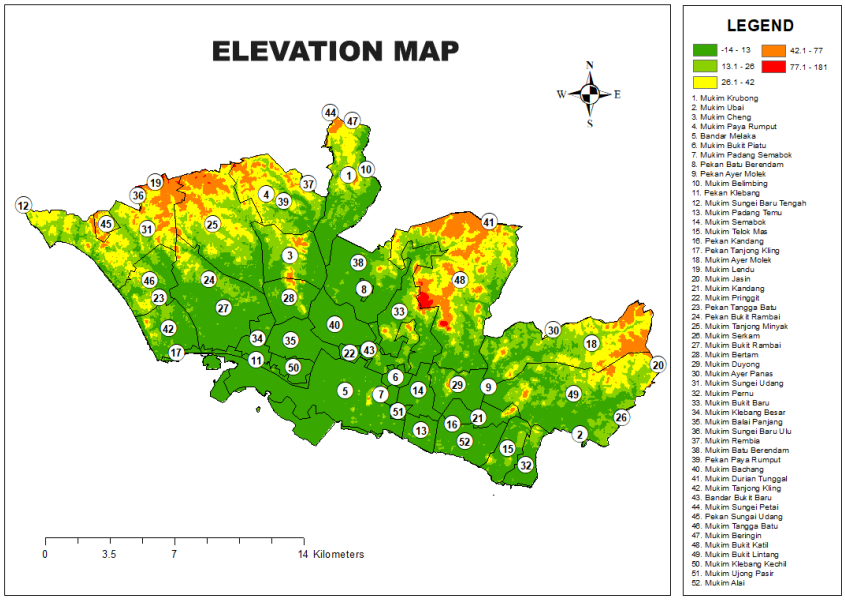


Figure 1: Elevation Map

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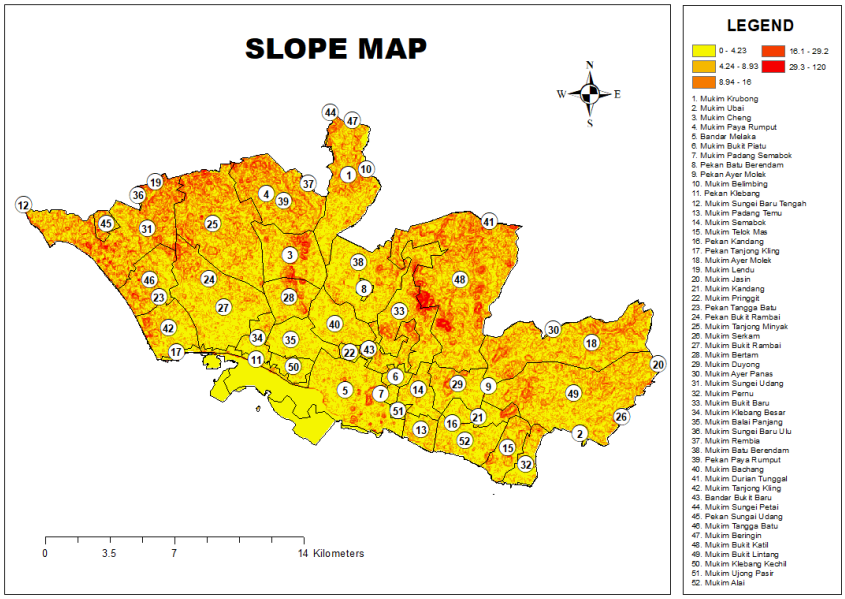


Figure 2: Slope Map

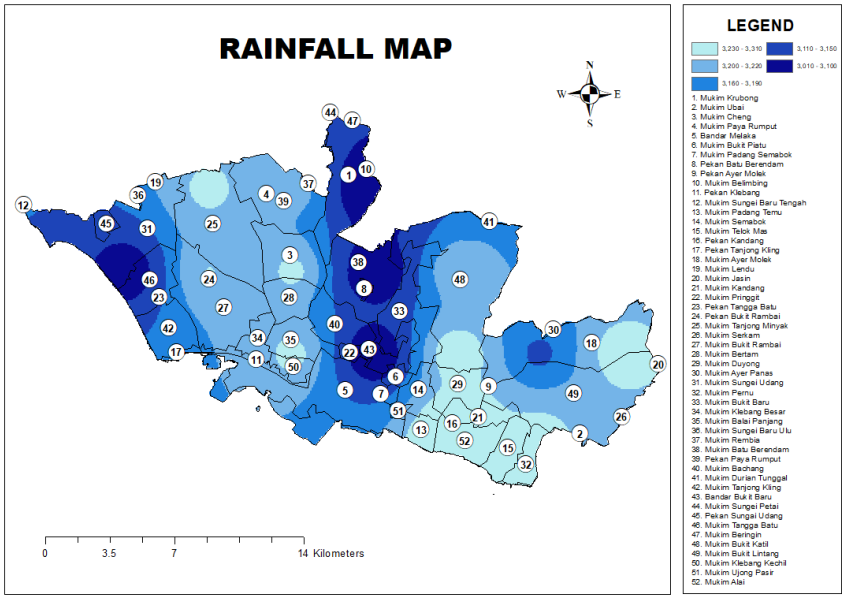


Figure 3: Rainfall Map

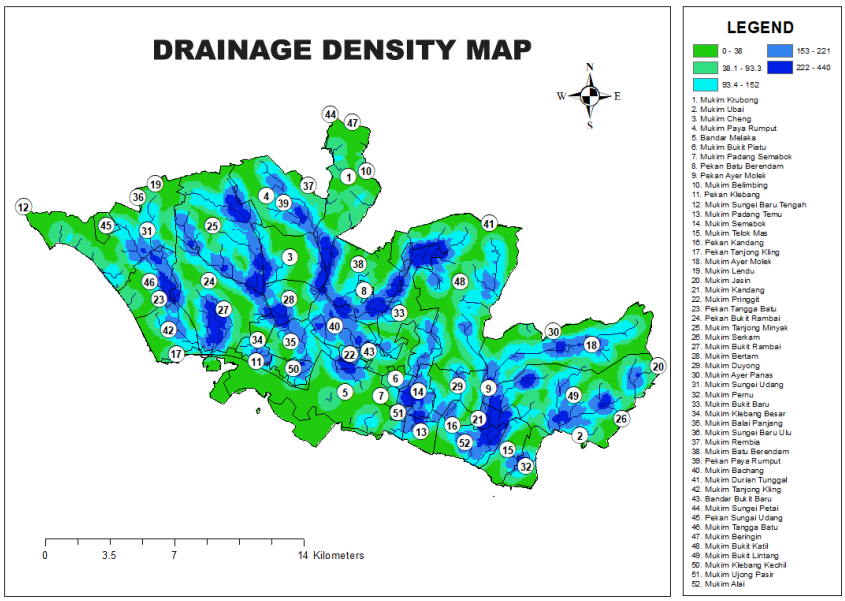


Figure 4: Drainage Density Map

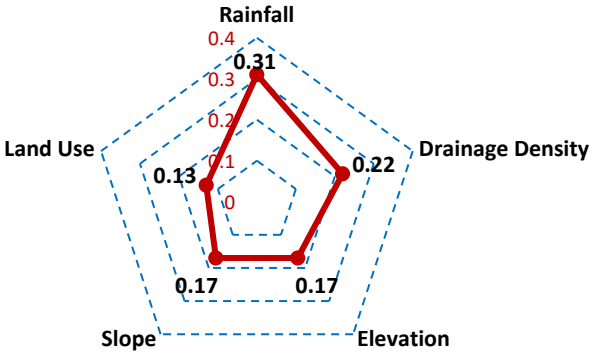


Figure 5: Assigned weights of flood causative factors used in determining flood risk zones

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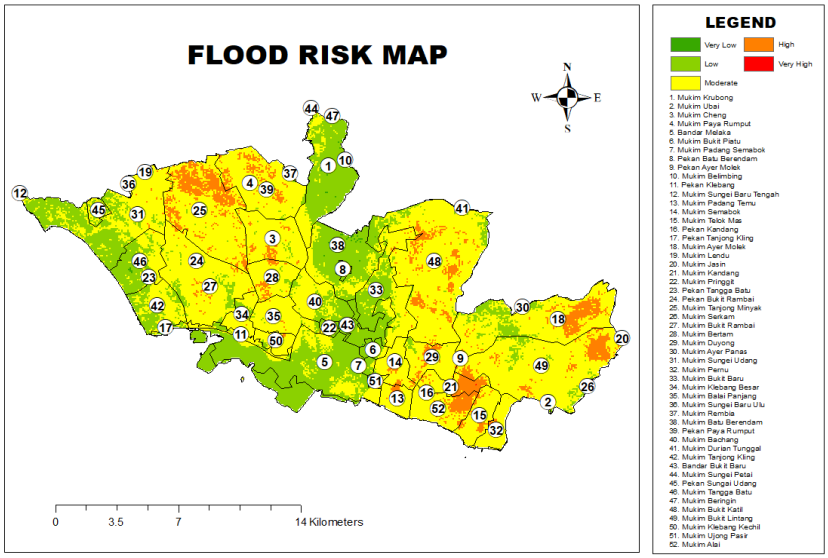


Figure 6: Flood risk maps derived from AHP analysis: (a) distribution of all risk levels (very low to very high)

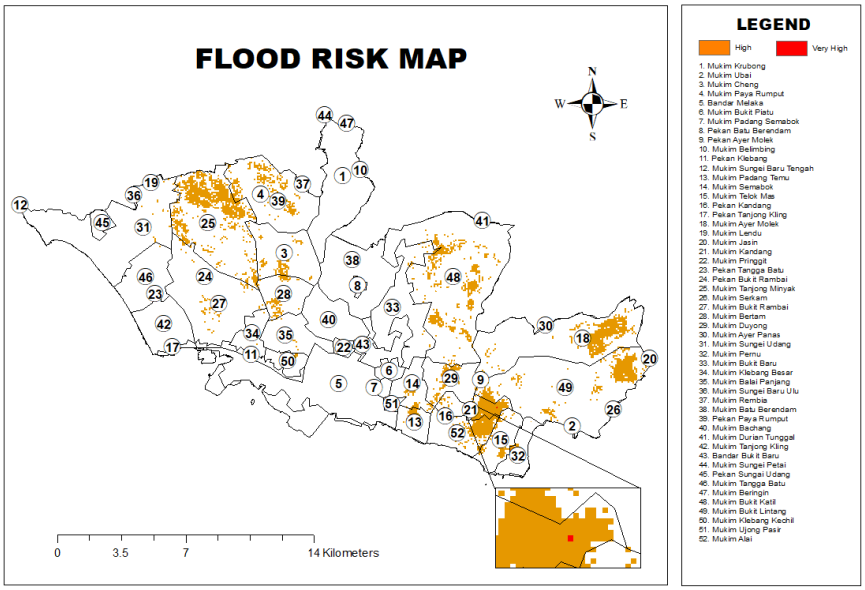


Figure 7: Flood risk maps derived from AHP analysis delineation of high and very high flood risk areas.

Flood risk mapping and Spatial Planning Implications

Flood susceptibility in the research area is primarily moderate-risk, covering 250.32 km² (64.9%) according to the AHP assessment. This means heavy weather might cause flooding across most of the region. The very low-risk class covers only 0.27 km² (0.07%), whereas the very high-risk zone is a minuscule 0.0063 km² (**Figure 6**). In addition, 30.24 km² (7.80%) is identified as high risk, highlighting locations that may require targeted mitigation measures, drainage upgrades and stricter land-use controls (**Figure 7**). This distribution is comparable to other AHP and multicriteria studies where moderate classes dominate, with smaller but critical high-risk pockets that align with historical events (Abdrabo et al., 2020a; Rendana et al., 2025b; Souissi et al., 2020a; Vashist & Singh, 2024).

From a spatial planning perspective, these risk classifications provide an empirical basis for targeted zoning interventions. High and very-high risk zones, typically low-lying, densely drained urban areas adjacent to river corridors, warrant priority allocation for structural enhancements, strict redevelopment constraints, and strategic emergency shelter zoning, mirroring global urban resilience frameworks (Abdrabo et al., 2020b; Rendana et al., 2025c; Rivera & Aguirre, 2025). The selected high-risk zones (30.24 km²) support the enforcement of development and plot-ratio limits in the Historic Melaka City Council Local Plan 2035 (*Rancangan Tempatan MBMB 2035*). The moderate-risk class (64.9%) dominates Melaka Tengah, warranting policy attention given Malaysia's 2,500 mm mean annual precipitation. Very high-risk locations are statistically negligible. (Kia et al., 2012). Due to hydrological extremes, moderate-risk zones require proactive spatial design, structural drainage modifications, community readiness, and early warning frameworks to mitigate flood vulnerabilities (Kafi & Ponrahono, 2025; Tang, 2019), validating the utility of AHP and multicriteria models as reliable tools for baseline risk delineation (Abdrabo et al., 2023; Kafi & Ponrahono, 2024). Translating these findings into practice, high and very-high risk zones warrant restrictive zoning controls, stringent development restrictions, priority drainage upgrading, and dedicated emergency-shelter planning, while the dominant moderate-risk class calls for climate-resilient land-use policy, such as sustainable urban drainage systems and preserved green-blue infrastructure, and low-risk zones can absorb higher-density growth away from vulnerable corridors

Data Limitations, Recommendations, and Regional

The proposed GIS–AHP framework is constrained by its reliance on open-source 30 m DEMs, gridded rainfall, and land-use layers, which may omit fine-scale terrain and urban drainage features, thereby affecting susceptibility precision (Swain et al., 2020; Zhu & Chen, 2024). Lack of hydrological records and flood

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inventories limits quantitative validation, making outputs decision-support tools rather than exact predictions. This flexible multi-criteria procedure has been successfully adopted internationally in dry, tropical, and data-scarce catchments by calibrating factor selection and expert weights to local conditions (Kader et al., 2024; Pimenta et al., 2025; Souissi et al., 2020b).

CONCLUSION

By integrating LULC, rainfall, elevation, slope, and drainage density within a GIS-AHP framework, this study demonstrates that Melaka Tengah's flood susceptibility is primarily driven by intense precipitation and high drainage density, with expanding urban impervious surfaces creating significant areas of vulnerability. Despite localised data limitations, these mapped susceptibility patterns strongly align with historical records, providing a practical, scalable decision-support tool to guide climate-resilient, heritage-sensitive urban planning and drainage investments in comparable coastal cities.

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EVALUATION OF DISASTER MANAGEMENT POLICIES FOR COMMUNITY FLOOD RESILIENCE IN MALAYSIA

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Abstract

The risk of floods is expected to increase as the frequency of extreme weather events driven by climate change increases. Strengthening community flood resilience requires an effective governance framework. This study uses a qualitative approach to examine the extent to which existing disaster management and other relevant policies in Malaysia support community resilience to floods amid climate change. National policy documents related to disasters, floods, and climate change were analysed using the multidimensional Flood Resilience Measurement for Communities framework, complemented by semi-structured interviews with key informants from government agencies. The study found that Malaysia's existing policy framework provides a foundation for community flood resilience, although important gaps remain across financial, human, social, physical, and natural capitals. Financial capital remains largely reactive, while physical capital focuses on large-scale infrastructure. Human capital development is uneven, social capital remains constrained by limited community participation, and natural capital is weakly integrated at the community level. Addressing these gaps is essential to enhance community-level preparedness, adaptive capacity, and long-term flood resilience in Malaysia.

Keywords: Community resilience, flood, disaster risk reduction, institutional governance, policy.

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INTRODUCTION

Climate change increases the vulnerability and severity of flood hazards globally through multiple pathways. These include increased atmospheric moisture, sea-level rise, altered weather patterns, urbanisation, land-use changes and deforestation. Consequently, floods now affect more people globally than any other natural disaster. The risk levels are exacerbated by both climatic changes and the rapid expansion of socioeconomic activities (Mehryar & Surminski, 2021). In response, many countries have begun integrating climate change considerations into disaster-related policies to strengthen resilience to emerging risks.

In Malaysia, flood risks have been exacerbated by local factors, including rapid urbanisation, ineffective drainage systems, deforestation and logging, and climate change. Traditional flood management strategies that focus solely on structural defences are insufficient to mitigate these risks (Abid et al., 2024; Chan et al., 2012). Therefore, community flood resilience must be strengthened. Yet critical gaps remain in understanding how existing policies and governance mechanisms contribute to improving community-level resilience. Currently, Malaysia has no national legislation specifically on flood management. The government uses an executive route to govern the matter through disaster- and climate change-related policies.

This study aims to assess the extent to which Malaysia's disaster management and related policy frameworks support community flood resilience through the five-capital framework. Specifically, the study first examines how existing national policies address financial, human, social, physical, and natural capital to strengthen community resilience to floods. Secondly, it identifies gaps and limitations in the current policy framework. Finally, the study explores institutional perspectives on implementing community flood resilience strategies in Malaysia.

LITERATURE REVIEW

Flood and Its Impacts

Floods are the most frequent natural disaster in Malaysia and have significant impacts on both human and environmental systems. Between 2021 and 2023 alone, the country incurred RM 7.9 billion in flood-related losses (DID, 2022). The highest losses were recorded in public assets and infrastructure, followed by residential areas and agriculture (Norizan et al., 2021).

Floods may increase the spread of waterborne and vector-borne diseases due to contaminated water supplies and poor sanitation systems. In Malaysia, post-flood conditions have been associated with diseases such as leptospirosis, dengue, and gastrointestinal infections (Chan, 2012). Flood events may also introduce emerging pollutants, including pharmaceutical contaminants,

into water sources, although Malaysian legislation provides limited regulatory attention to this issue (Othman & Ariffin, 2019). In addition, recurring floods may contribute to mental health problems and social isolation among affected communities, particularly older adults (Song et al., 2025). Flooding also affects ecosystems through soil erosion and vegetation damage, which may increase future flood risks. Floods are complex socio-environmental challenges that undermine community resilience, particularly under intensifying climate change.

Governance of Disaster Management

In the absence of specific flood legislation, Malaysia's flood risk management (FRM) is governed through the national disaster management policy and institutional framework (Mabahwi et al., 2020b). Since 1997, disaster management has been guided by the National Security Council (NSC) Directive No. 20, which was updated in 2012 to align with the international disaster management framework (Khairilmizal et al., 2016). The revised directive strengthened multi-agency coordination and incorporated preparedness, response, and recovery processes (Khairilmizal et al., 2016). In December 2015, the National Disaster Management Agency (NADMA) was established to coordinate disaster management nationwide.

Despite these developments, studies continue to identify poor inter-agency coordination and communication as major barriers to effective FRM (Mabahwi & Nakamura, 2020; Mah Hashim et al., 2023). Agencies often operate in silos (Zakaria et al., 2018), while limited enforcement capacity, manpower, logistics, information sharing, and resource alignment remain significant challenges (Mabahwi & Nakamura, 2020; Mah Hashim et al., 2023). Consequently, NSC Directive No. 20 was criticised as outdated and inadequate for addressing contemporary community resilience needs (Sulaiman et al., 2019).

To address these challenges, Malaysia introduced NADMA Directive No. 1 in August 2024 to replace NSC Directive No. 20. Unlike its predecessor, which focused primarily on disaster response and command structures, NADMA Directive No. 1 adopts a more comprehensive approach by emphasising disaster risk reduction, prevention, preparedness, response, and recovery. Reflecting Malaysia's federal system, the directive establishes Disaster Management Committees at the federal, state, and district levels (Figure 1), strengthening coordinated and continuous disaster risk management.

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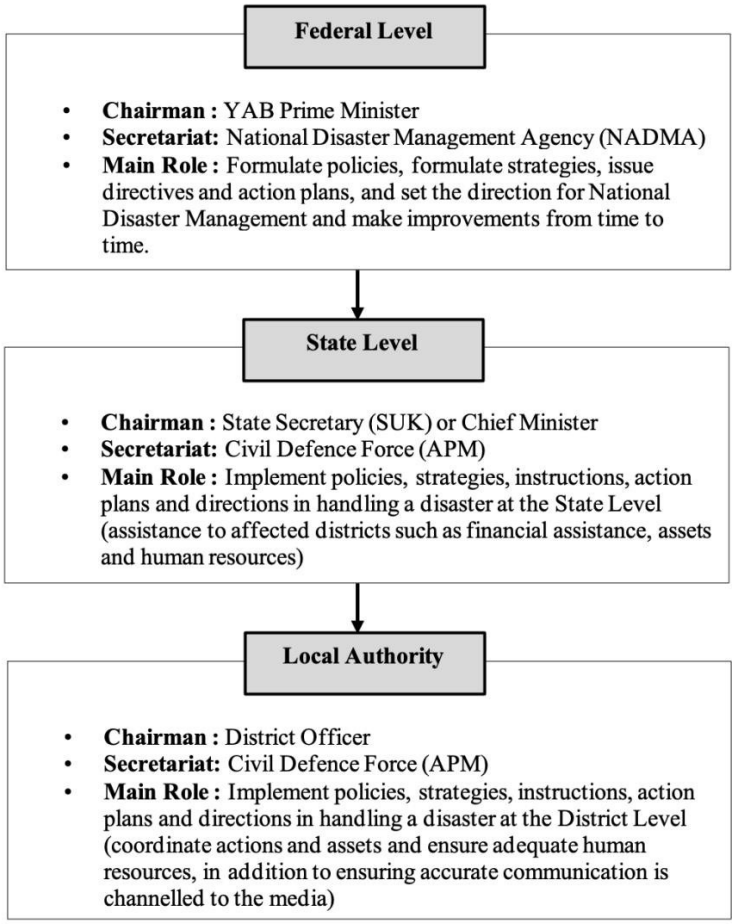


Figure 1: Disaster Management Committees
Source: NADMA Directive No. 1

Community Flood Resilience

There is a growing recognition of the need for community-level flood resilience. This encompasses not only physical infrastructure but also social, economic, institutional, and ecological capacities to anticipate, adapt to, and recover from floods (Xu et al., 2023). Community resilience is shaped by a complex interplay of factors, requiring multidimensional and context-sensitive indicators for effective assessment (Rana et al., 2021). Similarly, Xu et al. (2023) argued that resilience depends on interconnected financial and physical capacities rather than isolated interventions.

In Malaysia, there remains limited understanding of how the existing policy and governance framework supports community resilience. For instance, Omar Chong and Kamarudin (2018) found that the lack of a bottom-up approach and long-term post-disaster recovery planning hampers community resilience. Assessing gaps in the current policy framework is therefore essential to identify opportunities for improvement and strengthen community resilience (Mehryar & Surminski, 2021).

Existing Malaysian studies primarily focus on institutional coordination, disaster response mechanisms, infrastructure, or community participation in isolation (Mabahwi & Nakamura, 2020; Sulaiman et al., 2019). Limited attention has been given to evaluating disaster management policies through an integrated resilience framework encompassing financial, human, social, physical, and natural capitals. This study addresses that gap by applying the Flood Resilience Measurement for Communities (FRMC) framework to assess how Malaysia's disaster and climate-related policies support community flood resilience, thereby providing a more holistic and policy-oriented understanding of flood resilience governance.

RESEARCH METHODOLOGY

This study adopts a qualitative policy-analysis approach to assess how Malaysia's flood- and climate change-related policies support community flood resilience. Secondary data comprised national disaster directives, development plans, and climate policies (Table 1). Policy documents were selected purposively based on three criteria: (i) relevance to disaster management, flood risk reduction, climate adaptation, or national development planning; (ii) national-level applicability; and (iii) availability during the study period. These documents represent the principal policy instruments guiding disaster governance and climate resilience in Malaysia.

Table 1: National Policy Documents Relevant to Flood Risk Management

Policy Documents	Description
NADMA Directive No.1	Current principal operational directive outlining disaster risk reduction, preparedness, response, and recovery mechanisms.
NSC Directive No. 20 (1997 - 2024)	Established the structural command-and-control architecture that underpins current disaster governance practices.
13th Malaysia Plan (2026-2030)	Primary socio-economic development blueprints that allocate resources, set priorities, and integrate flood mitigation and

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Policy Documents	Description
12th Malaysia Plan (2021-2025)	climate adaptation. They provide insight into financial, physical, and governance investments at the macro level.
National Climate Change Policy 2.0	Integrating climate risks into disaster risk reduction and resilience strategies.

In addition, primary data were collected through semi-structured interviews with representatives from relevant government agencies selected purposively based on their expertise in Malaysia's flood management policy framework. A snowball sampling technique was used to identify potential informants. Despite efforts to recruit participants from a wider range of agencies, only representatives from NADMA (Key Informant 1 - KI1), the Department of Irrigation and Drainage (Key Informant 2 - KI2), and the Department of Social Welfare (Key Informant 3 - KI3) were available during the study period. These agencies were selected because they represent the key institutional functions of national disaster coordination, flood mitigation, and disaster relief, providing complementary perspectives relevant to the five-capital framework. Interviews were conducted between November 2024 and January 2025, lasting approximately 40–60 minutes each. An interview guide based on the five-capital framework ensured consistency while allowing participants to elaborate on emerging issues. Prior informed consent was obtained from all participants before the interviews.

Data from the policy documents were analysed using thematic analysis, supplemented by insights from key informants. The analysis was conducted through a community flood resilience lens adapted from the internationally applied Flood Resilience Measurement for Communities (FRMC) framework (Keating et al., 2017; Keating et al., 2025). As shown in Table 2, the analysis focused on five types of capital: financial, human, social, physical, and natural. Policy documents were coded manually according to the five capital dimensions of the FRMC framework through iterative reading. Within each dimension, policy provisions were assessed against predefined coding categories, while interview data were used to corroborate and contextualise the findings. Emergent themes relating to governance gaps, implementation barriers, and community participation were subsequently identified through iterative analysis.

Triangulation was undertaken by comparing themes identified from the policy documents with the perspectives of key informants. Areas of convergence were treated as corroborated findings, while discrepancies were analysed to identify implementation gaps and contextual insights beyond the policy documents. This study is limited by the small number of available key informants

and its focus on national-level policy documents. Future studies should incorporate wider stakeholder participation and comparative local-level analysis to provide a more comprehensive understanding of community flood resilience in Malaysia.

Under the FRMC framework, financial capital reflects both the level of fiscal commitment and the accessibility of financial resources. Human capital emphasises a comprehensive approach to ensure communities are informed and prepared for any eventuality, with a focus on actions that enhance their knowledge of FRM. Meanwhile, social capital evaluates whether flood resilience is supported by strong social networks, inclusive participation, and effective multi-level coordination. Physical capital considers how Malaysia's policies and governance promote infrastructure and essential services that can withstand flood impacts and support rapid community recovery. Finally, natural capital assesses the extent to which the framework integrates ecosystem-based approaches and recognises natural systems as vital components of flood resilience.

Table 2: Coding Framework Used for Policy Document Analysis

Five-Capital Dimension	**Assessment Focus**	**Illustrative Coding Categories**
Financial Capital	Policy provisions that support financial preparedness, response, and recovery	Disaster relief funds, insurance, business continuity, flood risk reduction investment, disaster response budget
Human Capital	Policy measures that strengthen community knowledge, awareness, and preparedness	Evacuation planning, flood-risk awareness, first aid, environmental awareness, governance awareness
Social Capital	Policy provisions promoting community participation and institutional coordination	Community participation, local disaster planning, mutual assistance, inter-agency coordination, social inclusiveness
Physical Capital	Policy measures supporting resilient infrastructure and essential services	Flood protection infrastructure, early warning systems, evacuation centres, transport, water, communication, emergency services
Natural Capital	Policy provisions supporting ecosystem-based flood resilience	Watershed protection, ecosystem conservation, natural flood protection, habitat restoration

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ANALYSIS AND DISCUSSION

While resilience can be measured at different scales, the study focuses on the community level in Malaysia, where the effects of floods are felt most acutely and where many actions are undertaken to enhance resilience. This study reveals that Malaysia's disaster policies provide a reactive rather than proactive approach to community flood resilience, with gaps in financial, human, social, physical, and natural capital as explained below (Table 3).

Table 3: Assessment of Community Flood Resilience Policies Using the Five-Capital Framework

Capital	Key Policy Strengths	Key Gaps Identified
Financial	Relief funds, infrastructure allocation	Reactive financing, low insurance uptake
Human	Awareness programmes, training	Weak localisation, limited environmental awareness
Social	Inter-agency coordination	Limited participatory governance
Physical	FEW systems, drainage projects	Reactive infrastructure planning
Natural	Watershed conservation	Weak ecosystem-based FRM

Financial Capital

Financial capital encompasses the economic resources that support household asset recovery, business continuity, community disaster response, and risk-reduction investments, including grants, funds, compensation, and insurance provided by the government or the private sector. NADMA Directive No. 1 explicitly establishes NADMA's role in managing the National Disaster Relief Trust Fund, which provides financial assistance to disaster victims. It is funded through both public donations and government allocations to enable rapid assistance to affected communities. Despite these provisions, the study found that government support remains limited and largely ad hoc. For example, compassionate aid for flood-affected household heads or heirs of deceased victims, as well as compensation for crop damage, is minimal and triggered by specific disaster events. These measures may provide essential recovery support and reflect recognition of community vulnerability. However, they are primarily reactive with less emphasis on preventive measures or long-term resilience. Malaysia's financial capital should shift from reactive aid to proactive investment. This aligns with Xu et al. (2023), who pointed out that investment in disaster prevention is a primary determinant of community flood resilience. This

highlights the importance of proactive financial allocation rather than reactive post-disaster assistance.

Private insurance offers potential for more effective asset recovery, yet uptake among Malaysians remains low. Even motor insurance policies rarely include flood coverage. According to KI2, insurance uptake remains low due to the public's reliance on government assistance and limited awareness of disaster-risk financing. Similarly, KI1 highlighted that business continuity support is similarly constrained. Business interruption insurance is available, but it depends on sector participation and institutional support. In the meantime, government-subsidised insurance models face implementation challenges due to insurers' risk concerns. The situation leaves disaster insurance largely voluntary.

The findings showed that policy-driven investments in flood risk reduction focus on large-scale infrastructure projects that aim to mitigate climate-induced floods and develop flood-resilient cities. These initiatives strengthen preventive and mitigation capacities at the system level. They may also enhance communities' ability to prepare for, respond to, and recover from flood impacts. NCCP 2.0, for example, proposes sustainable drainage and tidal gate systems at the local level, although limited financial resources may hinder implementation.

The policy analysis and interviews suggest that while financial mechanisms exist, structural and behavioural barriers may limit their effectiveness in fostering community-level financial resilience. Malaysia needs a greater allocation of resources to local disaster response and risk-reduction investments. Mehryar & Surminski (2020) emphasise that national policy and legislation can enhance financial capital by regulating or promoting the creation and distribution of economic resources that support recovery and risk-reduction measures. Complementary strategies, including public education, wider insurance penetration, and robust mitigation planning, are critical to achieving a balanced and sustainable disaster management system.

Human Capital

The study found that human capital provisions are partially addressed in existing policies, but remain uneven and largely general. For example, RMK13 prioritises strengthening disaster preparedness through community awareness and capacity-building programmes. Similarly, the policies include preparedness initiatives such as training sessions and evacuation simulations. However, there is no explicit requirement for community-specific evacuation plans, indicating limited localisation of preparedness measures. Efforts to raise flood-risk awareness are evident through the dissemination of disaster information (Kamarudin et al., 2022). For example, communities can access daily disaster reports, maps of affected areas, weather updates, river water levels, and impact assessments via the NADMA website. Nevertheless, communication on future flood risks,

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including climate change impacts, remains general, with limited mechanisms for effective community-level risk communication. Although disaster management training incorporates safety and health components, first-aid knowledge is not explicitly operationalised as a distinct community capacity. Likewise, there are no clear provisions to ensure continuity of education during floods, revealing a gap in safeguarding essential social services.

The policies also address asset protection and sanitation awareness during response and recovery phases. However, these measures remain general rather than community-targeted. There is also limited emphasis on environmental and governance awareness, constraining community understanding of broader risk drivers and institutional responsibilities. KI1 and KI3 highlighted waste management and sanitation challenges in evacuation centres during prolonged flood events. Particularly, they pointed to the extensive use of disposable food packaging and utensils, which generate solid waste and may contribute to health risks, odour pollution, and environmental degradation. Greater environmental awareness could enhance preparedness and reduce flood impacts, but this aspect remains underemphasised within the current framework.

KI2 observed that disaster management is increasingly framed beyond post-disaster response by drawing on sectoral laws to promote a more holistic and preventive approach. Nevertheless, the policy analysis and interview findings suggest that this emphasis remains largely institutional, with limited translation into community-level understanding or capacity-building, thereby constraining the development of comprehensive human capital for flood resilience. Similarly, Mehryar and Surminski (2020) note that plans, SOPs, and risk maps are often designed primarily for government and disaster management agencies rather than for public awareness. Consequently, government information should be communicated in more accessible, user-friendly formats for all age groups, alongside greater community involvement in decision-making to support locally relevant and inclusive resilience-building strategies.

Social Capital

Social capital fosters an environment in which communities can act collectively and engage with broader governance systems (Visave & Aldrich, 2025). Community networks are strengthened through local flood response and recovery plans that coordinate activities and improve safety in flood-prone areas. The study found that existing policies mandate continuous public awareness programmes to enhance preparedness and resilience, coordinated by the Disaster Management Committee and centralised through the National Disaster Command Centre (NDCC) to ensure inter-agency cooperation.

In addition, the policy framework supports community flood resilience primarily through institutional preparedness and coordination. For example, pre-

monsoon meetings conducted by NADMA review past events, assess resources, plan for worst-case scenarios, and coordinate multi-level assistance across local, national, and international actors. While these mechanisms strengthen operational readiness and inter-agency collaboration, they remain largely state-centric, focusing on logistics, asset mobilisation, and response planning, with limited integration of local knowledge or direct community involvement. Consistent with earlier reviews (Sulaiman et al., 2019), the findings show that Malaysia's disaster governance remains policy-driven but lacks an integrated community resilience framework linking planning, risk-reduction initiatives, and community empowerment.

Community-based disaster management also remains underdeveloped. Abid et al. (2024) note that Malaysian communities often rely on external assistance rather than actively participating in flood risk management (FRM). Empowering communities through planning and preparedness training is therefore essential, as it enables them to identify effective local solutions based on their flood experience (Kamarudin et al., 2022). However, the participating agencies indicated that community engagement remains concentrated during emergency response phases, with limited involvement in preparedness and recovery. KI1 similarly observed that community participation is rarely integrated into preparedness planning. Structured awareness and participation programmes also remain underdeveloped in Malaysia's resilience framework (Sulaiman et al., 2019). Communities actively involved in mitigation efforts, such as early warning systems and nature-based solutions, demonstrate stronger resilience (Abid et al., 2024).

Enhancing community awareness and participation can strengthen social capital and collective action. Akhir et al. (2021) highlight that fostering community spirit and self-efficacy reduces reliance on external resources and improves coping strategies. Similarly, Vázquez et al. (2024) emphasise that interactive communication through social media or interpersonal discussions enhances risk awareness, collective action, and resilience, particularly among older adults and marginalised groups. In general, while Malaysia’s existing policy framework supports institutional coordination, greater emphasis on community engagement, participatory planning, and proactive preparedness is needed to fully leverage social capital for community resilience to floods.

Physical Capital

The study found that existing policies support physical capital primarily through large-scale infrastructure projects designed to reduce flood risks, as reflected in earlier findings on financial capital. These infrastructures include flood-protection structures, drainage improvements, and flood early warning (FEW) systems. Such projects are manifested clearly under RMK12 and RMK13.

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Consistent with Xu et al. (2023), flood control and drainage capacity, together with disaster relief capability, are critical structural determinants of community resilience. This reinforces the importance of strengthening physical capital. However, most infrastructural interventions in Malaysia remain reactive, constructed within already developed or urbanised areas prone to flooding. Although NCCP 2.0 proposes integrating climate-change risk-based planning into land use and building regulations, this strategy has yet to be fully implemented. This integration is important because, as climate change intensifies, early integration of flood and climate considerations into physical development is essential to enhance resilience.

The existing framework also provides community services during flood events, including temporary shelters for evacuees and logistical support. Necessities such as food, clothing, blankets, and mats are also distributed to affected families. All key informants stressed the importance of maintaining evacuation facilities and essential services during flood events. In addition, emergency services and critical infrastructure protection are primarily addressed in the water supply sector. Beyond this, the current framework lacks provisions for other essential services, including the identification of structural hazards and the restoration of electricity and gas by professional services. The findings suggest that physical capital is strengthened through large-scale infrastructure and emergency services, but existing policies remain reactive and sector-specific. This highlights the need for more comprehensive, proactive, and multi-sectoral approaches to flood resilience in Malaysia.

Natural Capital

The study found that while the current disaster management policy framework provides only limited explicit recognition of natural capital in the context of flood resilience, RMK13 strengthens ecosystem-based adaptation by promoting watershed protection, riparian forest conservation, and improved water resource management. Together with RMK12's emphasis on the transition to a low-carbon economy, these initiatives indirectly contribute to flood risk reduction by mitigating the impacts of climate change. The development plans also promote the conservation of wetland habitats to reduce disaster risk, including flooding.

Despite these measures, the existing framework lacks explicit provisions for implementing natural flood-protection measures at the community level, thereby limiting the integration of natural systems as a core component of flood resilience. KI2 similarly observed that ecosystem-based approaches, such as river reserve protection and wetland conservation, are recognised at the policy level but remain inadequately translated into local implementation and community-based initiatives. Although the current policy framework demonstrates a broader commitment to environmental sustainability and climate

mitigation, greater emphasis on community-level natural capital and ecosystem-based flood management is still needed to strengthen resilience to flood risk in Malaysia.

CONCLUSION

Malaysia should strengthen community flood resilience through more targeted and actionable reforms that enhance community preparedness before flood events rather than relying primarily on post-disaster response. These include expanding subsidised flood insurance, integrating flood-risk zoning into land-use planning, improving evacuation-centre planning and strengthening participatory disaster governance. In addition, greater emphasis should be placed on ecosystem-based flood mitigation through watershed protection, riparian forest conservation, wetland conservation, and improved water resource management. More importantly, the country's disaster management should move beyond reactive response approaches towards preventive and adaptive strategies that empower communities as active resilience actors.

This study demonstrates that Malaysia's existing disaster management and related policy framework provides a foundation for community flood resilience across financial, human, social, physical, and natural capitals. However, important gaps remain. Financial and physical capital continue to rely heavily on reactive measures, while human and social capital are constrained by limited community participation and localised preparedness planning. Although natural capital is recognised through environmental sustainability initiatives, ecosystem-based flood management remains weakly integrated at the community level. The findings highlight the need for a more balanced, integrated, and community-centred resilience framework in Malaysia. Priority should be given to integrating flood-risk zoning into spatial planning, improving evacuation-centre planning, strengthening participatory governance, expanding community preparedness programmes, and adopting ecosystem-based flood mitigation strategies.

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ECONOMIC VALUATION OF ECOSYSTEM SERVICES FOR COMMUNITY-BASED PES: A CASE STUDY OF ULU TAMPIK WATERFALL, MALAYSIA

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Abstract

The degradation of forest ecosystems due to expanding development and unsustainable land use continues to threaten the provision of essential ecosystem services. This study evaluates the economic value of ecosystem services at Ulu Tampik Waterfall (UTW), Malaysia, to inform the design of a community-based Payment for Ecosystem Services (PES) scheme. Employing the Contingent Valuation Method (CVM) using a dichotomous choice–double-bounded format, the study estimates the mean willingness to pay (WTP) between RM12.51 and RM30.89, generating a projected annual revenue of RM60,048 to RM148,272. Complementing the valuation, the stakeholders' analysis was also applied to assess community engagement in conservation and livelihood enhancement. Results indicate that community-based PES can effectively support biodiversity conservation, improve household income, and contribute to state revenue. This research underscores the critical role of economic valuation and inclusive management strategies in advancing sustainable forest resource governance towards more enforceable roles, standards, and rules for future reference and service quality for the economic value of ecosystem services.

Keywords: Payment for Ecosystem Services, Economic Valuation, Contingent Valuation, Forest Policy, Malaysia

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INTRODUCTION

Forest management has recently shifted from the conventional conservation and restoration practices to a more dynamic approach for sustainable management. This shift takes place because the capacity of forest resources continuously weakens in order to provide goods and services that are fundamental to the livelihoods of local communities. Human activities and other factors have threatened forest ecosystems, especially in developing countries like Malaysia. Addressing this phenomenon, the Malaysian Government has continuously intensified efforts to reduce forest loss due to forest clearance or the conversion of forested lands to other land uses, including converting forest areas for agricultural purposes and other land use changes. Based on this scenario, introducing the payment for ecosystem services (PES) scheme is deemed fitting.

Moreover, the concept of ecotourism development has become increasingly popular in Malaysia (Manohar et al., 2020). With its promising prospects, ecotourism development in terms of the development and conservation of forests provides valuable opportunities that benefit the local communities Wood et al., 1991). A well-planned and properly managed ecotourism programme can provide sustainable returns for the local communities. Therefore, the PES scheme is deemed as one of the most effective solutions to achieve the following two aims: (1) to generate financial support for the local communities; (2) to conserve the forest ecosystems (Wunder 2005).

Thus, the current study aimed to estimate the economic value of environmental services and to establish the Payment for Ecosystem Services (PES) scheme for the local communities in Janda Baik as financial incentives to be involved in the environmental conservation is to establish the Payment for Ecosystem Services (PES) scheme in creating financial incentives. Focusing on the Ulu Tampik Waterfall (UTW), which is one of the nature ecotourism sites in Malaysia, this study consisted of two phases. The first phase focused on estimating the value of environmental services or determining the price to be paid for environmental services, while the second phase focused on the development of the PES scheme in terms of design and implementation.

LITERATURE REVIEW

Valuation of an Environmental Good

Total economic value (TEV) is a useful concept to measure the economic value of an environmental good. The TEV of an area can broadly be divided into two types: use and non-use values. The direct-use values are derived from the direct uses of the environmental goods for recreation, tourism, natural resource harvesting, hunting, gene pool services, education and research. These activities can be commercial, meaning they are traded in a market or non-commercial, meaning there is no formal or regular market in which they are traded. The values

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of commercial uses will generally be a straightforward process of directly obtaining market-priced values. Valuing non-commercial uses is more complex and entails a range of techniques which solicit values for goods and services of a roughly similar nature from other markets (Mohd Shahwahid, 2005).

Non-Market Valuation Methods

Revealed-preference methods infer the value of non-market goods by studying the actual behaviour in a closely related market. The normally used methods are hedonic pricing (HP) and travel cost (TCM). HP and TCM are the most well-known and extensively used to estimate the benefits of non-market valuation, such as ecotourism and recreational opportunities (Hanley, 2001). However, the stated-preference method assesses the values of non-market goods by using individual stated behaviour in a hypothetical setting. The method includes choice modelling and contingent-valuation methods (CVM). In most applications, the CVM has been the most commonly used approach, directly asking respondents whether or not they would be willing to pay a certain amount of money to realise the level of the non-market good described (Bateman and Willis, 1999).

Willingness to Pay

The value of WTP will eventually show whether the visitors are satisfied with the current entrance fee or prefer another value they are willing to pay (Loomis and White, 1996). However, the new value might not represent a true WTP of visitors because some individuals might state what they believe is a fair price rather than what they would pay. The empirical work of Mitchell and Carson (1995) looked at the issue of the effect of question sequence concentrated almost entirely upon whether a broader definition of a public good will reveal what the authors call "component insensitivity". If there is component insensitivity, then a broader description of the good (or more of it) will not yield a higher WTP value than a narrower description of the good (or less of it).

Payment for Ecosystem Services (PES)

Studies on PES in Malaysia are primarily at the conceptual and pilot stages. Mohamed et al. (2012) studied watershed conservation at Hulu Langat, Selangor. Krishnan et al. (2017) studied household involvement in pioneering PES in Langat River Basin. Abdulkarim et al. (2017) studied the PES scheme on water conservation for agricultural irrigation in Peat Swamp Forest, Selangor, and Zaiton et al. (2020) also studied the concept of PES on watershed conservation for domestic water in Perak. Therefore, this study not only focuses on valuing ecosystem services but also develops the PES scheme for forest conservation and ecotourism benefits to the local community. Furthermore, to the Author's

knowledge, this study was the first attempt to implement the PES Scheme in Malaysia.

PES has attracted increasing interest as a mechanism to translate external, non-market values of the environment into real financial incentives for local actors to provide such services (Engel et al., 2008). According to Savy and Turpie (2004), a PES scheme can develop in one of two ways: either at least one set of stakeholders recognises a noticeable depletion in resources, leading to true demand, or a particular aim is identified, usually concerning the protection or management of national resources and a PES system is introduced to create a market for the service. For PES to work, it must provide a "win-win" opportunity for both the supplier and service buyers. The buyer covers the cost of provision, which must be (1) lower than any alternative method by which the buyer might secure the same service and (2) sufficient to ensure that the alternatives, for example, conversion of land to alternative use, are less economically attractive (Emily et al., 2014).

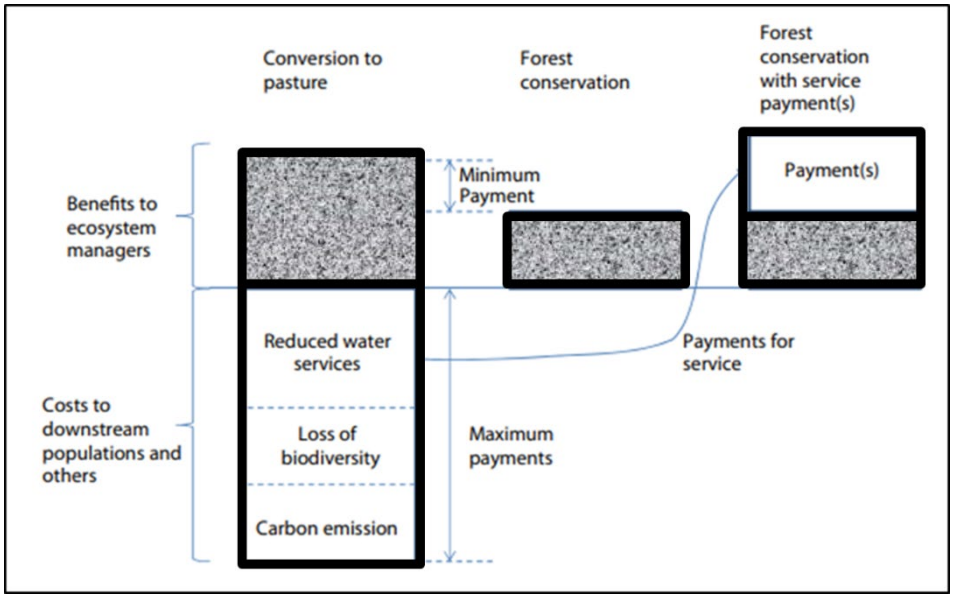


Figure 1.1: Structure for Payments Under PES
Source: Engel et al., 2008

RESEARCH METHODOLOGY

Description of Study Site

Ulu Tampik Waterfall (UTW), which is located at Janda Baik, Bentong, Pahang, Malaysia, was selected as the study site. This location is an approximately 45-

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minute drive from the city centre of Kuala Lumpur. The surrounding area of UTW in Compartment 51, Lentang Forest Reserve (LFR) is generally unique, and it serves as an exciting recreational area. In terms of topography, this study site is located within the Titiwangsa Range. LFR is a hilly area, with an altitude between 600 m and 800 m above sea level. The main physical element of LFR is its unique, clear waterfall. UTW and its surrounding area represent a popular leisure site for the residents of Janda Baik and visitors, both locals and foreigners, as presented in Figure 1.

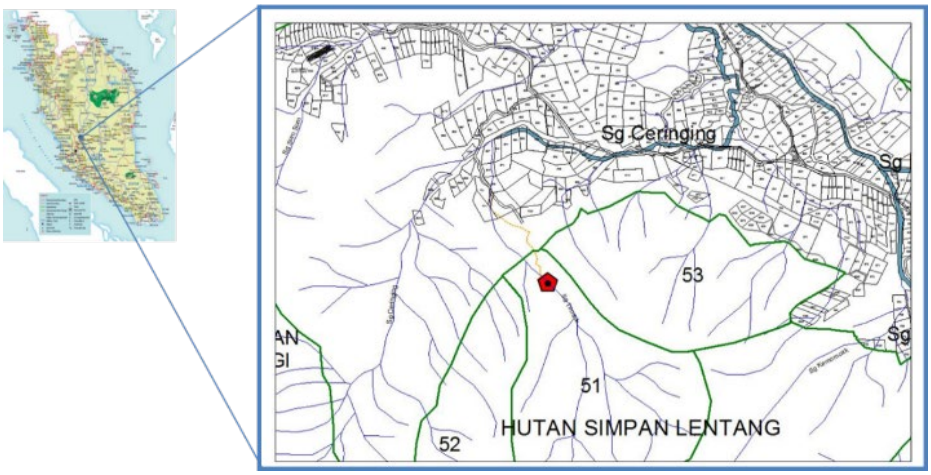


Figure 1.2: Location of Study Site at Janda Baik, Pahang

Estimation of the Economic Valuation

As previously highlighted, this study consisted of two main phases. The first phase involved the economic valuation of the study site as a nature tourism area. The economic benefits of preserving the study site were estimated based on public preferences. In particular, this study measured whether visitors would pay for the conservation of natural resources. Meanwhile, the second phase of this study focused on the development of the PES scheme. This phase first explored the involvement of the local communities in managing the project area, assisting in the conservation activities, and improving their livelihoods (Kurniati et al., 2024). This phase also focused on developing organisations at the community level that can be actively involved in the management of the project area.

The contingent evaluation method (CVM) was used to quantify public preferences. Through this method, the net economic value of non-market goods and services to individuals can be quantified by measuring the consumer surplus (Walsh, 1986). The "willingness to pay" (WTP) for the conservation of natural resources, which serves as an indicator of demand, was also used. This method

enables people to express how they would act if they were to be placed in certain contingent situations. As for the current study, the maximum WTP to preserve UTW was determined.

In particular, the double-bounded dichotomous choice was used in this study. This format provides a single dollar amount offer and a simple response of either "yes" (take it) or "no" (leave it). The obtained responses were measured as this study's dependent variable, with the dollar amount (WTP) for the changing environment and other relevant data as the independent variables. There were four models for estimating WTP for each sample.

Questionnaire Design and Sampling Procedure

A structured questionnaire survey was used in this study. The developed questionnaire survey was designed and divided into four sections. CVM that involved a double-bounded dichotomous choice (DBDC) format was applied. This particular format allowed the respondents to choose the amount of WTP. All respondents were also required to indicate "yes" or "no" for the question related to WTP. The question presented six different bid prices for the respondents to select: RM 2.00, RM 5.00, RM 8.00, RM 10.00, RM 15.00, and RM 20.00.

For sampling, this study applied the non-probability convenience sampling strategy to obtain insights from a broad population perspective. The face-to-face survey, which involved 322 visitors. All respondents were first briefed on the purpose and objectives of the survey prior to answering the questions. For this study, the sample size estimation was based on the estimated number of visitors to UTW. Based on the number of current visitors, those who came on weekdays and weekends are considered. It is estimated that the number of visitors is 480 people monthly. However, the area will usually be closed in November and December due to weather conditions. The estimated number of visitors per year is around 4,800 people. Therefore, a simplified version of the formula from Yamane (1985) was used to help determine the required sample size of 369 respondents.

Development of PES Scheme

This study adopted the appreciative inquiry (AI) process as a research tool to explore how community involvement in the management of natural areas can improve environmental conservation and the livelihoods of local communities and further develop the community-based PES scheme (Figure 2). The design and development of the PES scheme in this study involved a series of workshops and panel discussions. This approach is suitable for collectivist societies where each member mainly interacts with the members of a specific religious, ethnic, or familial group, and they feel involved in the lives of other members of their group (Greif, 1994).

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This study's AI process involved a few steps with certain modifications, which incorporated five phases: grounding phase, discovery phase, dream phase, design phase, and destiny phase. Firstly, the grounding phase involved the inception phase that consisted of rapport building, stakeholder identification, selection of participants, and orientation on this study's objectives and methods. Secondly, in the discovery phase, the selected participants were required to discuss and identify (in terms of clear boundaries) UTW and its surrounding area to be preserved and managed or maintained by the local communities as a community-based PES project.

Thirdly, the dream phase involves co-creating a shared image or vision of the preferred future. All participants were required to discuss and visualise the ideal relationships they would expect for the livelihood, conservation, and tourism programmes. Following that, the design phase serves as the process of drawing community socio-technical architecture to achieve the "dreams". Lastly, the destiny phase addresses how to empower, learn, and adjust or improvise. It represents the time of realising the "dreams" due to work done in the design phase, as well as the moment of continuous learning, adjustment, and improvisation. For the current study, this phase served as the existence phase of the community-based PES scheme and physical translation of its existence as presented in Figure 1.3.

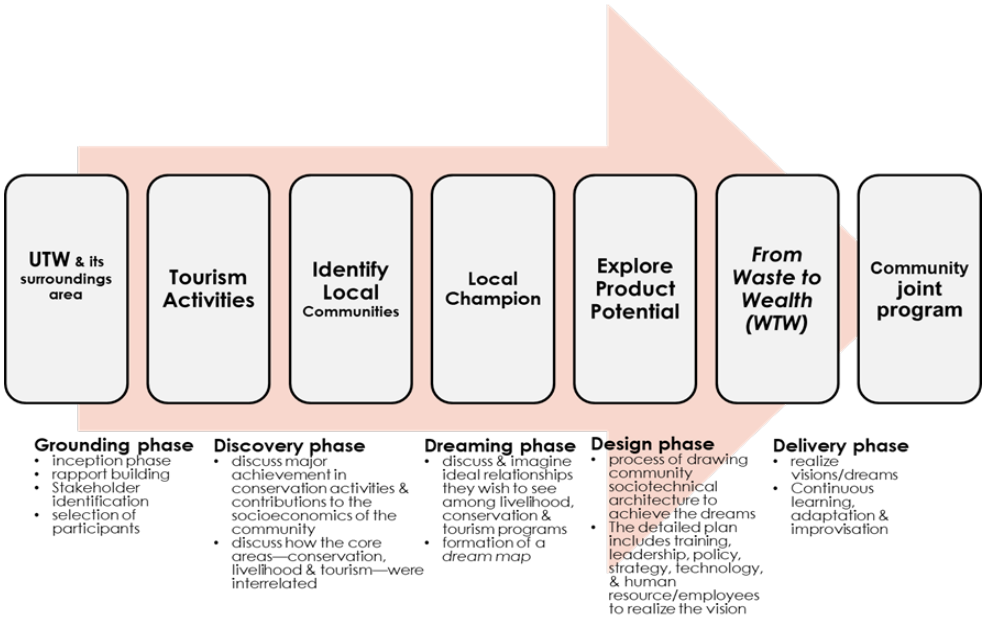


Figure 1.3: Phases and Processes of a Community Development Programme

RESULTS AND FINDINGS

This section presents and discusses the obtained results of this study into four subsections. The first subsection presents the results of the economic valuation study using CVM. Meanwhile, the second subsection discusses the development of financial incentives for the local communities in environmental conservation, focusing on the conservation of natural resources. The third subsection deliberates the institutional and legal framework of the community-based PES scheme and its implementation with the active involvement of the local communities. The economic contribution and its impact on various stakeholders through the development and implementation of this community-based PES scheme are discussed in the final subsection.

Estimation of the Mean of WTP

In this study, the mean of WTP was estimated based on Logistic, Bivariate Probit, Ordinary Least Squares (OLS), and Tobit models. Table 1 presents the calculated mean and median values according to these different approaches. As for positive responses of WTP, the mean of WTP was found to be rather close to the median of WTP for the Logistic model. The estimated mean of WTP recorded RM 23.05. As for the Bivariate Probit model, the mean of WTP ranged from RM 23.83 to RM 30.89, which was slightly higher than the recorded mean of WTP for the Logistic model. On the other hand, the Tobit model recorded a lower estimate (RM 17.03) than the recorded estimate for the Logistic model. The OLS model provided the lowest estimate at RM 12.51.

Table 1: Means and medians of WTP for different models

Model		**Mean of WTP (RM)**	**Median of WTP (RM)**
Logistic	Initial bid	23.05	22.95
Bivariate Probit	Initial bid	23.83	22.86
	Follow-up bid	30.89	28.92
Open-ended OLS		12.51	N/A
Tobit		17.03	N/A

Source: Own Survey and Author's Calculation

The aggregation of WTPs for the conservation of UTW for recreation and ecotourism was determined based on the resultant outcomes of the multiplication of individual WTPs by the number of visitors to UTW. Table 2 presents the yearly calculated conservation values or benefits for UTW based on the mean of WTP for the respective models.

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Table 2: Estimated benefits (in RM) for the conservation of UTW based on WTP for different models

Estimated Number of Visitors to UTW (in 2018)	**Logistic**	**Bivariate Probit**		**OLS**	**Tobit**
	Initial bid	**Initial bid**	**Follow-up bid**		
	WTP = 23.05	WTP = 23.83	WTP = 30.89	WTP = 12.51	WTP = 17.03
4,800	110,640	114,384	148,272	60,048	81,744

Source: Own Survey and Author's Calculation

Determination of the Marketable Value

The price for an ecosystem service is ultimately determined by what the buyer is willing to pay and what the seller accepts and delivers. In regulated markets, WTP is often mandated. Meanwhile, in voluntary PES deals, WTP is open to negotiation. Based on the results of the economic valuation study, the values of WTP ranged from RM 12.51 to RM 30.89 per person per visit, as presented in Table 2.

The obtained results showed high economic value for the environmental conservation activities of UTW among the participating visitors who came for the purpose of leisure or recreation. Using the estimated data on the number of visitors to UTW in 2018 (n = 4,800), the aggregate value was expected to be between RM 60,048.00 and RM 148,272.00 per year. The promotion and future development of basic facilities were expected to increase the number of annual visitors. In other words, visitors do not mind paying a certain amount of entrance fee if the UTW and its surrounding area are protected and preserved for the benefits of the present and future generations.

ANALYSIS AND DISCUSSION

Institutional and Legal Framework of PES Scheme

A part of the Tampik river basin, Janda Baik, Pahang (30 hectares), is leased and managed by the local communities under a local community group, specifically Sahabat Alam Tampik Janda Baik (SATJB) Association. As for the current study, the Pahang Forestry Department cooperated with SATJB Association for the implementation of "joint management" to manage the UTW environment. The developed concept of joint management and benefit-sharing is presented in Figure 3. In particular, the members of the SATJB Association were assigned to a community-based PES project of managing the recreational and ecotourism activities at the 30-hectare UTW environment in the Lentang Forest Reserve.

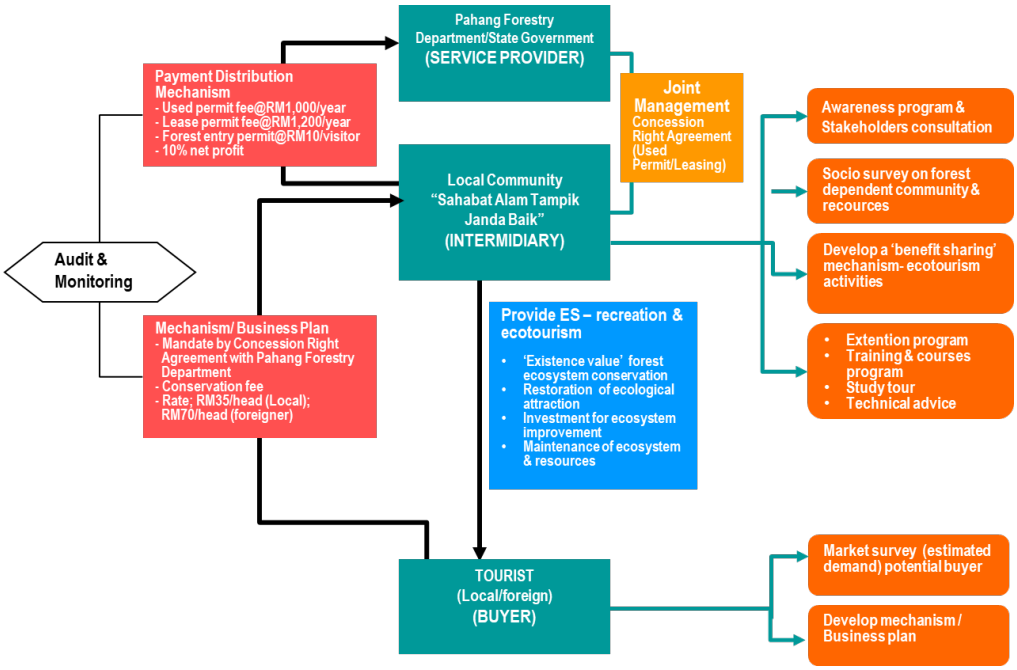


Figure 3: Joint Management and Benefit-Sharing Between the Pahang Forestry Department and the Local Communities in the Community-Based PES Scheme for UTW

Economic Return of the PES Scheme Development—Preliminary Findings

The economic impact of the environmental development of UTW, as a community-based ecotourism project under the PES scheme, on the local communities, specifically the involved members of the SATJB Association, can be observed in terms of household income and job opportunities. The participating members of the SATJB Association received income for their involvement. The ecotourism activities in the UTW environment under this project provided job opportunities and improved the socio-economy. For the management of the UTW ecotourism area, 20 job opportunities were available, including administrative work and fieldwork. Most of these job opportunities were part-time.

In the first year of operation (with an estimated capacity to operate for 10 months in 2018), SATJB Association was estimated to generate a total gross income of RM 153,650.00. To a certain extent, this amount benefited the participating members who were involved in the ecotourism tour packages. Based on the actual number of visitors, a part-time worker was estimated to earn (ancillary income) of RM 477.00 per month. A direct employee can earn up to

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RM 800.00 per month. This revenue estimate was determined based on the average number of 439 visitors per month.

The local community group that operated UTW as a community-based PES project was charged with a Used Permit Fee and annual lease fee. Besides that, 10% of the net profit must be remitted to the State Government. Based on the financial cash flow of the SATJB Association from August 2020 to November 2020 (four months of operation), the Association made a payment of RM 20,280.00 to the Pahang Forestry Department and State Government. However, in early 2020, the Association was unable to carry out full operations due to the Movement Control Order (MCO) imposed by the Malaysian Government. Under normal circumstances, the project can contribute up to RM 47,330.00 per year (based on a 10-month operation in one year) as state revenue.

CONCLUSION

The current study developed a community-based PES scheme for UTW, which can generally strengthen the community-based practices of forestry activities. The developed PES scheme successfully serves as a development strategy to help improve the socio-economy and livelihoods of the local communities and contribute to the sustainable conservation of forest ecosystems. This effort clearly supports the sustainable use of natural resources with respect to the Sustainable Development Goals and national development policies in environmental and forestry management.

The introduced PES scheme is one of the initiatives and strategies that can improve the efficiency of forest management and biodiversity resources through active involvement and cooperation of the local communities (Azwar et al., 2023). Under such an initiative, the active participation of the local communities can reduce environmental damage and restore forest areas. This study highlighted innovation in a community-based PES scheme involving ecotourism and ecosystem services to support the country's sustainable forest management (SFM). This study proved that effective management under the proposed community-based PES scheme can elevate the socio-economic conditions of the local communities and contribute to the sustainable conservation of forest ecosystems and state revenue simultaneously.

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SUSTAINABLE GREEN TRANSPORTATION UTILISATION: A GENERATIONAL COMPARATIVE STUDY ON FACTORS INFLUENCING MALAYSIAN ELECTRIC VEHICLE ADOPTION INTENTION

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Abstract

As climate change intensifies, the Malaysian government is promoting SDGs to mitigate the impacts through carbon emission reduction, renewable energy, and adaptation strategies. This study explores factors influencing EV purchase intention among Generation X and Y in Klang Valley, Malaysia. Specifically, it examines the roles of environmental concern (EC), social influence (SI), perceived economic benefits (PEB), and perceived ease of use (PEOU), with perceived usefulness (PU) as a mediating factor. Multigroup analyses were employed to investigate gender differences in the model. Findings revealed that EC significantly affects PU, indicating that environmentally conscious individuals view EVs as more beneficial. Moreover, PU mediates the relationship between EC and purchase intention, suggesting that concern for the environment enhances the PU of EVs, thereby increasing purchase likelihood. SI and PEB also significantly impact EV purchase intention. Gender does indeed play a moderating role, with significant differences between men and women. These findings support an extended TPB framework and offer practical insights for policymakers and industry players. By aligning environmental values with tangible benefits, stakeholders can more effectively promote EV adoption among Malaysian consumers, particularly in targeted generational groups.

Keywords: Payment for Ecosystem Services, Economic Valuation, Contingent Valuation, Forest Policy, Malaysia

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INTRODUCTION

In recent years, Malaysia has been confronted with increasingly severe challenges of air pollution and carbon emissions. In addition, Malaysia's greenhouse gas emissions have been continuously rising. In 2024, energy-related carbon dioxide emissions reached 296.3 million tons (Mt), setting a new historical record. Malaysian CO2 emissions grew 2% annually in the past decade (Energy Institute, 2025). The energy structure is still dominated by fossil fuels, with natural gas and oil accounting for 73% of the total supply, while the proportion of renewable energy is less than 2%. Despite net-zero targets for 2050, Malaysia remains locked into fossil fuel dependency (CREA, 2025). The most significant factor among them is the transportation system's high reliance on fuel-powered vehicles. By 2025, Malaysia had 36.3 million registered cars, mostly ICE vehicles (RimbaWatch & CREA, 2025). Without accelerating green transportation, Malaysia risks missing its 2030 and 2050 climate goals. The Malaysian government plays a pivotal role in fostering the EV sector (Sulaiman et al., 2023; Noorzai, M. Q., Hosni, N., & Pashton, N., 2026). Government initiatives like the National Automotive Policy 2020 (NAP 2020) and the Low Carbon Mobility Blueprint (LCMB) 2021–2030, alongside plans for 10,000 charging stations by 2025, are fostering EV adoption (MMR, 2023; Chawla et al., 2023).

Malaysians from Generation X and Y, comprising individuals aged 28–59, are a significant demographic in Malaysia. Their financial capacity and dominant presence in the labour market position them as key target populations for studying EV adoption, making them ideal for this research. Despite the global growth of the EV market, adoption in Malaysia remains minimal, comprising just 0.4% of vehicle sales (International Trade Administration, 2023). This highlights the urgent need to investigate factors influencing purchase intentions, particularly among Gen X and Y in the Klang Valley. Moreover, Malaysian consumers tend to be price-sensitive (International Trade Administration, 2024), necessitating a deeper understanding of economic-related factors on EV purchase intention. Range anxiety and charging time remain key functional concerns raises questions about whether the ease of use of EVs will influence their purchase intentions. Thus, this research aims to address these factors comprehensively, offering insights into the unique drivers and barriers shaping EV purchase intention in Malaysia.

LITERATURE REVIEW

Theoretical Background

The Theory of Planned Behavior (TPB), an extension of the Theory of Reasoned Action (TRA), enhances purchase intention models by incorporating attitude, social norms, and perceived behavioural control (Ajzen, 1991). While TPB is robust, incorporating additional constructs can increase its relevance in specific

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contexts (Moon, 2021; Yeğin & Ikram, 2022). Accordingly, this research extended the TPB as the underpinning framework. Existing research by Moon (2021) extended the TPB in his research on EV purchase intention in Korea. The study discovered that the extended factors, environmental propensity and consumer innovation propensity, had substantial indirect impacts on EVs' purchase intention, which are mediated by attitude, subjective norms, and perceived behavioural control. This suggests that the extended TPB model is relevant and applicable in this research context.

Purchase intention

Purchase intention, rooted in the 1980 work of Ajzen and Fishbein, is defined as the probability that an individual will engage in a specific behaviour linked to decision-making, with higher intention increasing the likelihood of purchase (Dodds et al., 1991; Schiffman and Kanuk, 2007). It reflects consumer sentiment towards goods or services (Soebagyo, 2014).

Environmental concern, Perceived usefulness and Purchase intention

Environmental concern (EC), initially defined by Dunlap and Van Liere (1978) in the New Ecological Paradigm (NEP) scale, encompasses concern for specific environmental issues like waste disposal or water pollution, as well as broader ecological problems and attitudes towards the human-environment relationship. This concern is closely linked to individuals' understanding of environmental issues and their willingness to support solutions (Khasanov et al., 2026). In the EV context, Yegin and Ikram (2021) and Sukma et al. (2023) used the extended TPB to demonstrate that EC positively influences EV purchase intentions in Turkey and Indonesia, respectively. However, limited research has explored the mediating effect of perceived usefulness in the EV sector, highlighting a gap, particularly in specific demographics like Gen X and Y in Klang Valley, Malaysia. Based on these insights, two hypotheses were developed:

H_1: Environmental concern has a significant impact on perceived usefulness among Gen X and Y in Klang Valley, Malaysia.
H_2: Perceived usefulness mediates the relationship between environmental concern and EV purchase intention among Gen X and Y in Klang Valley, Malaysia.

Social influence and Purchase intention

Social influence (SI), as defined by Turner (1991), occurs when individuals adjust their ideas, attitudes, or actions in response to cultural and social cues. Societal perspectives and peer group interests significantly influence purchasing behaviour, as evidenced by Khazaei's (2019) study on EV purchase intention

among lecturers, postgraduate students, and employees in Malaysia. However, variability exists in this domain; Lim et al. (2019) observed that SI did not significantly affect EV purchase intentions among Malaysian consumers in Penang and Kuala Lumpur. These highlight the need for localised investigations, leading to the hypothesis:

H3: Social influence has a significant impact on EV purchase intention among Gen X and Y in Klang Valley, Malaysia.

Perceived economic benefits and Purchase intention

Perceived economic benefits (PEB) refer to the financial advantages individuals believe they will gain from specific decisions, encompassing subjective perceptions of cost savings and value (Verhaegen et al., 2014). In the context of EVs, these benefits include lower purchase, maintenance, and operational costs, as well as savings from government subsidies and zero fuel expenses (Ghadikolaei et al., 2021). Similarly, Wang et al. (2024) demonstrated a significant positive impact of PEB on consumer satisfaction and purchase decisions. However, contrasting findings by Khurana et al. (2020) in India showed no significant relationship between perceived economic benefits and EV adoption intentions, highlighting the need to account for contextual differences. To address these variations, the following hypothesis is proposed:

H4: Perceived economic benefits have a significant impact on EV purchase intention among Malaysians from Gen X and Y.

Perceived ease of use, Perceived usefulness, and Purchase intention

Perceived ease of use (PEOU) encompasses factors like the simplicity of operating an EV, the availability and proximity of charging infrastructure, recharging time, and durability assurance (Prabaharan & Selvalakshmi, 2022). Hasan and Erni (2024) further emphasise that PEOU not only shapes perceptions of usefulness but also indirectly influences purchase intention through the mediating role of perceived usefulness. This underscores the dual role of ease of use in enhancing PU and influencing decision-making. Based on these insights, the following hypotheses are proposed:

H_5: Perceived ease of use has a significant impact on perceived usefulness among Gen X and Y in Klang Valley, Malaysia.
H_6: Perceived usefulness mediates the relationship between perceived ease of use and EV purchase intention among Gen X and Y in Klang Valley, Malaysia.

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Perceived usefulness and Purchase intention

Perceived usefulness (PU), introduced in the TAM by Davis (1986), refers to the extent to which a user believes a technology enhances productivity, effectiveness, and performance. Research highlights its role in shaping EV purchase intentions, as shown by Alberto and Riza (2023) in Jakarta, Zhang et al. (2023) in China, and Liu et al. (2023) in Beijing. Saleh et al. (2024) similarly confirmed its significance, though Krishnan and Koshy (2021) found no impact in a different context, highlighting market-specific variations. To explore its role in Malaysia, the following hypothesis is proposed:

H_7: Perceived usefulness significantly impacts EV purchase intention among Gen X and Y in Klang Valley, Malaysia.

The Moderating Role of Gender

In the field of EV adoption research, gender has been treated in various ways, ranging from a control variable to a mediator or moderator (Bhasin & Srivastava, 2024). Empirical findings indicate that Jaiswal et al. (2025) found males to have significantly stronger behavioural intentions toward adopting electric vehicles than females, while Bhasin and Srivastava (2024) confirmed a significant role of gender in influencing electric vehicle adoption intention in the Indian context.
H_8: Gender serves as a moderating variable in the model among Gen X and Y in Klang Valley, Malaysia.

RESEARCH METHODOLOGY

Figure 1 illustrates the research framework of the study based on the extended TPB. It focuses on how consumers' purchase intentions towards EVs are directly influenced by PEB, PEOU, and PU. Meanwhile, the mediating role of PU is explored in the relationship between EC and PI, as well as in the relationship between SI and PI. All questions were contextualised to the research context.

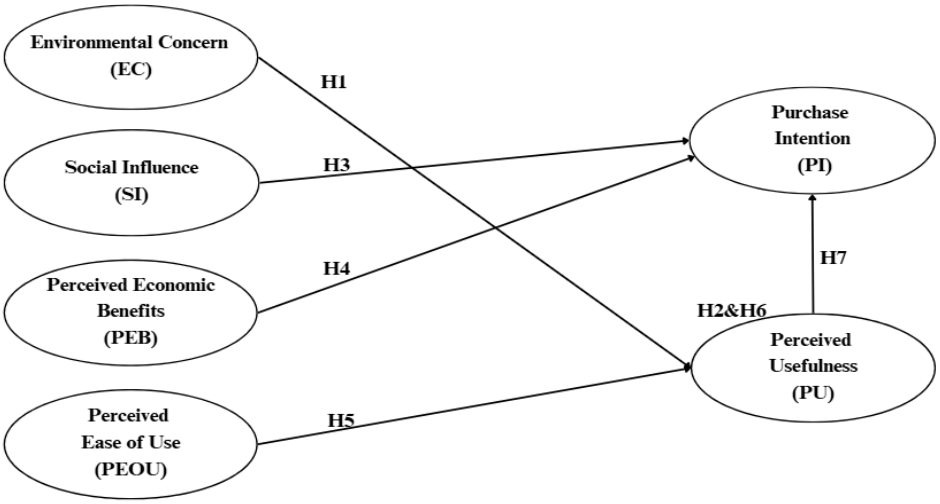


Figure 1: Research Framework

Research Design

Convenience sampling was used to collect samples. The first section on demographic information. The second section consisted of 29 question items for formal measurement of the constructs, with four to six items for each construct. The majority of the population in the Klang Valley is of Gen X (born 1965-1980) and Gen Y (born 1981-1996). According to the DOSM Malaysia (2024), there are about 4.92 million inhabitants in the Klang Valley aged between 25 and 59 years. Since the population is more than 1 million, a minimum sample size of 384 is recommended according to Krejcie and Morgan (1970). The questions were systematically quantified using a five-point Likert scale. Partial Least Squares Structural Equation Modelling from SmartPLS version 4 used for data analysis.

RESULTS AND FINDINGS

A total of 384 valid questionnaires were obtained after excluding 27 non-Klang Valley samples. Table 1 presents a comprehensive view of the demographic data of the respondents with categories such as gender, age group, education level, and income level. The gender distribution was balanced, with 51% female and 49% male, providing for gender subgroup analyses. Gen Y was in the majority (89%), with the younger generation tending to favour sustainability and innovation, while Gen X (11%) provided the perspective of an older cohort with different priorities (e.g., family needs and practicality).

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Table 1: Profiles of Respondents.

Items	Category	Frequency	Percentage
Gender	Female	196	51%
	Male	188	49%
Age Group	Gen Y	340	89%
	Gen X	44	11%
Education Level	Primary School	3	1%
	Secondary School	15	4%
	Higher or Further Education	36	9%
	Undergraduate Degree	201	52%
	Postgraduate Degree	129	34%
Income Level	Below RM1,000	38	10%
	RM1,001 - RM3,000	99	26%
	RM3,001 - RM5,000	115	30%
	RM5,001 - RM7,000	78	20%
	Above RM7,000	54	14%

Source: Own Survey (2025)

The majority of respondents have an undergraduate (52%) or graduate degree (34%), and this higher level of education is likely to make them more knowledgeable about environmental and technology issues. Income levels were mixed, with 30% of respondents earning between RM3,001 and RM5,000 and 26% earning between RM1,001 and RM3,000, representing the middle-income group of the potential audience for EVs.

Measurement Model Assessment

As can be seen in Table 3, all factor loadings exceeded the critical value of 0.5, while the AVE values of the constructs all exceeded 0.50, demonstrating good convergent validity (Hair et al., 2022). In addition, the CR values of the constructs were in the optimal range of 0.7 to 0.95 (0.840 to 0.944), demonstrating good internal consistency (Hair et al., 2017). The Cronbach's alpha values (0.774 to 0.928) were categorised as excellent reliability. It is worth noting that EC had the lowest AVE, CR, and Cronbach's alpha values, which may be due to the low factor loadings of items EC3 and EC5 (0.596 and 0.621, respectively).

Table 3: Measurement Model Evaluation.

Construct	Items	Loadings	AVE	CR	Cronbach's Alpha
EC	EC1	0.830	0.517	0.840	0.774
	EC2	0.657			
	EC3	0.596			
	EC4	0.852			
	EC5	0.621			
SI	SI1	0.850	0.703	0.922	0.895
	SI2	0.830			
	SI3	0.840			

Construct	Items	Loadings	AVE	CR	Cronbach's Alpha
	SI4	0.847			
	SI5	0.825			
PEB	PEB1	0.837	0.622	0.867	0.795
	PEB2	0.815			
	PEB3	0.807			
	PEB4	0.686			
PEOU	PEOU1	0.774	0.681	0.914	0.883
	PEOU2	0.795			
	PEOU3	0.856			
	PEOU4	0.844			
	PEOU5	0.853			
PU	PU1	0.814	0.737	0.944	0.928
	PU2	0.902			
	PU3	0.870			
	PU4	0.903			
	PU5	0.849			
	PU6	0.808			
PI	PI1	0.879	0.786	0.936	0.909
	PI2	0.834			
	PI3	0.910			
	PI4	0.921			

Source: Own Survey and Author's Calculation

Table 4: HTMT ratio.

	EC	PEB	PEOU	PI	PU	SI
EC						
PEB	0.689					
PEOU	0.612	0.800				
PI	0.666	0.768	0.789			
PU	0.561	0.777	0.698	0.751		
SI	0.693	0.810	0.709	0.802	0.808	

Structural Model Assessment

Figure 2 provides a comprehensive understanding of the research analysis structure and results. Factor loadings and p-values, path coefficients and p-values, and model R^2 and Q^2 values are included in the figure.

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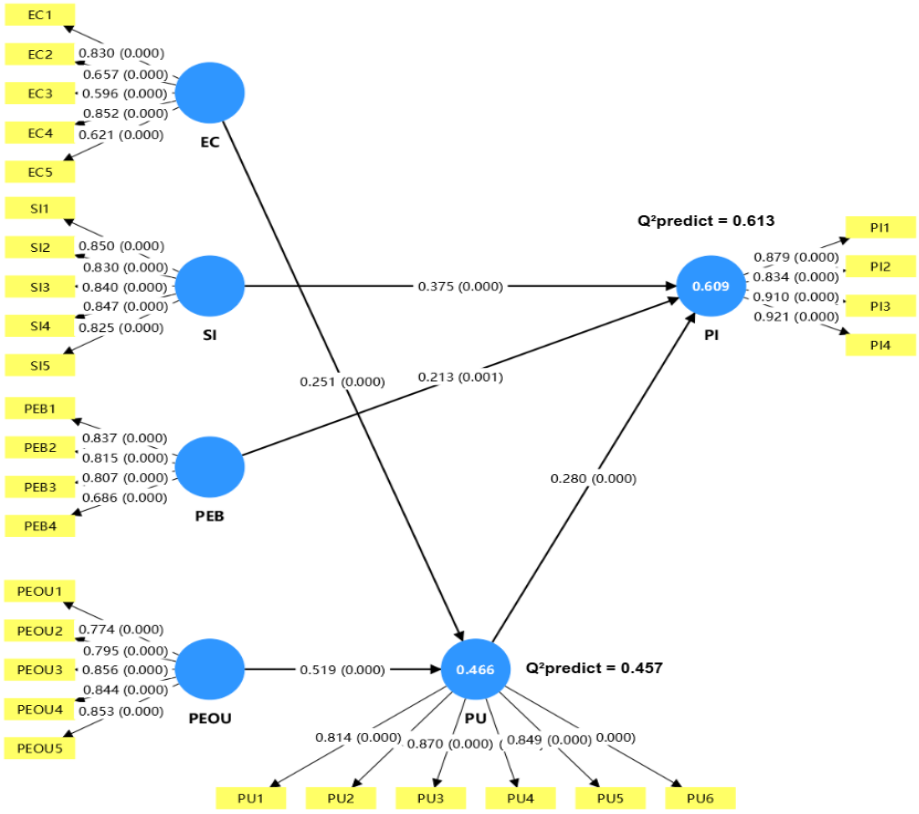


Figure 2: Overall Model Overview

From Table 5, the VIF (internal model) values are between 1.358 and 2.570, which are all less than the suggested value of 5. Therefore, according to Hair & Alamer (2022), it can be stated that there is no problem of covariance between the constructs.

Table 5: Collinearity Assessment

Relationship	VIF
EC -> PU	1.358
SI -> PI	2.570
PEB -> PI	2.120
PEOU -> PU	1.358
PU -> PI	2.485

Table 6: Hypothesis Testing of Direct Effect

Hypothesis	Relationship	Std Beta (β)	Sample mean	Std Error	T-value	P-value
H_1	EC -> PU	0.251	0.254	0.044	5.659	0.000
H_3	SI -> PI	0.375	0.373	0.061	6.153	0.000
H_4	PEB -> PI	0.213	0.216	0.062	3.450	0.001
H_5	PEOU -> PU	0.519	0.519	0.043	11.974	0.000
H_7	PU -> PI	0.280	0.280	0.061	4.625	0.000

Source: Own Survey and Author's Calculation

Table 6 summarizes the results of the structural model. The data indicate that all hypothesized relationships are supported at the 5% level. H_1 is supported, and Environmental Concern (EC) has a significant positive effect on Perceived Usefulness (PU) ($\beta = 0.251$, $t = 5.659$, $p < 0.001$). H_3 was supported ($\beta = 0.375$, $t = 6.153$, $p < 0.001$), with Social Influence (SI) as the first influential factor significantly predicting Purchase Intentions (PI). H_4 is supported ($\beta = 0.213$, $t = 3.450$, $p = 0.001$), with Perceived Economic Benefits (PEB) positively influencing Purchase Intentions (PI). H_5 is supported by the data ($\beta = 0.519$, $t = 11.974$, $p < 0.001$), with Perceived Ease of Use (PEOU) as the strongest influencing factor, strongly influencing PU. Finally, H_7 was supported ($\beta = 0.280$, $t = 4.625$, $p < 0.001$), with PU significantly influencing PI. Overall, Social Influence (SI) and Perceived Usefulness (PU) are the key determinants of purchase intention for EVs, while Perceived Ease of Use (PEOU) plays the most important role in shaping Perceived Usefulness (PU).

Table 7: R-squared and Explanatory Power

	R-square	R-square adjusted	Explanatory power
PU	0.466	0.463	Moderate
PI	0.609	0.606	Strong

Source: Own Survey and Author's Calculation

As can be seen from Table 7, in terms of model explanatory power, the model explained 46.6 % of the variance of the PU ($R^2 = 0.466$), which has moderate explanatory power (Sarstedt et al., 2021). For Purchase Intentions, the model explains 60.9 % of the variance and is considered to have strong explanatory power (Sarstedt et al., 2021).

Table 8: f-Square and Effect Size

Hypothesis	Relationship	f^2	Effect size
H1	EC -> PU	0.087	Small
H3	SI -> PI	0.140	Small
H4	PEB -> PI	0.055	Small
H5	PEOU -> PU	0.371	Large
H7	PU -> PI	0.081	Small

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From Table 8, the results of the effect size analysis show that PEOU has the largest effect on PU ($f^2 = 0.371$). While the effect sizes of the other paths are defined as small effects (Hair et al., 2013). The robustness of the model is further ensured by the results of the prediction-related Q^2predict. From Table 9, the Q^2 values for both PU and PI exceeded the threshold value of 0, indicating the model's solid predictive ability. The Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values for both PI (RMSE = 0.628, MAE = 0.463) and PU (RMSE = 0.742, MAE = 0.571) illustrate acceptable prediction accuracy (Sarstedt et al., 2021).

Table 9: Predictive Relevance of the Model

	Q^2predict	RMSE	MAE
PI	0.613	0.628	0.463
PU	0.457	0.742	0.571

Source: Own Survey and Author's Calculation

Mediating Effect

Table 10: Hypothesis Testing for Indirect Effect

Hypothesis	Relationship	Std Beta (β)	Sample mean	Std Error	T-value	P-value
H_2	EC -> PU -> PI	0.070	0.071	0.020	3.436	0.001
H_6	PEOU -> PU -> PI	0.145	0.146	0.036	4.050	0.000

Source: Own Survey and Author's Calculation

Table 10 summarises the results of the mediation effect, with both mediation paths accepted. H_2 is supported by the data ($\beta = 0.093$, $t = 3.660$, $p < 0.001$), with PU significantly mediating the relationship between EC and PI. H_6 was also supported ($\beta = 0.145$, $t = 4.050$, $p < 0.001$), showing the significant mediating effect of PU in the relationship between PEOU and PI.

Multi-Group Analysis

Table 11: Results of MICOM

Constructs	Equal Mean Assessment			Equal Variance Assessment			Full Measurement Invariance Established
	Differences	Confidence Interval	Equal	Differences	Confidence Interval	Equal	
EC	0.001	(-0.216, 0.199)	YES	-0.188	(-0.302, 0.298)	YES	YES
SI	-0.146	(-0.213, 0.194)	YES	-0.017	(-0.273, 0.259)	YES	YES
PEB	-0.166	(-0.198, 0.193)	YES	-0.043	(-0.247, 0.244)	YES	YES
PEOU	-0.237	(-0.198, 0.187)	NO	0.167	(-0.296, 0.317)	YES	NO
PU	-0.025	(-0.202, 0.186)	YES	0.018	(-0.237, 0.249)	YES	YES
PI	-0.084	(-0.206, 0.196)	YES	0.069	(-0.330, 0.334)	YES	YES

Source: Own Survey and Author's Calculation

In order to test the moderating effect of gender on the hypothesised relationships in the model, a multi-group analysis was conducted. From Table 11, MGA results showed significant gender differences for three direct pathways (H_{8c}, H_{8e}, H_{8g}). H_{8c} was supported by the fact that there is a significant difference between males and females on the relationship between SI and PI, with the effect being stronger among male respondents (β_female = 0.255, β_male = 0.487, Δβ = –0.232, p = 0.047). H8e was supported by the fact that men and women reflect a significant difference in the relationship between PEOU and PU, with the effect being stronger in the female group (β_female = 0.604, β_male = 0.426, Δβ = 0.179, p = 0.034). H_{8g} was supported, and there was a significant difference between males and females on the relationship between PU and PI, with a stronger effect for female respondents (β_female = 0.496, β_male = 0.070, Δβ = 0.426, p < 0.001). However, H_{8a} (EC to PI) and H_{8d} (PEB to PI) were not supported, and the gap between men and women on these two paths was not statistically significant. The mediating paths were also analysed by gender subgroups. This suggests that the mediating effect of PU on the relationship between EC and PI is more significant for females. H_{8f} was also supported that the indirect path effect of PEOU to PU to PI was stronger among female respondents (β_female = 0.300, β_male = 0.030, Δβ = 0.270, p < 0.001). This finding suggests that this indirect path of easy-to-use feelings translating into PU and then ultimately into purchase intentions is more effective in the female cohort.

Table 12: Multi-Group Hypothesis Testing for Direct Effect3

Path Coefficient (β)				Confidence Interval (2.5%; 97.5%)	p-Value (2-tailed)	
Relationship	Female	Male	Difference (Δβ)			Moderation Supported
H_{8a}. EC -> PU	0.222	0.286	-0.064	(-0.170; 0.175)	0.457	NO
H_{8c}. SI -> PI	0.255	0.487	-0.232	(-0.248; 0.230)	0.047	YES
H_{8d}. PEB -> PI	0.136	0.291	-0.155	(-0.239; 0.264)	0.206	NO
H_{8e}. PEOU -> PU	0.604	0.426	0.179	(-0.171; 0.163)	0.034	YES
H_{8g}. PU -> PI	0.496	0.070	0.426	(-0.236; 0.242)	0.000	YES

Source: Own Survey and Author's Calculation

ANALYSIS AND DISCUSSION

H_1 reveals that Environmental Concern (EC) has a significant positive effect on Perceived Usefulness (PU). Emphasising EVs' environmentally friendly attributes can increase their appeal. Additionally, H_2 reveals that perceived usefulness serves as a mediator in the relationship between environmental concern and EV purchase intention, supporting research by Gawshinde and

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Alaflak (2024) that reveals how environmentally conscious consumers form purchase intentions by perceiving green products as more useful. This emphasises how peers, family, and community affect choices, especially in Malaysia's tradition of collectivism, where communal views frequently take precedence over individual preferences. It is in line with findings by Abbasi et al. (2021) and Cui et al. (2021). Additionally, EV purchase intentions are significantly influenced by PEB, which is consistent with Wang et al. (2024). Complex systems can discourage potential buyers by lowering their PU. The relationship between ease of use and EV purchase intentions is then mediated by PU, which is consistent with Hasan and Erni (2024). It emphasises presenting EVs' features and benefits as competitive substitutes for conventional automobiles. Gender does play a moderating role in the TPB model. Specifically, SI had a stronger effect on men, indicating that their purchase decisions are more susceptible to peer and community opinions, consistent with Malaysia's collectivist culture. In contrast, women were more strongly influenced by PEOU and PU, suggesting that usability and functional value are particularly salient to female consumers. These findings align with Bhasin & Srivastava (2024) and Jaiswal et al. (2025), which emphasise gender differences in technology adoption and the need for gender-sensitive marketing strategies in Malaysia's EV sector.

In addition, the results indicated that the study predominantly captures insights from Gen Y, who are often more inclined towards sustainability, technology adoption, and innovation, which are key factors that influence EV purchase intention. This group is typically more tech-savvy and receptive to new trends, making their purchase behavior particularly relevant to this study. The smaller representation from Gen X, as of 2026, means Gen Xers are aged between 46 and 61, making them mature drivers in making an EV purchase decision. Ultimately, their perspective adds insights from a slightly older demographic, who may have different considerations regarding EV adoption, such as family needs, practicality, and financial stability. This age distribution ensures that the study reflects both youthful enthusiasm for technological advancements and the more measured approach of middle-aged consumers, offering a comprehensive understanding of EV purchase intention across these two generational groups.

CONCLUSION

Remarkably, this study extends the TPB model by utilising different variables to explore its application in the context of electric vehicle consumer purchasing behaviour. In Addition, this study sets the research context in the Klang Valley, Malaysia, to explore the importance of cross-cultural research in understanding consumer decision formation based on the unique geographical context. The findings provide important insights into understanding the consumer perceptions and decision-making process of Gen X and Y towards EVs. As an extension

study, this study explored gender differences in EV purchase intentions using multicohort analyses. Males were more likely to translate being influenced by the social environment into PIs. In contrast, women are more likely to convert PEOU into PI, and are more significantly influenced by PU. Therefore, marketing to women can emphasise hands-on experience, test drives, clear explanations of features, and after-sales service.

Limitations

There are obvious limitations to the convenience sampling method, which may introduce bias due to non-random sampling. Convenience sampling ranges from individuals who are easily accessible. The target group of the study was narrowly focused and consisted of 89 % Gen Y respondents and 11 % Gen X respondents, thus limiting the richness of the study and its representation of Gen X. Future studies could target Gen X to fill this gap.

Suggestions for Future Research

As a suggestion, future research on EV purchase intentions in Malaysia could benefit from other exploratory models such as the S-O-R model, which emphasises functional and non-functional values, and the Consumer Value Theory (Zamil et al., 2023). Additionally, age, education level, and income level could be used as extended moderating variables to explore the differences in purchasing behaviours they cause to better understand their role in shaping EV purchase intentions. In conclusion, this study addressed are crucial perspectives for automakers, dealerships, and investors to tap into the latent market potential.

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COMPARATIVE ANALYSIS OF PM_{10} CONCENTRATIONS BETWEEN SEMI-ENCLOSED AND ENCLOSED STATIONS OF MASS RAPID TRANSIT IN KLANG VALLEY, MALAYSIA

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Abstract

Urban air quality is a growing concern in rapidly developing regions, where the physical structure of public spaces often dictates the level of pollutant exposure. Within this urban landscape, public transport systems like the Mass Rapid Transit (MRT) serve as critical environments where commuters are frequently exposed to varying levels of particulate matter such as PM_{10}. The concentration of pollutants in these spaces is largely determined by station design. This study investigates PM_{10} concentrations in semi-closed and enclosed stations of MRT in Klang Valley, Malaysia to determine the influence of specific station designs and ventilation systems towards the indoor air quality. The results show that there are significant differences in PM_{10} concentrations between these two types of stations ($t=-35.805$, $df=142.00$, $p<0.05$). These variations indicate that semi-enclosed stations often experience higher PM_{10} accumulation due to the influence of external ambient air, where concentrations fluctuate based on nearby traffic density and local wind patterns. Conversely, enclosed stations are depending more on the ventilation conditions and occupancy levels. These findings highlight the need to give extra consideration to station design and ventilation in managing PM_{10} exposure, as different station designs can lead to varying air quality levels that directly impact commuters' health.

Keywords: Indoor Air Quality, Railway Station, Particulate Matters, Ventilation Systems, Transportation Management, Sustainable Transport

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INTRODUCTION

Railways, often described as the "lifeline of urban development," connect city regions, reduce road congestion, and serve as hubs for commerce and public activity (Reche et al., 2017). With the continuous improvement of the urban railway system, people's daily travel patterns have become increasingly diverse. Transit-oriented developments (TODs) gradually emerging as a new model for urban growth, leveraging railway accessibility to shape cities more efficiently (Abdullah et al., 2023). The railway system can alleviate surface traffic pressure, make full use of underground or above-ground space, and is considered an efficient and sustainable form of public transportation (Papa & Bertolini, 2015; Ramlan et al., 2021). As a result, an increasing number of people are relying on railways as their primary mode of travel (Azizan et al., 2021). Compared with cars and buses, railways primarily use electric power, contributing to improved urban air quality (Zheng et al., 2019).

While railways provide significant benefits for urban mobility and air quality, the internal environment of railway station platforms is relatively confined. Such confinement can result in the accumulation of air pollutants, particularly particulate matter, which may pose health risks to commuters. In recent years, particulate matter (PM) has attracted increasing attention from the public and researchers due to its potential toxicity and its role in transmitting pathogenic agents (Thangavel et al., 2022). The airborne particulates are designated as Group I carcinogen by International Agency for Research on Cancer (IARC) (Loomis et al., 2013). In fact, no matter short-term or long-term exposure of the relatively high PM concentrations, people may suffer from the particle-related diseases (Kloog et al., 2013). Megido et al. (2017) assessed the toxicity of PM with an aerodynamic diameter less than 10 μm (PM_{10}) and found that 40.2% of total studied particles would be deposited in respiratory tract through inhalation, leading to respiratory diseases.

During the daily operation of trains, a certain amount of airborne PM is generated from the friction between the railway and the wheel brake system (Martins et al., 2015). At the same time, the piston effect produced by the movement of the trains also brings outdoor pollutants into the platform, which affects the air quality of the railway platform (Wang et al., 2016). In addition, different types of ventilation systems in the station will also have corresponding impacts on PM_{10} concentrations. In semi-enclosed stations, natural ventilation is more commonly used. The concentrations of PM_{10} are more susceptible to the influence of outdoor air quality (Pan et al., 2019). However, in enclosed stations, more mechanical ventilation is used. PM_{10} concentrations are often influenced by human flow, as high commuters' density and movement were seen to have associated with the increase of airborne particulate levels (Beanabed and Boulbair, 2022). Kim et al. (2019) also reported that physical parameters, such as

air temperature (AT), relative humidity (RH), and air movement (AM) give significant contribution to the airborne particulates in the indoor environments.

Therefore, this study aims to compare PM_{10} concentrations and identify the key factors influencing air quality in two different types of railway stations. The findings can reveal critical factors controlling PM_{10} accumulation and support strategies to enhance the safety and comfort of station environments. Ultimately, these insights can inform strategies for the sustainable management of air quality within railway stations.

RESEARCH METHODOLOGY

Study Area

The study was conducted along the Putrajaya Line, the second mass rapid transit line in the Klang Valley region of Malaysia. The line serves a corridor with an estimated population of approximately two million people, extending from Kwasa Damansara in the northwest of Kuala Lumpur to Putrajaya in the south. The 57.7km-long Putrajaya Line, consisting of 44.2km of elevated tracks and 13.5km underground tunnels. The line has 36 operational stations, consisting of both elevated and underground stations (Md Zin et al., 2025). For this study, a total of six stations were selected. Among them, three stations are semi-enclosed stations, which are UPM station (S1), Kuchai station (S2), and Sungai Besi station (S3). In addition, this study also selected three enclosed stations, which are Raja Uda (UTM) station (E1), Tun Razak Exchange (TRX) station (E2) and Titiwangsa station (E3). (Table 1).

Table 1: Details of the selected MRT stations

Code	Station	Size of Area (m^2)	Type of Station	Category of Station
S1	UPM	1069.76		Educational
S2	Kuchai	1065.65	Semi-enclosed	Commercial
S3	Sungai Besi	2179.71		Interchange
E1	Raja Uda (UTM)	1247.18		Educational
E2	Tun Razak Exchange	1647.24	Enclosed	Commercial
E3	Titiwangsa	1127.28		Interchange

The stations were selected based on their surrounding land-use characteristics, representing educational, commercial, and interchange station environments. S1 and E1 were selected to represent educational areas, while S2 and E2 were chosen as commercial stations. S3 and E3 were included as interchange stations, reflecting locations where multiple lines intersect and commuter transfers are frequent. Selecting stations from different functional categories enables the analysis of how PM_{10} levels vary with station type.

Data Collection

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Data monitoring in this study was conducted during peak periods, specifically from 7:00 to 9:00 a.m., 12:00 to 2:00 p.m., and 5:00 to 7:00 p.m., when higher numbers of commuters are reported due to work-related travel and lunchtime activities (Zhang et al., 2023). These times were chosen because PM_{10} concentrations are expected to be higher due to increased movement and crowding, providing a clear understanding of air quality under typical peak conditions. Data were monitored at 5-minute intervals, corresponding to the train frequency during peak hours. Data collected at each station throughout the weekdays, with each measurement representing the PM_{10} concentration during its corresponding 5-minute monitoring period. Therefore, each observation was treated as an independent measurement representing a distinct time interval. PurpleAir Flex Air Quality, which operates using a built-in sampling system with an approximate flow rate of 0.1 L min^{-1} was used to monitor PM_{10}, while a Kestrel 4500 Weather Meter was used to monitor physical parameters i.e. AT, RH and AM. Both equipment were installed at the passenger waiting area on the platform of each station. To minimize the influence of nearby structures on airflow and particle dispersion, the equipment were mounted on a tripod, at least 1 meter away from any obstruction with the inlets of the monitors positioned at a height between 75 cm and 120 cm, preferably 110 cm from the floor, to represent the typical breathing zone of a person (DOSH, 2010).

Data Analysis

The collected data were analyzed using statistical methods to examine the variations in PM_{10} concentrations and their potential influencing factors. Descriptive analysis was first conducted to summarize the PM_{10} concentrations, the number of occupants, and the measured physical parameters, i.e. AT, RH and AM in enclosed and semi-closed stations. Descriptive analysis mainly describes the mean, standard deviation, as well as the maximum and minimum values of different parameters. This analysis provides a clear overview of the main characteristics of a dataset and helping to identify patterns or trends (MacFarland & Yates, 2020; Xu et al., 2025). The independent samples t-test is commonly used to determine whether there is a significant difference in the mean values between two independent groups (Pallant, 2020). In this study, the test was applied to examine whether there is a significant difference in the mean PM_{10} concentrations between semi-enclosed and enclosed stations, which were the main groups in this study. PM_{10} concentrations were measured at 5-minute intervals, with each measurement representing a separate monitoring interval. Although measurements were collected from multiple stations within each station type, the analysis focused on comparing the overall mean PM_{10} concentrations between the two station types rather than differences among individual stations. Therefore, the independent-samples t-test was considered appropriate for

comparing the two independent groups. The analysis was conducted at a 95% confidence level ($\alpha = 0.05$). A p-value of less than 0.05 indicates that there is a statistically significant difference in PM_{10} concentrations between the two station types (Xu et al., 2024). According to Field (2024), the test may perform well even without normal distributions in practice, particularly when sample sizes are sufficiently large as the test is considered robust to moderate violations of the normality assumption. In addition, Pearson correlation analysis was applied to evaluate the relationships between PM_{10} concentrations and the number of occupants as well as the measured physical parameters. The results of the Pearson correlation analysis are categorized into three main types which are no correlation, positive correlation, and negative correlation. Schober et al. (2018) highlighted that the correlation coefficient (r) closer to −1 and 1, indicate a strong negative and positive relationship, respectively. Meanwhile, values near 0 indicate little or no relationship between variables. The strength of the correlation coefficients can be interpreted based on Table 2.

Table 2: Pearson correlation coefficient and its strength

Correlation Coefficient Size	Strength of Coefficient
0.91 to 1.00 or -0.91 to -1.00	Very strong positive or negative correlation
0.71 to 0.90 or -0.71 to -0.90	Strong positive or negative correlation
0.51 to 0.70 or -0.51 to -0.70	Medium positive or negative correlation
0.31 to 0.50 or -0.31 to -0.50	Weak positive or negative correlation
0.01 to 0.30 or -0.01 to -0.30	Very weak positive or negative correlation
0.00	No correlation

Source: Antonov (2019)

ANALYSIS AND DISCUSSION

Descriptive Analysis of Semi-enclosed and Enclosed stations

Table 3 and Figure 1 present the descriptive statistics and temporal trends of PM_{10} concentrations measured at both semi-enclosed and enclosed stations. The mean PM_{10} concentrations for all semi-enclosed stations were observed to be almost similar with the highest mean PM_{10} concentrations was recorded at S1 ($58 \pm 4\mu g/m^3$), followed by S3 ($56 \pm 3\mu g/m^3$) and S2 ($49 \pm 3\mu g/m^3$). This observation is further supported by the temporal trend graph, which demonstrates consistent PM_{10} patterns among the semi-enclosed stations throughout the monitoring period. This is due to comparable station designs and ventilation conditions. Semi-enclosed stations allow greater interaction with the outdoor environment, enabling particulate matter to disperse more easily through natural airflow. As a result, PM_{10} concentrations in such stations are often influenced by ambient outdoor air and tend to show less variation between stations with similar structural characteristics (Pang et al., 2020). In contrast, the enclosed stations exhibited more significant differences in mean PM_{10} concentrations between

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stations. E2 was recorded the highest, followed by E1 and E3 with mean PM_{10} concentrations of 72 ± 9μg/m^3, 28 ± 5μg/m^3 and 8 ± 2μg/m^3, respectively.

Table 3: Descriptive Statistics of Semi-Enclosed and Enclosed Stations

Parameters	N total	Mean ± SD	Min	Max	N total	Mean ± SD	Min	Max
	Semi-Enclosed Stations				**Enclosed Stations**			
		S1				**E1**		
PM_{10} (μg/m^3)	72	58 ± 4	51	66	72	28 ± 5	16	46
AM (m/s)	72	0.27 ± 0.15	0.04	0.64	72	0.00 ± 0.00	0.00	0.02
AT (°C)	72	29.2 ± 1.9	26.2	31.6	72	22.8 ± 0.3	22.5	23.8
RH (%)	72	68 ± 8	58	81	72	60 ± 2	57	63
No. of occupants	72	28 ± 14	5	52	72	30 ± 15	5	60
		S2				**E2**		
PM_{10} (μg/m^3)	72	49 ± 3	44	57	72	72 ± 9	56	89
AM (m/s)	72	0.41 ± 0.22	0.04	0.97	72	0.00 ± 0.00	0.00	0.03
AT (°C)	72	28.2 ± 2.0	25.8	31.6	72	27.0 ± 0.2	26.6	27.3
RH (%)	72	72 ± 9	57	81	72	67 ± 1	64	69
No. of occupants	72	42 ± 25	8	98	72	340 ± 232	85	802
		S3				**E3**		
PM_{10} (μg/m^3)	72	56 ± 3	49	64	72	8 ± 2	4	11
AM (m/s)	72	0.04 ± 0.05	0.00	0.27	72	0.00 ± 0.00	0.00	0.00
AT (°C)	72	29.6 ± 1.6	27.3	32.2	72	21.8 ± 0.4	21.1	23.1
RH (%)	72	68 ± 7	56	77	72	66 ± 1	63	68
No. of occupants	72	121 ± 65	23	221	72	148 ± 86	20	297
		Overall				**Overall**		
PM_{10} (μg/m^3)	72	54 ± 2	50	58	72	36 ± 4	29	43
AM (m/s)	72	0.24 ± 0.12	0.06	0.54	72	0.00 ± 0.00	0.00	0.01
AT (°C)	72	29.0 ± 1.8	26.4	31.6	72	23.9 ± 0.2	23.5	24.7
RH (%)	72	69 ± 8	59	79	72	65 ± 1	62	65
No. of occupants	72	63 ± 34	16	117	72	173 ± 105	47	365

*S1: UPM station; S2: Kuchai station; S3: Sungai Besi station; E1: Raja Uda (UTM) station; E2: Tun Razak Exchange station; E3: Titiwangsa station

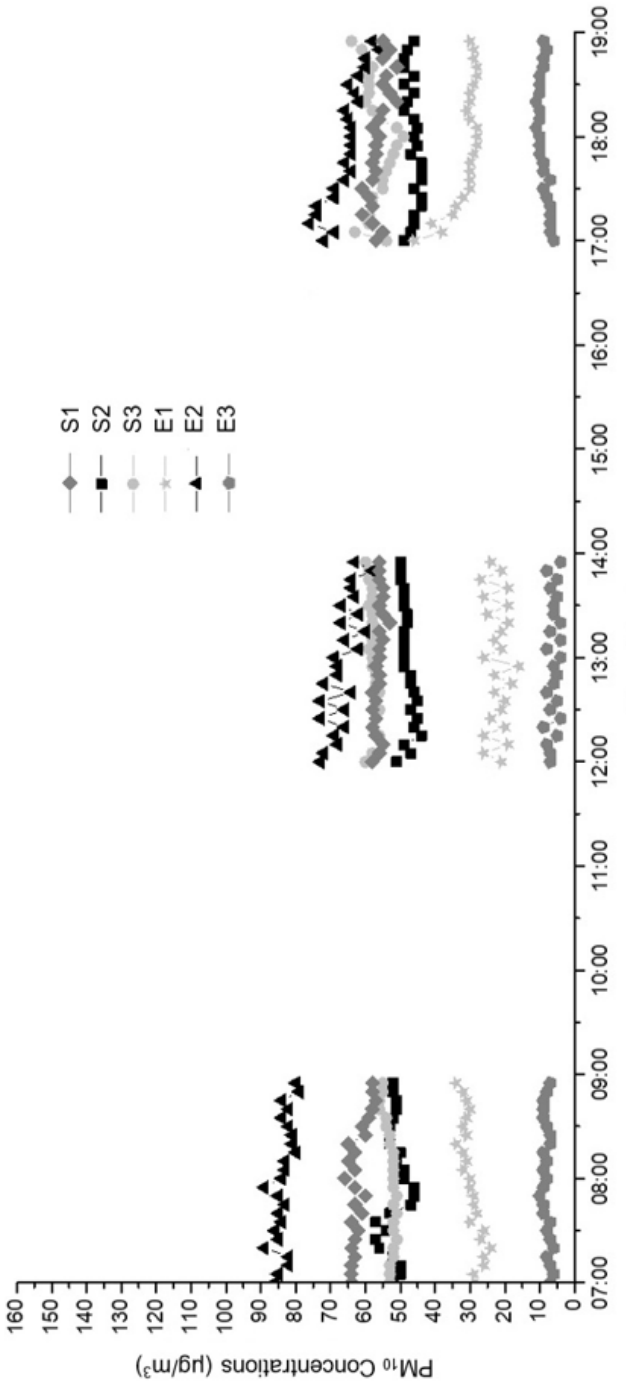


Figure 1 Temporal trend of PM_{10} concentrations at semi-enclosed and enclosed stations

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The elevated PM_{10} concentrations at E2 were attributed to its fully enclosed design combined with its location in close proximity to a busy commercial and business hub, resulting in higher occupant density and increased external particulate influx. Frequent occupant activity within the station may also contribute to the resuspension of settled particles. In comparison, the lower concentrations observed at E1 and especially E3 suggest lower occupancy levels and/or more effective airflow conditions that facilitate particle dispersion within the station environment (Wang et al., 2023). To provide a reference for interpreting the measured PM_{10} concentrations, the results were compared with the acceptable limit for respirable particulates of 150 $\mu g/m^3$ specified in the Malaysian Industry Code of Practice on Indoor Air Quality (ICOP) 2010 (DOSH, 2010). All PM_{10} concentrations in both semi-enclosed and enclosed stations were below this guideline value. However, because the ICOP 2010 limit is based on an 8-hour time interval, the comparison is intended to provide context for the measured concentrations rather than to demonstrate regulatory compliance.

Although the mean PM_{10} concentration was highest at S1, S2 recorded the highest, AM and RH with the mean values of 0.41 ± 0.22m/s and $72 \pm 9\%$, respectively. The higher AM observed at S2 may have contributed to lower PM_{10} concentrations, as increased airflow can enhance the dispersion and dilution of particulate matter. Previous studies have reported that ventilation and air movement play an important role in reducing the accumulation of particulate matter in railway stations and other indoor transport environments (Moreno et al., 2014). Meanwhile, AM was observed to be stagnant across all enclosed stations. Limited air movement reduces the dispersion of particles, which may increase exposure risks during periods of high occupancy or activity (Yang et al., 2023).

Higher AT and number of occupants were recorded at S3. Similar trend was observed at E2. The elevated occupancy level was observed to be the factor that influencing the PM_{10} concentrations through the resuspension of settled particles caused by occupant movement and activities (Zainordin et al., 2022). In addition, human presence can influence indoor thermal conditions, leading to higher air temperatures within the station environment (Beanabed and Boulbair, 2022).

Overall, it was observed that mean PM_{10} concentrations in semi-enclosed stations were higher than enclosed stations. This trend may be attributed to the greater influence of outdoor air and resuspension from passenger movement in semi-enclosed stations, which allows more particulate matter to enter and circulate on the platform compared with enclosed stations where airflow is more restricted (Wang and Li, 2025).

Independent Samples T-Test between Semi-enclosed and Enclosed station

The results of the independent t-test analysis (Table 4) indicated a significant difference in PM_{10} concentrations between semi-enclosed and enclosed stations ($t = -35.805$, $df = 142.00$, $p < 0.05$). This significant difference is largely due to the higher PM_{10} concentrations observed in semi-enclosed stations compared to enclosed stations, suggesting that station design and ventilation characteristics strongly influence particulate matter levels. Semi-enclosed stations, which are more exposed to outdoor air, may experience greater PM_{10} intrusion from ambient sources, leading to elevated concentrations despite the absence of major indoor particle emissions. This aligns with previous research indicating that higher ventilation and air exchange rates can increase indoor PM concentrations by outdoor particles rather than merely recirculating indoor air (Ben-David et al., 2018).

Table 4: Independent Samples T-Test of PM_{10} Concentrations between Semi-enclosed and Enclosed Station

				95% Confidence Interval of the Difference	
t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
-35.805	142.00	.000	-18.50	-19.52140	-17.47860

Moreover, studies have consistently shown that indoor PM concentrations are often dominated by outdoor sources, particularly in spaces with limited indoor emissions, emphasizing the importance of considering both outdoor air quality and station design when assessing particulate matter exposure (Liao et al., 2004; Li et al., 2005; Massey et al., 2012).

Pearson Correlation of Semi-enclosed and Enclosed Stations

The result from Pearson correlation analysis is presented in Table 5. The findings indicate that in semi-enclosed stations, PM_{10} concentrations were correlated with all measured physical parameters ($P < 0.05$) except for the number of occupants. Meanwhile, in enclosed stations, PM_{10} concentrations showed correlations with all parameters ($P < 0.01$) except for AM. In semi-enclosed stations, the correlation coefficients (r) between PM_{10} concentrations and AM, air temperature (AT), and relative humidity (RH) were −0.269, −0.376, and 0.294, respectively. However, these parameters demonstrated very weak to weak relationships with PM_{10} concentrations. Both AM and AT showed weak negative correlations with PM_{10} concentrations, while RH indicated a very weak positive correlation with PM_{10} concentrations. The weak negative correlations between PM_{10} concentrations and both AM and AT suggest that increased airflow and higher

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temperatures may contribute to the dispersion of particulate matter in semi-enclosed stations (Avdakovic et al., 2016). Greater AM can enhance particle dilution, reducing the accumulation of PM_{10} within the platform environment. Meanwhile, RH may slightly influence particle suspension in the air. This may be due to absorption of moisture by airborne particles, which increases particle size and contributes to higher PM_{10} levels (Tai et al., 2010). However, no significant correlation was observed between PM_{10} concentrations and the number of occupants. This may be due to the semi-enclosed station design, which allows continuous air exchange with the outdoor environment, thereby reducing the impact of passenger activities on PM_{10} levels (Pang et al., 2020).

For enclosed stations, AT, RH and number of occupants showed positive medium to strong relationship with PM_{10} concentrations with the correlation coefficients (r) of 0.749, 0.572, 0.821, respectively. This indicates that higher commuters' density and warmer indoor conditions may contribute to increased PM_{10} concentrations in enclosed stations, likely due to particle resuspension from human activities and the accumulation of particulate matter in confined environments (Abdul Shakor et al.,2020). According to Yuan et al. (2023), warmer indoor conditions may enhance particle suspension and reduce deposition rates, allowing PM_{10} to remain airborne for longer periods. Meanwhile, the positive relationship with RH may be associated with the hygroscopic growth of particles, where higher humidity levels can cause particles to absorb moisture, increase in size, and alter their behavior in indoor environments (Qiu et al., 2024).

In enclosed stations, no significant relationship was observed between PM_{10} concentrations and AM. This is likely because AM was recorded at very low and almost stagnant levels across these stations, limiting its ability to disperse particulate matter. In such confined environments, the effects of airflow on PM_{10} concentrations are minimal, and particle behavior is instead primarily influenced by occupancy levels, air temperature, and relative humidity. Choi et al. (2022) highlighted that when airflow or ventilation is very low or nearly stagnant, indoor particulate matter levels tend to remain elevated due to limited dispersion and removal, emphasizing the critical role of adequate airflow in controlling PM concentrations.

The findings from this study indicate that PM_{10} concentrations in railway stations are influenced by occupancy levels, indoor environmental conditions such as temperature and humidity, and ventilation or air movement. These findings highlight the importance of considering both human activity and built-environment characteristics, such as station enclosure, ventilation design, and platform layout, in managing air quality and reducing potential health risks for commuters. Despite temporal variability in the measured concentrations, consistent differences between station types remain evident, supporting the

comparison of PM_{10} concentrations between semi-enclosed and enclosed railway stations and reinforcing the influence of built-environment design on indoor particulate exposure in transit environments.

Table 5: Pearson Correlation Analysis of Semi-Enclosed and Enclosed Stations.

Parameters		PM_{10} ($\mu g/m^3$)	AM (m/s)	AT (°C)	RH (%)	No. of occupants	PM_{10} ($\mu g/m^3$)	AM (m/s)	AT (°C)	RH (%)	No. of occupants
		Semi-Enclosed Stations					**Enclosed Stations**				
PM_{10} ($\mu g/m^3$)	Pearson Correlation	1	-.269*	-.376**	.294*	.023	1	-.071	.749**	.572**	.821**
	Sig. (2-tailed)		.022	.001	.012	.845		.555	.000	.000	.000
AM (m/s)	Pearson Correlation		1	.859**	-.841**	-.793**		1	-.049	-.140	-.200
	Sig. (2-tailed)			.000	.000	.000			.684	.241	.092
AT (°C)	Pearson Correlation			1	-.986**	-.803**			1	.455**	.614**
	Sig. (2-tailed)				.000	.000				.000	.000
RH (%)	Pearson Correlation				1	.851**				1	.715**
	Sig. (2-tailed)					.000					.000
No. of occupants	Pearson Correlation					1					1
	Sig. (2-tailed)										

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

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CONCLUSION

The findings from this study provide a comprehensive understanding of factors influencing PM_{10} concentrations in railway stations. This study highlights that PM_{10} concentrations in railway stations are influenced by a combination of environmental conditions, ventilation, and commuter activity. Descriptive analysis revealed variations in PM_{10} levels across stations and highlighted the influence of environmental parameters such as air temperature, relative humidity, and air movement, as well as number of occupants. Independent t-test results confirmed significant differences in PM_{10} concentrations between different station types, emphasizing the role of station design and ventilation in particle accumulation. Pearson correlation analysis further identified that PM_{10} concentrations were associated with all the measured parameters depending on the station types. Collectively, these findings indicate that both human activity and indoor environmental conditions are critical drivers of particulate matter exposure, providing essential insights for the related stakeholders to implement effective air quality management strategies that protect commuters' health and promote sustainable transit environments.

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FROM CLAIMS TO ACTIONS: HOW GREEN MARKETING SHAPES SUSTAINABLE TOURIST BEHAVIOUR

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Abstract

This study examines how green marketing influences sustainable tourist behaviour by identifying the mediating roles of perceived green business practices (PGBP) and environmental knowledge (EK). Drawing on the Theory of Planned Behaviour and Social Practice Theory, survey data from 1,037 tourists in Langkawi, Malaysia were analysed using PROCESS Model 4 parallel mediation with HC3 heteroskedasticity-consistent standard errors and 5,000 bootstrap resamples. The direct effect of green marketing on sustainable tourist behaviour becomes non-significant once mediators are included, whereas indirect effects through PGBP and EK are both significant. PGBP represents the larger indirect pathway, while environmental knowledge provides a complementary mechanism by strengthening tourists' ability to interpret sustainability cues and enact responsible practices. These findings suggest that aligning sustainability communication with verifiable green practices and embedding knowledge-building interventions throughout the tourist journey may help translate claims into action. Causal inference should be reserved for experimental or longitudinal designs.

Keywords: Green Marketing, Sustainable Tourist Behaviour, Environmental Knowledge, Perceived Green Business Practices, Theory of Planned Behaviour, Social Practice Theory

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INTRODUCTION

Tourism is increasingly scrutinised for its environmental impacts, yet it also offers a pathway to promote sustainable lifestyles through tourists' actions. Sustainable tourist behaviour such as waste reduction, energy conservation, low-carbon mobility, and support for environmentally responsible firms has therefore become a central destination management outcome (Bhagat & Chauhan, 2021; Vicente, 2024; Colasante et al., 2024). In this context, marketing and communication are expected not only to promote destinations but also to be associated with tourists' behaviours compatible with environmental limits and long-term resilience (de Araújo et al., 2025; Mohd Esa & Ismail, 2026).

Green marketing through environmental claims, eco-brands, eco-labels, certification schemes, and sustainability campaigns aims to communicate "green" attributes and encourage responsible consumption (Peattie & Crane, 2005; Leonidou & Skarmeas, 2017; Yildiz et al., 2024). While it can support sustainable choices and patronage of responsible businesses (Han et al., 2010; Grimmer & Woolley, 2014; Chang et al., 2025), evidence shows the direct effect of green marketing on actual behaviour is often weak or inconsistent (Yadav & Pathak, 2017; Sharma, 2021; Škatarić et al., 2021; Thongmun et al., 2025). Recent work suggests green marketing operates mainly through mechanisms that translate messages into action, including credibility and capability-building processes (Chang et al., 2025; Nguyen et al., 2025; Zheng et al., 2025).

Two mechanisms dominate this translation. First, environmental knowledge reflects eco-literacy and understanding of sustainability issues and practices; it shapes attitudes, perceived behavioural control, and values, and is associated with greener choices and willingness to pay for sustainable options (Bhagat & Chauhan, 2021; Jiang et al., 2025; Alashiq & Aljuhmani, 2025; Shrivastava & Gautam, 2024; Shimul et al., 2024; de Araújo et al., 2025). Second, PGBP captures visible sustainability practices including credible eco-certifications, transparent reporting, and operational policies that signal commitment, reduce perceived risk, and strengthen trust in green claims (Font & McCabe, 2017; Martínez et al., 2019; Yildiz et al., 2024; Chang et al., 2025). Although these pathways are frequently discussed, studies often test them separately or focus on single tools and mediators, leaving limited evidence on their comparative roles, particularly in emerging markets such as Malaysia (Qiu et al., 2025; Elshaer et al., 2025).

These evidence gaps matter particularly for planning contexts in Langkawi, a designated UNESCO World Geopark and major Malaysian island destination where tourism growth, conservation standards, and green consumption must be managed together (Mohd Esa & Ismail, 2026; Rijal et al., 2025). Understanding whether green marketing works through perceived green business practices and environmental knowledge can inform destination

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planning, eco-certification, visitor management, and green business communication. To address these gaps, this study integrates the Theory of Planned Behaviour and Social Practice Theory to examine a dual-pathway model in which green marketing is associated with sustainable tourist behaviour indirectly through perceived green business practices and environmental knowledge (Ajzen, 1991; Shove et al., 2012; Liu et al., 2020). Using survey data from 1,037 tourists in Langkawi, Malaysia, and PROCESS-based parallel mediation with HC3 standard errors (Hayes, 2017), the study asks: (1) How does green marketing influence sustainable tourist behaviour? (2) To what extent do perceived green business practices and environmental knowledge transmit this relationship? and (3) Which indirect pathway is larger?

LITERATURE REVIEW

Green marketing and sustainable tourist behaviour

Within a Theory of Planned Behaviour (TPB) framework, green marketing is expected to shape sustainable tourist behaviour by influencing attitudes towards eco-friendly practices, perceptions of social expectations, and perceived control (Ajzen, 1991; Han et al., 2010; Zhao et al., 2025). Tourism studies demonstrate that exposure to green marketing messages, eco-brands, and eco-labels can enhance eco-friendly attitudes, destination trust, and visit intentions for sustainable destinations (Chang et al., 2025; Hanafiah et al., 2025; Vicente, 2024). Although direct effects on actual behaviour are often modest, the total effect of green marketing on sustainable behaviour is generally positive when both direct and indirect pathways are considered (Alhomaid, 2025; Zheng et al., 2025).

Accordingly, the present study posits that perceived green marketing efforts at the destination level will be positively associated with tourists' self-reported sustainable behaviours.

H1. Green marketing (GM) has a positive total effect on sustainable tourist behaviour (GC).

Mediation via perceived green business practices (PGBP)

Social Practice Theory and signalling perspectives highlight that marketing claims must be backed by credible, visible practices if they are to influence behaviour. Eco-certifications, operational policies, transparent reporting, and environmental investments function as signals of genuine commitment, reducing scepticism and reinforcing normative expectations around sustainable conduct (Font & McCabe, 2017; Yildiz et al., 2024). Empirical studies in hotels and destinations show that eco-labels and sustainability practices enhance customer trust, perceived value, and willingness to choose green options, frequently

mediating the relationship between green marketing exposure and behavioural responses (Chang et al., 2025; Alhomaid, 2025).

In this study, PGBP is conceptualised as tourists' perceptions of the destination's and firms' sustainability practices. Green marketing is expected to strengthen these perceptions, which in turn promote sustainable behaviour by making sustainable options more visible, credible, and socially normative.

H2. Green marketing (GM) exerts an indirect effect on sustainable tourist behaviour (GC) through perceived green business practices (PGBP).

Mediation via environmental knowledge

Information-based mechanisms remain central within both TPB and broader environmental behaviour frameworks. Green marketing that educates through eco-guides, interpretive content, or micro-educational messages can enhance EK, which in turn supports pro-environmental attitudes, perceived control, and values (Bhagat & Chauhan, 2021; Jiang et al., 2025). In hospitality and tourism, EK has been found to mediate the relationship between sustainability cues and outcomes such as eco-resort intentions, green hotel patronage, and green purchase behaviour (Shrivastava & Gautam, 2024; Shimul et al., 2024; Muna et al., 2025). Studies grounded in value–belief–norm theory further show that EK influences eco-destination image and biospheric values, which subsequently drive support for sustainable tourism (Alashiq & Aljuhmani, 2025).

In line with this evidence, the present study posits that green marketing contributes to sustainable tourist behaviour partly by enhancing tourists' environmental knowledge, making them more aware of impacts, more capable of evaluating options and more motivated to act in environmentally responsible ways.

H3. Green marketing (GM) exerts an indirect effect on sustainable tourist behaviour (GC) through environmental knowledge (EK).

Comparative strength and complementarity of mediators

Although both PGBP and EK are expected to mediate the GM–GC relationship, prior work suggests their relative contribution may differ. Practice-based and signalling perspectives emphasise that credible business practices and eco-labels often exert strong effects on trust and choice, particularly when consumers are sceptical of green claims (Font & McCabe, 2017; Yildiz et al., 2024). Environmental knowledge enhances the interpretability and value of these signals, enabling tourists to understand and act upon them (Bhagat & Chauhan, 2021; Zheng et al., 2025). We therefore expect PGBP to account for a larger share of the mediated effect, while EK provides a complementary contribution.

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H4. The magnitude of mediation via perceived green business practices (PGBP) is greater than the magnitude of mediation via environmental knowledge (EK).

Together, these hypotheses articulate a dual-pathway model in which green marketing shapes sustainable tourist behaviour indirectly through practice-based signals (perceived green business practices) and cognitive competences (environmental knowledge), grounded in an integrated TPB–SPT perspective.

Table 1: Theoretical Mapping of Constructs across TPB and SPT

Construct	Role in model	Theory linkage
GM	External communication cue shaping green attitudes and perceived expectations	TPB: attitude, subjective norm, perceived behavioural control
EK	Cognitive eco-literacy enabling interpretation of sustainability claims	TPB: perceived behavioural control; SPT: competence
PGBP	Visible green practices, eco-certifications, and operational sustainability signals	SPT: materials and meanings; credibility signalling
GC	Enacted sustainable tourist behaviour	TPB: behaviour; SPT: practice enactment

RESEARCH METHODOLOGY

Research Design

This study employed a quantitative, cross-sectional survey design to test the mediating roles of PGBP and EK in the relationship between GM and sustainable tourist behaviour (GC). This approach is appropriate for modelling relationships among latent constructs at a single point in time and for testing theoretically specified mediation paths in tourism settings.

Sample and Data Collection

Data were collected from January to August 2025 via structured intercept surveys at major tourism zones in Langkawi: Pantai Cenang (beach and commercial zone), Oriental Village, the Kilim Geoforest Park mangrove jetty area, and Langkawi Craft Cultural Complex. These zones represent high-traffic concentrations of domestic and international tourists across recreational, cultural, and nature-based experiences, and were selected to ensure diversity in visitor type and activity context. Trained enumerators approached adult visitors (aged 18 and above) in public areas and invited them to participate voluntarily. Eligibility required at least one overnight stay in Langkawi during the current trip. After removing incomplete or inconsistently answered questionnaires, 1,037 fully usable responses were retained for analysis.

A non-probability convenience sampling strategy was used, consistent with recent sustainable tourism studies that rely on on-site intercept samples due to access and cost constraints (Zheng, 2018; Gomes & Lopes, 2023; Alashiq &

Aljuhmani, 2025). In accordance with the research ethics guidelines of Universiti Utara Malaysia (UUM) and the Malaysian Ministry of Higher Education, formal institutional ethics board approval was not required for this study because: (1) the survey was anonymous and involved no personal identifying information; (2) participation was entirely voluntary; (3) participants were adults in public settings; and (4) the research posed no physical or psychological risk. Participants were informed of the study's purpose and their right to withdraw at any time.

Measures

The questionnaire comprised four sections (A–D), each with 10 items on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). GM functions as the external stimulus activating attitudes and subjective norms (TPB) and as a communication cue shaping practices (SPT). EK reflects perceived behavioural control and cognitive competence. PGBP captures material and symbolic sustainability signals observable at the destination. GC represents the enacted behaviour outcome. Items were adapted from established scales (Han et al., 2010; Olya et al., 2019; Nekmahmud & Fekete-Farkas, 2020) and updated to reflect recent operationalisations (Alhomaid, 2025; Jiang et al., 2025; Dodds & Holmes, 2025). One weak item per construct was removed after diagnostic checks, yielding nine retained items per construct.

Table 2: Questionnaire Constructs and Retained Items

Construct	Item focus	Retained items
Green Marketing (GM)	Eco-label attention, branding, credibility, and message framing	9
Environmental Knowledge (EK)	Awareness, literacy, and ability to interpret sustainability practices	9
Perceived Green Business Practices (PGBP)	Eco-certification, sustainable operations, and transparency of tourism providers	9
Sustainable Tourist Behaviour (GC)	Recycling, reduced plastic use, conservation activities, and support for green enterprises	9

Note. One weak item from each construct was excluded based on corrected item-total correlation, alpha-if-item-deleted, and factor loading criteria.

Measurement model

Measurement quality was assessed using SPSS-based reliability analysis and exploratory factor diagnostics. Cronbach's alpha, corrected item-total correlations, and alpha-if-item-deleted statistics were examined.

Table 3: Reliability and Exploratory Factor Diagnostics

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Construct	Items retained	Cronbach's α	Standardised α	Interpretation
GM	9	.804	.802	Acceptable
EK	9	.873	.873	Strong
GC	9	.857	.855	Strong
PGBP	9	.858	.852	Strong

Note. One item per construct was excluded based on CITC, alpha-if-item-deleted, and factor loading criteria.

The refined measurement structure retained nine items per construct. Cronbach's alpha ranged from .804 to .873, while standardised alpha ranged from .802 to .873, indicating acceptable to strong internal consistency. The overall retained measurement set also demonstrated strong sampling adequacy and factorability, KMO = .946, Bartlett's test of sphericity, $\chi^2(630) = 26{,}949.705$, $p < .001$. The retained factor loading ranges further supported the exploratory measurement structure. Therefore, the constructs were considered suitable for subsequent correlation and mediation analyses (Table 3). Collinearity diagnostics confirmed that VIF values did not exceed 5.0 (Hair et al., 2020), and strong inter-construct correlations are consistent with the integrated TPB–SPT framework (Ajzen, 1991; Shove et al., 2012).

Analysis Techniques

Descriptive statistics and Pearson correlations were computed first. Mediation hypotheses were then tested using PROCESS macro (version 5.0) for SPSS, Model 4, with GM as the independent variable, PGBP and EK as parallel mediators, and GC as the dependent variable. Indirect effects were evaluated via non-parametric bootstrapping with 5,000 resamples and bias-corrected 95% confidence intervals (Hayes, 2017; Igartua & Hayes, 2021). HC3 heteroskedasticity-consistent standard errors were employed. Harman's single-factor test indicated the first unrotated factor accounted for 39.20% of total variance, suggesting common method bias is unlikely to fully explain the observed relationships. VIF values in the GC outcome model ranged from 2.7469 (PGBP) to 3.5361 (EK), all below the 5.0 benchmark (Hair et al., 2014).

ANALYSIS AND DISCUSSION

Descriptive Statistics and Correlations

Table 4 reports means and standard deviations for the constructs (n = 1,037). Mean scores ranged from 3.76 (GC) to 3.86 (PGBP), indicating generally positive perceptions across all constructs. All Pearson correlations were positive and significant (all $p < .001$), ranging from $r = .687$ (GM–GC) to $r = .836$ (GC–PGBP), confirming strong theoretical proximity consistent with the integrated TPB–SPT framework.

Table 4: Descriptive Statistics (n = 1,037)

Construct	Valid n	Mean	SD	Min	Max
GM	1,037	3.80	0.45	2.00	5.00
EK	1,037	3.83	0.55	1.75	5.00
GC	1,037	3.76	0.48	1.78	5.00
PGBP	1,037	3.86	0.52	1.00	5.00

Mediation Analysis

Table 5 presents the individual regression paths from PROCESS Model 4 together with collinearity diagnostics. GM significantly predicted both EK (B = 0.9647, HC3 SE = 0.0328, t = 29.45, p < .001, 95% CI [0.9004, 1.0290]) and PGBP (B = 0.8505, HC3 SE = 0.0386, t = 22.03, p < .001, 95% CI [0.7748, 0.9263]).

Table 5: PROCESS Model 4 Individual Regression Paths and Collinearity Diagnostics

Outcome	Predictor / Path	B	SE	t	p	95% CI	VIF
EK	GM to EK	0.9647	0.0328	29.45	< .001	[0.9004, 1.0290]	1.0000
PGBP	GM to PGBP	0.8505	0.0386	22.03	< .001	[0.7748, 0.9263]	1.0000
GC	GM to GC	0.0774	0.0656	1.18	.2378	[−0.0512, 0.2061]	3.1087
GC	EK to GC	0.1458	0.0617	2.36	.0183	[0.0247, 0.2668]	3.5361
GC	PGBP to GC	0.6049	0.0507	11.94	< .001	[0.5055, 0.7043]	2.7469

Note. Coefficients are unstandardised estimates (HC3 standard errors). VIF values for the GC outcome model ranged from 2.7469 to 3.5361, below the 5.0 benchmark, indicating no severe multicollinearity.

In the GC outcome model, both EK (B = 0.1458, HC3 SE = 0.0617, t = 2.36, p = .0183) and PGBP (B = 0.6049, HC3 SE = 0.0507, t = 11.94, p < .001) significantly predicted GC, while the direct effect of GM on GC was non-significant (B = 0.0774, p = .2378). VIF values were below 5.0, confirming no severe multicollinearity.

Table 6 presents the direct, total indirect, and total effects from the bootstrap analysis. The direct effect of GM on GC was non-significant after including both mediators (B = 0.0774, 95% CI [−0.0512, 0.2061]), indicating that the relationship operates primarily through indirect pathways and supporting the view that green messages rarely translate into pro-environmental actions without additional psychological or contextual mechanisms (Yadav & Pathak, 2017; Zheng et al., 2025; Hanafiah et al., 2025). Both indirect effects were statistically significant, as their bootstrap confidence intervals excluded zero. The pathway through PGBP was substantially larger (B = 0.5145, BC 95% CI [0.4252, 0.6022]) than the pathway through EK (B = 0.1406, BC 95% CI [0.0247,

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0.2504]). This indicates that tourists' perceptions of eco-certifications, visible sustainable operations, and transparency of tourism providers play a particularly important role in transmitting the effect of green marketing to sustainable behaviour, consistent with studies showing that eco-labels and credible green practices foster trust and encourage green behavioural responses (Yildiz et al., 2024; Chang et al., 2025).

Table 6: Direct and Indirect Effects of GM on GC (PROCESS Model 4, n = 1,037)

Effect	Estimate	BootLLCI	BootULCI
Direct effect: GM to GC	0.0774	−0.0512	0.2061
Indirect via PGBP	0.5145	0.4252	0.6022
Indirect via EK	0.1406	0.0247	0.2504
Total indirect effect	0.6551	0.5551	0.7569
Total effect: GM to GC	0.7325	0.6853	0.7797

Note. Bootstrap estimates based on 5,000 resamples with bias-corrected 95% confidence intervals. LLCI = lower-limit confidence interval; ULCI = upper-limit confidence interval. A confidence interval that excludes zero indicates a significant indirect effect.

The significant indirect pathway via EK supports the view that green marketing also works by enhancing tourists' environmental literacy, which in turn promotes pro-environmental actions (Bhagat & Chauhan, 2021; Jiang et al., 2025; Alashiq & Aljuhmani, 2025). The total indirect effect (B = 0.6551, BC 95% CI [0.5551, 0.7569]) and total effect (B = 0.7325, BC 95% CI [0.6853, 0.7797]) confirm that green marketing is meaningfully related to sustainable behaviour when both direct and mediated components are considered.

Overall, these results support H1, H2, and H3. In line with H4, the indirect effect via PGBP (B = 0.5145) was descriptively larger than the indirect effect via EK (B = 0.1406), echoing evidence from hospitality and destination studies in which credible business practices often emerge as particularly powerful drivers of tourists' green responses (Font & McCabe, 2017; Elshaer et al., 2025). The significant contribution of EK underscores its complementary role in equipping tourists with the cognitive resources needed to interpret and act upon sustainability signals (Muna et al., 2025; de Araújo et al., 2025).

DISCUSSION

This study finds that the association between green marketing and sustainable tourist behaviour becomes non-significant once PGBP and EK are introduced as mediators, indicating the relationship operates primarily through indirect pathways. Because the design is cross-sectional and relies on self-reported behaviour, no causal claims are made; the findings describe patterns of association consistent with the theoretical model. This pattern supports the view that tourism sustainability messages rarely translate into action through persuasion alone; behavioural change tends to occur when marketing is

embedded in credible organisational practice and supported by eco-literacy (Font & McCabe, 2017; Liu et al., 2020; Zheng et al., 2025). In TPB terms, green marketing may not directly move behaviour unless tourists also perceive feasibility and legitimacy for acting sustainably in-destination (Ajzen, 1991; Han et al., 2010).

The stronger mediation through PGBP highlights the central role of visible sustainability practices and signals. Eco-certifications, transparent operations, and demonstrable green innovations act as credibility cues that reduce scepticism and provide normative guidance for tourists (Font & McCabe, 2017; Yildiz et al., 2024; Chang et al., 2025). This result is consistent with evidence that eco-labels and credible practices strengthen trust and green behavioural responses in hospitality and destination contexts (Martínez et al., 2019; Alhomaid, 2025). Environmental knowledge significantly transmits the effect of green marketing as well, supporting research showing that eco-literacy enhances tourists' ability to interpret sustainability cues and undertake responsible actions (Bhagat & Chauhan, 2021; Jiang et al., 2025; Rijal et al., 2025; Shrivastava & Gautam, 2024; Shimul et al., 2024). From an SPT perspective, knowledge functions as a competence resource enabling enactment, while PGBP reflects material and symbolic arrangements that make responsible behaviour easier and more meaningful (Shove et al., 2012). Taken together, the findings provide empirical support for integrating TPB and SPT: green marketing contributes to sustainable behaviour when it both strengthens competence (EK) and is backed by credible practice arrangements (PGBP) (Ajzen, 1991; Shove et al., 2012; Liu et al., 2020).

CONCLUSION AND FUTURE RESEARCH

This study examined how green marketing is associated with sustainable tourist behaviour through PGBP and EK. Using survey data from 1,037 tourists in Langkawi, Malaysia, and PROCESS Model 4 parallel mediation with HC3 standard errors and 5,000 bootstrap resamples, the results show that the direct effect of GM on GC becomes non-significant once both mediators are included. Both indirect effects are significant, with PGBP (B = 0.5145) representing the larger indirect pathway and EK (B = 0.1406) providing a complementary mechanism. Green marketing is most strongly associated with sustainable behaviour when sustainability claims are supported by credible, visible business practices and when tourists possess sufficient eco-literacy, supporting an integrated TPB–SPT explanation (Ajzen, 1991; Shove et al., 2012).

The study contributes by demonstrating that green marketing operates primarily through mediated mechanisms, extending work that focuses on single pathways such as trust, green image, or warm glow (Nguyen et al., 2025; Qiu et al., 2025). By comparing PGBP and EK within one model, the study shows that

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tourists require both visible business practices to validate green claims and sufficient knowledge to interpret and act upon them (Bhagat & Chauhan, 2021; Jiang et al., 2025; Yildiz et al., 2024; Chang et al., 2025). The findings carry differentiated implications across stakeholder groups. Destination managers and local authorities (e.g., Langkawi Development Authority) should incorporate PGBP and EK criteria into destination planning and visitor management frameworks. Green business licensing conditions could require recognised eco-certifications (e.g., Malaysia Responsible Tourism Standards, Green Key) as a condition for inclusion in official destination marketing materials and tourism concession renewals. Visitor information centres and geopark interpretation points can serve as structured EK-delivery channels at high-traffic entry and transit points (Rijal et al., 2025; Zhao et al., 2025). Tourism firms and hospitality operators should invest in third-party eco-certifications, transparent sustainability reporting, and in-property communication tools (e.g., QR-linked sustainability dashboards, eco-practice signage) to make green practices visible and credible to guests (Font & McCabe, 2017; Yildiz et al., 2024; Chang et al., 2025). For national and state tourism policy, embedding PGBP standards and EK interventions within Malaysia's National Tourism Policy 2020–2030 governance framework can align destination branding with accountability mechanisms that deter greenwashing (Font & McCabe, 2017; de Araújo et al., 2025).

Several limitations suggest future research directions. The cross-sectional design limits causal inference; longitudinal and experimental studies could test whether changes in eco-certification visibility or knowledge interventions produce durable behavioural effects (Liu et al., 2020; Zheng et al., 2025). Self-reported behaviour may be subject to social desirability bias, where respondents overstate their pro-environmental conduct; future studies could incorporate revealed behavioural indicators such as actual booking choices, opt-in programme participation records, or waste audit data to corroborate self-reports (Nguyen et al., 2025; Elshaer et al., 2025; Dodds & Holmes, 2025). The convenience sample from a single island destination also limits generalisability to other Malaysian destinations with different governance structures and visitor profiles. Comparative research across regions can test generalisability and identify context-specific differences in the relative strength of PGBP and EK (Vicente, 2024; Colasante et al., 2024; Alashiq & Aljuhmani, 2025). Digital technologies and AI-enabled nudges may further strengthen both pathways by increasing practice visibility and supporting eco-literacy at scale (Nguyen et al., 2025; Yu et al., 2025).

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DISCLOSURE STATEMENT
The authors report there are no competing interests to declare. This study did not require formal institutional ethics board approval because it involved an anonymous, minimal-risk questionnaire administered to adult tourists in public settings; no sensitive or personal identifying information was collected; participation was entirely voluntary; and the research posed no physical or psychological risk. These criteria are consistent with the ethics exemption guidelines of Universiti Utara Malaysia (UUM) and the Malaysian Ministry of Higher Education. Participants were informed of the study's purpose and their right to withdraw at any time without consequence.

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CULTURAL SPACES IN ORANG ASLI ORAL TRADITIONS

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Abstract

This study develops a spatially grounded Intangible Cultural Heritage (ICH) framework for Orang Asli (OA) oral traditions. The study interprets oral heritage through cultural spaces linked to ancestry, *Adat*, sacred ecology, place memory, mobility, restriction and cosmological meaning. Existing documentation is dispersed across separate studies of myths, folktales, historical narratives, transmitted beliefs and proverbs, making it difficult to interpret Orang Asli oral traditions as an integrated ICH system. The study combined interviews with OA knowledge holders and community representatives with ethnographic records, publications and heritage reports. Content analysis identified manifestations by narrative form, function, symbolic meaning and community context. Inductive-deductive thematic analysis organized them into codes, facets and themes. Six experts assessed the framework using the Content Validity Index, informing four themes and sixteen facets. Spatial interpretation generated four conceptual layers and eight cultural spaces covering lineage, customary order, sacred landscapes, story landmarks, mobility routes, restricted areas, spirit guardians and cosmic time. The framework supports documentation, place-memory mapping, cultural-route planning, sacred-site protection and community-led safeguarding.

Keywords: Orang Asli, Oral Traditions and Expressions, Intangible Cultural Heritage, Place-Based Narratives, Cultural Landscape

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INTRODUCTION

This paper forms part of a continuing effort to document and classify Orang Asli [OA] Intangible Cultural Heritage [ICH] across five ICH domains, with this study focusing specifically on Domain 1, Oral Traditions and Expressions.

Across Peninsular Malaysia, OA oral traditions preserve ancestry, moral order, cosmological beliefs and place-based memory. Distinct from related OA ICH papers on performing arts, social practices and ecological knowledge, this paper focuses on spoken narratives, verbal transmission and story-linked places. This study develops an expert-informed framework linking oral manifestations to heritage-mapping categories for planning and community documentation.

LITERATURE REVIEW

The oral traditions of the OA in Peninsular Malaysia are living systems of cultural transmission through which myths, legends, proverbs, chants and oral histories preserve relationships between people, nature, belief and place. As part of UNESCO's ICH Domain 1, these spoken forms carry collective memory, ethical values and cultural identity (UNESCO, 2003). They also function as knowledge systems that help communities remember origins, regulate conduct and sustain continuity across generations (Abu Bakar et al., 2025a, 2025b). Recent studies increasingly approach OA oral traditions as dynamic cultural knowledge rather than static folklore, especially in work on Jakun oral-story preservation, Semai folktale adaptation, and ethnohistorical naming practices (Sa'ad et al., 2023; Saad & Mansor, 2024; Gianno, 2023). However, existing studies often focus on individual Orang Asli communities or selected oral forms, with limited cross-comparison across myths, legends, historical narratives, beliefs and proverbs.

A place-based perspective is important because OA oral traditions frequently anchor memory in kinship lines, migration routes, rivers, forests, settlements, named landscapes and spirit-related sites. Semai origin myths, animal stories, ethnonyms and place names show how narrative retains moral meaning, ecological relations, descent, movement and ancestral continuity (Sa'ad et al., 2023; Gianno, 2023; Heikkilä & Williams-Hunt, 2024). These materials support heritage mapping by revealing cultural spaces that are absent from formal records, including sacred landscapes, remembered routes, forest-river settings and communal narrative spaces. Studies on Temiar shamanism, indigenous astronomy and celestial symbolism further show that OA oral traditions connect cosmology, ecology and moral order within lived landscapes (Salem et al., 2025; Majid, 2025; Hamacher et al., 2023). Yet the subtypes of the forms within oral tradition and expression remain underexplored (Pelet et al., 2025a, 2025b; Suhaimi et al., 2025; Khiangte et al., 2025). A Domain 1 framework is therefore needed to thematically classify oral genres while supporting heritage mapping, cultural-space recognition, and ongoing digital documentation efforts.

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METHODOLOGY

This study forms part of an ongoing effort to document and OA ICH across five ICH domains. While the related OA ICH papers share a similar methodological structure, phases and validation stages to ensure consistency and comparability, this paper applies the process specifically to Domain 1: Oral Traditions and Expressions. The data extraction, coding and thematic categorization were therefore guided by forms of oral tradition and expression.

The study treated oral tradition as a system of spoken transmission rather than a collection of isolated stories. Data were drawn from interview transcripts with OA knowledge holders and community representatives, supported by ethnographic records, academic publications and heritage reports.

The first stage involved close reading of the corpus to identify manifestations of oral tradition and expression, including myths, origin and historical accounts, folktales, chants, proverbs, and ancestral narratives. Through content analysis, each manifestation was recorded according to its narrative form, symbolic meaning, cultural function and community context. The coded materials were then organized using inductive-deductive content and thematic analyses, moving from specific manifestations to manifestation codes, facets and broader themes. The resulting framework was assessed by OA cultural and heritage experts using the Content Validation Index (CVI). Their evaluation focused on whether the classification was clear, relevant, coherent and culturally appropriate for representing ICH Domain 1 Oral Tradition and Expression.

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 1 manifestations. Symbolic meaning, oral form and normative function were recorded	Dataset of identified ICH manifestations, segmented corpus of data excerpts
Stage 2: Coding of ICH Manifestations under Domain 1	Identified manifestations were assigned manifestation codes to organize recurring oral expressions, narratives, transmitted beliefs and wisdom forms.	Coded dataset of OA Oral Tradition and Expression
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 1 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 1

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Semi-Structured Interviews

Semi-structured interviews were guided by a checklist covering settlement context, family structure, socio-demographic and socio-economic background, governance, environmental influence, cultural practices and heritage continuity. The checklist ensured core inquiries were secured while allowing follow-ups based on each participant's role, knowledge and community context. Participants included *Tok Batin*, elders, committee representatives and village members from various OA subgroups. To protect confidentiality, names are withheld and replaced with codes, while role, OA subgroup and village location are retained for context (Table 2). Table 3 shows the coding trail from transcript excerpt to theme, illustrating how selected evidence was condensed, coded and grouped into the relevant facets and themes of the Domain 1 framework.

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	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. Cepat balik, berteduh dan 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, Animal Myths
5	Final Code	Ecological Agency Belief
6	Facet	Animistic Beliefs
7	Theme	Cosmological and Astral Transmitted Beliefs

Document Analysis

Document analysis complemented interviews by reviewing 403 academic, institutional, community and media sources relevant to Orang Asli oral traditions and expressions. Sources were screened for subgroup context, extractable cultural evidence and Domain 1 relevance, then condensed into meaning units and coded into manifestation codes, facets and themes to support interview-based classification (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 oral traditions, expressions, narratives, beliefs, language, transmission, subgroup context or place memory.	No ICH or oral tradition 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 oral narratives, cultural expression, heritage documentation or oral knowledge 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 folklore, legends, histories, beliefs or cultural meanings.	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 stories, customs, beliefs, language, oral knowledge or community history.	Outdated claims without cultural relevance, unclear source basis or no link to oral tradition.
5	Theses and Dissertations	University repositories, institutional libraries and postgraduate research databases.	Empirical or ethnographic findings on OA cultural practices, oral knowledge and 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 domains and oral traditions.	Unrelated to ICH concepts or documentation.
8	Museum Archives	Museum records, exhibition notes, archive descriptions and heritage documentation.	Descriptions of OA cultural objects, stories, beliefs, performances, or intangible meanings of oral heritage.	Records with unclear provenance and no identification of subgroups.
9	Community Publications	NGO materials, local publications, blogs, community websites and informal documentation.	Community-based accounts of OA stories, beliefs, customs, oral histories, or cultural events.	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 oral narratives, expressions, cultural practices, beliefs, performances 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.

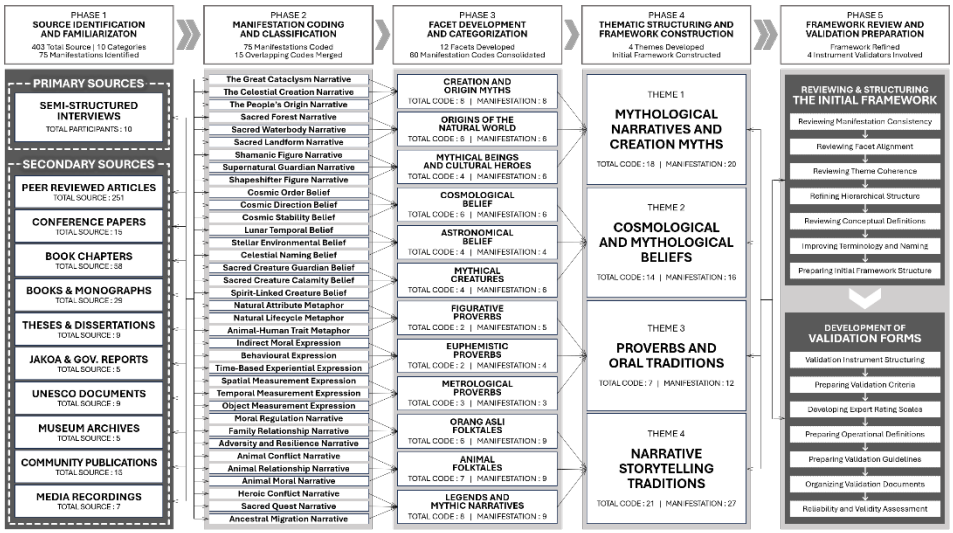


Figure 1: Initial Development and Construction of the ICH Domain 1 Framework

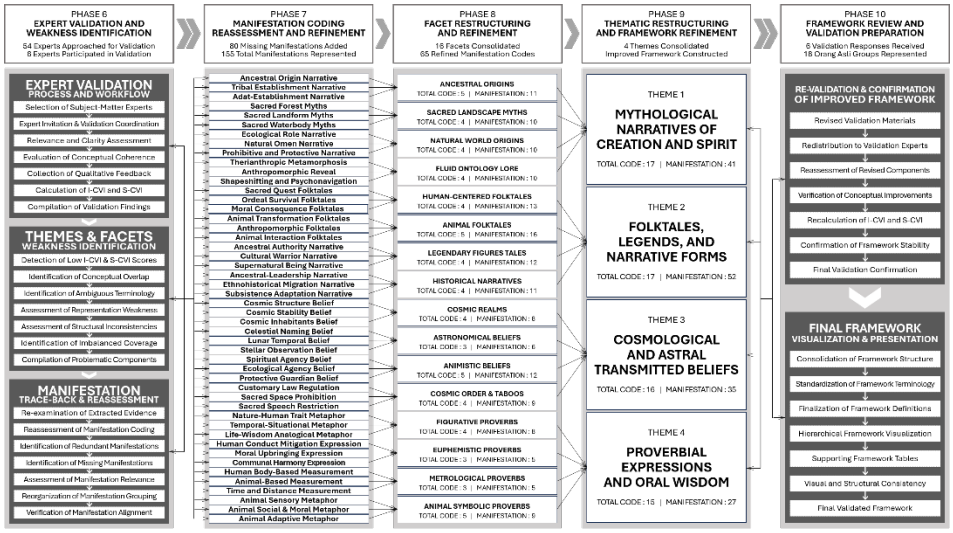


Figure 2: Expert Validation and Refinement of the ICH Domain 1 Framework

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 Department of Orang Asli Development (JAKOA) Expert in Indigenous welfare management and community support services	Recommended incorporating culturally significant locations, pathways, and landmarks into oral tradition narratives. Noted overlap between other domains and oral tradition categories.	Spatial and sacred environmental meanings were incorporated through *Sacred Landscape Myths*, *Sacred Space Prohibition*, and *Natural World Origins*. Manifestation codes were reassessed, merged, and redistributed into more distinct facets to reduce conceptual duplication.
Expert 2 Department of Orang Asli Development (JAKOA) Expert in Indigenous welfare management and community support services	Recommended clarifying whether traditions are community-specific or shared across groups. Suggested differentiating kinship-based oral traditions due to variations in social structures	Manifestations were refined to better distinguish localized narratives, ancestral systems, and culturally specific oral traditions. Community-oriented narratives and ancestral structures were reorganized within facets such as *Ancestral Origins* and *Historical Narratives*.
Expert 3 GERIMIS Art Project (Cultural Organization) Expert in Indigenous Knowledge, Cosmologies, and Eco-Critical Cultural Studies	Recommended expanding framework elements to capture sacred functions and beliefs. Emphasized preserving indigenous terminology from Orang Asli languages.	The revised framework integrated sacred beliefs, cosmological systems, taboos, and oral transmission structures into dedicated facets. Indigenous concepts and culturally specific expressions were retained and refined within narrative, cosmological, and proverbial facets.
Expert 4 Institute of Environment and Development, Universiti Kebangsaan Malaysia Expert in Sustainable Livelihoods of Indigenous Communities, Heritage Conservation	Suggested positioning cosmological and mythological narratives more prominently, and indicated conceptual overlap between oral traditions, beliefs, rituals, and narrative forms.	The structures were elevated into dedicated themes with additional and more specific facets, such as *Cosmic Realms* and *Fluid Ontology Lore.* Broad narrative categories were consolidated into more differentiated facets to improve thematic consistency.
Expert 5 Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin Expert in Indigenous people studies, Social Anthropology	Recommended including ritual narratives related to environmental practices and ecological customs.	Ecological and sacred landscape narratives were expanded through facets such as *Sacred Landscape Myth*s, with dedicated facets: *Ecological Role Narratives*, and *Protective Guardian Beliefs*.
Expert 6 Kulliyyah of Sustainable Tourism and Contemporary Languages, International Islamic University Malaysia Expert in Humanities, Linguistic and Literature, Malay Language and Literature	Recommended clearer mapping between ritual narratives, healing expressions, and storytelling forms. Suggested clearer definitions for classification terminology and themes.	The revised framework separated cosmological beliefs, oral wisdom, folktales, and mythological narratives into independent thematic structures. Revised facets adopted more culturally grounded and functionally differentiated terminology across narrative and belief domains.

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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
Mythological Narratives and Creation Myths	0.67	Creation and Origin Myths	0.67	0.67
		Origins of the Natural World	0.67	
		Mythical Beings and Cultural Heroes	0.67	
Cosmological and Mythological Beliefs	0.50	Cosmological Belief	0.67	0.56
		Astronomical Belief	0.50	
		Mythical Creatures	0.50	
Proverbs and Oral Traditions	0.67	Figurative Proverbs	0.67	0.67
		Euphemistic Proverbs	0.67	
		Metrological Proverbs	0.67	
Narrative Storytelling Traditions	0.50	Orang Asli Folktales	0.67	0.56
		Animal Folktales	0.50	
		Legends and Mythic Narratives	0.50	

Table 7: Revised Theme and Facets

Themes	Facets
Mythological Narratives of Creation and Spirit	Ancestral Origins
	Sacred Landscape Myths
	Natural World Origins
	Fluid Ontology Lore
Folktales, Legends, and Narrative Forms	Human-Centered Folktales
	Animal Folktales
	Legendary Figures Tales
	Historical Narratives
Cosmological and Astral Transmitted Beliefs	Cosmic Realms
	Astronomical Beliefs
	Animistic Beliefs
	Cosmic Order and Taboos
Proverbial Expressions and Oral Wisdom	Figurative Proverbs
	Euphemistic Proverbs
	Metrological Proverbs
	Animal Symbolic Proverbs

The validation results showed that several initial categories were too broad to capture the range of OA oral traditions. Origin stories, cosmological beliefs, folktales, taboos, and proverbial expressions often overlapped, making the earlier structure less precise. The revised framework therefore reorganizes the materials into clearer domains of mythological narratives, folktales and legends, cosmological and astral beliefs, and oral wisdom. This allows ancestral origins, sacred landscape myths, animal and human-centered folktales, animistic beliefs, and metaphorical expressions to be interpreted according to their specific oral functions. The revised structure is more useful for reading OA oral heritage as a system of memory, moral guidance, belief, and place-based transmission.

Table 8: Revised Themes and Facets Definitions

Themes & Definitions	Facets & Definitions
Mythological Narratives of Creation and Spirit *Oral narratives explaining origins of the world, people, and places, involving spiritual beings and reflecting community worldview, values, and relationships with nature and the unseen.*	**Ancestral Origins** *Narratives articulating community origins through ancestry, lineage, and establishment of cultural practices grounded in spiritual beliefs.*
	Sacred Landscape Myths *Myths interpreting origins and cultural significance of landscapes, linking geographical features with spiritual meaning, memory, and identity.*
	Natural World Origin *Narratives explaining formation of the natural world, including earth, sky, and living elements through symbolic and mythological representations.*
	Fluid Ontology Lore *Narratives of transformation between human, animal, and spirit forms, conveying moral, ancestral, and ecological meanings.*
Folktales, Legends, and Narrative Forms *Spoken stories including folktales, legends, and personal accounts that entertain, teach lessons, and preserve community history, identity, and collective memory across generations.*	**Human-Centered Folktales** *Folktales portraying ordinary human life, social relationships, cultural values, and behavioural lessons within Orang Asli communities.*
	Animal Folktales *Folktales featuring animals as central characters, reflecting human traits, conflicts, and survival strategies within environmental contexts.*
	Legendary Figures Tales *Narratives emphasizing mythic figures and beings whose actions shape cultural identity, values, and collective worldview.*
	Historical Narratives *Narratives recounting past events, community history, and collective memory, preserving knowledge of origins, experiences, and transformations.*
Cosmological and Astral Transmitted Beliefs *Beliefs explaining structure of the universe, celestial phenomena, and relationships among humans, nature, and spiritual realms, guiding understanding of time, order, and environmental interactions.*	**Cosmic Realms** *Beliefs explaining the structure of the universe, celestial phenomena, and relationships between humans, nature, and the spiritual realm.*
	Astronomical Beliefs *Orally transmitted beliefs about celestial bodies guiding time, seasonal cycles, navigation, and daily activities within Orang Asli communities.*
	Animistic Beliefs *Beliefs that natural elements possess spiritual essence, shaping how communities perceive, interact with, and respect the environment.*
	Cosmic Order and Taboos *Beliefs regulating human behaviour through taboos based on cosmological order to maintain balance between physical and spiritual worlds.*
Proverbial Expressions and Oral Wisdom *Short sayings, idioms, and expressions encapsulating cultural wisdom and moral values, used in communication and storytelling to transmit knowledge, norms, and ethical guidance across generations.*	**Figurative Proverbs** *Proverbs using metaphor and imagery to convey cultural wisdom, values, and shared understandings within Orang Asli communities.*
	Euphemistic Proverbs *Proverbs conveying meaning indirectly to soften expression, avoid offence, and encode sensitive cultural ideas within social communication.*
	Metrological Proverbs *Proverbs conveying measurement, estimation, and practical quantification knowledge used in daily activities and environmental interactions.*
	Animals Symbolic Proverbs *Proverbs using animals symbolically to describe human behaviour, convey values, and reflect relationships between humans and nature.*

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 – Mythological Narratives of Creation and Spirit

Facets	Codes	Examples of Manifestation	Groups
Ancestral Origins	Ancestral Origin Narrative	***Great Flood Myth:*** Ancestral survival of a primordial flood, symbolizing human origin and continuity after disruption.	Tem/Sem /Jak
		Ancestral Genealogies: Encodes lineage through place-based narratives linking ancestors to natural elements.	Che/Tem /Jak/Seq
	Tribal Establish-ment Narrative	***Semelai Sura:*** Community formation, customary laws, and social order via narratives rooted in forest-spirit relationships.	Sel
		***Kanaq*:** Etiological origin of taboos and rituals of the tribe, linking cultural rules to mythic events and geographic contexts.	Ork
	Adat-Establish-ment Narrative	**The Law of *Talaiden:*** The story of a sudden tropical storm that targets a village because the hunters mocked a helpless creature.	Che
		***Adat*:** Etiological narratives of instruction and consequence, regulating behaviour and maintaining social order.	ALL
Sacred Landscape Myths	Sacred Forest Myths	***Tuhad*:** The forest is regarded as *Tuhad*, a sacred creator that gives life and should be treated with care and respect.	Ter
		Gool-War Watershed: Located in the Bukit Tapah Forest Reserve and serves as one of the ancestral forest domains.	Sem
	Sacred Landform Myths	***Gunung Rajah*:** A sacred mountain as ancestral refuge from flood, symbolizing continuity between landscape and origin.	Tem
		***Bukit Pasir Puteh/ Bukit Pelandok**:* A sacred hill where the Bamboo Prince was found in bamboo (*buluh bentong*)	Ken/Kiq Jah/Lan
	Sacred Waterbody Myths	***Naga Seri Gumum*:** The origin and sacredness of Lake Chini where a mythical serpent with spiritual power resides.	Jak/Sel
		***Jeram Buaya Sangkut*:** Etiological waterfall named after crocodile spirit encounters, linking place identity to spirits.	Jak
Natural World Origin	Ecological Role Narrative	**Insect Myth:** Insects' roles within forest systems, framing them as essential components of environmental balance.	Jak/Che/ Sem/Ter
		The Concept of *Penani*: The belief of food sharing as essential to maintain harmony and avoid upsetting the forest spirits.	Sem/Ter
	Natural Omen Narrative	**Tiger Dream:** Dreaming of a tiger showing its fangs warns of a future encounter with a tiger symbolizing caution.	Sem/Ter
		***Takat Kunyit*:** The tale warns against unsafe river behaviour by linking crocodiles with danger, reinforcing aquatic caution.	Jak
	Prohibitive and Protective Narrative	***Sentoyot Lidah Rusak:*** Prohibition of using Nepenthes for cooking, linking misuse with misfortune and imbalance.	Jak/Sem/ Ter
		Pangolin Scales: Etiological tale of burning or wearing pangolin scales to ward off evil spirits or repel elephants.	Bat/Sem/ Ter
Fluid Ontology Lore	Therian-thropic Meta-morphosis	***Moyang Lembu*:** To cure a skin disease, a man abandons human food, eats wild grass, and transforms into a wild cow.	Mah/Jah
		***Moyang Buaya*:** Ignoring ancestral warnings, a villager hides in a river during a heatwave and transforms into a crocodile.	Jak/Jah/ Mah
	Anthro-pomorphic Reveal	***Cermor Mawak Kerdor:*** A gibbon zips off her white fur coat to bathe, but a hunter steals it and forces her to remain a human.	Sem
		Bongso and the Frog Woman: A frog transforms into a woman and marries Bongso, only to become a frog again after an insult.	Che/Tem /Jak
	Shape-shifting and Psycho-navigation	***Shaman-Tiger:*** A shaman projects his soul into a tiger's body during a trance to protect his community from forest predators.	Bat/Sem/ Tem
		***Ruwai* Col Bird Journey:** To recover a stolen soul, a shaman projects his spirit as a swift forest bird, while his body chants.	Sem/Jah/ Che

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 – Folktales, Legends and Narrative Forms

Facets	Codes	Examples of Manifestation	Groups
Human-Centered Folktales	Sacred Quest Folktales	***Bah Luit*'s Jungle Quest:** *Bah Luit*'s quest of following rituals and seeking blessings ensures treasure without misfortune.	Sem
		***Bah Luj* and *Garuda*:** Bah Luj's quest, helping a sultan defeat a seven-headed Garuda, symbolizing heroism over chaos.	Sem
	Ordeal Survival Folktales	***Bah Luj* and Seven *Batak*:** *Bah Luj*, a frail man, overcomes *Bataks* who devoured his family, symbolizing resilience.	Sem
		***Bah Luj* and *Jak Cemenak*:** *Bah Luj'* steps as savior and outsmarts the evil spoirit who devoured unsuspecting villagers.	Sem
	Moral Conse-quence Folktales	**Perang Kera:** A story of a war between monkeys that cause a chaos and displacement of Orang Asli ancestors.	Sem
		***Bah Bertai*:** The tale of a tiger (*serenglog*) as a supernatural enforcer, punishing broken promises to uphold moral order.	Sem
Animal Folktales	Origin and Etiological Folktales	***Asal-Usul Badak Tampung:*** Animals bound a white sheet around tapir to sap its aggression, creating its white saddle.	Sem/Tem
		Kubung Sorok Ekor: The proud flying lemur, shamed by vanity, concealed its tail and became a nocturnal glider.	Sem/Tem
	Anthropo-morphic Folktales	**The *Bat* and The Seven Siblings:** A tale narrating a bat who lives differently from its siblings and chooses a separate life.	Sem/Tem
		The *Moonrat*: A tale narrating the clever, trickster nature of the moonrat, highlighting social cunning.	Sem/Tem
	Animal Interaction Folktales	**The Rooster and The Deer:** A tale narrating a rooster challenging a deer through loud crowing and persistence.	Sem/Tem
		The Tale of Elephant: A tale of careless elephants hurting small animals, then taught by mice to be more respectful.	Sem/Tem
Legendary Figures Tales	Ancestral Authority Narrative	***Halaq*:** Etiological narrative of the first shaman (*Halaq*), establishing foundations of spiritual ritual authority.	Mah/Jah
		The *Moyangs*: The ancestors, *Moyang Getah/Melur/Bojos* as figures who performed miraculous feats of survival.	Mah/Jah
	Cultural Warrior Narrative	***Orang Laut* Maritime Battles:** A series of historic naval conflicts fought during the Triangular War (16th- 17th centuries)	Ors/Orl Ors
		***Prak Sangkiil (Perang Sangkil)*:** A dark war where the tribe was hunted and captured by outsiders to be sold into slavery.	Sem/Tem
	Super-Natural Being Narrative	***Sang Kelembai*:** A giant woman, weirdly shaped boulders, sacred caves, or prominent rock structures.	Sem/Tem /Jak
		***Bawak Gerai*:** Blood-thirsting, a King-Kong-like forest creature symbolizing strength and fear of the unknown.	Bat/Sel/ Tem/Jak
Historical Narratives	Ancestral-Leadership Narrative	**Leadership Succession:** A system of leadership inheritance through lineage, maintaining governance continuity.	Bat/Sem/ Tem/Jak
		Ancestral Lineage: A belief linking identity to ancestral lineage, reinforcing obligations to heritage and memory.	Se/Tem/ Jak
	Ethno-historical Migration Narrative	***Orang Laut*:** Narrative of nomadic boat-dwellers' maritime migration from Singapore, across the Tebrau Straits to Johor.	Ors
		***Halbəw*:** Networks and pathways that guide the family camps through the rainforest following seasonal food and fruit cycles.	Bat
	Subsistence Adaptation Narrative	**Nomadic Movement Patterns:** The regular movement and relocation of the OA explaining adaptation in forest landscapes.	Bat/Jah/ Seq
		Community Name Etymology: *Semoq Beri (*forest people*)*, *Temuan (*meeting point*)* signify history and identity.	Seq/Sem/ 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 – Cosmological and Astral Transmitted Beliefs

Facets	Codes	Examples of Manifestation	Groups
Cosmic Realms	Cosmic Structure Beliefs	**7 Layered Earth–Sky Structure:** A stratified cosmos of named earth–sky layers with rationale and spatial significance.	Seq/Bat/ Che
		Three-Tier Order: An understanding of the universe divided into sky, earth, and underworld, guiding human orientation.	Bat
	Cosmic Stability Beliefs	***Tiang Seri* and *Tiang Tompang*:** The sacred pillars of Earth, maintaining stability within a structured cosmological system.	Seq
		Guardians of 4 Directions: A spatial model of the universe organized into four cardinal directions, each with a guardian.	Sem/ Jah
	Cosmic Inhabitants Beliefs	**Inhabited Realm:** Layered cosmic realms inhabited by distinct beings, reflecting ordered spiritual-physical relationships.	Seq/Bat/ Che
		Kerei: Karei is a supernatural force believed to control natural elements such as thunder, lightning, and storms	Che/Bat/ Jai/Ken
Astrono-mical Beliefs	Celestial Naming Belief	***Bintang Lunga* and *Denai*:** Culturally assigned names for celestial bodies, the Pleiades and the Milky Way.	Bat/Tem/ Sel
		***Tohan*:** An origin account of the sun, moon, and stars through a creator figure (*Tohan*) providing light and life.	Bat/Seq/ Tem
	Lunar Temporal Belief	***Rahu' (Eclipse)*:** When the sun hunts the moon, cosmic time falters, stopping agricultural and communal practices.	Sem/Jah/ Tem
		Lunar Phase Timekeeping: A cyclical temporal system where lunar phases govern daily life and ritual practices.	Sem/Sel/ Bat
	Stellar Obser-vation Belief	***Ruwai*:** Rather than an aesthetic wonder, a shooting star signifies a spirit (*Ruwai*) moving between cosmic layers.	Sem/Jah/ Che
		Stellar Knowledge: A star-based knowledge system shaping environmental interaction and practical decisions.	Sel/Tem
Animistic Beliefs	Spiritual Agency Belief	***Pehunan/Kempunan*:** Unfulfilled cravings create spiritual vulnerability, exposing individuals to misfortune in the jungle.	Sem/Tem /Bat
		***Bes-Ruwai* Capture:** Illness occurs when Bes (malevolent spirits) prevents Ruwai's (the soul) safe return during sleep.	Jah
	Ecological Agency Belief	***Penunggu:*** Guardian spirits dwell in natural locations and respond according to human treatment of these places.	ALL
		Semangat: Plants, animals, and landscapes are viewed as sentient beings capable of rewarding or punishing humans.	ALL
	Protective Guardian Belief	**7 Semenggot:** An account of protective supernatural guardians mediating relationships between humans and unseen entities.	Sem/Tem /Jak/Jah
		***Moyang* Carvings:** Ancestral spirit carvings serve as protective guardians that absorb disease and repel malevolent forces.	Jah/Mah
Cosmic Order and Taboos	Customary Law Regulation	***Lawad, Ye'Yo* and *Tum Yap*:** A system of forest laws governing behavior, violations, and ritual forgiveness.	Bat
		Penehad: A customary law prohibiting the mixing of personal odors and possessions to personal sovereignty.	Ken/Bat
	Sacred Space Prohibition	***Serenglog* Taboo:** A prohibition observed in forest settings, to avoid angering spiritual entities or causing disturbances.	Sem
		Tualang* Shadow Perimeter*: The immediate ground underneath Tualang trees are treated as spirit-inhabited spaces.	Sem/Jah/ Tem
	Sacred Speech Restriction	**Predator Avoidance Naming:** Respectful substitute names are used for predators to prevent attracting their presence.	ALL
		Bahasa Kapur: Sacred camphor harvesting requires the use of a secret language to avoid disturbing protective spirits.	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).

Table 12: Theme 4 – Proverbial Expression and Oral Wisdom

Facets	Codes	Examples of Manifestation	Groups
Figurative Proverbs	Nature-Human Trait Metaphor	**Fruit Maturation:** Fruit ripening represents human growth, maturity, and natural progression across life stages.	Sem/Tem / Bat
		Floral Femininity: Comparison between women's beauty and flowers, fruits, or landscapes representing cultural ideals.	Sem/Mah
	Temporal-Situational Metaphor	**Time and Distance:** Interpretations of time through daily activities, linking temporal understanding to lived experience.	Bat/Tem/ Sem
		Hot and Cool Times: Temporal states are judged by spiritual balance rather than fixed clock-based measurements.	Sem/Che
	Life-Wisdom Analogical Metaphor	**Oath and Custom Morality:** Emphasis on honouring oaths and customs, reinforcing proper conduct for social order.	Che/Sem/ Tem
		Leadership: Customary framework emphasizing leadership responsibilities, decision-making, and community wellbeing.	Sem/Jak/ Tem
Euphe-mistic Proverbs	Human Conduct Mitigation Expression	***Begei Entag Semeu*:** An expression comparing stubbornness to a bear's ear, softening direct behavioural criticism.	Sem
		***Begei Caknak Pug*:** A symbolic expression someone who eats messily, spilling crumbs and scattering their food everywhere.	Sem
	Moral Upbringing Expression	***Berayot:*** A mischievous behavior of a child in softened terms, literally means 'walking without purpose'.	Sem
		Cip Punan: Symbolic food-touching customs reinforce gratitude and respect within communal interactions.	Sem
	Communal Harmony Expression	***Pet Poi:*** A communal expression about finishing tasks fully and avoiding unnecessary leftovers.	Sem
		Mai ni-nyea: Gentle communal expressions are used to defuse conflict and restore social harmony.	Sem
Metro-logical Proverbs	Body-Based Measure-ment	**Measurement of Size:** Proverbial expressions of using the human body as a standard to explain object size.	Sem/Bat
		Measurement of Length: Proverbial expressions of body spans functioning as natural rulers for measuring length.	Sem/Tem
	Animal-Based Measure-ment	**Measurement of Area:** Proverbial expressions of animals and nature as cultural reference to measure land and space.	Sem/Tem
		Measurement of Height: Proverbial expressions of building safety through comparison of house height with animals.	Sem/Jak
	Time and Distance Measure-ment	**Measurement of Time:** Expression of time, measured through daily tasks, enabling tracking of duration.	Sem/Bat
		Measurement of Distance: Expression of distance through movement or simple acts to describe short or long distances.	Sem/Tem
Animal Symbolic Proverbs	Animal Sensory Metaphor	**Animals as Colour Indicator:** Referring to the level of ripeness (maturity) of fruits or agricultural produce.	Sem/Bat/ Tem
		Animals as Sensory References: Animal characteristics as sensory experiences such as touch, sound, and condition.	Sem/Tem /Jah
	Animal Social and Moral Metaphor	**Animals as Social Boundary Markers**: Animals function as symbolic markers of proper and improper social conduct	Che/Tem /Sem
		Animals as Social Models: Human relationships, conflicts, and social patterns interpreted through animal interactions.	Bat/Tem/ Jak
	Animal Adaptive Metaphor	**Weaving Architecture:** Nest structures used as metaphorical models for weaving and shelter-building techniques.	Mah/Tem /Sem
		Hunting Weaponry: Hunting poisons are developed through metaphorical imitation of animal defensive adaptations.	Tem/Sem /Bat

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 classification in Tables 9–12 shows that OA oral traditions repeatedly attach meaning to particular forms of space. The manifestation codes were therefore re-read for their spatial implications, not only for their narrative or symbolic functions. Ancestral origin narratives, genealogies, leadership accounts and community-name etymologies point to spaces of lineage and identity. *Adat*-establishment narratives, customary law regulation, moral folktales and oral wisdom point to spaces where conduct, responsibility and social order are remembered or reinforced. Sacred forest, landform and waterbody myths, together with ecological role narratives and animal symbolic proverbs, indicate natural settings that carry ecological and sacred meanings. Historical migration narratives, subsistence adaptation narratives, metrological expressions and time-distance measurements point to routes, camps, pathways and livelihood spaces.

From this reading, the cultural spaces in Table 13 were developed by grouping recurring spatial meanings into four planning-oriented layers. Community identity and social order were represented through Origin Lineage Space and Adat Order Space. Sacred Landscape and Place-Memory were drawn from codes linked to sacred ecology and named story landmarks. Movement and Livelihood were derived from codes involving migration, subsistence, routes, taboos, restrictions and controlled access. Spiritual and Cosmological Sensitivity was developed from codes involving spirit guardians, unseen beings, transformations, celestial signs, lunar time and cosmic order. Table 14 then applies these spaces back to each manifestation code, showing how oral traditions can be translated into cultural spaces categories. This strengthens the planning relevance of the paper by treating oral traditions as spatial knowledge that can inform cultural routes, place-memory mapping, sacred-site protection, ecological sensitivity and culturally appropriate development control.

Table 13: Planning-Oriented Cultural Space Framework

Layers	Code	Cultural Spaces	Definition
Community Identity and Social Order	**A**	Origin Lineage Space	Spaces linked to ancestry, genealogy, origin narratives, and community identity transmission.
	B	Adat Order Space	Spaces linked to customary law, leadership, conduct, responsibility, and communal regulation.
Sacred Landscape and Place-Memory	**C**	Sacred Ecology Space	Natural settings carrying sacred, ecological, symbolic, or oral heritage meanings.
	D	Story Landmark Space	Named places preserved through myths, folktales, legends, histories, or place-based narratives.
Movement and Livelihood	**E**	Mobility Livelihood Space	Routes, pathways, camps, and resource areas linked to movement and subsistence memory.
	F	Taboo Restriction Space	Places governed by avoidance, prohibition, speech control, access limits, or buffer needs.
Spiritual and Cosmological Sensitivity	**G**	Spirit Guardian Space	Spaces associated with spirits, guardians, ancestors, transformations or unseen presence.
	H	Cosmic Time Space	Spaces interpreted through cosmology, stars, moon, directions, seasons, or time reckoning.

Table 14: Spatial Interpretation of ICH Manifestation Codes

Themes	Facets	Manifestation Codes	Cultural Spaces (Coded)							
			A	B	C	D	E	F	G	H
Mythological Narratives of Creation and Spirit	**Ancestral Origins**	Ancestral Origin Narrative	/		/	/				
		Tribal Establishment Narrative	/	/	/			/	/	
		Adat-Establishment Narrative		/				/		
	Sacred Landscape Myths	Sacred Forest Myths	/		/	/			/	
		Sacred Landform Myths	/		/	/			/	
		Sacred Waterbody Myths			/	/			/	
	Natural World Origin	Ecological Role Narrative			/		/		/	
		Natural Omen Narrative			/	/		/		
		Prohibitive & Protective Narrative			/		/	/	/	
	Fluid Ontology Lore	Therianthropic Metamorphosis			/				/	
		Anthropomorphic Reveal			/				/	
		Shapeshifting & Psycho-Navigation			/				/	/
Folktales Legends, and Narrative Forms	**Human-Centered Folktales**	Sacred Quest Folktales			/		/		/	
		Ordeal Survival Folktales		/	/				/	
		Moral Consequence Folktales		/	/			/	/	
	Animal Folktales	Origin & Etiological Folktales			/					
		Anthropomorphic Folktales		/	/					
		Animal Interaction Folktales		/	/					
	Legendary Figures Tales	Ancestral Authority Narrative	/	/					/	
		Cultural Warrior Narrative	/	/		/	/			
		Super-Natural Being Narrative			/	/			/	
	Historical Narratives	Ancestral-Leadership Narrative	/	/						
		Ethnohistorical Migration Narrative	/		/	/	/			
		Subsistence Adaptation Narrative	/		/	/	/			
Cosmological and Astral Transmitted Beliefs	**Cosmic Realms**	Cosmic Structure Beliefs							/	/
		Cosmic Stability Beliefs							/	/
		Cosmic Inhabitants Beliefs							/	/
	Astronomical Beliefs	Celestial Naming Belief								/
		Lunar Temporal Belief					/	/		/
		Stellar Observation Belief					/		/	/
	Animistic Beliefs	Spiritual Agency Belief			/			/	/	
		Ecological Agency Belief			/		/	/	/	
		Protective Guardian Belief			/	/			/	
	Cosmic Order and Taboos	Customary Law Regulation		/			/	/	/	
		Sacred Space Prohibition			/	/		/	/	
		Sacred Speech Restriction			/		/	/	/	
Proverbial Expressions and Oral Wisdom	**Figurative Proverbs**	Nature-Human Trait Metaphor		/	/					
		Temporal-Situational Metaphor					/		/	/
		Life-Wisdom Analogical Metaphor		/						
	Euphemistic Proverbs	Human Conduct Mitigation		/						
		Moral Upbringing Expression		/						
		Communal Harmony Expression		/						
	Metrological Proverbs	Body-Based Measurement					/			
		Animal-Based Measurement			/		/			
		Time and Distance Measurement					/			/
	Animals Symbolic Proverbs	Animal Sensory Metaphor			/		/			
		Animal Social & Moral Metaphor		/	/					
		Animal Adaptive Metaphor			/		/			

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DISCUSSION

The findings demonstrate an improved organization of OA oral traditions and expression by distinguishing four knowledge functions: (i) mythological narratives, (ii) folktales and legends, (iii) cosmological and astral beliefs, and (iv) proverbial wisdom. The initial I-CVI and S-CVI scores of 0.50–0.67 revealed conceptual overlap and insufficient differentiation among themes and facets. Expert feedback therefore guided the restructuring into clearer categories representing ancestry, moral and social regulation, ecological knowledge, cosmological beliefs, collective memory, and proverbial wisdom.

The major discovery is that OA oral traditions are also place-based cultural systems. Origin narratives, sacred landscape myths, migration accounts, taboos, astronomical beliefs and proverbial expressions repeatedly refer to forests, rivers, mountains, routes, settlements, resource areas and celestial-temporal conditions. Tables 13 and 14 translate these relationships into four heritage-mapping layers and eight spaces covering lineage, *Adat*, sacred ecology, story landmarks, mobility, restrictions, spiritual guardianship and cosmic time.

This approach extends heritage planning beyond fixed monuments by recognizing sites, territories, routes, seasonal-use areas, restricted zones and interconnected cultural landscapes to ICH manifestations. The framework support cultural landscape assessment, heritage inventories, development screening and community-based documentation. Its mapping categories also provide a basis for participatory heritage documentation guided by community consent and appropriate protection of sensitive or sacred oral knowledge.

CONCLUSION

This study forms part of ongoing efforts to document and classify OA ICH, with a specific focus on Domain 1, Oral Traditions and Expressions. The findings show that oral tradition encapsulates what is spoken, narrated, remembered, believed, and verbally transmitted. OA oral tradition captures myths, folktales, legends, cosmological beliefs, proverbs, idioms, omens, and oral wisdom. The study proposed an expert-informed framework that organizes OA oral heritage into four themes, sixteen facets, and related manifestation codes. This structure clarifies mythic origins, folk narratives, cosmic beliefs, and oral wisdom. The main value for planning is that the structure brings the spatial dimensions of oral tradition and expression into view. Lineage spaces, Adat jurisdictions, sacred ecological spaces, story landmarks, livelihood-mobility spaces, taboo-restriction spaces, and spirit-guardian spaces constitute the spatial framework through which oral traditions are anchored and safeguarded as ICH manifestations. The framework serves as a conceptual foundation for heritage mapping rather than a completed spatial inventory. Future site-specific mapping should be refined through sustained OA community participation and validation.

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SPATIAL INTERPRETATION OF ORANG ASLI PERFORMANCE HERITAGE

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Abstract

This paper identifies the cultural spaces sustaining Orang Asli (OA) performing arts within a planning-oriented framework for Intangible Cultural Heritage (ICH) Domain 2. Existing records often isolate dances, chants, healing ceremonies, instruments and symbolic enactments, obscuring their relationships within performance settings. The study combined semi-structured interviews with OA knowledge holders and community representatives with ethnographic materials, studies and heritage reports. Content analysis classified manifestations by performance form, occasion, cultural purpose, symbolic meaning and practice setting. Inductive-deductive thematic analysis interpreted their ritual, sonic, bodily and communal functions. Six experts assessed the framework using the Content Validity Index, informing four themes and sixteen facets. These encompass ritual and ceremonial performances, vocal and oral expressions, embodied enactments and instrument-led performances. Spatial analysis produced four conceptual layers and eight performance spaces, including healing grounds, ancestral settings, seasonal landscapes, processional routes and soundscapes. The framework strengthens performance-space inventories, landscape assessment, development screening and place-sensitive safeguarding.

Keywords: Orang Asli, Performing Arts, Intangible Cultural Heritage, Cultural Performance Spaces, Cultural Landscape

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INTRODUCTION

This paper forms part of a continuing effort to document and classify Orang Asli [OA] Intangible Cultural Heritage [ICH] across five ICH domains, with this paper focusing on Domain 2, Performing Arts.

OA performances in Peninsular Malaysia combine ritual, voice, movement, music and symbolic enactment. Distinct from related papers on oral traditions, social practices and ecological knowledge, this paper examines performative acts such as dances, chants, instruments and narrative performances. The study generates an expert-informed framework linking OA performance arts to ritual grounds, ancestral settings, seasonal landscapes, processional routes, vocal settings, soundscapes, movement arenas and symbolic stages.

LITERATURE REVIEW

Performing arts include music, dance, theatre, and embodied expressions that sustain cultural identity, social ties, and community values (UNESCO, 2003; Abu Bakar et al., 2025b). Among the OA, performance is rarely confined to one artistic form; song, movement, instruments, ritual and spiritual mediation often operate together. Studies of *Sewang* and related ceremonies show how performance translate to healing, ancestral relations and ecological balance (Jalaludin & Abdullah, 2020; Chan & Saidon, 2021; Salem et al., 2025a). *Hari Moyang* and masked performances likewise combine offerings, staged movement and symbolic objects to sustain ancestral memory and communal participation (Linggang et al., 2024; Zamzuri et al., 2024). Performative vocal traditions derived from dreams, ritual encounters and inherited narratives carry cosmological knowledge and collective memory, while instrumental and dance forms organize rhythm and gestures (Chan, 2023a; Narasid & Abdul Rahman, 2025). These studies establish the interdependence of performance forms, yet documentation remains dispersed across communities and subtypes, limiting comparative interpretation and access to heritage records.

OA performances largely depend on spatial conditions. Communal grounds accommodate circular formations and collective movement; ceremonial settings structure proximity between performers, healers and participants; and ancestral-related sites establish the spiritual context of particular rites (Chan & Saidon, 2021; Salem et al., 2025b; Linggang et al., 2024). Place therefore influences choreography, sound, audience arrangement, ritual sequence and the use of instruments or symbolic objects. Heritage mapping can record performance locations alongside their spatial configuration, seasonal use, access, environmental setting and community custodianship. A structured Domain 2 framework is needed to thematically classify OA performing arts and their spatial conditions, strengthening digital documentation, heritage planning, and community safeguarding (Abu Bakar et al., 2025a, 2025b).

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METHODOLOGY

This study forms part of a broader effort to document and classify OA ICH across five ICH domains. Although the related OA ICH papers use comparable methodological phases and validation procedures, this paper applies the process specifically to Domain 2: Performing Arts, with attention to embodied, vocal, ritual and instrumental expressions.

The corpus combined interview transcripts with OA knowledge holders and community representatives, supported by ethnographic records, academic publications and heritage reports. Analysis focused on performative manifestations, including healing rites, ceremonial performances, chants, dances, narrative enactments, instrumental practices and ensemble traditions. Each manifestation was examined through content analysis based on performance form, occasion, cultural function, symbolic meaning, participant role and practice setting. The coded materials were then interpreted using inductive-deductive thematic analysis to develop manifestation codes, facets and broader themes. This process enabled OA performing arts to be understood through ritual, sonic, bodily and communal dimensions. The resulting framework was reviewed by OA cultural and heritage experts using the Content Validation Index [CVI] to assess 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 2 manifestations. Symbolic meaning, performance form and cultural function were recorded.	Dataset of identified ICH manifestations, segmented corpus of data excerpts
Stage 2: Coding of ICH Manifestations under Domain 2	Identified manifestations were assigned manifestation codes to organize recurring cultural performances, ritual enactments, instrumental practices and ensemble forms.	Coded dataset of OA Performing Arts
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 2 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 2

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Semi-Structured Interviews

Semi-Structured interview sessions followed a checklist that ensured consistent coverage across communities while allowing participants to expand on their own performance knowledge. The checklist first recorded settlement background, social organization, household context, socio-demographic and socio-economic conditions, governance, environmental setting and heritage continuity. The interview directed discussion toward performing arts practices, including ritual performances, chants, songs, dances, narrative enactments, instruments, performer roles, learning processes, and performance settings. Participants comprised *Tok Batin*, elders, committee representatives and village members from different OA subgroups. Names were anonymized using codes, while role, subgroup and village location were retained for contextual analysis.

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 strengthened the interview findings through a review of 403 academic, institutional, community and media sources related to OA performing arts. Materials were selected for subgroup context, performance evidence and ICH Domain 2, performing arts relevance, then condensed into meaning units and organized into manifestation codes, facets and themes to support the performance-heritage classification (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 ritual performances, songs, chants, dances, musical instruments, movement, performance setting, and subgroup context.	No ICH or performing arts 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 performance arts, ritual enactment, music, dance, ceremonial performance or cultural presentation.	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 dances, chants, music, ritual performances, and performance roles.	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 performing arts, rituals, musical practices, dance forms, instruments or performance contexts.	Outdated claims without cultural relevance, unclear source basis or no link to performing arts.
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 domains and oral traditions.	Unrelated to ICH concepts or documentation.
8	Museum Archives	Museum records, exhibition notes, archive descriptions and heritage documentation.	Descriptions of OA performance objects, instruments, costumes, recordings and exhibition.	Records with unclear provenance and no identification of subgroups.
9	Community Publications	NGO materials, local publications, blogs, community websites and informal documentation.	Community-based accounts of OA dances, songs, rituals, performers, instruments or events.	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 performative expressions, cultural practices, beliefs, musical performances 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.

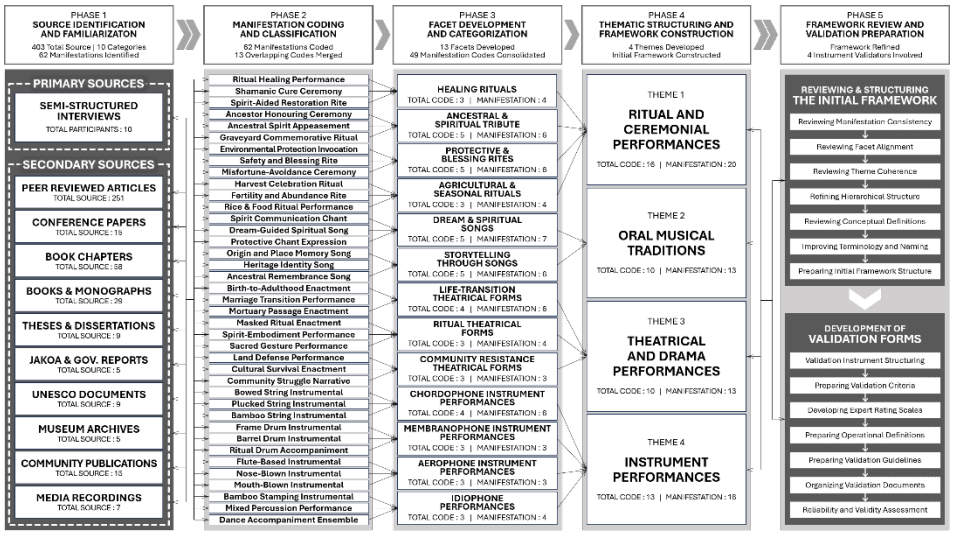


Figure 1: Initial Development and Construction of the ICH Domain 2 Framework

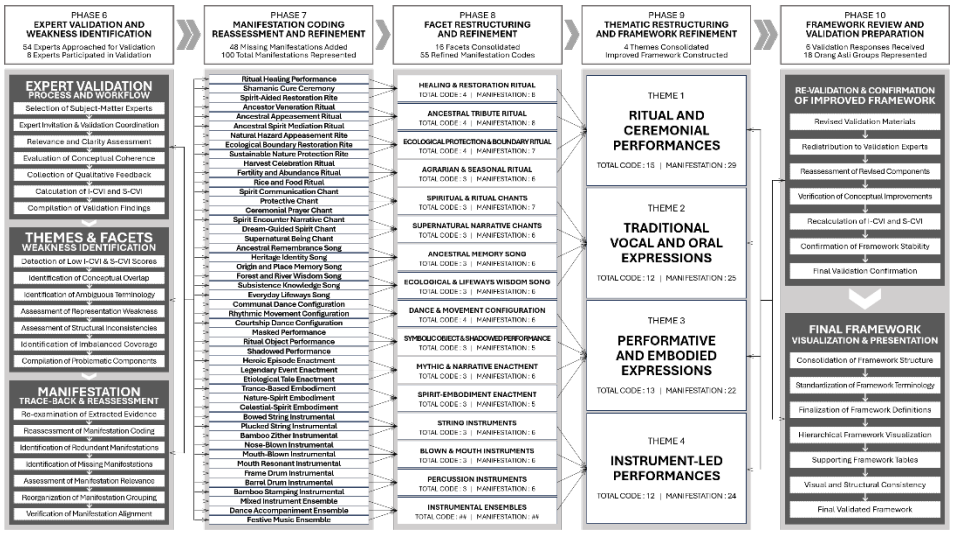


Figure 2: Expert Validation and Refinement of the ICH Domain 2 Framework

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 Department of Orang Asli Development (JAKOA) Expert in Indigenous welfare management and community support services	Suggested adding pathways, directions, landmarks, and culturally significant places, as location carries meaning in Orang Asli communities. Overlapping manifestations need clearer differentiation.	Landscape meanings are captured through ecological boundary, seasonal, forest-river wisdom, and harvest codes. Vocal forms and narrative enactment are separated by classifying chants, songs, and embodied stories under distinct performance categories.
Expert 2 Department of Orang Asli Development (JAKOA) Expert in Indigenous welfare management and community support services	Recommended that terms such as performer, audience, and genre should be localized or redefined, so they better reflect Orang Asli modes of practice, narration, and transmission.	Manifestations were refined to distinguish localized narratives, ancestral systems, and culturally specific oral traditions. Community and ancestral narratives were reorganized under *Ancestral Origins and Historical Narratives*.
Expert 3 GERIMIS Art Project (Cultural Organization) Expert in Indigenous Knowledge, Cosmologies, and Eco-Critical Cultural Studies	Recommended adding occasion, community significance, and belief-system integration. Each manifestation should state the Orang Asli group, area, and village, as practices vary by community and location. Indigenous terminology needs greater specificity.	The revised themes and facets clarify ritual purpose, belief-related performance, and sound-based forms. Metadata on tribe, locality, occasion, and context is needed because similar forms differ across OA groups. Analytical names ensure consistency, while Indigenous names remain at manifestation level to preserve community-specific terminology.
Expert 4 Institute of Environment and Development, Universiti Kebangsaan Malaysia Expert in Sustainable Livelihoods of Indigenous Communities, Heritage Conservation	Noted that the framework is a valuable effort but highlighted the overlapping and intersecting nature of domains, themes, and facets as a classification challenge requiring further refinement.	The framework was reorganised into four clearer themes to separate ritual action, vocal performance, embodied enactment, and instrumental expression, while still allowing intersections between belief, movement, sound, and ceremonial practice to be recognized.
Expert 5 Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin Expert in Indigenous people studies, Social Anthropology	Suggested incorporating Orang Asli pre-tree-cutting rituals, as they reflect belief systems and customary practices tied to the natural environment.	Theme 1 was refined by replacing the broad protective category with Ecological Protection and Boundary Ritual, capturing ecological and landscape rituals involving ceremony, invocation, or performative practice.
Expert 6 Kulliyyah of Sustainable Tourism and Contemporary Languages, International Islamic University Malaysia Expert in Humanities, Linguistic and Literature, Malay Language and Literature	Highlighted overlap across ritual, healing, and performance domains. Recommended clearer cross-domain mapping improve consistency. Some terms also require refinement to better reflect local cultural context.	Healing practices are placed under Restoration Ritual only when expressed through ceremony, chanting, or embodied action. Theme 2 was refined as *Traditional Vocal and Oral Expressions*, covering ritual chants, supernatural chants, and ancestral songs.

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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
Ritual and Ceremonial Performances	0.67	Healing Rituals	0.67	0.67
		Ancestral and Spiritual Tribute	0.67	
		Protective and Blessing Rites	0.67	
		Agricultural and Seasonal Rituals	0.67	
Oral Musical Traditions	0.50	Dream and Spiritual Songs	0.67	0.67
		Storytelling Through Songs	0.67	
Theatrical and Drama Performances	0.67	Life-Transition Theatrical Forms	0.67	0.61
		Ritual Theatrical Forms	0.67	
		Community Resistance Theatrical Forms	0.50	
Instrument Performances	0.67	Chordophone Instrument Performances	0.67	0.67
		Membranophone Instrument Performances	0.67	
		Aerophone Instrument Performances	0.67	
		Idiophone Performances	0.67	

Table 7: Revised Theme and Facets

Themes	Facets
Ritual and Ceremonial Performances	Healing and Restoration Ritual
	Ancestral Tribute Ritual
	Ecological Protective Blessing Ritual
	Agrarian and Seasonal Ritual
Traditional Vocal and Oral Expressions	Spiritual and Ritual Chants
	Supernatural Narrative Chants
	Ancestral Memory Songs
	Ecological and Lifeways Wisdom Songs
Performative and Embodied Expressions	Dance and Movement Configuration
	Symbolic Object and Shadow Performance
	Mythic and Narrative Enactment
	Spirit-Embodiment Enactment
Instrument-Led Performances	String Instruments (Chordophones)
	Blown and Mouth Instruments (Aerophones)
	Percussion Instruments (Membranophones & Idiophones)
	Instrumental Ensembles

The initial performing arts framework required refinement because several categories combined forms that operate differently in OA performance contexts. Songs, chants, ritual movements, spirit embodiment, symbolic objects, and instrumental practices were not clearly separated. The revised framework responds to this by distinguishing ritual and ceremonial performances, vocal and oral expressions, embodied enactments, and instrument-led performances. These groupings make it easier to identify how healing, ancestral tribute, ecological ritual, chant, dance, narrative staging, and musical accompaniment function within performance. Rather than treating OA performing arts as isolated artistic forms, the revised structure presents them as interconnected expressions shaped by sound, movement, belief, and communal participation.

Table 8: Revised Themes and Facets Definitions

Themes & Definitions	Facets & Definitions
Ritual and Ceremonial Performances *Performative acts carried out in sacred, communal, or ceremonial contexts to restore balance, honour spiritual relations, secure protection, or mark seasonal cycles.*	**Healing and Restoration Ritual** *Ritual acts aimed at curing illness, restoring balance, and renewing spiritual or communal well-being.*
	Ancestral Tribute Ritual *Ritual acts honouring ancestors, Moyang, or spiritual predecessors through offerings, music, dance, or invocation.*
	Ecological Protection and Boundary Ritual *Ritual acts protecting communities from natural misfortune and restoring respectful human–nature relations.*
	Agrarian and Seasonal Ritual *Ritual acts marking planting, harvest, fertility, seasonal change, or human relationships with land and nature.*
Traditional Vocal and Oral Expressions *Orally transmitted songs, chants, and verbal forms that preserve cultural memory, spiritual knowledge, ecological values, and communal identity.*	**Spiritual and Ritual Chants** *Chanted vocal forms used in healing, trance, Sewang, spirit contact, or sacred ritual communication.*
	Ancestral Memory Songs *Songs preserving ancestral remembrance, village history, past events, lineage memory, or inherited communal knowledge.*
	Spirit Encounter Songs *Songs narrating encounters with spirits, dragons, Moyang, forest beings, or other supernatural presences.*
	Ecological and Lifeways Wisdom Songs *Songs conveying ecological knowledge, everyday experiences, moral values, social norms, gratitude, warnings, and cultural identity within community life.*
Performative and Embodied Expression *Cultural expressions using bodily movement, dramatic enactment, staged play, or symbolic embodiment to communicate shared meanings.*	**Dance and Movement Configuration** *Bodily performances using coordinated movement, gesture, rhythm, or dance to express cultural meaning.*
	Symbolic Object and Shadowed Performance *Performances using crafted figures, objects, shadows, or symbolic forms to animate stories and cultural meanings.*
	Mythic and Narrative Enactments *Dramatized storytelling that performs myths, origin tales, legends, or heroic episodes through narrated action.*
	Spirit-Embodiment Enactment *Ritualized performances where performers embody spirits, animals, ancestors, or sacred beings through movement and presence.*
Instrument-Led Performances *Musical expressions centred on traditional instruments that shape rhythm, melody, atmosphere, accompaniment, or ensemble participation.*	**String Instruments** *Instruments producing sound through vibrating strings, used for melody, accompaniment, or expressive performance.*
	Blown and Mouth Instruments *Instruments sounded by blown air, through the mouth, tube, reed, or bamboo body, used for melody, signalling, ritual ambience, or communication.*
	Percussion Instruments *Instruments producing rhythm through striking, shaking, scraping, stamping, or vibrating bodies and membranes.*
	Instrumental Ensembles *Combined instrumental performances where multiple instruments create coordinated rhythm, melody, or communal accompaniment.*

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 – Ritual and Ceremonial Performances

Facets	Codes	Examples of Manifestation	Groups
Healing and Restoration Rituals	Ritual Healing Performance	***Niksoi Belak Penyakit*:** A communal Sewang (singing and dancing) performed to heal someone who has fallen ill.	Jah
		***Ngilai* Ritual:** A therapy for the sick and a strengthening community ties and spiritual balance.	Ter
	Shamanic Cure Ceremony	***Kabut Sewang:*** A rite led by a shaman who sings *Jenulak* songs believed to have been gifted in dreams.	Sem
		***Cucaw* Ritual:** A shaman-led ritual to protect family members from the deceased's harmful spiritual influence (*Badi*).	Sem
	Spirit-Aided Restoration Rite	***Tenamoh* Ritual:** A gathering with songs, drumming, and dancing to comfort the deceased's spirit and family.	Sem
		***Gabag Gelap* Ritual:** A nighttime ritual in complete darkness to drive away sickness and danger.	Sem
Ancestral Tribute Ritual	Ancestor Veneration Ritual	***Ari Muyang Darat:*** A communal and family gathering within village with dance and music to joyfully honor the ancestors	Mah
		***Berjerom* Ritual:** A lively *Sewang* honoring ancestors through dance, music, songs, and carved spirit figures.	Jah
	Ancestral Appeasement Ritual	***Jis Genggulang:*** A three-night dance circle to appease land spirits and show communal respect before jungle clearing.	Sem
		Sewang Chenchem: Slow rhythmic dance in darkness, with shamanic song, guides a grieving spirit toward peaceful release.	Tem
	Ancestral Spirit Mediation Ritual	***Puja Pantai:*** A beachward community procession of dance and song, accompanying the shaman's ancestral spirit descent.	Mah
		Genabak Pehnooh: a Sewang sing and dance to communicate with forefathers to heal illness, seek blessings and uplift spirits.	Tem
Ecological Protection and Boundary Ritual	Natural Hazard Appeasement Rite	***Sewang Karei:*** Desperate chanting and frantic dancing appease thunder deity *Karei* after environmental taboos are broken.	Bat/Ken/ Jai/Tem
		Sewang Genggulang: Altar dancing, incantations, and bamboo stamping ward off climate anomalies and environmental curses.	Sem/Mah
	Ecological Boundary Restoration Rite	***Sewang Selombang:*** Frantic circle-dancing, chants, and bamboo rhythms to restore boundaries with water systems.	Tem
		Sewang Kabut: Overnight closed ritual dance and bamboo stamping to cool forest *ruwai* and restore balance.	Sem
	Sustainable Nature Protection Rite	***Sewang Pungei:*** Circle-dancing, chanting, and bamboo stamping appease plant spirits and prevent over-harvesting.	Sem/Tem
		Sewang Semak Alam: Rhythmic animal mimicry encouraging interspecies empathy and sustainable harvesting.	Sem/Tem
Agrarian and Seasonal Ritual	Harvest Celebration Ritual	***Tarian Siamang Tunggal:*** A harvest celebratory performance honoring the forest through animal-mimicry dance.	Tem
		***Ngengsaak**:* Dance circle with singing (*jenulak*) and music (*gengsak*) staged for harvest thanksgiving celebration.	Sem
	Fertility and Abundance Ritual	***Nopoh Bukau:*** Sacred singing séance ritual performed to ask spirit to blossom more flowers in the forest for fruit seasons.	Che
		Pinloin: A song-and-dance performance asking the spirit (*chenoi*) to help the tree produce abundant fruit.	Jah
	Rice and Food Ritual	***Sewang Semangat Padi***: Post-harvest group *Sewang* thanking hill-rice spirits and celebrating completion of paddy harvesting.	Tem/Sem /Sel
		Sewang Uwi: A grateful Sewang honoring cassava and forest tubers through song, dance, and thanksgiving.	Tem/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).

Table 10: Theme 2 – Traditional Vocal and Oral Expression

Facets	Codes	Examples of Manifestation	Groups
Spiritual and Ritual Chants	Spirit Communication Chant	***Lagu Jo'o Balai:*** An opening chant to o summon, greet, and open communication lines between Tok Halak and spirits.	Tem
		Amek Tolong Jar: A pleading chant to establish direct contact with ancestral protectors during times of great vulnerability	Bat
	Protective Chant	***Lagu Tepung Tawar:*** A defence chant to ward off gunik and block bad luck from breaching the community.	Tem/Sem /Mah
		Irama Rambutan Gading: An ancient protective chant to ward off environmental toxins, spiritual decay, and misfortune.	Sem
	Ceremonial Prayer Chant	***Lagu Pusing Tamuk Tawin:*** A rhythmic prayer song to seek communal rejuvenation, vitality, and health.	Bat
		Lagu Pulai Bergantung: A ceremonial chant of gratitude to the canopy and forest spirits for shelter and foraging materials.	Tem/Sel
Super-natural Narrative Chants	Spirit Encounter Narrative Chant	***Pinloin Cel Yop Selantis:*** A vocal narrative of the shaman's owl-spirit encounter, tracing its calls, movements, and omens.	Jai
		Moyang Bojos: A song narrating an ancestral encounter with the playful yet volatile *Bojos* spirit in coastal mangroves.	Mah
	Dream-Guided Spirit Chant	***Chinchem:*** A dream-revealed chant restoring community morale and spiritual boundaries against outside chaos.	Tem
		Pinloin Salom Pangwei: A dream-taught chant tracing wild Salom fruit drifting through forest rivers.	Jai
	Super-natural Being Chant	***Awang Muda Diawan:*** A heavy incantatory ritual song summoning *Awang Muda Diawan* from the celestial heavens.	Jah
		Telei Bah Peb: A ritual song invoking Telei, the flora deity of jungle vegetation, life cycles, and rebirth.	Tem
Ancestral Memory Song	Ancestral Remembrance Song	***Song of Ganding***: A lively rhythmic song performed during ancestral days, recalling Carey Island's natural environment.	Mah
		Song of Tok Naning: A song that narrates the story of Tok Naning, an ancestral spirit who protects the village.	Mah
	Heritage Identity Song	***Jinjang:*** A song passed down from pre-war era as oral archive to retain and safeguard specific tribal histories.	Tem/Sem
		Kamiq Kon Seletar: A song narrating the history of nomadic sea people (*Orang Laut*) navigating Straits of Johor	Ors
	Origin and Place Memory Song	***Ajin:*** A spirit-given settlement song guiding migration and founding Ajin through sung geographic knowledge.	Tem
		Kod Angkod: A rhythmic foraging song that maps ancestral lands and guides movement through forest food routes.	Bat/Men
Ecological and Lifeways Wisdom Song	Forest and River Wisdom Song	***Lagu Kuwang Kuit:*** A lyrical river-lore song teaching river health through flying foxes, archer fish, and dusk fishing.	Mah
		Lagu Ce'ep Tiong: A bird-wisdom song tracking Hill Myna flight patterns to predict monsoon shifts and storms.	Tem
	Subsistence Knowledge Song	***Lagu Tualang:*** A harvesting song whose rhythm and humming soothe wild honeybees during *Tualang* tree honey extraction.	Jak/Tem
		Lagu Menyumpit: A narrative hunting song about forest tracking, blowpipe traditions, and ipoh sap knowledge.	Sen/Tem
	Everyday Lifeways Song	***Lagu Menganyam Tikar:*** A conversational song sung while weaving pandanus or nipah leaves into mats and baskets.	Tem/Mah
		Lagu Dodoi Anak: A gentle native lullaby using forest imagery to soothe infants to sleep.	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 – Performative and Embodied Expressions

Facets	Codes	Examples of Manifestation	Groups
Dance and Movement Confi-guration	Communal Dance Confi-guration	***Sewang Lanok:*** A full-community dance uniting villagers through parallel formations, and resonant bamboo percussion.	Tem
		Tarian Monggeng: A communal festival dance mimicking forest animal migration through lines and circles.	Mah
	Rhythmic Movement Confi-guration	***Tarian Ketam Jengkeng:*** A synchronized low-line dance mimicking mangrove crabs through sideways movements.	Ors
		Floor Stamping: Tightly spaced dancers perform heavy synchronized foot-stamping to accent bamboo percussion.	Sem/Ter
	Courtship Dance Confi-guration	***Tarian Saputangan:*** A courtship dance where dancers use cloths to create rhythmic closeness without physical contact.	Tem
		Ragam Kapek: A formation using mirrored twists and shuffling steps to express playful attraction without physical contact.	Tem
Symbolic Object and Shadow Perfor-mance	Masked Perfor-mance	***Genggulang:*** A masked land-clearing performance using woven leaf to symbolize forest gatekeepers.	Sem
		Mayin Jo'oh: A masked ancestral performance using carved wooden spirit figures to enact pranks and teach moral lessons.	Mah
	Ritual Object Perfor-mance	***Bunga Moyang:*** Ancestral offering object carried and ritually activated during Hari Moyang ceremonies.	Mah
		Lancang: A boat-making and performance that carries away illness and misfortune through a miniature wooden vessel.	Mah
	Shadowed Perfor-mance	***Wayang Kulit* Adaptation:** Shadow puppetry using bark or leaf figures to perform early encounters with jungle spirits.	Sem
		Grassroots Silhouette: A contemporary shadow theatre performance contrasting nature with destructive machinery.	Sem
Mythic and Narrative Enactment	Heroic Episode Enactment	***Tok Naning:*** A dramatic song-and-dance re-enactment of Tok Naning defending Carey Island from historical invaders.	Mah
		Mamak Bongsu: A survival chant with bamboo stamping, voicing flood panic and heroic endurance triumphant tone.	Tem
	Legendary Event Enactment	***Bujang Manau***: Reenactment of the Rotan Manau harvesting expedition through synchronized hauling movements.	Tem
		The Great Celau Deluge: Reenactment of the great flood caused by broken taboos through frantic, panicked movements.	Bat/Tem
	Etiological Tale Enactment	***Moyang Ampai:*** Reenactment portraying the legendary birth of the first jellyfish through drifting ocean-like movements.	Mah
		The Origin of Sewang: Reenactment the ancestral dream where spirits taught sacred healing rhythms and chants.	Sem/Ter
Spirit Embo-diment Enactment	Trance-Based Embo-diment	***Gabag Gelap:*** A trance performance where dancers strike themselves with sacred flower bundles during Dark Sewang.	Ter
		Sewang Nyuk: A trance embodiment performance where *nyuk* dancers chant mantras before becoming possessed by spirits.	Sem/Ter
	Nature-Spirit Embo-diment	***Sewang Panoh:*** Embodiment of the tiger spirit through crouching, growling, and pouncing movements of a wild tiger.	Ter
		Moyang Buaya: Embodiment of the crocodile spirit through flatten body, slithering and snapping movements.	Mah
	Celestial-Spirit Embo-diment	***Sewang Chenoi:*** Embodiment of the sky entity (*cenoi*) through ethereal vocals and weightless movements.	Ter
		Sewang Karei: Embodiment of thunder (*karei*) through urgent chanting, forceful footwork, and storm-calming movement.	Ter/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).

Table 12: Theme 4 – Instrument-Led Performance

Facets	Codes	Examples of Manifestation	Groups
String Instrument	Bowed String Instru-mental	***Biola:*** Bowed string performance producing sustained melody and ornamented phrasing through controlled bowing.	ALL
		Rebab: Bowed lute performance producing melodic tones through bowing, fingering, and pitch shaping.	ALL
	Plucked String Instru-mental	***Gitar Kayu:*** Wooden six-string performance using finger-plucked tones from a triangular-bodied chordophone.	ALL
		Ukulele: Modern-adapted plucked string performance producing bright chords and light melodic accompaniment.	ALL
	Bamboo Zither Instru-mental	***Kereb:*** Bamboo zither performance using plucked or struck strings to create resonant melodic-rhythmic patterns.	Sem/Ter/ Jah/Seq
		Keranting: Bamboo string performance using plucked multi-string resonance to produce layered melodic-rhythmic tones.	Sem/Ter/ Jah/Seq
Blown and Mouth Instrument	Nose-Blown Instru-mental	***Pensol:*** Nose-flute performance producing breath-softened melodies through nostril airflow and finger-controlled pitch.	Sem
		Bangsi: Nose-flute performance producing airy melodies through nasal airflow, controlled fingering, and tonal shading.	ALL
	Mouth Blown Instru-mental	***Seruling:*** Mouth-flute performance producing clear melodies through breath control, embouchure, and finger-hole variation.	ALL
		Si-oi/Sioi: Transverse bamboo flute performance producing side-blown melodies through breath control and fingering.	Sem/Ter/ Jah/Seq
	Mouth Resonant Instru-mental	***Ginggong:*** Natural mouth-resonant performance producing insect-like tones through finger-and-tongue vibration.	ALL
		Genggong: Metal mouth-resonant performance producing buzzing tones through finger-and-tongue vibration.	ALL
Percussion Instrument	Frame Drum Instru-mental	***Rebana:*** Frame-drum performance producing hand-struck rhythmic accents, rolling beats, and repeated pulse structures.	ALL
		Kompang: Hand-held frame-drum performance producing interlocking beats, syncopation, and rhythmic layering.	ALL
	Barrel Drum Instru-mental	***Tambur:*** Barrel-drum performance using beaters to produce deep rhythmic pulses and strong percussive emphasis.	ALL
		Gendang Semarang: Drum performance using alternating strikes to produce rhythmic variation and dynamic accents.	Mah/Ors/ Orl/Jak
	Bamboo Stamping Instru-mental	***Tung-Tung:*** Bamboo percussion performance using paired striking to produce hollow rhythmic cycles and tempo control.	Mah
		Buluh Centong: Bamboo stamping performance producing repeated pitched rhythms through floor-struck bamboo tubes.	ALL
Instru-mental Ensembles	Mixed Instrument Ensemble	***Kereb–Pensol Ensemble:*** Instrumental pairing of kereb and pensol producing string resonance and nose-flute melody.	Sem
		Contemporary String Ensemble: Combination of Gitar Kapok, Ukulele, Biola, or Seruling for evolving performance.	ALL
	Dance Accom-paniment Ensemble	***Oghayo-Oghayo:*** Ensemble using *Buluh Centong* with rhythmic stamping patterns to support Seletar dance movement.	Ors
		Sewang Ensemble: Ensemble combining *pensol, tung-tung, rebana*, and vocal rhythm to support Sewang movement.	ALL
	Festive Music Ensemble	**Drum-Led Festivity:** Ensemble using *Tambur, Gendang Semarang, Rebana*, or *Kompang* for rhythmic accompaniment.	ALL
		Puja Pantai Ensemble: Coastal festival ensemble using drums, gongs, and bamboo rhythm for procession performances.	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).

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Tables 9–12 establish the internal classification of OA performing arts through themes, facets and manifestation codes. To develop the cultural spaces component, these codes were then re-read for the spatial conditions embedded in their examples. Healing rituals, shamanic cure ceremonies, spirit-aided restoration rites and trance-based embodiments pointed to healing and restoration spaces. Ancestor veneration, ancestral appeasement, *Moyang*-related rituals and spirit mediation indicated ancestral tribute spaces. Ecological boundary rituals, harvest celebrations, fertility rites and rice or food rituals pointed to seasonal ritual landscapes. *Puja Pantai*, festive ensembles and ceremonial movements indicated processional routes. Chants, ancestral songs, spirit encounter songs and ecological wisdom songs pointed to vocal transmission spaces. Instrumental codes involving strings, blown instruments, percussion, bamboo stamping and ensembles indicated soundscape spaces. Dance formations, courtship movement, masked performance, symbolic objects, mythic enactments and spirit embodiment pointed to movement arenas and staged performance spaces.

Based on this reading, Table 13 groups the recurring spatial meanings into four planning-oriented cultural spaces: restorative and ancestral ritual, ritual landscape and procession, vocal and instrumental soundscape, and embodied performance and symbolic staging. The eight cultural spaces under these layers were derived from the performance functions and spatial requirements found across the manifestation codes. Table 14 then applies these spaces back to each code, showing how OA performing arts can inform planning concerns related to ritual grounds, processional routes, performance arenas, soundscape protection, symbolic staging areas and culturally appropriate spaces for safeguarding living performance heritage.

Table 13: Planning-Oriented Cultural Space Framework

Layers	Code	Cultural Spaces	Definition
Restorative and Ancestral Ritual	**A**	Healing Trance Performance Space	Spaces for healing rituals, shamanic curing, trance, and spirit restoration.
	B	Ancestral Tribute Performance Space	Spaces for ancestral honouring, *Moyang* veneration, offerings, and spirit mediation.
Ritual Landscape and Procession	**C**	Ecological Seasonal Ritual Landscape	Landscapes for ecological protection, harvest thanksgiving, fertility, and seasonal renewal.
	D	Processional Festive Performance Route	Routes for ceremonial movement, beachward procession, village circulation, and festivity.
Vocal and Instrumental Soundscape	**E**	Vocal Chant Transmission Space	Settings for ritual chants, spirit communication, ancestral memory, and songs.
	F	Instrumental Ensemble Soundscape Space	Spaces structured for bamboo stamping, rhythm, melody, and other instruments ensembles.
Embodied Performance and Symbolic Staging	**G**	Communal Dance Movement Arena	Arenas for dance circles, formations, courtship movement, and communal participation.
	H	Spirit Narrative Staging Space	Stages for myths, spirit embodiment, masked enactment, and symbolic objects.

Table 14: Spatial Interpretation of ICH Manifestation Codes

Themes	Facets	Manifestation Codes	Cultural Spaces (Coded)							
			A	B	C	D	E	F	G	H
Ritual and Ceremonial Performances	Healing & Restoration Ritual	Ritual Healing Performance	/				/		/	
		Shamanic Cure Ceremony	/				/			/
		Spirit-Aided Restoration Rite	/				/	/	/	/
	Ancestral Tribute Ritual	Ancestor Veneration Ritual		/			/	/	/	/
		Ancestral Appeasement Ritual		/	/		/		/	/
		Ancestral Spirit Mediation Ritual		/		/	/	/	/	/
	Ecological Boundary Ritual.	Natural Hazard Appeasement Rite			/		/	/	/	/
		Eco-Boundary Restoration Rite			/		/	/	/	/
		Sustainable Nature Protection Rite			/		/	/	/	/
	Agrarian and Seasonal Ritual	Harvest Celebration Ritual			/	/	/	/	/	
		Fertility and Abundance Ritual			/		/		/	/
		Rice and Food Ritual			/	/	/		/	/
Traditional Vocal and Oral Expressions	Spiritual and Ritual Chants	Spirit Communication Chant		/			/			/
		Protective Chant			/		/			/
		Ceremonial Prayer Chant	/		/		/			/
	Supernatural Narrative Chants	Spirit Encounter Narrative Chant			/		/			/
		Dream-Guided Spirit Chant			/		/			/
		Supernatural Being Chant			/		/			/
	Ancestral Memory Songs	Ancestral Remembrance Song		/	/		/			/
		Heritage Identity Song		/		/	/			
		Origin and Place Memory Song		/	/	/	/			/
	Lifeway Wisdom Songs	Forest and River Wisdom Song			/		/			
		Subsistence Knowledge Song			/		/			
		Everyday Lifeways Song					/			
Performative and Embodied Expressions	Dance and Movement Configuration	Communal Dance Configuration			/	/		/	/	
		Rhythmic Movement Config.			/			/	/	
		Courtship Dance Configuration							/	
	Symbolic Object Performance	Masked Performance		/	/					/
		Ritual Object Performance	/	/						/
		Shadowed Performance			/					/
	Mythic and Narrative Enactment	Heroic Episode Enactment		/	/	/	/	/	/	/
		Legendary Event Enactment			/	/			/	/
		Etiological Tale Enactment		/	/		/	/	/	/
	Spirit-Embodiment Enactment	Trance-Based Embodiment	/				/		/	/
		Nature-Spirit Embodiment			/				/	/
		Celestial-Spirit Embodiment			/		/		/	/
Instrument-Led Performances	String Instruments	Bowed String Instrumental						/		
		Plucked String Instrumental						/		
		Bamboo Zither Instrumental						/		
	Blown and Mouth Instruments	Nose-Blown Instrumental						/		
		Mouth-Blown Instrumental						/		
		Mouth-Resonant Instrumental						/		
	Percussion Instruments	Frame Drum Instrumental						/		
		Barrel Drum Instrumental						/		
		Bamboo Stamping Instrumental						/	/	
	Instrumental Ensembles	Mixed Instrument Ensemble						/		
		Dance Accompaniment Ensemble					/	/	/	
		Festive Music Ensemble				/		/	/	

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DISCUSSION

The validation findings guided refinement of the initial framework. Theme-level I-CVI values ranged from 0.50 to 0.67, while S-CVI values ranged from 0.61 to 0.67, indicating overlap among vocal, theatrical, ritual and instrumental categories. Expert feedback informed a revised structure comprising (i) Ritual and Ceremonial Performances, (ii) Traditional Vocal and Oral Expressions, (iii) Performative and Embodied Expressions, and (iv) Instrument-Led Performances. These themes distinguish healing, chanting, storytelling, movement, symbolic enactment and musical accompaniment while retaining their interconnections.

The result further shows that OA performing arts depend on spatial conditions. Healing and trance practices require restorative ritual settings; ancestral ceremonies occupy tribute and mediation spaces; ecological and seasonal performances are tied to forests, agricultural areas, beaches and other ritual landscapes. Processions rely on connected routes, while chants and instrumental traditions require settings that support vocal transmission, rhythm and communal listening. Dance formations, spirit embodiment, masks and ritual objects also require movement arenas and culturally appropriate staging areas.

Tables 13 and 14 translate these relationships into four heritage-mapping layers and eight performance spaces. This broadens heritage planning beyond fixed venues by recognizing ritual grounds, processional routes, soundscapes, seasonal landscapes, dance arenas and symbolic stages as living cultural infrastructure. The framework support cultural landscape assessment, performance-space inventories and community-based safeguarding.

CONCLUSION

OA performing arts emerge from this study as integrated systems of ritual, voice, movement, symbolic enactment and instrumental sound. Their organisation into four themes and sixteen facets provides a clearer basis for distinguishing performance functions without separating elements that operate together in practice. The heritage-mapping analysis adds an important planning dimension by identifying the settings that enable these performances to continue. Ritual grounds, ancestral spaces, ecological landscapes, procession routes, soundscapes, dance arenas and symbolic staging areas function as cultural infrastructure for the ICH manifestations. Recognizing these spaces strengthen heritage inventories, cultural landscape assessment and community-based safeguarding.

As a planning foundation, the framework guide later site-level mapping across OA communities by documenting performance locations, movement routes, spatial requirements, access conditions and seasonal use. Its application should be sustained through long-term collaboration with communities, while respecting local performance contexts, community custodianship and the protection of sacred or restricted knowledge.

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VISITORS' WILLINGNESS TO PAY FOR IMPROVED SOLID WASTE MANAGEMENT AT BATU HITAM BEACH

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Abstract

Batu Hitam Beach is a growing tourism site in Pahang that offers an aesthetic view, particularly its black volcanic stones along the shoreline. However, the rising number of visitors and the expansion of beach activities have increased solid waste generation. It creates challenges for the current solid waste management at Batu Hitam Beach. This study aims to estimate the visitors' willingness to pay and to analyse the factors influencing visitors' willingness to pay for improved solid waste management at Batu Hitam Beach. This study employs a questionnaire survey using the Contingent Valuation Method with integration of the Theory of Planned Behaviour. This study focuses on how sociodemographic factors and behavioural determinants, which are attitude and perceived behavioural control influences willingness to pay. A questionnaire survey was conducted among 166 visitors, and the data were analysed using descriptive statistics and logistic regression. The estimated average willingness to pay is RM2.12 per visit for improved solid waste management provides a useful reference for designing a small visitor contribution scheme to strengthen solid waste management services. The findings also show that visitors' willingness to pay was positively influenced by their perceived behavioural control, while attitude was not found to be a significant factor. It suggests the management strategies to prioritise strengthening visitors perceived ease and confidence to contribute through clear information on fund use, simple payment options, and visible improvements in cleanliness and facilities.

Keywords: Contingent Valuation Method, Perceived Behavioral Control, Coastal Tourism, Visitor Contribution

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INTRODUCTION

Solid waste management (SWM) refers to the systematic handling of solid waste from generation to final disposal, including storage, collection, transport, treatment, and disposal, supported by administrative, financial, legal, planning, and technical functions (UNEP, 2016). In Malaysia, more than 38,000 metric tons of solid waste are generated daily, with an annual growth of 3% (SWCorp, 2022). Malaysia's heavy reliance on landfilling raises long-term concerns related to land scarcity, pollution, and greenhouse gas emissions (Afroz & Masud, 2011; Fauziah & Agamuthu, 2012). This creates greater pressure on SWM including in critical tourism-growing areas, where there are rising solid waste generation due to tourism activities.

The coastal tourism sector further intensifies these challenges. Common beach activities such as picnicking, swimming, and street vending generate considerable amounts of solid waste, particularly plastics and food packaging. In addition, inadequate infrastructure, such as insufficient bins, and limited recycling facilities, together with weak enforcement against littering can further deteriorate beach conditions (Saengsupavanich et al., 2024). These conditions add pressure on local authorities responsible for SWM, especially as many already face financial constraints that limit their ability to cope effectively with rising solid waste generation (Yusof et al., 2025).

This issue is particularly relevant in Pahang coastline, a growing coastal tourism destination in Malaysia. This includes Batu Hitam Beach, a popular coastal attraction that experiences increasing visitor arrivals, especially during weekends and public holidays. This trend intensifies pressure on the existing SWM due toincreasing solid waste generation. Kamarudin et al., (2021) found that most marine litter, including Batu Hitam Beach shoreline, originated from land-based sources with plastics being the dominant component.

Despite the clear link between tourism and solid waste, empirical evidence on visitors' willingness to pay (WTP) for improved SWM at Malaysian coastal sites is limited. This study addresses the gap by assessing Batu Hitam Beach visitors' WTP to support improved SWM by employing the Contingent Valuation Method (CVM), together with the Theory of Planned Behaviour (TPB). As applied in previous studies, CVM is used to value non-market environmental improvements and estimate WTP through hypothetical scenarios (Carson et al., 2001; Mitchell & Carson, 2005; Afroz & Masud, 2011; Subhan et al., 2020; Haron et al., 2023; Girma et al., 2023).

The objectives of this study are to analyse the factors influencing WTP for improvements in SWM at Batu Hitam Beach and to estimate the value of WTP for such improvements. The findings are expected to provide insights into visitors' demand for improved SWM to support the development of practical and publicly supported SWM strategies by the local authority. Given the financial

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constraints often faced by local authorities, evidence on visitors' WTP may provide a useful basis for more targeted and feasible SWM improvements at Batu Hitam Beach.

LITERATURE REVIEW

Solid Waste Management

SWM remains a critical global environmental challenge due to its implications for public health, environmental sustainability, and overall quality of life (Nik Ab Rahim et al. 2024). The issue is especially pronounced in coastal tourism areas, where recreational activities contribute to rising volumes of solid waste. Poorly managed solid waste, particularly plastics, food packaging, and other non-biodegradable materials, can significantly degrade coastal ecosystems and reduce the aesthetic value of beach destinations. Effective SWM is therefore essential to preserve environmental quality, protect public health, and sustain tourism appeal (UNEP, 2016). In Malaysia, these challenges are intensified by rapid tourism growth, while limited financial resources and public participation continue to constrain effective implementation (Agamuthu & Fauziah, 2011).

Willingness to Pay for Solid Waste Management

WTP refers to the maximum amount individuals or households are prepared to spend for improved SWM and is widely used in environmental economics to value non-market goods (Mitchell & Carson, 2005). Previous studies showedpositive public support for improved SWM in Sri Lanka, Ethiopia, and India, with WTP influenced by income, awareness, and service quality (Yohannes et al., 2021; Wana & Ali, 2024). In Malaysia, studies similarly reportedhousehold willing to pay for better solid waste collection, recycling, and disposal systems. However, WTP declines as proposed charges increase (Othman, 2006; Haron et al., 2023; Nik Ab Rahim et al. 2024).

Factors Influencing Willingness to Pay

Various factors influence people's WTP for improved SWM, including socio-economic aspect. Household income is one of the most consistently identified factors. Households with higher income typically show greater WTP, as they have more financial flexibility to pay for SWM. Boateng et al. (2019) found that households with higher monthly income were more likely to pay additional charges for solid waste collection. Similarly, Wana and Ali (2024) reported that households in Srinagar, India, with stable and higher income levels had a greater likelihood of paying for improved SWM. These findings are consistent with economic theory, which suggests that affordability influences both the ability and WTP for non-market services.

Educational level also significantly influences WTP. Individuals with higher levels of education are generally more willing to financially support SWM improvements. It is because they tend to be more environmentally aware and better informed about the consequences of improper SWM. Alam et al. (2010) and Zhang et al. (2016) found that respondents with higher educational attainment were more likely to support and pay for SWM. This suggests that education can enhance public trust in government and service providers, thereby increasing compliance with user-funded schemes, including visitors' payments for SWM at beach destinations.

Integration of Contingent Valuation Method with Theory of Planned Behaviour

CVM is a stated preference technique widely used in environmental economics to estimate the value of non-market goods and services. In this method, individuals are presented with a hypothetical market in which they are asked their maximum WTP for a specific environmental improvement or to avoid a potential loss. As formalised by Mitchell and Carson (2005), CVM is particularly useful for valuing public goods without observable market prices, such as SWM, water supply, or sewage treatment. In the context of SWM, CVM has been widely applied to assess public support for SWM improvements in both developed and developing countries. Mitchell and Meade (2001) noted that CVM remains a reliable valuation method for policy analysis, while Whittington (2010) highlighted its relevance in low- and middle-income countries where formal pricing systems for public services are often limited.

To complement the economic focus of CVM, this study draws on selected elements of TPB, a psychological framework developed by Ajzen (1991) to explain deliberate behaviour. Although TPB consists of attitude towards behaviour, subjective norm, and perceived behavioural control, this study focuses only on attitude and perceived behavioural control for conceptual and practical reasons. In the context of Batu Hitam Beach, WTP for a small parking-fee mechanism is mainly an individual, on-site economic decision. Therefore, visitors' personal evaluation of the benefits and their perceived affordability are expected to be more influential than social pressure from others.

Attitude towards behaviour refers to an individual's positive or negative evaluation of performing a behaviour, which it relates to visitors' views on paying for better SWM services at Batu Hitam Beach. Visitors who believe that such contributions will improve beach cleanliness and environmental quality are more likely to report positive WTP. Subjective norm refers to an individual's perception of social pressure from important others to perform or not perform a behaviour. In this context, it reflects whether visitors feel encouraged by family, friends, or society to support or contribute financially to improved SWM services.

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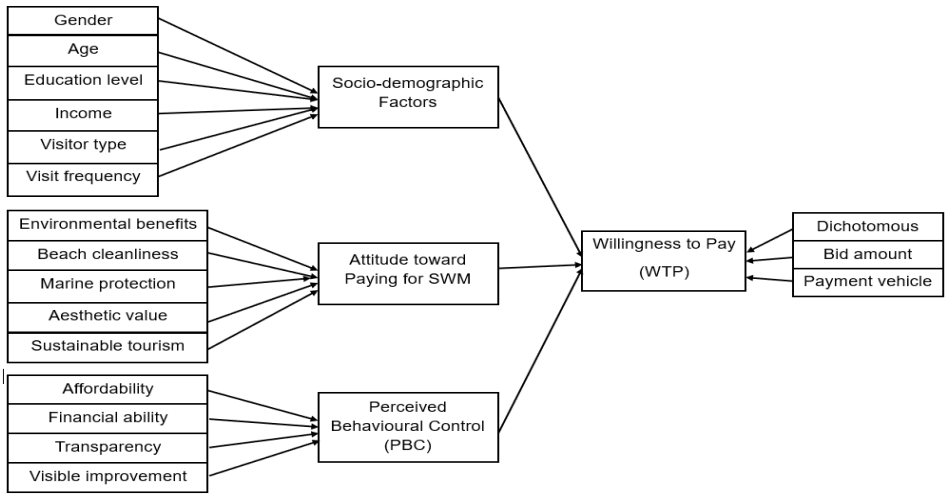
Perceived behavioural control refers to an individual's perception of their ability to perform the behaviour, including whether they feel financially capable of contributing through voluntary fees or environmental charges.

These two TPB elements help explain the psychological factors underlying stated WTP responses. Previous studies have shown that positive environmental attitudes and stronger perceived control can significantly increase WTP for environmental improvements (Chen & Tung, 2010; Ramayah et al., 2012; Irfan et al., 2020). Studies such as Subhan et al. (2020) and Girma et al. (2023) further demonstrated that attitude and perceived control were significant predictors of WTP for improved SWM. By combining CVM with these selected TPB constructs, this study provides a more comprehensive basis for understanding and promoting community-supported SWM at Batu Hitam Beach.

Research Gap

Despite increasing research on WTP for improved SWM, several gaps remain. Most previous studies were conducted in urban residential settings, limiting their applicability to coastal tourism areas such as Batu Hitam Beach, where waste generation patterns, visitor behaviour, and environmental pressures are different. Behavioural factors are also often underexplored, as many studies do not integrate established frameworks such as the TPB. Therefore, this study addresses these gaps by focusing on a semi-urban coastal tourism site and integrating the CVM with selected TPB constructs**.**

RESEARCH METHODOLOGY



This study develops a conceptual framework based on the TPB and the CVM to examine visitors' WTP for improved SWM at Batu Hitam Beach, Kuantan. The framework focuses on how sociodemographic and behavioural factor shape visitors' WTP for environmental management initiatives. Although TPB comprises attitude towards behaviour, subjective norms, and perceived behavioural control, this study includes only attitude and perceived behavioural control. This is because WTP is largely an individual and hypothetical economic decision, where subjective norms often show weaker or less consistent influence than other TPB constructs (Liu et al., 2018; Irfan et al., 2020). Attitude towards behaviour refers to visitors' evaluation of paying for improved SWM, including perceived benefits such as cleaner beaches, better environmental quality, and support for sustainable tourism. Perceived behavioural control refers to visitors' perceptions of affordability, financial capability, and confidence in the effectiveness of their contribution. Previous studies have shown that both constructs significantly influence WTP for environmental improvements (Chen & Tung, 2014; Subhan et al., 2020; Girma et al., 2023).

The framework also incorporates sociodemographic variables, including age, gender, education, income, visit frequency, and visitor type, as control variables due to their influence on environmental awareness and payment behaviour (Afroz et al., 2011; Han et al., 2019). WTP is measured using a dichotomous choice CVM, in which respondents accept or reject a specified bid amount, allowing the study to estimate WTP while examining its factors.

Following the framework, the study was conducted at Batu Hitam Beach, a growing coastal tourism site known for its black volcanic rocks, which are naturally embedded along the shoreline. The beach has become increasingly popular leading to a noticeable surge in visitor volume and associated solid waste generation. The beach starts to face overflowing waste bins and littering along the coastal edge and recreational zones that contributes to coastal pollution and ecosystem degradation at Batu Hitam (Baharuddin et al., 2024). Moreover, there is currently no formal entry fee implemented at the site, placing the financial burden of SWM solely on the local authorities. This context makes Pantai Batu Hitam an appropriate case study location for assessing visitors' WTP for improved SWM.

This study adopts a quantitative research design using a structured questionnaire survey. The use of the CVM further supports this design by enabling the estimation of WTP for non-market environmental goods through hypothetical scenarios. The questionnaire was developed as the main research instrument. Content validation was conducted with three subject matter experts using the Content Validity Index (CVI), while a pilot test involving 15 respondents was carried out to assess the clarity, structure, and practical suitability of the instrument in the field. Reliability testing indicated acceptable

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to good internal consistency, with Cronbach's Alpha values of 0.770 for attitude towards improved solid waste management and 0.821 for perceived behavioural control. The final instrument consisted of four sections covering socio-demographic profile, attitudes towards improvement of solid waste management, perceived behavioural control, and WTP. The WTP section presented a hypothetical beach SWM programme funded through a parking fee mechanism, followed by a dichotomous choice bid question.

A parking-fee mechanism was selected because most visitors access Batu Hitam Beach by vehicles and pass through designated parking areas, making fee collection practical and non-intrusive. Respondents were informed that the fee would be collected at the parking area and the fund will be managed by the local authority to support SWM improvements. The fund would support improvements such as additional bins and more frequent solid waste collection during peak periods, with routine auditing and public reporting to ensure transparency and visitor trust. In the dichotomous choice question, respondents were randomly assigned RM1.00 or RM3.00 per visit. These bids were based on an open-ended pretest with Batu Hitam visitors, which identified realistic and affordable WTP values. Following these procedures, the questionnaire was finalised in both English and Malay and included ethical elements such as informed consent, confidentiality assurance, and voluntary participation prior to data collection.

The target population of this study comprises visitors aged 18 years and above who visit Batu Hitam Beach during weekends and public holidays. This age criterion was used to make sure they can make independent financial decision regarding their willingness to pay for improved SWM. A non-probability convenience sampling technique was employed due to the transient nature of beach visitors and there is no formal visitor registry or sampling frame that would allow probability-based selection. Since no official published visitor data were available, the estimated population of 1,000 visitors per weekend day was derived from simple field observations conducted at Batu Hitam Beach during weekends and public holidays. Visitors were counted at different times of the day, and the daily total was estimated based on these counts. Based on this estimated population and using the Krejcie and Morgan (1970) formula with an 8% margin of error at the 95% confidence level, the minimum required sample size was 131 respondents. Although lower margins of error are generally preferred, higher values are acceptable for transient populations with limited sampling frames and fieldwork constraints (Memon et al., 2020; Deepa & Anwar, 2023). To account for non-response and incomplete questionnaires, the target sample was increased to 166 respondents. The adoption of an 8% margin of error is considered acceptable in applied social science research and is also supported by similar

beach-based CVM studies including a study by Setiawan and Saptutyningsih (2022).

Survey data were analysed using descriptive statistics and logistic regression analysis to estimate visitors' WTP for improved SWM at Batu Hitam Beach. Descriptive statistics were used to summarise respondents' socio-demographic characteristics, attitudes, perceived behavioural control and payment responses. To examine the determinants of WTP, logistic regression was applied, as it is appropriate for dichotomous contingent valuation responses in which respondents either accept or reject a proposed bid amount. The model estimates the probability of a "yes" response based on variables such as sociodemographic characteristics, attitude, and behavioural factors. Following Getinet, (2024), the mean WTP was then estimated from the logistic regression coefficients using the standard formula proposed by Hanemann, (1984).

ANALYSIS AND DISCUSSION

Descriptive Analysis

Table 1: Visitors' Socio-Demographic Information

Variables	Items	Frequency	Percentage (%)
Gender	Male	72	43.4
	Female	94	56.6
Age	<19	6	3.6
	20-24	70	42.2
	25-29	20	12.0
	30-34	8	4.8
	35-39	11	6.6
	40-44	9	5.4
	45-49	14	8.4
	50-54	19	11.4
	55-59	6	3.6
	>60	3	1.8
Highest education	Secondary school	18	10.8
	Professional Certificate/ Diploma	48	28.9
	Bachelor's degree	99	59.6
	PhD	1	0.6
Estimated gross income (RM)	<2500	83	50.0
	2501-4850	56	33.7
	4851-10,970	24	14.5
	>10,971	3	1.8
Visitor type	Local resident	34	20.5
	Domestic visitor	132	79.5
Visiting frequency	First time visit	19	11.4
	Every day	6	3.6
	Every week	2	1.2
	Every month	14	8.4
	Few times a year	125	75.3

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Table 1 shows that the 166 respondents were slightly dominated by females (56.6%) compared to males (43.4%). Most respondents were young adults, particularly those aged 20–24 years (42.2%), indicating that Batu Hitam Beach is especially popular among younger visitors. In terms of education, the majority held a bachelor's degree (59.6%), followed by a diploma or professional certificate (28.9%), reflecting a relatively well-educated sample. Half of the respondents (50.0%) earned below RM2500 per month, while 33.7% earned between RM2501 and RM4850, suggesting that most visitors were from low- to middle-income groups. Most respondents were domestic visitors (79.5%), and the majority visited the beach only a few times a year (75.3%), indicating mainly occasional visitation.

Table 2 shows that respondents had highly positive attitudes towards improving solid waste management at Batu Hitam Beach, with mean scores ranging from 4.34 to 4.87. The highest mean score was recorded for the statement that beaches with proper solid waste management attract more visitors (mean = 4.87), followed by items related to coastal beauty and support for sustainable tourism. Although still positive, the lowest mean score (4.34) was related to personal responsibility for payment, suggesting that individual obligation was slightly less strongly recognized. Overall, the findings indicate a favourable attitude towards contributing to improved solid waste management at the beach consistent with UNEP (2016), which emphasises that effective SWM is important for protecting environmental quality and public health.

Table 2: Visitors' Attitudes towards paying for improvement of Solid Waste Management

Attributes	Mean	Std. Deviation
Paying for solid waste management at the beach is beneficial for improving beach cleanliness.	4.42	0.825
Paying for solid waste management at the beach helps protect marine life.	4.43	0.834
Paying for solid waste management at the beach keeps the coastline beautiful.	4.51	0.769
My payment for solid waste management at the beach can help reduce litter.	4.39	0.830
My payment for solid waste management at the beach supports sustainable tourism.	4.49	0.863
Beaches with proper solid waste management improve my recreational experience.	4.47	0.695
Beaches with proper solid waste management attract more visitors.	4.87	0.629
I feel responsible for paying for solid waste management at the beach to keep it clean.	4.34	0.857

Table 3 shows that respondents generally reported moderate to high perceived behavioural control towards paying for improved SWM, with mean

scores ranging from 3.90 to 4.41. The highest mean scores were recorded for affordability and transparency of the payment system, indicating that respondents' willingness to contribute was strongly influenced by how the payment mechanism was structured. In contrast, the lowest mean score was related to the ability to pay on every visit, suggesting that financial capability may vary depending on personal circumstances and visit frequency. Overall, the findings indicate that visitors generally felt capable of contributing, particularly when the payment system was perceived as affordable and transparent. Similar findings were reported by Subhan et al. (2020) and Girma et al. (2023), who found that perceived control and confidence can significantly influence WTP for improved SWM.

Table 3: Visitors' Perceived Behavioural Control towards improvement of Solid Waste Management

Attributes	Mean	Std. Deviation
I can afford to pay the small contribution for solid waste management at the beach.	4.10	0.945
I am financially able to pay for solid waste management at the beach.	3.93	1.048
I can make the payment for the solid waste management if I know its benefits.	4.20	0.929
I can pay for solid waste management at the beach whenever I visit.	3.90	1.031
I can pay for solid waste management if the improvements are visible.	4.21	0.933
Easy payment methods would make paying for solid waste management at the beach simple.	4.38	0.806
A transparent system makes paying for solid waste management at the beach easier.	4.40	0.793
Affordable pricing makes paying for solid waste management at the beach possible.	4.41	0.763

Table 4 summarises respondents' WTP for the proposed improvement of SWM at Batu Hitam Beach. A large majority of respondents a total of 91.6%, expressed willingness to pay for the improvement program, while only 8.4% indicated unwillingness. This reflects strong overall support for the proposed initiative. The high "yes" rate is also consistent with the finding that perceived behavioural control is a strong positive predictor of WTP, indicating that many surveyed visitors felt both able and willing to contribute within the proposed bid range; however, this does not eliminate the possibility that responses were inflated by hypothetical and social desirability effects. The finding is consistent with previous CVM studies showing that respondents are willing to pay when the proposed environmental improvement is clear and relevant to their daily or recreational experience (Afroz & Masud, 2011; Haron, 2023; Girma et al., 2023).

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Table 4: Visitors' Willingness to Pay

WTP	Frequency (n)	Percentage (%)
Yes	152	91.6
No	14	8.4

Logistic Regression

Table 5 shows that the logistic regression model explaining how the selected variables influence visitors' WTP for improved SWM at Batu Hitam Beach. Among the variables tested, perceived behavioural control was the only significant predictor at the 1% level, suggesting that visitors who felt more financially capable and confident about the payment mechanism were much more likely to be willing to pay consistent with the results from previous related studies (Ajzen, 1991; Subhan et al., 2020; Girma et al., 2023). Visiting frequency showed a marginally significant negative relationship, indicating that more frequent visitors may be less willing to pay than occasional visitors. In contrast, socio-demographic factors and attitude, were not statistically significant, implying that WTP was influenced more by perceived affordability than by demographic characteristics. The insignificant findings may be due to the respondents relatively dominated by younger, educated, domestic visitors and low- to middle-income groups. This may have reduced variation across socio-demographic characteristics.

The positive but statistically insignificant coefficient for bid price also contradicts standard WTP theory. In this study, this result is likely due to the relatively low and narrow bid range (RM1 and RM3), where most respondents considered the proposed amounts affordable, leading to a high acceptance rate of 91.6%. Therefore, the bid coefficient is interpreted as a statistical artefact arising from the bid structure and high overall support for the SWM programme, rather than as a substantive price effect. Similarly, although the logistic regression model was statistically significant (Model $\chi^2 = 65.309$, $p < 0.001$), the high Nagelkerke R^2 value of 0.740 should be interpreted with caution. This high value may reflect the high proportion of "yes" responses, the narrow-bid range, and limited variation across several predictors, which may cause quasi-complete separation or overfitting. The Hosmer–Lemeshow test was not significant, $\chi^2(8) = 1.505$, $p = 0.993$. This suggests that the model fits the data adequately, with no major difference between the predicted and observed WTP responses. Overall, the findings should be used mainly to highlight perceived behavioural control as the main determinant of WTP ($B = 3.709$, $p = 0.002$, $Exp(B) = 40.817$), while suggesting that affordable, transparent, and outcome-oriented payment mechanisms are important to strengthen public support for improved coastal SWM.

Table 5: Logistic Regression Results

Variable	Coefficient (B)	Significance (p)	Exponential (B)
Gender	0.664	0.553	1.943
Age	0.013	0.795	1.014
Education	1.782	0.134	5.942
Income	1.073	0.475	2.923
Visitor type (VT)	1.956	0.178	7.070
Visiting frequency (VF)	-1.368	0.100	0.255
Attitude towards solid waste management (A)	-1.048	0.143	0.351
Perceived behavioural control (PBC)	3.709	0.002	40.817
Bid price	2.772	0.139	15.984
Constant	-12.667	0.036	0.000
Model χ^2 (Omnibus test)	65.309	< 0.001	
Nagelkerke R^2	0.740		
Hosmer and Lemeshow Test	1.505	0.993	

Willingness To Pay Estimation

The estimated average WTP of RM2.12 shows that surveyed visitors are willing to make a small financial contribution to improve SWM at Batu Hitam Beach. However, the RM2.12 estimate should be viewed as an indicative mean WTP for the surveyed visitors, given the relatively small, non-probability convenience sample and its dominance by younger, well-educated domestic visitors who visit Batu Hitam only a few times a year. This suggests that they support better environmental quality, although the level of contribution can be considered moderate. In this study, "moderate" means that the WTP value is positive but relatively small. It may be affordable for visitors but may not be sufficient to fully cover the cost of improved SWM services. In practice, such a contribution could help the local authority co-finance improved waste bins, more frequent collection, cleaner visitor areas, and other basic facilities, while reinforcing environmental governance through transparent fund management and visible service improvements. In CVM studies, WTP is usually interpreted based on the payment context, the proposed environmental improvement, and comparison with similar studies. For instance, Setiawan and Saptutyningsih (2022) reported an average WTP of IDR15,000, approximately RM3.34, for beach destination quality improvement, while Chea (2019) found WTP values of RM2.60 and RM2.30 for heritage conservation in Melaka and George Town. Compared with these studies, the RM2.12 estimated in this study reflects moderate public support. This may be influenced by visitors' expectation that SWM should be funded mainly by local authorities, especially among non-local visitors. The finding also suggests that affordability and perceived value are important in shaping payment decisions.

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$$\text{WTP} = -\left(\frac{\beta\text{constant} + \beta\text{gender} + \beta\text{age} + \beta\text{education} + \beta\text{income} + \beta\text{VT} + \beta\text{VF} + \beta\text{A} + \beta\text{PBC}}{\beta\text{bidprice}}\right)$$

$$WTP = -\left[\frac{(-12.667)+(0.664)+(0.013)+(1.782)+(1.073)+(1.956)+(-1.368)+(-1.048)+(3.709)}{2.772}\right]$$

$$\text{WTP} = RM2.12$$

LIMITATIONS

This study has several limitations. First, convenience sampling limits representativeness because respondents were selected from available visitors during the survey period. Since the sample mainly consisted of younger, educated domestic visitors who visit only occasionally, other visitor groups may be under-represented. Therefore, the findings reflect surveyed respondents rather than the whole Batu Hitam Beach visitor population. Second, the high WTP acceptance rate of 91.6% may have reduced variation in the dependent variable and contributed to the high Nagelkerke R^2 (0.740) in the logistic regression model. Third, the insignificant bid price effect may reflect the low and narrow bid range, which may not capture price sensitivity. Finally, subjective norm was excluded from the TPB framework. Future studies may improve logistic regression model robustness by using wider bid ranges, including full TPB constructs, and applying systematic visitor sampling.

CONCLUSION

This study examined visitors' WTP for improved SWM at Batu Hitam Beach, Kuantan, and identified the main factors influencing their payment decisions. Using the logistic regression analysis, the study found that perceived behavioural control was the most significant determinant of WTP, while socio-demographic factors were not statistically significant. The estimated average WTP of RM2.12 indicates that visitors are generally willing to make a modest financial contribution to support better SWM, reflecting positive public support for environmental improvements in a coastal tourism setting. From a policy perspective, the findings suggest that local authorities may consider introducing a small and affordable parking-based contribution as a part of broader coastal tourism planning. The mechanism is transparent, practical, and clearly linked to visible improvements such as cleaner beach areas, additional waste bins, and more frequent solid waste collection. Overall, the study highlights the importance of integrating behavioural considerations with economic valuation in designing publicly supported coastal SWM strategies.

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BEHAVIOUR DETERMINANTS OF INDIVIDUAL INTENTIONS FOR CLIMATE CHANGE ADAPTATION IN KLANG VALLEY, SELANGOR

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Abstract

Climate change poses increasing environmental, social, and economic challenges, particularly in highly urbanised regions such as the Klang Valley, Malaysia, where strengthening climate resilience has become an important environmental planning priority. Understanding the behavioural factors that influence individuals' intentions to adopt climate change adaptation measures is essential for developing effective community-based adaptation strategies and supporting climate-resilient urban planning. This study applied the Protection Motivation Theory (PMT) to examine the influence of threat appraisal and coping appraisal on behavioural intention towards climate change adaptation. A quantitative survey involving 450 respondents was conducted using a multistage cluster sampling technique, and the data were analysed using descriptive statistics and ordinal logistic regression. The findings revealed that the overall level of behavioural intention towards climate change adaptation was medium-high. Response efficacy ($\beta = 1.534$, $p < 0.001$), self-efficacy ($\beta = 1.331$, $p < 0.001$), and response cost ($\beta = 0.480$, $p < 0.001$) were significant predictors of behavioural intention, whereas perceived severity and perceived vulnerability were not statistically significant. The positive association observed for response cost suggests that perceived financial and practical challenges did not necessarily discourage respondents from adopting climate change adaptation measures. These findings provide valuable insights for environmental planners, local authorities, and policymakers in designing targeted interventions that strengthen community preparedness, enhance adaptive capacity, and support climate-resilient urban development.

Keywords: Climate Change Adaptation; Protection Motivation Theory; Behavioural Intention; Climate Resilience; Urban Planning

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INTRODUCTION

The phenomenon of climate change originates from global warming, in which the average temperature of the Earth's surface increases as the concentration of greenhouse gases in the atmosphere rises. These gases absorb more solar radiation and trap more heat, thereby warming the planet. Climate change refers to long-term changes in the Earth's climate that warm the atmosphere, oceans, and land. The impacts of climate change have become increasingly severe worldwide, resulting in substantial environmental degradation, biodiversity loss, and adverse effects on human health.

In Malaysia, the effects of climate change are becoming increasingly severe. Rising temperatures and erratic rainfall patterns are exacerbating health problems and other challenges faced by the population. This deterioration is largely attributed to heightened greenhouse gas emissions stemming from energy production and waste management practices (Mahmood & Guinto, 2022). Studies indicate that these emissions contribute significantly to the country's vulnerability to climate-related impacts, making it imperative for Malaysia to adopt more sustainable practices to mitigate these effects. Climate change adaptation has become an essential component of environmental planning and sustainable urban development. Strengthening adaptive capacity at the household and community levels is therefore fundamental to achieving long-term urban resilience and supporting local climate action initiatives.

The escalating threats of climate change to society and the environment necessitate proactive adaptive behaviour. While existing literature suggests that factors such as attitude, self-identity, and economic capacity influence adaptation, there is no consensus on which determinants most effectively foster individual readiness and long-term resilience among the public. This study aims to bridge that gap by investigating the specific behavioural and socio-economic factors influencing climate change adaptation intentions in the Klang Valley, ultimately seeking to inform policies that encourage meaningful community engagement and positive behavioural change.

The objective of this paper is (i) to identify the level of behavioural intention to adapt to climate change among individuals in Klang Valley and (ii) to examine the direct impact of behavioural determinants on individuals' intention to adapt to climate change in Klang Valley. The outcome of this paper examines the behavioural determinants, namely perceived severity, perceived vulnerability, response efficacy, self-efficacy, and response cost, that influence climate change adaptation intentions among individuals in the Klang Valley. By identifying the factors that promote or hinder behavioural change, the research aims to provide a framework for developing effective policies and practical solutions that enhance societal resilience.

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LITERATURE REVIEW

Climate Change

Climate change has become one of the most pressing global environmental challenges. Scientifically, it can be defined as long-term changes in temperature, precipitation, wind patterns and other aspects of the Earth's climate system caused by both natural factors, such as volcanic eruptions and solar radiation variations and human-induced factors, primarily greenhouse gas emissions from activities like fossil fuel combustion, deforestation and industrial processes (Olaniyi, 2020). A key focus is on greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Most of these greenhouse gases result from human activities, including utilising fossil energy, cutting down trees, and raising animals.

Climate Change Adaptation

Climate change adaptation refers to the process of responding to and managing the current and anticipated impacts of climate change through measures that reduce vulnerability and enhance resilience. These measures aim to minimise or avoid the adverse effects of climate change on human health, ecosystems, biodiversity, and the built environment (Ogada et al., 2020). In rapidly urbanising regions such as the Klang Valley, effective adaptation requires strong collaboration among government agencies, local authorities, communities, and other stakeholders to facilitate knowledge exchange, strengthen community participation, and promote adaptive behavioural change. Community-based adaptation approaches, including the integration of indigenous knowledge and locally appropriate practices, provide cost-effective and context-specific solutions that enhance local resilience to climate-related risks. Given the increasing frequency and intensity of climate-related hazards, integrating climate adaptation into environmental planning and local development strategies has become essential for improving urban resilience and supporting sustainable community development.

Theoretical Underpinnings

Several theories have been applied in previous studies to understand the behavioural determinants of individuals' intentions to adapt to climate change in the Klang Valley. One prominent theory is the Theory of Planned Behaviour (TPB), which suggests that behavioural intentions are influenced by attitudes, subjective norms, and perceived behavioural control (Zhang et al., 2020). This theory has been instrumental in explaining how social and personal factors shape climate-related behaviours.

Another frequently used theory is the Protection Motivation Theory (PMT), which asserts that individuals are motivated to adopt adaptive behaviours

when they perceive a significant threat and believe that protective measures are effective and feasible (Xue et al., 2021). Its focus on both threat appraisal and coping mechanisms makes it particularly relevant for understanding climate adaptation behaviour. PMT has been widely applied and is an appropriate theory for studying behavioural intentions in the context of climate change adaptation. Its emphasis on threat perception, coping appraisal, and motivation provides a comprehensive lens for analysing the complex interplay of factors influencing adaptive behaviours. This makes PMT especially valuable for addressing the challenges posed by climate change in Klang Valley.

Protection Motivation Theory (PMT)

Climate change has received much attention in recent years and affects everyone around the world. In the Klang Valley, Selangor, Malaysia, determining antecedent factors for individual-level intention to adapt to climate change would serve as a useful tool for developing effective adaptation measures. PMT has been widely used to explain the psychological factors that influence people's decisions to adopt protective behaviours (Marikyan & Papagiannidis, 2023; Asma et al., 2024). According to this theory, perceived threat severity, perceived vulnerability, response efficacy, and self-efficacy dictate individuals' intentions to adapt.

Previous literature has guided the use of PMT, particularly in climate change adaptation. Another analysis indicated that perceived responsibility and self-efficacy were important factors of public acceptance of climate politics in Taiwan to some extent (Chen et al., 2021). A similar study conducted in the United States also found that perceived risk, threat appraisal, Attitude, Subjective Norm, Perceived Behavioural Control, vulnerability, response efficacy, and self-efficacy had a significant influence on perceived behavioural control and, therefore, consistent with individuals' adaptive behaviour intentions, increased water and energy conservation (Kothe et al., 2023). In summary, the PMT is a useful model for understanding and predicting many individuals' intentions to adapt to climate change. Previous studies conducted in Malaysia also demonstrated that behavioural adaptation towards environmental issues is strongly influenced by individual perceptions, attitudes, and coping mechanisms (Sahrir et al., 2022).

Behavioural Intentions

Behavioural intention represents an individual's readiness to perform a specific behaviour. Recent studies highlight the critical role of behavioural intentions in influencing health behaviours and risk mitigation strategies. For instance, research in public health demonstrates that behavioural intentions predict adherence to COVID-19 preventive measures, such as mask-wearing and social

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distancing (Chen et al., 2023). Similarly, in the context of environmental behaviours, intentions to reduce plastic waste correlate with sustainable practices (Wang et al., 2020). In summary, behavioural intentions are a crucial determinant of action across various domains.

Perceived Severity

Perceived severity refers to the extent to which an individual believes a threat will have serious consequences. Recent evidence underscores its role in motivating action during global health crises. For example, higher perceived severity of COVID-19 has been linked to greater compliance with vaccination campaigns (Zhou et al., 2022). In cybersecurity, individuals who perceive severe consequences of cyberattacks are more likely to adopt protective software (Chen et al., 2020). Perceived severity significantly influences individuals' motivation to take protective actions across various domains.

Perceived Vulnerability

Perceived vulnerability is the degree to which individuals believe they are susceptible to a threat. Recent studies emphasise its importance in contexts like climate change and infectious disease prevention. For example, perceived vulnerability to extreme weather events has been found to predict preparedness behaviours, such as installing flood barriers (Bubeck et al., 2023). Similarly, during the COVID-19 pandemic, perceived vulnerability influenced individuals' intentions to seek testing and vaccination (Tsai et al., 2021). Perceived vulnerability significantly shapes adaptive and preventive actions across various threats. In Malaysia, vulnerability assessments have shown that adaptive capacity and perceived exposure to flood hazards are important determinants of adaptation responses among affected communities (Said et al., 2024).

Response Efficacy

Response efficacy refers to the belief that a recommended action or behaviour will effectively mitigate or eliminate a perceived threat. It has been identified as a critical determinant in promoting protective behaviours across various domains. For instance, in climate change adaptation, individuals who believe in the effectiveness of energy-efficient technologies or reforestation programs are more likely to adopt these measures (Xue et al., 2021). Similarly, in disaster preparedness, the perceived efficacy of flood barriers or early warning systems significantly influences household preparedness actions. In summary, response efficacy plays a pivotal role in motivating individuals to adopt behaviours that address environmental and societal risks.

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Self-Efficacy

Self-efficacy is the confidence in one's ability to perform a specific behaviour successfully. Studies from 2019 onward confirm its role as a strong predictor of protective actions. For instance, higher self-efficacy has been associated with better adherence to home-based exercise programs during lockdowns (Wright et al., 2021). In cybersecurity, individuals with greater confidence in their ability to recognise phishing attempts are less likely to fall victim to scams (Yadav et al., 2023). Self-efficacy empowers individuals to adopt protective and preventive behaviours across diverse domains.

Response Cost

Response cost refers to the perceived financial, time, effort, or psychological sacrifices associated with adopting recommended protective behaviours. Recent studies illustrate how high response costs deter protective actions. For example, perceived financial costs of installing solar panels remain a barrier despite environmental benefits (Green et al., 2024). In healthcare, the time required for vaccine appointments was a deterrent for many during mass vaccination campaigns (Lee et al., 2023). In summary, minimising response costs is essential to encourage greater participation in beneficial behaviours.

RESEARCH METHODOLOGY

This study employed a quantitative research design grounded in the Protection Motivation Theory (PMT) to examine the behavioural determinants of climate change adaptation intentions among individuals in the Klang Valley, Malaysia. Data were collected using a validated bilingual (Malay and English) structured questionnaire comprising five-point Likert-scale items measuring the PMT constructs of perceived severity, perceived vulnerability, response efficacy, self-efficacy, response cost, and behavioural intention. Prior to the main survey, a pilot study was conducted to evaluate the questionnaire's clarity, feasibility, and reliability. The pilot study also enabled refinement of questionnaire wording before the actual survey.

A multistage cluster sampling technique was employed to obtain a representative sample of households across the Klang Valley. In the first stage, the Klang Valley was divided into eleven administrative districts. Subsequently, three districts (Gombak, Sepang, and Hulu Selangor) were purposively selected to represent different geographical settings. In the second stage, several town growth centres within each district were randomly selected, followed by the selection of residential neighbourhoods. Finally, systematic household sampling was used, whereby every *kth* household was selected from an ordered list of households, and one eligible household representative aged 18 years or older was

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invited to participate in the survey. A total of 450 completed questionnaires were successfully collected and included in the final analysis.

Prior to the main survey, the questionnaire underwent expert content validation and reliability testing. All constructs exceeded the minimum recommended Cronbach's alpha value of 0.70, indicating satisfactory internal consistency and reliability of the measurement instrument (refer to Table 1). Descriptive statistics, including frequencies, percentages, and mean scores, were used to summarise respondents' characteristics and behavioural determinants. Ordinal logistic regression was employed because the dependent variable was measured using an ordinal five-point Likert scale. This technique is appropriate for modelling the relationship between multiple predictor variables and an ordered categorical outcome variable while providing reliable parameter estimates.

Table 1: Cronbach's alpha

Construct	No. of Items	Cronbach's α
Perceived Severity	11	0.846
Perceived Vulnerability	9	0.805
Response Efficacy	9	0.805
Self-Efficacy	10	0.722
Response Cost	10	0.939
Behavioural Intention	10	0.769

ANALYSIS AND DISCUSSION

Table 2 presents the nine items in this section: gender, age, race, dependent, educational level, occupation, disability status, income, and type of housing.

Table 2: Respondents' Demographics.

Characteristics	Description	Frequency (N)	Percentage (%)
Gender	Male	261	58.0
	Female	189	42.0
Age	18-24	31	6.9
	25-34	187	41.6
	35-44	115	25.6
	45-59	101	22.4
	60 and above	16	3.6
Race	Malay	317	70.4
	Chinese	64	14.2
	Indian	69	15.3
Educational Level	Secondary School	206	45.8
	STPM / Matriculation / Foundation	18	4.0
	Diploma	84	18.7
	Degree	124	27.6
	Master	18	4.0
	PhD	0	0.0

Characteristics	Description	Frequency (N)	Percentage (%)
Income Level	≤ RM 2560	169	37.6
	RM 2 560 - RM3 439	110	24.4
	RM 3 440 - RM 4 309	80	17.8
	RM 4 310 - RM 5 249	40	8.9
	RM 5 250 - RM 6 339	33	7.3
	RM 6 340 - RM 7 689	15	3.3
	RM 7 690 - RM 9 449	3	0.7
Type of Housing	Shop lot	10	2.2
	Flat House	68	15.1
	Terrace house	207	46.0
	Village house	128	28.4
	Condominium	17	3.8
	Apartment	20	4.4

Table 2 summarises the socio-demographic characteristics of the 450 respondents involved in this study. The respondents were predominantly male (58.0%), with the largest proportion aged 25-34 years (41.6%), indicating that the sample was largely composed of economically active adults. Most respondents were Malay (70.4%) and had attained secondary school education (45.8%), while 27.6% possessed a bachelor's degree. In terms of monthly household income, the largest share earned RM2,560 or less (37.6%), reflecting a predominantly low- to middle-income population. Regarding housing characteristics, terrace houses constituted the largest residential category (46.0%), followed by village houses (28.4%) and flats (15.1%). Collectively, these findings indicate that the respondents represent an urban population with diverse socio-economic backgrounds, providing an appropriate basis for examining behavioural intentions towards climate change adaptation in the Klang Valley.

The level of behavioural intention to adapt to climate change among individuals in Klang Valley.

The first objective of this study was to determine the level of behavioural intention to adapt to climate change among individuals in the Klang Valley. Mean score analysis was conducted to evaluate the level of each PMT construct and behavioural intention using the interpretation proposed by Nunnally and Bernstein (1994). Based on Nunnally and Bernstein (1994), mean scores were interpreted as follows: low (1.00–2.00), medium-low (2.01–3.00), medium-high (3.01–4.00), and high (4.01–5.00).

Table 3: Results of Mean Score

Behavioural Determinants	Mean Score	Category
Perceived Severity	3.76	Medium-High
Perceived Vulnerability	3.57	Medium-High
Response Efficacy	3.98	Medium-High

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Behavioural Determinants	Mean Score	Category
Self-Efficacy	3.84	Medium-High
Response Cost	3.78	Medium-High
Behavioural Intention	3.86	Medium-High

Table 3 shows that all PMT constructs and behavioural intention recorded mean scores within the medium-high category, indicating generally positive perceptions and intentions towards climate change adaptation among respondents. Response efficacy recorded the highest mean score (M = 3.98), followed by behavioural intention (M = 3.86) and self-efficacy (M = 3.84), indicating that respondents perceived climate adaptation measures to be effective and expressed confidence in their ability to implement them. Response cost also recorded a medium-high mean score (M = 3.78), suggesting that respondents recognised financial and practical constraints associated with climate change adaptation, although these constraints were not perceived to substantially discourage adaptation intentions. Meanwhile, perceived severity (M = 3.76) and perceived vulnerability (M = 3.57) also fell within the medium-high category, reflecting respondents' awareness of climate-related risks, although perceived vulnerability recorded the lowest mean score among all constructs. These descriptive findings provide an initial understanding of respondents' perceptions towards climate change adaptation. However, descriptive statistics alone do not determine whether these behavioural determinants significantly influence adaptation intention. Therefore, ordinal logistic regression analysis was subsequently performed to examine the significance and relative contribution of each PMT construct in predicting behavioural intention towards climate change adaptation.

Behavioural Determinants Influencing Climate Change Adaptation Intention

Ordinal logistic regression analysis was performed to examine the influence of the Protection Motivation Theory (PMT) constructs on individuals' behavioural intention to adapt to climate change in the Klang Valley. Prior to interpreting the regression coefficients, the overall model fit and goodness of fit were assessed to determine the model's suitability.

Table 4: Goodness-of-fit

Test	Chi-square	p
Pearson	15105.553	<0.001
Deviance	2452.725	1.000

As presented in Table 4, the deviance goodness-of-fit statistic was not statistically significant (p = 1.000), indicating that the fitted model adequately represented the observed data. Therefore, the ordinal logistic regression model

was considered appropriate for examining the relationship between the PMT constructs and behavioural intention to adapt to climate change.

Following confirmation of the model adequacy, the parameter estimates were examined to determine the influence of each behavioural determinant on climate change adaptation intention. The regression coefficients, Wald statistics, significance values, and 95% confidence intervals are presented in Table 5.

Table 5: Parameter Estimates

	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Threshold							
Behavioural Intention – Disagree	10.431	2.078	25.192	1	.000	6.357	14.504
Behavioural Intention – Neutral	12.278	2.019	36.972	1	.000	8.320	16.236
Behavioural Intention – Agree	15.268	2.049	55.506	1	.000	11.251	19.285
Behavioural Intention – Strongly Agree	19.386	2.105	84.808	1	.000	15.260	23.512
Location							
Perceived Severity	-.084	.185	.206	1	0.910	-.447	.279
Perceived Vulnerability	.015	.130	.013	1	0.650	-.240	.270
Response Efficacy	1.534	.182	70.943	1	<0.001	1.177	1.891
Self-Efficacy	1.331	.159	69.653	1	<0.001	1.018	1.644
Response Cost	.480	.135	12.730	1	<0.001	.217	.744

The ordinal logistic regression analysis revealed that response efficacy ($\beta = 1.534$, $p < 0.001$), self-efficacy ($\beta = 1.331$, $p < 0.001$), and response cost ($\beta = 0.480$, $p < 0.001$) were significant predictors of behavioural intention towards climate change adaptation. In contrast, perceived severity ($\beta = -0.084$, $p = 0.910$) and perceived vulnerability ($\beta = 0.015$, $p = 0.650$) were not statistically significant. Among the significant predictors, response efficacy demonstrated the strongest positive association with behavioural intention, followed by self-efficacy and response cost.

The direct impact of behavioural determinants on individuals' intention to adapt to climate change in Klang Valley

The findings indicate that response efficacy and self-efficacy were significant positive predictors of behavioural intention to adapt to climate change. These results suggest that individuals were more likely to adopt adaptation measures when they believed that such measures were effective and had confidence in their ability to implement them. The findings are consistent with recent studies

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demonstrating that efficacy beliefs play a central role in promoting climate adaptation behaviour. For example, van Valkengoed et al. (2024) found that self-efficacy and outcome efficacy were directly associated with stronger intentions to adapt and actual adaptation behaviour, whereas climate risk perception alone was insufficient to predict adaptation actions. Similarly, the non-significant effects of perceived severity and perceived vulnerability observed in the present study suggest that recognising climate-related risks alone may not be sufficient to motivate adaptive behaviour unless individuals also believe that adaptation measures are effective and that they possess the capability to implement them. These findings reinforce the importance of strengthening coping appraisal, rather than relying solely on threat communication, to encourage climate change adaptation.

Response cost was identified as a significant positive predictor of behavioural intention ($\beta = 0.480$, $p < 0.001$), where higher perceived response costs are generally expected to reduce individuals' motivation to undertake protective actions. Rather than indicating that higher costs encouraged adaptation, the findings suggest that respondents remained willing to adopt climate change adaptation measures despite perceiving financial, time, and practical constraints. One possible explanation is that the perceived effectiveness of adaptation measures and respondents' confidence in implementing them outweighed the perceived implementation costs. Given that response efficacy and self-efficacy recorded the largest regression coefficients in this study, coping appraisal appears to have exerted a stronger influence on behavioural intention than perceived barriers. This interpretation is also consistent with van Valkengoed et al. (2024), who concluded that efficacy beliefs directly promote adaptation behaviour, while risk perceptions mainly influence adaptation through their effects on efficacy beliefs rather than independently. From an environmental planning perspective, these findings suggest that climate adaptation strategies should prioritise strengthening adaptive capacity through community-based adaptation programmes, household flood preparedness initiatives, practical training, and local climate action programmes coordinated by local authorities to enhance community resilience and support climate-resilient urban planning.

CONCLUSION

This study examined the behavioural determinants influencing individuals' intentions to adapt to climate change in the Klang Valley, Malaysia, using the Protection Motivation Theory (PMT). The findings revealed that the overall level of behavioural intention towards climate change adaptation was medium-high, indicating that respondents generally demonstrated a favourable willingness to adopt adaptive measures. Among the PMT constructs, response efficacy and self-efficacy emerged as the strongest predictors of behavioural intention, suggesting

that individuals were more likely to engage in adaptation when they believed that adaptation measures were effective and had confidence in their ability to implement them. In contrast, perceived severity and perceived vulnerability did not significantly influence behavioural intention, indicating that awareness of climate-related risks alone is insufficient to encourage adaptive behaviour without strong efficacy beliefs.

Interestingly, response cost was identified as a significant predictor of behavioural intention. Although respondents perceived financial, time, and practical challenges associated with climate change adaptation, these perceived costs did not appear to discourage their intention to undertake adaptive actions. This finding suggests that the perceived effectiveness of adaptation measures and individuals' confidence in implementing them may outweigh the constraints associated with adaptation, highlighting the dominant role of coping appraisal in shaping behavioural intention.

From an environmental planning perspective, the findings provide important implications for strengthening climate resilience at the community level. Rather than focusing solely on raising awareness of climate change risks, local authorities and environmental planners should prioritise programmes that enhance individuals' adaptive capacity, improve confidence in implementing adaptation measures, and strengthen community preparedness. Practical initiatives such as household flood preparedness programmes, heat-health awareness campaigns, water conservation practices, community-based adaptation programmes, and locally coordinated climate action plans can encourage greater public participation in climate change adaptation while supporting resilient and sustainable urban development.

Despite its contribution, this study is limited to respondents residing in the Klang Valley and focuses primarily on behavioural determinants within the PMT framework. Future research should expand the geographical scope to other regions of Malaysia, incorporate additional psychological and contextual factors, and examine actual adaptation behaviour using longitudinal or mixed-method approaches to provide a more comprehensive understanding of climate change adaptation.

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A REVIEW OF RISK CATEGORIES IDENTIFICATION ON HIGH-RISE RESIDENTIAL BUILDING (STRATA) OPERATIONS

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Abstract

High-rise residential buildings, or know as strata, significantly influence urban living, necessitating effective operation to preserve property values and harmonious communities. Generally, rapid urbanisation has expanded strata-titled properties, due to scarcity of land, congested building structures and of preferred property style living. Despite regulatory oversight, high-rise residential building communities face complex risks, prompting a need for tailored risk management strategies. The crucial process in risk management is risk identifying. Risk in strata can be varies based on its environment and purposes. This paper aims to identify risk categories inherent in high-rise residential building (strata) management. Using an interpretive in-depth literature review and selected strata cases as secondary documentary evidence of issues in high-rise residential building, nine critical risk categories were identified which is financial, legal and compliance, structural and maintenance, management and operational, resident-related, security and safety, environmental, technological, and reputational risks. Each risk significantly consequences on building operation, resident satisfaction, and overall sustainability. Conclusively, identify these risks through holistic review tailored to Malaysian strata buildings is vital in risk management process. Future proper risk management must emphasise and embedded in high-rise residential building (strata) operations to ensure excel building operation and satisfaction within resident communities.

Keywords: High-rise Residential, Strata Residential, Risk Categories, Risk Identification, Operation

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INTRODUCTION

The increasing trend towards high density residential and commercial strata schemes in urban Malaysia highlights the need for a structured property oversight. In such complexes, effective management is the linchpin that protects real estate equity and reconciles the differing priorities of owners, residents and management bodies. So upgrading these administrative systems is key to dealing with the difficulties associated with shared space living (Abdullah et al., 2024). The management of strata properties under the Strata Titles Act 1985 requires a very structured approach. Those who are in charge need to balance the management of shared spaces with good financial stewardship and be deeply engaged in the social fabric and dynamics of the community residents (Mohd Hanafi & Hassan, 2019). Titled strata developments are an administrative nightmare to manage. It is a constant balancing act of conflicting interests of stakeholders from the spectrum of investors, tenants, management councils and service providers, while making sure that each stakeholder remains firmly within their own area of responsibility, in the community structure (Farhana et al., 2023).

High-rise residential building operation must execute effective risk management strategies to prevent these risks while building resilience and maintaining sustainability across strata communities. The complex aspects of managing high-rise residential building in Malaysia brings forward specific difficulties which require customised risk management strategies (Sufiya et al., 2023). Conventional risk management practices prove beneficial but fail to fully address the specific Malaysian context of strata management which includes strict regulations and diverse cultural aspects together with financial variation (Farhana et al., 2023). For an example the combination of inadequate reserve fund management along with delayed payments leads to poor property upkeep which then negatively influences resident satisfaction and lowers property market prices (Ismail et al., 2023). Organisations must carefully guide their operations through complex regulatory requirements set by the Strata Titles Act because improper management will create both major legal liabilities and operational disruptions (Kathitasapathy et al., 2023). As a result, this paper aims to identify risk categories inherent in high-rise residential building which known as strata management and its impact through comprehensive and in-depth literature review.

LITERATURE REVIEW

High-Rise Residential Building Management

Malaysia's current practices in high-rise residential building management are primarily governed by the Strata Management Act 2013, which establishes a comprehensive framework for the administration and regulation of strata-titled properties. According to Vern et al., (2019), the performance of Malaysian strata

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schemes hinges largely on the Management Corporation (MC) as the primary regulatory body for communal upkeep, financial administration and strict enforcement of bylaws. Contemporary practices are actively promoting the integration of digital technology for maximising the ecosystem and promoting communal harmony. It simplifies fiscal reporting and communication, thereby strengthening the structural accountability (Radha & Najib Razali, 2023). The importance of professional building managers continues to grow as they manage property complexities and maintain legal compliance while representing property owners' various requirements.

Construction of strata complexes is speeding up, but management bodies still face considerable operational hurdles. These include rampant disputes between proprietors, weak enforcement of statutory bylaws and unfair charges for communal upkeep. According to (Ashiqin et al., 2023) argue that successful conflict resolution methods combined with ongoing professional development for building managers are essential elements of improved strata management systems. Strata development projects now increasingly adopt eco-friendly measures due to the rising focus on sustainable building practices (Ashiqin et al., 2024). Environmental conservation benefits from these initiatives because they simultaneously raise both property appeal and perceived value of high-rise building developments. In contrast, the interaction between the strata managers and occupants gives rise to significant socio-operational risks. These pre-existing frictions often take the form of competing stakeholder interests, territorial disputes over shared facilities, and persistent obstacles to cohesive dialogue and mutual cooperation (Abdul Jalil et al., 2023).

Risks In High-Rise Residential Building (Strata) Management

The management risks of strata residential complexes are direct threats to the functional, financial and statutory integrity of a building. Without mitigation, these structural and operational deficiencies greatly impact the habitability of the premises, and detract from the overall quality of life in the community (Hillson & Murray-Webster, 2017).Consequently, these volatile variables add considerable uncertainty to strata governance. They demand rigorous diagnostic protocols and strong administrative controls to effectively prevent serious systemic failures. The risk assessment process requires comprehension of potential dangers together with evaluations regarding both how those threats might occur and their potential effects within strata communities (Rampini & Berssaneti, 2022). Within strata management operations numerous risks originate from financial misconduct alongside structural problems but also from legal violations and tensions between residents (Porath, 2023). The management of the buildings throughout Malaysia faces multiple risks which relate to issue and challenges toward both the functionality of operations and resident satisfaction.

The comprehensive examination of literature has identified nine (9) critical risk categories which primarily affect strata building operations. The table 1.0 summarise critical risk categories from selected literature review.

Table 1: Critical risk categories from selected literature review.

Risk Categories	Issues Arise	Source
Governance and Legal Risk	Difficulties understanding Strata Act 2013	(Izanda et al., 2022)
	Poor decision-making by developers can result in governance structures	(Johnston & Too, 2015)
Structure & Maintenance Risk	Common maintenance issues	(Ashiqin et al., 2023)
	Structural defects	(Sood, 2016)
	Poor maintenance practices	(Zaimah Che-Ghani et al., 2016)
	Infrastructure limitations	(Harun et al., 2022)
Financial Risk	Financial constraints	(Aripin et al., 2024)
	Inaccurate budgeting, Unforeseen expenditures Low collection service charges	(Shazrin et al., 2023)
	Arrears of bills (utilities, quit rent, assessment, insurance)	(Mohamad, 2015)
Management and Operational Risks	Service quality gaps	(Zahari et al., 2014)
	Hierarchical structure	(Wernz & Deshmukh, 2007)
Resident-related risks	Diverse socioeconomic backgrounds of residents	(Mehmood et al., 2024)
	Conversion of residential units into housing for foreign workers	(Suratman et al., 2019)
	Noise, parking, cleanliness, pets	(Mohamad, 2015)
Environmental Risks	Flood risk management that does not address	(Moulds et al., 2021)
	Energy waste-electrical	(Ashiqin et al., 2024)
Technological risks	Needs of digitalization of property management Financial systems and community communication	(Abdul Jalil et al., 2023)
	Challenges in terms of privacy and system transparency	(Pettit et al., 2018)
Reputation Risks	Short-term residential accommodations in strata.	(Chua Abdullah & Ramly, 2024)
	Associated with a modern lifestyle, offering amenities	(Abdullah et al., 2024)
Security & Safety Risk	Limited by regulatory gaps	(Pang & Chair, 2023)
	Fire safety challenges due to their architecture and multifunctionality	(Poliakova & Grigoryan, 2018)

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Risk Categories	Issues Arise	Source
	Conflicts and unneighboured	(Levin & Arthurson, 2020)
	Well-being critical factor for sustainable living	(Danivska et al., 2019)

Financial Risk

The high-rise residential building management currently faces the financial risk as one of its top challenges. Flawed budget estimates combined with deficient financial strategy will result in inadequate money reserves which become critical when addressing standard maintenance needs or handling unexpected fix requirements and will challenge the building's structure integrity and ongoing functionality (Aripin et al., 2024). As funds reserved for emergencies dry up, they compound building management issues by forcing building management to request special payments from owners thereby damaging both resident relationships and financial health (Shazrin et al., 2023). The delay in receiving strata fees causes cash flow problems that forces difficult financial management in meeting timely obligations. These financial strains create operational difficulties for building management and produce unfair financial burdens for residents which can then lead to conflict in the community.

Governance and Legal risks

This risk category emerges from mandatory compliance with Malaysian laws namely the Strata Management Act 2013 and the Strata Titles Act 1985. Failure to comply with regulations leads to legal challenges and financial consequences which damage both the power and functional capability of the strata council (Izanda et al., 2022). Poor bylaw enforcement by management combined with resident violations leads to disruptive situations in shared housing arrangements which require strong conflict management systems to sustain neighbourhood equilibrium. The legal risk experienced by strata communities creates management resource burdens and reduces residents' feelings of safety and equality. Additionally, the lack of proper governance in strata management can result in legal disputes, as disagreements over rules and financial management may escalate into lawsuits, further complicating the management of the property. These outcomes emphasize the importance of effective governance to maintain property values, ensure resident satisfaction, and prevent legal challenges (Johnston & Too, 2015).

Structural and maintenance risks

The physical structure of the building stands under scrutiny. Neglected maintenance produces major structural problems like roof leaks and foundation problems while increasing repair costs and endangering resident safety (Ashiqin et al., 2023). Preventative maintenance saves infrastructure condition status from

deterioration several setbacks effect timely support when financial shortages exist together with poor management (Zaimah Che-Ghani et al., 2016). A reliable approach to maintenance and structural problems protects building lifespans and keeps residents healthy. Furthermore, maintenance challenges in risk management grow alongside environmental adjustments due to climate change and technology improvements which result in additional elements like sustainable building requirements and data protection threats these challenges highlight the inadequacy of existing management to fully encompass the unique and evolving risk landscape of Malaysian high-rise residential building management (Kathitasapathy et al., 2023).

Management and Operational Risks

The efficiency of building operations remains dependent on the performance quality of the strata council together with property management procedures. Structures of poor governance and hidden transparency combined with ineffective communication diminish trust between management body and residents resulting in reduced cooperation and raised conflict levels (Zahari et al., 2014). The combination of insufficient record management and resource misallocation produces operational inefficiencies and financial issues which create additional operational risk for strata management (Wernz & Deshmukh, 2007).

Resident-related risks

Occupant or tenant of strata actions could lead the building environment because their behaviours create distinct risk. Community harmony breaks down while living quality falls deteriorates because residents fail to follow strata rules while adding noise and pet disturbances (Mehmood et al., 2024). The presence of high vacancy rates creates financial pressure on remaining property owners whom are forced to shoulder heavier burdens which together with resident dissatisfaction reduces their interaction with the community (Suratman et al., 2019). To preserve both peace and fiscal health while ensuring cooperative neighbour relationships within the strata community owners must tackle resident-related risks.

Security and safety risks

Security alongside safety risk stands as the primary concern when protecting the well-being of residents. The risks of building theft along with vandalism and unauthorized access rise due to inadequate security systems despite successful identification of weak surveillance options or short-handed security staff (Poliakova & Grigoryan, 2018). On the other hand, building safety requires thorough compliance to established safety rules and complete emergency planning because for instance fire risks together with poor emergency

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preparations threaten both human life and structural assets (Danivska et al., 2019). All residents need stringent security and safety measures to maintain both their comfort and security within their living environment.

Environmental Risks

Natural environmental hazards or natural disaster create an environmental risk that sustainability practices need to mitigate. As reported by the Malaysian Meteorological Department 2023, research shows that strata buildings face a growing threat from natural events such as floods and earthquakes which create destructiveness leading to substantial damage and lifestyle interruptions. The complete health assurance and protection of inhabitants demands urgent handling of environmental threats according (Moulds et al., 2021). Over time strata buildings operate successfully only if environmental risks receive proper management.

Technology risks

Technology risk involves both the implementation and administration of technological systems throughout strata operations. Security in cyber matters presents strong risks to the protection of residents' private data alongside management (Abdul Jalil et al., 2023). Old technology decreases management effectiveness and communication capability then building system breakdowns in heating, ventilation, and air conditioning (HVAC) and elevators destroy residential comfort and security (Pettit et al., 2018). For example, participants within residential settings experience direct effects on their safety and comfort when building systems experience failures from issues like HVAC system malfunctions and elevator or security system breaks which demand immediate repair work and system modernisation.

Reputation Risks

Public perception on strata building comes under its reputation which affects both its market desirability and monetary worth. Property value and occupancy rates suffer when potential renters or buyers withdraw because of negative public perceptions which arise from inadequate property management and ongoing problems (Chua Abdullah & Ramly, 2024). Hence, to ensure continues success, organisations need to actively manage their reputation since a positive community image depends on these efforts (Abdullah et al., 2024).

Therefore, each critical risk categories substantially affect high-rise building management operation together with residential quality of life standards. Strategic risk management plan with proactive attention needs to address these risk categories from financial stability, legal compliance, structural integrity, effective management, security safety practices, environmental sustainability

methods, resident relations quality, technological advancement implementation, till reputation management processes.

RESEARCH METHODOLOGY

This study undertakes a comprehensive review of the literature and selected Malaysian strata cases are incorporated as secondary documentary evidence to examine the risk categories associated with the management of high-rise residential (strata) buildings. The literature selection focused on journal articles, conference papers, legal and regulatory documents, and relevant studies related to strata management, high-rise residential building operations. The reviewed literature was selected based on its relevance to risk issues affecting strata building operations, particularly within the Malaysian context, while also considering international studies that provide useful comparisons.

The analysis of the literature was conducted using a thematic analysis approach. First, repeated issues and problems reported in previous studies were extracted, such as poor maintenance practices and financial constraints. These extracted issues were then group according to their nature and operational implications. For example, issues such as low collection of service charges, inaccurate budgeting, and arrears of bills were grouped under financial risk, while structural defects, poor maintenance, and infrastructure limitations were grouped under structural and maintenance risk. Following the grouping process, similar groups were grouped into broader themes to form the main risk categories. Through this process, nine critical risk categories were identified from financial risk, governance and legal risk, structural and maintenance risk, management and operational risk, resident-related risk, security and safety risk, environmental risk, technology risk, and reputation risk. These categories were developed by comparing recurring themes across the reviewed literature and assessing their relevance to the operation of high-rise residential strata buildings. The identified risk categories were then assessed based on their potential consequences to strata building management. Seven consequence areas were used to interpret the significance of each risk category.

Overall, the methodological process involved four main stages starting from literature identification and selection, extraction of recurring strata management issues, thematic grouping and categorisation of risks, and assessment of risk consequences. This systematic process provides a stronger foundation for identifying risk categories and supports the development of a more structured risk management framework for high-rise residential building management.

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RESULTS AND FINDINGS

Risk Categories Consequences in High-Rise Residential Building (Strata) Management

The findings of literature review and illustrative Malaysian case evidence reveal that in strata management risks of financial, legal, life-safety, stakeholder trust and operational are all interdependent and together they determine the operation and viability of a high-rise residential building. Poor financial planning, especially arrears in maintenance funding and poor management of reserves, may trigger financial cost stress, thus creating special levies or the need to borrow. Meanwhile, failure to govern or non-compliance with safety can subject the building to regulatory fines, lawsuits, and reputational damage. Life safety risks, including structural collapse or inadequate fire protection, directly jeopardize the welfare of residents and may trigger legal action and increased insurance rates. The lack of stakeholder trust, which is a result of poor communication, unaddressed conflicts, and unattended maintenance further worsens the position of the scheme, thus lowering property values and resident satisfaction. These pressures are compounded by operational inefficiencies, which may be caused by lack of management, misuse of resources, or technological breakdowns, and result in increased spending and poor quality of services. To ensure that these risks are mitigated, active managerial interventions and open communicative approaches are required to maintain a stable, efficient, and harmonious living environment. Table 2.0 below, interpret the consequences likelihood to happens associate with the identified critical risk categories of high-rise residential building management and Table 3.0 are findings from case studies evidence.

Table 2: The consequences likelihood to happen due to critical risk categories.

	Critical Risk Categories								
Impacts	**Structural and Maintenance**	**Financial**	**Management and Operational**	**Legal and compliance**	**Security and Safety**	**Technology**	**Reputation**	**Resident-related**	**Environmental**
Financial cost stress (Arkcoll et al., 2013), (Antoniades, 2008), (Peng Au-Yong et al., 2023), (Mohd Tawil Norngainy & Che-Ani A. I., 2010)	✓	✓	✓						

Impacts	Critical Risk Categories								
	Structural and Maintenance	**Financial**	**Management and Operational**	**Legal and compliance**	**Security and Safety**	**Technology**	**Reputation**	**Resident-related**	**Environmental**
Legal and Liability exposure (Hamzah & Abdullah, 2018), (Chong et al., 2021), (Zhang et al., 2024)				✓	✓				
Life-safety and Physical harm (Zhang et al., 2024),(Dan, 2021), (Gu et al., 2023)	✓				✓	✓			
Stakeholder trust and Reputation (Ashiqin et al., 2023), (Chong et al., 2021), (Antoniades, 2008)				✓			✓	✓	
Operational performance (Dan, 2021), (Arkcoll et al., 2013), (Dan, 2021)			✓			✓			
Environmental resilience (Farhana et al., 2023), (Ashiqin et al., 2023)									✓
Data and Cyber integrity (Spanca & Salihu, 2024), (Sándor & Rajnai, 2023)						✓			

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Table 3: Malaysian Case Evidence on Strata Building Risks

No.	Strata Case Study	Issues	Critical Risk Categories	Impacts
1.0	Flat PKNS Tapak Maha, Taman Datuk Harun, Petaling Jaya	Unpaid maintenance fees and owner default	Financial, maintenance, management and operation	Financial cost stress and operational disruption
2.0	Pangsapuri Selayang Segar, Batu Caves	Maintenance fee payment, management upkeep issue and local authority concern	Governance, financial and resident related	Poor upkeep, resident dissatisfaction, operational weakness.
3.0	Highland Towers, Ulu Klang	Drainage, retaining wall and slope-related failure	Structural and maintenance, environmental, safety	Life-safety harm, liability, reputation damage.
4.0	PJ8 Service Suite, Petaling Jaya	Service charge dispute and tribunal court proceeding	Financial and governance	Legal liability and stakeholder trust issue
5.0	Verve Suites Mont' Kiara	Short-term rental dispute and enforcement of house rules	Governance and legal, resident-related and reputation	Legal exposure, community conflict and reputation risk

Financial cost

Financial cost stress in strata schemes can be described as a situation where the owners corporation and by extension individual lot owners are required to cover expenditures that are beyond the expected inflow based on monthly levies and the ability of the sinking fund or maintenance fees. These shortcomings force the corporations to introduce special levies, borrow strata loans, or enforce arrears hence all of which impose a sudden or long-term financial burden on the household budgets (Arkcoll et al., 2013). A previous study proves that almost two-fifths of Australian schemes have already levied at least one special levy, thus showing the extent of the phenomenon and proving that poor reserve planning is one of the main triggers of owner distress (Antoniades, 2008). For example, reports on Flat PKNS Tapak Maha in Taman Datuk Harun, Petaling Jaya, highlighted long-standing unpaid maintenance fees, with one report stating that about 50% of owners had defaulted on the monthly maintenance fee (Bavani, 2023).

The first pathway through which financial cost impact occurs is structural and maintenance risk. Previous empirical survey of high-rise complexes in Malaysia shows that chronic defects such as cracks in the facade, water leakage, and clogged drainage are the most significant cause of unplanned spending since every unaddressed issue accumulates to larger cost repairs in the

long term (Ashiqin et al., 2023). Moreover, Peng Au-Yong et al., (2023) show that there is a statistically significant correlation between the ineffective preventive maintenance procedures and maintenance budget overruns, proving that physical neglect is directly converted into cost variance. Concisely, all deferred repairs translate to future capital shocks, which have to be financed by special assessments or new debt, thus increasing financial cost impacts.

Next, the management and operational risk is a compounding factor that increases the recurrent spending, reduces the revenue collection and continues the financial distress of community bodies corporate like JMB and MC. Mohd Tawil Norngainy & Che-Ani A. I., (2010) reveal that 50% of the strata building surveyed in Malaysia receive less than 50% of the prescribed service charges, generating an ongoing cash-flow deficit that slows down necessary works and triggers a downward spiral of non-payment and increasing arrears. Peng Au-Yong et al., (2023) then single out the lack of staffing, skills, and ineffective procurement as prevailing factors increasing operating expenses and maintenance outages. Duplicated contractor work and reactive maintenance build up, annual budgets are overrun, reserves are drawn down more quickly than anticipated and the building management is forced to request special levies or loans, thereby continuing the financial cost impact.

The three domains of risk that are intertwined, structure and maintenance risk, financial planning risk and managerial risk, interact to create a self-reinforcing cycle of unplanned spending and revenue deficit. The structural failures impose heavy capital needs, the reserve strategies are ineffective or none existent to cushion these needs and the operational weaknesses increase the operating costs and reduce the collection of revenue by imposing levies. The net effect is a state of financial cost impact that threatens the solvency of building management as well as the capacity of residents to afford high-rise residential housing.

Legal and Liability Exposure

Legal and liability exposure in a strata context refers to the likelihood that building management or owners will incur sanctions, claims of compensation or legal action because of a building failing to meet statutory requirements or generally accepted standards of care. The consequences of such exposure usually include tribunal fees, court costs, fines, rectification orders, and high insurance premiums, whereas owners have to deal with personal liability issues and risk losing their reputation (Hamzah & Abdullah, 2018). The PJ8 Service Suite case in Petaling Jaya shows how disagreement over service charges can escalate into tribunal and court proceedings, with the JMB counterclaiming a service-charge shortfall amounting to RM314,086 (Raymond Mah & Fung Kar Men,

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2024). Such exposures therefore undermine the financial stability of the common property and undermine the trust that the residents have in the governance system.

Failure of governance is one of the main channels through which liability can occur. Modern empirical studies of the Malaysian Strata Management Tribunal reveal that thousands of cases are recorded annually, many of which are initiated by failure to comply with the procedures of meetings, enforcement of by-laws, or misconduct of joint management body or management cooperation in their fiduciary duties (Hamzah & Abdullah, 2018). (Chong et al., 2021) also show that poor early briefings and poor stakeholder communication significantly raise the frequency of such disputes, thus causing legal costs, delaying decision making, and causing reputational damage.

Risk that are related to security and safety are equally a powerful source of liability. Zhanget al., (2024) reveal that the lack of fire protection and limited access to the appliances are the key factors that determine the occurrence of severe loss events in Chinese high-rise building, which highlights the legal responsibility of the management to ensure life-safety systems. Taken together, these studies demonstrate that physical safety deficiencies may trigger class actions, mandatory remediation orders, and increasing premiums each of which is a legal liability consequence.

Life safety and Physical harm

The sphere of strata building of life safety and physical harm risk includes those conditions that endanger the lives of occupants or cause them bodily harm, such as fires, structural collapse, equipment failures. The occurrence of these risks triggers the direct humanitarian impact, puts strata title committees in the line of fire, and can necessitate mandatory evacuation or compulsory rectification orders that ripple into the scheme finances and reputation.

Fire remains the most serious life safety hazard facing high-rise residential building, in large part due to high occupancy levels, limited escape routes, and high levels of combustible materials. (Zhang et al., 2024) show that residential towers with poor fire safety facilities have not only a high rate of fire incidence but also a greater level of negative consequences. These results confirm the legal duty that is placed on building managers to maintain safety systems that meet the existing building codes.

According to Dan, 2021 outlined repeated failures in cantilever-slab fractures, surface spalling, and balcony railing detachment, which were attributed to injuries and could lead to deaths victims. The study showed how the latent design defects in common property can unexpectedly transform the normal wear into life safety disasters. A case study of Highland Towers Condominium collapse in Taman Hillview, Ulu Klang, Selangor demonstrates unstable

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foundation, inadequate drainage, retaining-wall failure, and human reliability can escalate into severe physical harm (Bin Azuwa & Bin Mat Yahaya, 2023).

The third channel of harm is technological failures, especially elevator entrapment. Gu et al., (2023) also emphasised that the breakdown of elevator systems in a dense urban cluster would be even more dangerous in the case of an earthquake, as it could leave passengers trapped.

Stakeholder trust and Reputation

Trust and reputation of stakeholders in strata schemes are essential pillars that support the sustenance of peaceful communal coexistence and effectiveness of governance. The instances of governance failure, such as ineffective communication or lack of transparency, may have a significant adverse effect on the confidence of the stakeholders. Ashiqin et al., (2023) reveal that in the case of management bodies that experience insufficient interaction with owners, especially at the Annual General Meeting (AGM) or other critical decision-making points, the level of resident dissatisfaction increases and the reputation suffers. These findings support the importance of frequent, transparent communication as a necessary condition to maintain trust and reduce conflicts. In its turn, evidence of governance studies shows that unresolved disputes over common area use or financial mismanagement, when not addressed, contribute to the development of negative perceptions, further degrading reputation and overall satisfaction (Chong et al., 2021).

Previous record studies have linked substandard maintenance and safety related incidences to reputational damage that is attributed to strata schemes in Australia. Antoniades, (2008) states that the strata management failures such as frequent flooding or structural flaws erroneously reduce the satisfaction of the residents and destroy the interpersonal trust. When such issues are not addressed in a timely manner, they often lead to complaints by the people and media coverage, which damages the image of the scheme. Failure to carry out repairs and maintenance for a long time can also affect the sale of the property and deter potential tenants, thus affecting the image and financial stability of the strata community.

Operational performance

Operational performance consequences refer to the level of efficiency and effectiveness that defines the day-to-day management operations especially maintenance activities, financial management, security operations as well as the extent of communication between management body and residents. When performance in the operations is low, high costs, low quality of life and widespread dissatisfaction among residents usually follow, endangering property values and lowering resident retention rates. In addition, the Verve Suites Mont'

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Kiara case demonstrates how house rules, short-term rental activities and residents' use of strata parcels can create legal and governance challenges (Tuan Mat et al., 2020). On the other hand, an excellent performance of operations allows an easy management of the common property resources, increases the satisfaction of residents and encourages the long-term sustainability of the building.

Unacceptable performance of the operations often leads to high maintenance expenses. Poor maintenance planning and poor repair implementation increase the overall financial expenditure in the long run. The study conducted by Peng Au-Yong et al., (2023) shows that postponed maintenance, namely, the postponement of plumbing or structural repairs, usually ends up with a more costly remedial action later. This inefficiency increases the financial strain on strata cooperation management necessitating reallocation of funds across other budget items or introduction of special levies the cost pressure that follows only adds to the financial pressures already being experienced.

Inefficiencies in operations are a chronic problem in the strata housing. As the study by Arkcoll et al., (2013) shows, inappropriate financial management and failure to adhere to the planned operation budget may force strata corporations to spend more than they should. This kind of misuse of resources worsens the state of the common areas and lowers the overall quality of services provided to the residents. Poorly planned and implemented spending on key services such as cleaning, landscaping, and building security reeves dissatisfaction among property owners, creates conflict, and finally, lowers assessed values. Similarly, the case of Pangsapuri Selayang Segar in Batu Caves illustrates the connection between resident payment behaviour, JMB formation, common property upkeep and local authority intervention. These cases reflect the interdependence between financial risk, management and operational risk in strata building operations (Chen, 2026).

In addition to operational inefficiencies, security failures are another vector that may decrease performance. According to Dan, (2021), poorly maintained or insufficiently financed security systems, such as the access control systems of the building or video surveillance, increase the likelihood of safety violations, which undermines the feeling of security and the general confidence in management among residents. The more the security concerns, the worse the operational performance as more resources are needed to curb the same.

Environmental resilience

Environmental resilience has become a key managerial issue in high-rise residential buildings over the past years. Failure to consider resilient design and maintenance activities is likely to increase maintenance cost, trigger property deterioration, subject property owners to regulatory fines, and reduce asset value.

In the field of sustainable building design, reducing the energy requirement of a building is one of the most important factors that determine the overall performance. According to the results of Ashiqin et al., (2024), high-rise buildings with energy efficient technologies, demonstrate a lower level of operational expenses, which is explained by the decreased reliance on external sources of energy and drinking water. On the other hand, the failure to implement such sustainability interventions is associated with high utility costs, increased carbon footprint, and increased exposure to environmental fluctuations.

Furthermore, the direct impact of environmental resilience is on property values. The modern market players are placing high value on the assets that have sustainable characteristics. The properties with increased energy efficiency, resilience to climate effects and compliance with environmental regulations are typically evaluated as more appealing investment. Past studies show that such assets fetch better resale prices and have an increased demand. Farhana et al., (2023) in their study further show that real estate units that incorporate sustainability features, that is, energy-efficient lighting and climate-responsive design, perform better than traditional properties in marketability. In comparison, buildings that do not consider the resilience of the environment can face low marketability, triggering a decline in property values and negative impacts on the financial returns.

Data and Cyber integrity

Data management systems are currently a part and parcel of strata housing operation. The online platforms regulate communication, maintenance, security, and financial management in high-rise residential buildings. Even though such integration can be used to improve organisational efficiency, it also comes with significant risks of data security and vulnerabilities to cybersecurity attacks. The breach of data is one of the biggest risks to privacy, may interfere with regular business, and subject strata management bodies to legal and financial consequences. The management expose sensitive information, thus making identity theft, financial fraud, and reputation damage more probable (Spanca & Salihu, 2024).

The above highlight the likelihood of occurrence from various risks in high-rise residential building (strata) management. Having identified the most significant relationships between specific risks and their influence on the strata community, the research provides an in-depth understanding of how the operational, financial, legal, and safety issues can affect the stability and performance of high-rise residential projects. Most of the risk have consequences on life safety physical harm, operational performance and data cyber security towards high-rise residential (strata) management. Hence, it is vital to propose a

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systematic, efficient risk management framework for high-rise residential building management.

CONCLUSION

This study identified nine critical risk categories affecting high-rise residential building operations in Malaysia, namely financial, governance and legal, structural and maintenance, management and operational, resident-related, security and safety, environmental, technological, and reputational risks. The findings show that these risks are interdependent, where poor financial management may delay maintenance and affect safety, while weak governance may increase legal disputes, reduce resident trust, and disrupt operational performance. Therefore, risk management in strata buildings should be treated as an integrated governance and operational process rather than a fragmented response to individual problems. The study recommends that JMBs, MCs and property managers adopt a structured risk management approach based on MS ISO 31000 or AS/NZS ISO 31000, including the preparation of a building risk register, classification of operational risks, probability and impact assessment, assignment of responsible parties, and periodic review of mitigation actions. For policymakers, the findings suggest the need to strengthen strata governance through annual risk management plans, standardised risk reporting templates, and clearer guidance for COBs, JMBs and MCs in managing financial, maintenance, legal, safety, environmental and technological risks. Future research should validate the identified risk categories through interviews, focus group discussions or surveys involving strata stakeholders, develop a strata-specific risk assessment matrix, and compare risk priorities across strata buildings. Overall, this study provides an initial foundation for developing a practical risk management framework that can improve decision-making, reduce disputes, protect property value and promote safer and more sustainable high-rise residential communities. Finally, this research presented in this paper is initially and part of an ongoing PhD research in design and built environment of Universiti Teknologi MARA.

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EVALUATING THE QUALITY OF SERVICE (QOS) OF URBAN BUS PERFORMANCE IN THE CAPITAL STATE OF PERAK, MALAYSIA

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Abstract

Global urbanisation results from demographic trends, such as population growth, migration from less urban to developed areas and international migration to developed countries. Rapid population growth has increased the number of vehicles. Moreover, ongoing infrastructure development has struggled to keep pace with the urban population growth. The objective of this study was to assess the quality of urban bus services in Perak, Malaysia. The data were collected from Terminal Bus Medan Kidd in Ipoh, Perak. To assess bus performance in this study, the transit capacity and quality of service manual (TCQSM, 2013) were selected as the main guidelines. Results showed that the average operational duration was 14 h and 4 min with daily rating of QOS C. The average service frequency recorded a headway of 76 min, a corresponding rating of QOS E. Punctuality assessment had an average on-time departure rate of 80.74%, a corresponding rating of QOS D. The overall QOS corresponded to an overall classification of QOS C (QOS score of 3.75). Bus services in Ipoh are operationally sufficient, but operational optimisation is required to achieve a more reliable and user-oriented bus service.

Keywords: sustainable public transportation, urban bus performance, quality of service (QOS), carbon footprint, green energy

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INTRODUCTION

Global urbanisation results from three main demographic trends: population growth, migration from rural to urban areas and international migration to developed countries (Rodrigue, 2024). According to United Nations publications, more than half of the world's population now lives in cities and this is expected to reach nearly 70% within the next 25 years (UNDESA, 2023; Chuhdary et al., 2025). Rapid urbanisation and development have increased the number of motorised vehicles and current urban infrastructure development has struggled to keep pace with the current population and development (Chow et al., 2019). High volume of vehicles and congestion caused major extensive interruption for road users (Shaji et al., 2023). Therefore, the public bus services should serve as the main mode of transport in the city area, linking suburban and residential areas with the urban centre (Ngadiman et al., 2020; Norhisham et al., 2021).

Recent literature addressed the urgency for operators to improve the daily services in certain locations to accommodate passenger demand and needs. Bus services have a major role and influence on human's daily movement patterns (Lachapelle & Boisjoly, 2023). Addressing issues raised by passengers and the physical condition of buses remains essential for bus operators (Rong et al., 2022). Consequently, there is a necessity to determine the present quality of bus performance in urban areas (Sugito et al., 2025). Evaluation of current bus performance includes monitoring the daily operational services as well as understanding passenger and people expectations and perceptions (Esmailpour et al., 2024; Nor & Miskam, 2020). As customers passengers have their expectations towards the bus service, which play a significant role in informing passengers on daily services (Kerber et al., 2021).

Previous literature had addressed a significant concern about the QOS of public bus services amongst scholars due to issues with passenger satisfaction and the number of daily ridership. QOS formally refers to the operational standard adopted by the public transport authority (Ubaidillah et al., 2022). There are several factors and challenges affecting the QOS assessment, such as punctuality, frequency and crowding (Liu et al., 2025). The Malaysian Government, through the Inland Public Transport Authority (APAD), is committed to improve the quality of public bus services despite the huge competition faced by local bus operators in Malaysia (Ministry of Transport Malaysia, 2019). In developing nations, bus services remain as one of the travel options within major cities in developing nations (Ramli et al., 2017).

Hamzah et al. (2023) highlighted dissatisfaction due to limited operating hours, especially in the evenings and during weekends, which limited bus usage despite the escalating need in city and suburban areas. Assessing bus performance should consider aspects such as reliability, quality, efficiency and effectiveness (Ponrahono et al., 2017). Authorities were strongly advised to

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address the quality concerns raised by the local bus stakeholders (Pira et al., 2021). Various attributes affecting the quality, operational concerns raised by passengers to adapt their day-to-day movements effectively (Amir et al., 2025).

In literature concerns about the capability of bus drivers to follow the existing schedules were raised (Sogbe et al., 2025). Passenger and user trustworthiness towards the services was based on the on-time departure in the timetable (Bakar et al., 2022). Dependency and reliance towards bus services as the primary mode of connectivity declined due to lower service performance relative to other motorised modes (Shukri et al., 2020). In addition, recent challenges found an imbalance of demand and supply between bus services and passengers. Definitive solutions to improve urban public transportation were continuous planning and monitoring current services (Ponrahono et al., 2018). Bus authority and operators have addressed the preference and need for comfort, safety and cleanliness in the local bus station in Ipoh, Perak (Zulkiflee, 2020).

Therefore, all public bus stakeholders should play their roles to facilitate better information on current bus performance between the government, bus operators and public (Saad, 2016). Punctuality influences passengers' decisions about the daily travel (Borhan et al., 2019). Previous studies indicated that service frequency built passengers' expectations and perceptions as users of services (Deb & Ahmed, 2018). Services that adhere accurately to timetables build greater trust (Norhisham et al., 2021). Consequently, evaluating urban bus services, particularly in terms of service quality, is essential. Therefore, the objective is to determine the quality of urban bus performance in Ipoh, Perak.

RESEARCH METHODOLOGY

Study Area

This section explains essential methods taken to determine the QOS of urban bus services in the capital state of Perak, Malaysia. Data from the Terminal Bus Medan Kidd in Ipoh, Perak were assessed, which serves as the main terminal for the local bus services hub in Central Perak. It covers several districts in Perak, such as Kinta, Central Perak, Kuala Kangsar, Kampar and Manjung. The data were collected between Jun and October in 2023. The Perak Transit was the only bus operator operating local bus services during data collection.

Table 1: Selected location in Ipoh, Perak

State Capitals	Selected Bus Terminal	Routes
Ipoh	Medan Kidd	T30A, T30B, T31A, T31B, T32, T33A, T33B, T34, T35, T36, T37, F100, F101A, F101B, F102, F103, 35, 37, 39, 46, 66

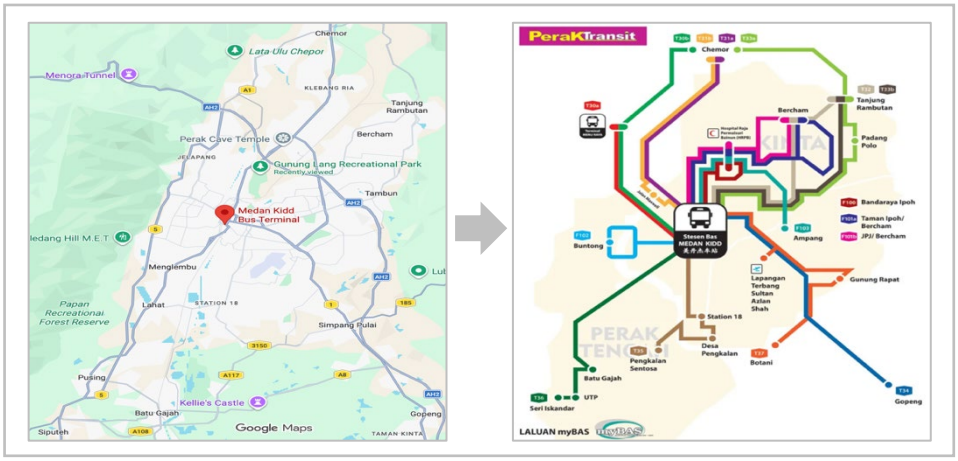


Figure 1: Map and bus route in Ipoh, Perak (Google Maps, 2025; Perak Transit, 2025)

Quality of services (QOS)

To measure the QOS of bus performance, the transit capacity and quality of service manual (TCQSM, 2013) (Transportation Research Board (TRB), 2013) were chosen as the main study guidelines. Therefore, this study presents the QOS of urban bus performance in Perak, Malaysia. At the end of this study, the QOS for each attributed were categorised based on grades stated in the guidelines and the overall QOS for bus performance in Ipoh was also identified.

Service hours

Service hours for bus services were determined by summing up the number of hours of bus operations, starting from the initial departure until the last departure across all routes in the selected location. The service hours for a specific route can be obtained from the service operator. Table 2 presents the QOS classification for service hours attributes according to TCQSM guidelines.

Table 2: Quality of services (QOS) for service hours (TRB, 2013)

Quality of Service (QOS)	A	B	C	D	E	F
Average Service Hours (Hours)	24 - 19	18 - 15	14 - 12	11 - 7	6 - 4	3 - 0

Service frequency

Service frequency of bus performance was assessed by calculating the average departure time for all routes in selected locations. Multiple headways were obtained for the entire day of bus services. Then, the average for each location was calculated. Frequency intervals were calculated by determining the different

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time intervals between current scheduled departure time and previous consecutive scheduled departure for each route. Table 3 presents the QOS classification for service frequency attributes based on TCQSM guidelines.

Table 3: Quality of services (QOS) for service frequency (TRB, 2013)

Quality of Service (QOS)	A	B	C	D	E	F
Service frequency (Minute)	< 10	10 - 14	15 - 20	21 - 30	31 – 60	> 60

Passenger load

Passenger load was determined based on the total number of passengers boarded and disembarked from the bus at every bus halt from the initial location to the destination. The total number of passengers was calculated for round-trip trips in each route. Data were collected during weekdays instead of weekends since the number of passengers on normal days was estimated to be greater than during weekends. Few routes were chosen in this analysis and passenger load was measured by dividing the overall number of passengers by the number of seats offered in each bus. Table 4 shows the QOS categorisation for passenger load attributes based on the TCQSM guidelines.

Table 4: Quality of services (QOS) for passenger load (TRB, 2013)

Quality of Service (QOS)	A	B	C	D	E	F
Passenger load (Passenger / Seat)	0.00 - 0.50	0.51 - 0.75	0.76 - 1.00	1.01 - 1.25	1.26 – 1.50	> 1.50

On-time performance

On-time performance refers to readiness of the bus to depart according to the timetables given by bus operators. It refers to the capability for buses depart and arrive at each bus stop based on the original timetable. The exact time of bus departure for the whole route was recorded and the exact time of bus departure was compared with the original schedule for all routes stipulated by the bus operators. On-time performance was categorised as the actual time departure between 1 min earlier and 5 min later than the timetable. To assess bus service quality, the percentage of on-time performance for overall routes was calculated accordingly. The percentage of on-time departures was stated after a comparison between the actual time of departure and scheduled departure. The QOS grade for each route was classified accordingly. Table 5 denotes the QOS grade for on-time performance service.

Table 5: Quality of services (QOS) for on-time performance (TRB, 2013)

Quality of Service (QOS)	A	B	C	D	E	F
On Time Performance (%)	100.0 - 95.0	94.9 - 90.0	89.9 - 85.0	84.9 - 80.0	79.9 - 75.0	< 75.0

RESULT AND DISCUSSION

Summary of Departure

This part describes the results of this study accordingly. The QOS results were gathered based on the procedure addressed in the Methodology part. Local bus services in Ipoh are operated by a single bus operator and the daily operation was controlled and monitored by the Transportation Ministry through Agensi Pengangkutan Awam Darat (APAD) under the Interim Stage Bus Support Fund (ISBSF) programme.

Service hours

Service hours are defined by the hours of bus services from the first departure until the last departure daily. Table 6 shows QOS for service hours attributes in this study. Analysis of the operating hours of bus operation in Ipoh indicated a moderate overall level of service availability, with an average operational duration of 14 h and 4 min daily, and thus corresponding to an overall QOS service hours rating of QOS C. Most route commenced operations between 5.40 AM and 7.10 AM and concluded between 7.00 PM and 9.55 PM, reflecting a general alignment with the typical daily travel demand, particularly for work and school related trips. Nevertheless, only a few of the routes, namely T30A, T30B, T32, T34 and T35, accomplished a rating of QOS B, which were mostly due to extensive service hours periods between 15 h and 16 h. These routes stipulated wider coverage hours of operation, which was very significant to cater to passenger demands in the early morning and late evening. On the other hand, most routes were graded as QOS C, with service hours stretching between 12 h and 14 h and 30 min, which showed the inadequate availability outside peak hours.

As a comparison based on an operational point of view, most routes graded as QOS C signified that public bus services in this study might have less demand after off-peak hours in the evening. Travel patterns were inconsistent, especially for students with extended schedules, shift workersector and unscheduled visitors. Routes such as 39 and 37, which operate for only 12 h daily, exhibited the shortest service hours period and may reduce the passenger expectation towards bus services and shift their travel option to the private mode. The current QOS study addressed that extended service hours improved the service reliability, user satisfaction and perceived accessibility, especially in

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urban areas with diverse passenger movements. Therefore, the mid-range service hours were recommended for service extension, especially in early morning and late evening services in primary routes with higher passenger demand. Overall, the existing service hours were adequate for minimal daily movement and required a strategic improvement to improve the QOS from basic to better grade, increase public transport usage and develop urban accessibility in Ipoh, Perak.

Table 6: Quality of services (QOS) for service hours attributes

Route	First trip	Last trip	Hours of services	QOS
T30A	6.00 AM	9.00 PM	15.00	B
T30B	6.30 AM	9.30 PM	15.30	B
T31A	6.10 AM	8.10 PM	14.00	C
T31B	7.10 AM	9.10 PM	14.00	C
T32	6.05 AM	9.05 PM	15.00	B
T33A	5.40 AM	7.40 PM	14.00	C
T33B	7.00 AM	9.00 PM	14.00	C
T34	6.15 AM	9.15 PM	15.00	B
T35	5.55 AM	9.55 PM	16.00	B
T36	6.00 AM	7.30 PM	13.30	C
T37	5.40 AM	7.00 PM	13.20	C
F100	6.30 AM	8.10 PM	13.40	C
F101A	6.00 AM	8.00 PM	14.00	C
F101B	7.00 AM	9.00 PM	14.00	C
F102	6.05 AM	8.05 PM	14.00	C
F103	5.55 AM	7.55 PM	14.00	C
35	6.00 AM	8.30 PM	14.30	C
37	7.00 AM	7.00 PM	12.00	C
39	6.30 AM	6.30 PM	12.00	C
46	6.00 AM	7.30 PM	13.30	C
66	6.00 AM	8.30 PM	14.30	C
		Average	14.04	C

**Score range: A = 6, B = 5, C = 4, D = 3, E = 2, F = 1*

Service frequency

The results of service frequency in this study showed that all routes had a long gap of operational frequency, with 76 min of total average headway, resulting in an overall QOS grade of QOS E. Table 7 indicates the overall results for service frequency attributes in this study. Most routes operated with extensive and inconsistent gaps between each departure, with intervals between 60 min and 120 min, signifying irregular service delivery through the bus network. There were several routes operating at approximately 60 min intervals, namely T30A, T30B, T32, F102 and F103, which were graded in QOS E. It showed the inadequate service attractiveness for time-sensitive travel trips. In addition, several routes involving T31A, T33A, T33B, F101A, F101B, and 39, revealed tremendously long headways surpassing 120 min between each trip, were classified as grade

QOS F. These outcomes recommended that service frequency still reflect a main limitation in the bus services, especially when linked to normal established urban public bus services targeted that aimed customer friendly services with more frequent and less waiting time.

Table 7: Quality of services (QOS) for the service frequency attribute

Route	Minute										Average interval	QOS
	210	150	120	90	80	60	45	40	30	20		
T30A						15					60	E
T30B						15					60	E
T31A			7								120	F
T31B			7								120	E
T32						15					60	E
T33A			7								120	F
T33B			7								120	F
T34						9			12		43	E
T35						10			12		44	E
T36							18				45	E
T37					1	12					62	F
F100										41	20	C
F101A			7								120	F
F101B			7								120	F
F102						14					60	E
F103						14					60	E
35						1	1	19			41	E
37						12					60	E
39	1	1	3								144	F
46				5		6					74	F
66						8			13		41	E
									Average		76	E

**Score range: A = 6, B = 5, C = 4, D = 3, E = 2, F = 1*

From an analysis perspective, only one route (F100) was classified as QOS C, with an average gap of nearly 20 min, showing a comparatively reliable and frequent service. This difference addressed a significant inconsistency in bus service delivery within routes in the same location. The present public transport study consistently highlighted that higher service frequency increased convenience for passengers, reduced waiting time and enhanced the overall service effectiveness against private vehicles. With regard to Ipoh, most routes were the QOS E and QOS F, which recommended that the existing service frequency may discourage consistent ridership, specifically for passengers, students and transit-based users. The result signified that while limited high-frequency service exists the bus network was unable to offer comprehensible and extensive frequency daily.

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Passenger load

The assessment of passenger load attributed for several bus routes in Ipoh, , suggesting a very significant level of service, with all measured routes accomplishing QOS of QOS A. Passenger load results within the assessed route were constantly low, going between 0.08 and 0.22, even with disparities in the total number of passengers boarding. For example, Route T30B and T100 recorded comparatively higher boarding counts, yet continued with low load factors, suggesting adequate bus capacity to accommodate the demand accordingly. Likewise, routes T34 and T37, which recorded lower passenger boardings and exhibited lower occupancy levels. The total average passenger load showed that bus services were managing under capacity, demonstrating slight crowding conditions and a high level of passenger comfort through the data collection period.

Table 8: Quality of services (QOS) for passenger load attribute

Routes	Number of passenger boarding	Passenger load	QOS
T30B	28	0.22	A
T34	5	0.08	A
T37	17	0.09	A
T100	15	0.22	A
F103	8	0.14	A
	Average	0.75	A

**Score range: A = 6, B = 5, C = 4, D = 3, E = 2, F = 1*

Based on the outcomes, it showed that low passenger load results were mostly linked with enhanced journey comfort, decreasing the standing situations and improving passenger satisfaction level, as underlined in current service quality of public transportation studies. In the circumstance of Ipoh, the consistently higher QOS evaluation designated that the current capacity provided was more than enough for existing demand and needs levels. While these conditions were a very positive point of passenger and user views, they showed an underutilisation of bus services, especially when the passenger load attributed findings were also considered with other service quality attributes. Literature outcomes recommend that low passenger loads reveal disparities between service supply and demand by users, possibly occurring from irregular services, low ridership levels or short operating hours. Generally, the passenger load outcomes not only exhibit a significant performance in terms of crowd and comfort, but also underline the importance of a combined assessment of service quality attributes to ensure that high QOS in passenger load contributes a significant service efficiency and continues to maintain a sustainable public transport in Ipoh.

On-time performance

Lastly, the on-time performance assessment for bus services in Ipoh exhibited a sufficient level of overall timetable compliance with an average on-time departure level of 80.74%, resultant to an overall QOS grade of QOS D. Considered disparities in timetable compliance were seen within routes in this study. Certain routes, such as T32, F102 and F103 attained a 100% of on-time performance according to the timetable, demonstrating highly reliable operations and classified as QOS A. Other routes, including T30B, T34 and 35, were also achieved, with an on-time percentage surpassing of 90%, reflecting higher timetable compliance. On the other hand, a few routes, namely T31A, F100 and 37, 39 and 66, indicated on-time performance lower than 70%, classifying QOS rating of QOS F. These difference highlighted irregularities in operational consistency within the bus services in this study.

Table 9: Quality of services (QOS) for on-time performance

Route	Total departure	Number of on time departure	On time percentage (%)	QOS
T30A	16	13	81.25	D
T30B	16	15	93.75	B
T31A	8	3	37.50	F
T31B	4	3	75.00	E
T32	16	16	100.00	A
T33A	8	7	87.50	C
T33B	8	7	87.50	C
T34	22	20	90.91	B
T35	23	20	86.96	C
T36	19	16	84.21	D
T37	14	11	78.57	E
F100	42	30	71.43	F
F101A	8	7	87.50	C
F101B	8	6	75.00	E
F102	15	15	100.00	A
F103	15	15	100.00	A
35	22	20	90.91	B
37	13	7	53.85	F
39	6	4	66.67	F
46	12	10	83.33	D
66	22	14	63.64	F
		Average	80.74	D

**Score range: A = 6, B = 5, C = 4, D = 3, E = 2, F = 1*

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Based on the previous study, on-time performance attributes are extensively known as a critical element of passenger expectation and trustworthiness towards the reliability of public transportation. Certain routes with high schedule compliance provided a high expectation, thereby reducing perceived waiting times and improving passenger trustworthiness. Contrariwise, routes with poor schedule compliance may cause substantial inconvenience to passengers, especially when merged with extensive service headways, as service interruptions can intensify uncertainty and lower the feasibility of travel time according to the permitted schedule by the public transportation authority. Current transport findings constantly address that unreliable service can deter existing users and play a part in total dependency towards private vehicles. In this study, most routes were classified as QOS D, QOS E, and QOS F, showing that several routes exhibited strong reliability and the overall bus service performance remained imbalanced. Improving schedule compliance, specifically on low-performing routes by managing punctuality, operational monitoring, and traffic management, would be important to improve the overall QOS and reinforce the function of bus services as a main transport mode in urban mobility.

Quality of Services (QOS)

The overall QOS assessment for bus services in Ipoh showed a sufficient level of service performance, with a mean QOS score of 3.75, resulting in an overall grade of QOS C, as shown in Table 10. The study result revealed a varied result within the assessed service quality attributes. Service hours, classified as QOS C (score = 4), indicated that operating hours were generally adequate for daily travel necessities but still limited in early-morning and late evening hours. In contrast, service frequency emerged as the lowest attribute, obtaining QOS E (score = 2), showing prolonged headways and infrequent services that lower convenience and accessibility. Conversely, passenger load is classified as QOS A (score = 6), indicating a low occupancy level and high passenger load within all routes. On-time performance, graded as QOS D (score = 3), revealed moderate timetable adherence for all routes. Collectively, these outcomes showed that a disparity in QOS attributes existed, whereby certain attributes had good reliability and limited availability.

Table 10: The overall quality of services (QOS) in Ipoh

Attributes	QOS	QOS Score	Mean QOS	Overall QOS
Service hours	C	4	3.75	C
Service frequency	E	2		
Passenger load	A	6		
On-time performance	D	3		

**Score range: A = 6, B = 5, C = 4, D = 3, E = 2, F = 1*

Current literature on public bus services highlights that overall service quality effectiveness is limited by its weakest service quality attributes, especially those related to availability and reliability. In the case of Ipoh, the strong performance showed by the passenger load attribute did not fully balance by deficiencies in service frequency and on-time performance, as infrequent and unreliable services can considerably diminish perceived service quality regardless of the comfort situation. The overall classification in this study was QOS C, which showed that the bus services offered a fundamental and functional bus service, but lack consistency and availability and are essential to remain competitive as compared to private transport and e-hailing modes. To improve service quality, room for improvement in service frequency and on-time performance are essential, together with enhancements to longer service hours. In summary, the integrated QOS outcomes proposed that while bus services in Ipoh are operationally adequate, strategic service planning and operational optimisation are essential to accomplish a more reliable, balanced, user-friendly services. The results show that bus services are aligned with the implementation of transit-oriented development (TOD) policy in Ipoh, Perak, where most of the urban areas are covered by stable and continuous public bus services. Bus operators and state authorities should monitor current bus services compared with the main principles of transit-oriented development (TOD), which are the transit system, density, and potential of land development, and economic development.

In addition, passengers and users also conveyed substantial concerns in certain areas, such as requiring real-time information on bus services along the whole route to promote usage of bus services as a preferred transportation mode. This study was conducted after the post-COVID-19 pandemic. The core limitation of this study was focus solely on a quantitative engineering approach to QOS attributes. Therefore, the recent study should act as a fundamental understanding of urban bus service quality in this country, and it is strongly suggested to combine both quantitative and qualitative methods, as well as the adaptation of the Internet of Things (IoT), in future studies in this area. Moreover, the public transport authority, states local council and bus operators should work closely together to improve bus services and urban public transportation for the benefits of passengers and users in Ipoh.

CONCLUSION AND RECOMMENDATION

The motivation of this study is to assess the QOS of urban bus performance in Ipoh, Perak. This study primarily evaluated bus services in Ipoh by assessing its QOS using the transportation engineering guidelines, Transit Capacity and Quality of Service of Manual (TCPRM, 2013). Four attributes were assessed in this study, which covered service hours, service frequency, passenger load and on-time performance. A total of 21 bus routes in Ipoh were assessed. The results

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demonstrated that the average operating hours were 14 h and 4 min daily, resultant to an overall QOS service hours rating of QOS C. The average service frequency recorded a headway of 76 min, reflecting an overall QOS rating of QOS E. Passenger load results across the route were consistently low, between 0.08 and 0.22, despite variations in the number of passengers boarding, corresponding to an overall QOS rating of QOS A.

On the other hand, the assessment of on-time performance for bus services in Ipoh demonstrated a moderate overall level of schedule adherence, with an average on-time departure rate of 80.74%, corresponding to an overall QOS rating of QOS D. The overall QOS assessment for bus services in Ipoh indicated a moderate level of system performance, with a mean QOS score of 3.75, corresponding to an overall classification of QOS C. The integrated QOS results suggested that while bus services in Ipoh are operationally sufficient, strategic service planning and operational optimisation are required to achieve a more balanced, reliable and user-oriented public bus service. The outcomes of this study can be a reference for the authority and bus operators to upgrade the QOS of urban bus services. Further study on this topic by other researchers is highly recommended.

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DISCLOSURE STATEMENT

The author declares that there is no conflict of interest in this research.

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HOW INDOOR ENVIRONMENTAL QUALITY AFFECTS RESIDENTIAL SATISFACTION BY CONSIDERING THE ROLE OF LIFE STRESS AND GENDER

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Abstract

Residential satisfaction, defined as individuals' evaluative responses to their living environments, is shaped by the interaction between physical environmental quality and psychological well-being. Although Indoor Environmental Quality (IEQ) has been widely studied in relation to residential comfort, the psychological mechanisms linking IEQ to satisfaction remain insufficiently understood. In particular, the role of life stress as a mediating or moderating factor has received limited empirical attention. Guided by Stimulus–Organism–Response (SOR) theory, this study examines how key IEQ dimensions—air quality, visual comfort, and acoustic comfort—influence residential satisfaction among working-age residents in high-rise apartment complexes, and whether these relationships are mediated by life stress and moderated by gender. A structured questionnaire survey was conducted with 454 residents of the Shengda Jingdu Apartment Complex in Haikou, China. Structural equation modelling (SEM) indicates that IEQ significantly predicts residential satisfaction both directly and indirectly through life stress. Furthermore, gender moderates these effects, with male residents deriving stronger life stress reducing benefits from IEQ. These results suggest that residential design should integrate environmental quality improvement with psychological well-being considerations to foster healthier and more satisfying indoor living environments.

Keywords: Indoor Environmental Quality, Life Stress, Residential Satisfaction, Apartment Complexes

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INTRODUCTION

In recent years, the indoor environment has been widely recognized as a critical determinant of residential satisfaction, particularly in high-density urban contexts where living conditions exert substantial influences on individuals' mental health and subjective well-being (Zhang & Yan, 2023). The World Health Organization (2022) emphasizes that indoor air quality, thermal comfort, acoustic conditions, and lighting constitute key environmental factors shaping quality of life. With the rapid advancement of urbanization in China and the continuous increase in residential density, the role of Indoor Environmental Quality (IEQ) in enhancing residential satisfaction has attracted growing scholarly attention (Bangwal et al., 2023; Xue et al., 2016) . Existing studies further demonstrate that improvements in IEQ not only enhance perceived comfort but also foster positive emotional experiences and favourable behavioural responses (Xu & Zhang, 2024). Urban office workers in high-density housing commonly experience high stress and anxiety due to frequent work–home mobility, making residential spaces key settings for psychological restoration (Chan et al., 2021). Accordingly, examining how residential environments influence psychological states and residential satisfaction is both theoretically and practically significant for housing optimization (F. Chen et al., 2023).

Despite growing interest in IEQ, two challenges remain. First, although technical studies show that optimal temperature and air velocity can improve satisfaction and energy efficiency (Rajput & Thomas, 2025), the psychological mechanisms linking IEQ to residential satisfaction remain unclear. Second, environmental psychology suggests that life stress may mediate the IEQ–satisfaction relationship. Bagais and Pati (2023) argue that indoor environments influence emotional regulation, while Bonanno (2004) notes that life stress affects how individuals process environmental stimuli. However, few studies have empirically tested life stress as a mediating or moderating factor between IEQ and residential satisfaction. Accordingly, this study examines both its mediating and moderating roles. Thirdly, gender differences also shape environmental perception. Men and women differ in sensory sensitivity and evaluative criteria (Hendy, 2015), and women are more likely to report dissatisfaction with residential conditions (Mridha, 2020), although gender effects across IEQ dimensions remain inconsistent (Psomas et al., 2024).

To address these gaps, this study adopts Stimulus–Organism–Response (SOR) theory, which conceptualises IEQ as an external stimulus influencing internal states (life stress) and behavioural outcomes (residential satisfaction). The objectives are to: (1) examine the effects of multiple IEQ dimensions on residential satisfaction; (2) test the mediating role of life stress; and (3) explore the moderating roles of gender difference. Data were collected from working-age residents in Shengda Jingdu Apartment Complex, Haikou, China. The findings

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contribute to environmental psychology by clarifying psychological pathways linking IEQ and residential satisfaction and offer implications for personalised and health-oriented interior design in rapidly urbanising contexts.

LITERATURE REVIEW

SOR Theory

The SOR model explains how environmental stimuli (S) shape internal cognitive or emotional states (O) and behavioural responses (R) (Mehrabian & Russell, 1974) and has been widely applied to examine links between environmental quality, psychological well-being, and satisfaction (F. Y. Wong et al., 2018; Zhou et al., 2021). In residential contexts, IEQ—comprising indoor air quality, visual comfort, and acoustic comfort (Y. Chen et al., 2023; Lai et al., 2009)—affects home experiences and mental health (Dreyer et al., 2018; Guo et al., 2024), with life stress acting as a key organismic mechanism linking IEQ to residential satisfaction (H. Tang et al., 2020; Xiaoxue & Huang, 2024), which represents the response component (Fernández-Portero et al., 2017; Xu & Zhang, 2024); accordingly, this study adopts the SOR framework to test IEQ–satisfaction pathways and gender differences (Goi et al., 2018; Hew et al., 2018).

IEQ and Residential Satisfaction

IEQ is a key determinant of residential satisfaction and occupant comfort, particularly in mid- to high-rise housing (H. Tang et al., 2020), and strongly affects physical health, psychological well-being, and quality of life. It is commonly defined by three interrelated dimensions—indoor air quality, luminous comfort, and acoustic comfort—which shape environmental adequacy and health-supportive housing (Dimitroulopoulou et al., 2023; Ma et al., 2021). Empirical studies show that IEQ and indoor greening enhance residential satisfaction and performance, with air quality exerting the strongest influence, followed by luminous and acoustic comfort (Xu & Zhang, 2024); however, the psychological effects of IEQ on working adults in high-rise apartments remain insufficiently examined, raising uncertainty about whether IEQ improvements enhance psychological perceptions and residential satisfaction in this group. Based on this premise, the following hypothesis is proposed:

H1: IEQ positively affects the residential satisfaction of apartment users.

The Role of Life Stress

Previous studies indicate that improved IEQ can reduce life stress (Thach et al., 2020). High noise levels increase tension and life stress, whereas better acoustic conditions enhance cognitive performance and psychological well-being (Lu & Kwan, 2025), and perceptions of indoor air quality and acoustic comfort are key

predictors of life stress symptoms (Awada et al., 2021). Life stress is therefore closely linked to higher residential satisfaction (Fornara et al., 2022), and individuals with greater life satisfaction show lower life stress reactivity over time (K. N. S. Tang & Chan, 2017). Although the life stress-mitigating role of IEQ has been acknowledged, its specific function in alleviating worry and its mediating role between IEQ and residential satisfaction remain underexplored, particularly among working residents in high-rise buildings. Accordingly, the following hypotheses are proposed:

H2: IEQ positively affects the life stress of apartment users.
H3: Life stress positively affects the residential satisfaction of apartment users.
H4: Life stress mediates the relationship between IEQ and residential satisfaction.

Demographic Differences: Gender

Gender differences in IEQ perception, especially regarding thermal comfort, are well established (Kim et al., 2013), with women showing greater sensitivity to low temperatures and distinct optimal comfort ranges (Hu et al., 2022). Given inconsistent findings across contexts, this study examines whether gender moderates the IEQ–residential satisfaction relationship and its underlying life stress.

H5: Associations between study variables differ by gender.

Figure 1 illustrates the proposed conceptual model, which examines the relationships among apartment complexes, IEQ, life stress, and residential satisfaction, while accounting for the moderating effects of gender.

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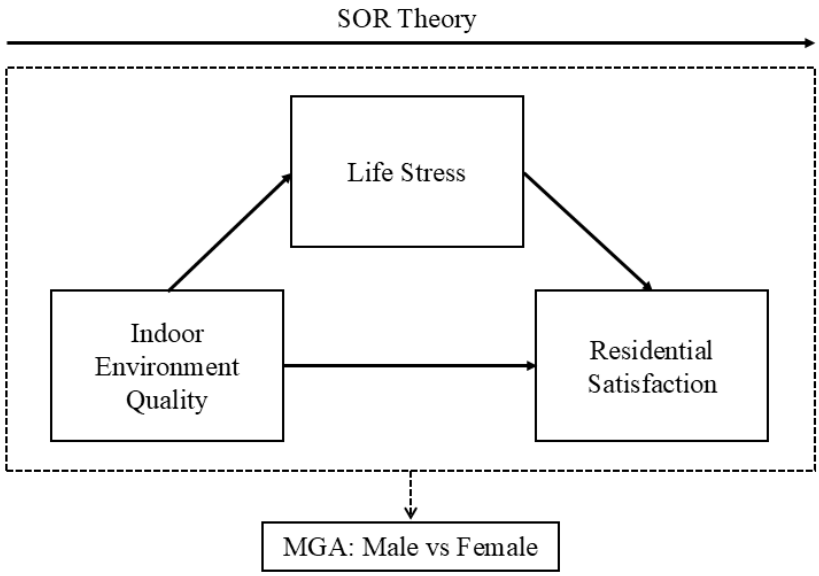


Figure 1: The Conceptual Pathway Between the Study Variables
Source: Author's Calculation

RESEARCH METHODOLOGY

Site Selection

Under Hainan's Free Trade Port strategy and the "Million Talents Recruitment Plan" (2018–2025), large numbers of young, highly educated professionals have relocated to the province, many experiencing relocation-related life stress and residential maladaptation (Stawarz et al., 2022). This study therefore targets the working-age population most vulnerable to such anxiety, examining how Indoor Environmental Quality (IEQ) influences life stress and residential satisfaction, with implications for talent retention and sustainable urban development. Haikou's tropical marine climate and rich ecological context further provide an appropriate setting to investigate the psychological effects of IEQ and the potential value of biophilic interior design in urban housing.

The empirical study was conducted at the Shengda Jingdu Residential Apartment Complex in Meilan District, Haikou City (Figures 2), which comprises three development phases with 976 households and approximately 2,437 residents, mainly young and middle-aged working adults. A stratified sampling strategy was employed by treating each phase as a stratum, and questionnaires were proportionally distributed and collected across the three phases, yielding 454 valid responses for quantitative analysis.

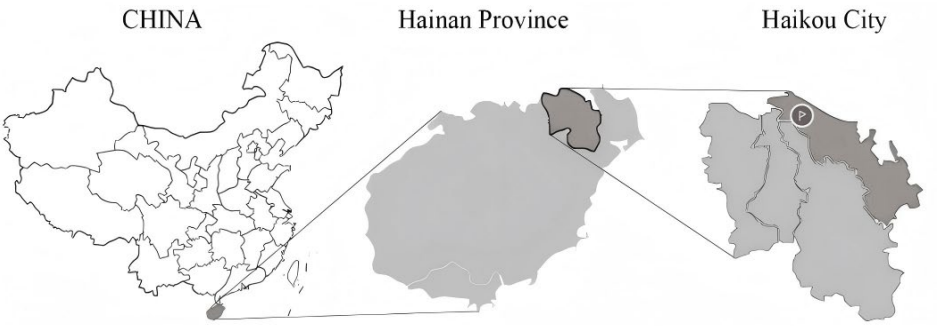


Figure 2: Location of Meilan District within Haikou City, Hainan Province, China
Source: Authors' elaboration based on Google Maps (2026)

Participants

Young working adults (≤35) are highly vulnerable to stress, depression, and burnout due to adverse work conditions (Baek & Yoon, 2024; Law et al., 2020), yet prior research has focused mainly on workplaces, overlooking the restorative role of residential environments (C. H. Wong & Abdul Aziz, 2020). Given elevated work–family conflict among adults aged 35–44 (Pien et al., 2020), this study targeted residents aged 18–40 and examined how interior design features, especially colour and light, contribute to life stress and residential satisfaction.

Data were collected via face-to-face questionnaires in Shengda Jingdu Residential Complex (September–November 2024). A total of 454 valid responses were analysed. The sample consisted mainly of females (68.3%) and Chinese nationals (96.3%), and was restricted to working-age adults aged 18–40 years, with the largest proportion aged 26–30 (43.2%). Most respondents had tertiary education (88.5%), were married (61.5%), and had children (54.8%). Household income was broadly distributed across income groups, with the largest share earning RMB 4,001–7,000 per month (40.3%), and residential tenure in the complex was relatively balanced, ranging from less than 3 years (17.0%) to more than 16 years (19.2%).

Survey Instrument

A structured questionnaire was used to examine the relationships among IEQ features, life stress and residential satisfaction (Table 1). It consisted of two sections: the first collected sociodemographic information (gender, age, education, nationality, marital status, parental status, income, and residential tenure), and the second measured the core constructs. IEQ was assessed through three validated dimensions—air quality, visual comfort, and acoustic comfort—using items adapted from prior studies (Jain & Bhandari, 2024; Larsen et al., 2020). Life stress and residential satisfaction were measured using established

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scales (Shahid et al., 2011; Wang et al., 2024). All items were rated on a five-point Likert scale (1 = extremely unsatisfied, 5 = extremely satisfied).

Analytical Techniques

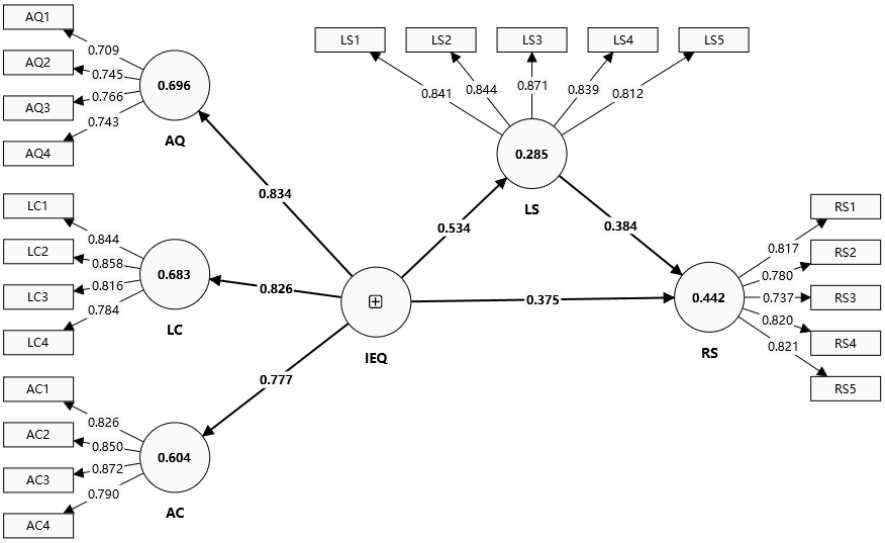
Given that the primary aim of this study is exploratory rather than focused on theoretical model development, an empirical analytical strategy was adopted to investigate both the direct and indirect effects of IEQ on residential satisfaction within apartment complexes. Structural Equation Modelling (SEM) was employed to test and validate the hypothesized relationships among the latent constructs. To further explore potential subgroup differences, a Multiple Group Analysis (MGA) was conducted to examine gender-based moderation effects, assessing whether the structural pathways differ significantly between male and female respondents.

RESULTS

Measurement Model Results

The reliability and validity of the constructs were assessed using statistical indices generated by SmartPLS based on the proposed measurement model. As shown in Table 2, all factor loadings (0.709–0.872) exceeded 0.708, indicating satisfactory indicator reliability (Hair et al., 2021). Cronbach's alpha (0.726–0.897) and composite reliability (0.830–0.924) both surpassed 0.70, confirming internal consistency. Convergent validity was supported by AVE values ranging from 0.549 to 0.708, all above the 0.50 threshold (Hair et al., 2021). Discriminant validity was established as HTMT values were below 0.85 and the square root of each construct's AVE exceeded its inter-construct correlations (Table 3), satisfying the Fornell–Larcker criterion (Hair et al., 2021). Overall, the measurement model demonstrated adequate reliability and validity, as illustrated by the parameter estimates of the PLS analysis in Figure 3.

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Source: Author's Calculation

Figure 3: Parameter estimates of the PLS analysis

Table 2. Reliability and Convergent Validity Results

Variable	Item	Factor loadings	Cronbach's alpha	CR	AVE
AQ	AQ1	0.709	0.726	0.830	0.549
	AQ2	0.745			
	AQ3	0.766			
	AQ4	0.743			
LC	LC1	0.844	0.844	0.896	0.682
	LC2	0.858			
	LC3	0.816			
	LC4	0.784			
AC	AC1	0.826	0.855	0.902	0.698
	AC2	0.850			
	AC3	0.872			
	AC4	0.790			
LS	LS1	0.841	0.897	0.924	0.708
	LS2	0.844			
	LS3	0.871			
	LS4	0.839			
	LS5	0.812			
RS	RS1	0.817	0.855	0.896	0.633
	RS2	0.780			
	RS3	0.737			
	RS4	0.820			
	RS5	0.821			

Source: Author's Calculation

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Table 3. Results of HTMT Ratios

	AC	AQ	LC	LS	RS
AC					
AQ	0.608				
LC	0.471	0.755			
LS	0.54	0.528	0.457		
RS	0.477	0.697	0.541	0.664	

Source: Author's Calculation

Following Hair et al. (2021), the R^2 value for residential satisfaction (RS) was 0.274, indicating modest but meaningful explanatory power without evidence of overfitting. All Q^2 values exceeded zero, confirming adequate predictive relevance of the PLS model (Hair et al., 2021), and the GoF index surpassed the conservative threshold of 0.462, suggesting a strong overall model fit (Hedayati Marzbali et al., 2016). Moreover, consistent with Shmueli et al. (2019), the PLS model outperformed the linear model in predictive accuracy, as indicated by lower prediction errors, demonstrating the robustness of the structural relationships among IEQ, life stress, and residential satisfaction.

Table 4. Coefficient of determination and predictive relevance and GOF of model calculation

	Items	PLS-SEM RMSE	LM RMSE	Q2	R2	AVE	GOF
IEQ (second order)	-	-	-	-	-	0.422	
LS	LS1	1.056	1.062	0.199	0.285	0.708	0.462
	LS2	1.048	1.070				
	LS3	1.007	1.020				
	LS4	1.001	1.024				
	LS5	0.982	0.999				
RS	RS1	0.802	0.809	0.274	0.442	0.633	
	RS2	0.761	0.763				
	RS3	1.034	1.046				
	RS4	0.819	0.830				
	RS5	0.887	0.896				

Source: Author's Calculation

Structural Model Results

As shown in Table 5, the structural model was evaluated following the PLS-SEM mediation guidelines of Hair Jr et al. (2021). IEQ is positively associated with Residential Satisfaction (H1: $\beta = 0.375$, $p < 0.01$) and life stress (H2: $\beta = 0.534$, $p < 0.01$), while life stress is also positively related to Residential Satisfaction (H3: $\beta = 0.384$, $p < 0.01$). A significant mediating effect of LS on the IEQ–RS relationship was confirmed (H4: $\beta = 0.205$, $p < 0.01$). Effect size (f^2) values met

the criteria proposed by Chin (1998), indicating meaningful explanatory power, and all VIF values were below 3.0, suggesting no multicollinearity concerns.

Table 5. Results of Path Coefficient and Hypothesis Testing (Direct and Indirect Effects)

H	Relationship	β	T	P	f 2	VIF	Decision
H1	IEQ -> RS	0.375	7.203	0***	0.181 (moderate)	1.398	Support
H2	IEQ -> LS	0.534	12.638	0***	0.398 (substantial)	1.000	Support
H3	LS -> RS	0.384	6.528	0***	0.189 (moderate)	1.398	Support
H4	IEQ -> LS -> RS	0.205	6.412	0***	-	-	Support

Source: Author's Calculation

MGA

MGA was conducted to test whether structural relationships differed across gender groups using non-parametric percentile bootstrapping and Henseler's MGA (Table 6). Prior to MGA, measurement invariance was verified via the MICOM procedure in SmartPLS 4.0, confirming partial invariance and the validity of cross-group comparisons (Barroso et al., 2018; Henseler et al., 2009). Significant gender differences were found in the direct effect of IEQ on LS (H1a: P(MGA) < 0.05; Table 7).

Table 7. Comparison of model relationships by the two groups using Henseler's MGA test

Relationship Multi-Group: Gender	β Female	P	β Male	P	PLS-MGA	Supported
IEQ -> LS	0.484	0***	0.644	0***	0.044	Yes/Yes

Source: Author's Calculation

DISCUSSIONS

This study extends the SOR framework by introducing life stress as a mediating mechanism and demonstrates that multidimensional IEQ significantly influences residential satisfaction, confirming that environmental stimuli shape internal emotional states and behavioural outcomes (Chang et al., 2024; Zhou et al., 2021). Consistent with evidence on air quality, luminous comfort, and acoustic comfort, favourable IEQ reduces discomfort and enhances perceived environmental control (Jara-Baeza et al., 2023; Vakalis et al., 2019) and indirectly improves residential satisfaction through life stress (H. Tang et al., 2020; Yin et al., 2020). By applying a comprehensive IEQ framework, this study

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reinforces the role of physical surroundings in shaping quality of life (Y. Chen et al., 2023; Mujan et al., 2019). Multi-group analysis further reveals gender differences, with men deriving greater life stress benefits from high IEQ, highlighting gender as a moderator and implying the value of gender-responsive design (Foye, 2017; Indraganti & Humphreys, 2021).

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This study advances theory by extending the SOR model to incorporate life stress as a key psychological mechanism linking IEQ and residential satisfaction, thereby integrating emotional resilience and psychological restoration into environmental–behaviour research (Huang et al., 2025). It further contributes by adopting a multidimensional IEQ framework (acoustic, visual, thermal, and air quality), addressing the lack of integrated assessment in prior studies (F. Chen et al., 2023; Mujan et al., 2019), and by identifying gender as a moderator of stimulus–organism processes, highlighting socio-psychological differences in environmental perception (Albuainain et al., 2021). Practically, the findings support holistic residential design that enhances air quality, luminous comfort, and acoustic comfort (Jara-Baeza et al., 2023) and promote strategies such as smart ventilation, daylight optimisation, quiet zones, and biophilic features to reduce psychological stress (Beemer et al., 2021), while underscoring the need for flexible and inclusive design responsive to gender differences (Indraganti & Humphreys, 2021). Given the gender-moderated findings, residential interiors should provide flexible and user-adjustable IEQ solutions, such as dimmable lighting, controllable ventilation, acoustic zoning, and privacy regulation (Fissore et al., 2023). These strategies can help accommodate gender-related differences in comfort perception and support more inclusive, restorative, and resident-centred housing design (Andreucci et al., 2021). These IEQ-based recommendations also align with the policy direction of Malaysia's UBBL and relevant Chinese residential standards, which emphasise adequate ventilation, daylighting, acoustic comfort, and healthy indoor living conditions (Deng et al., 2024; Mewomo et al., 2023).

This study is limited by its single-city sample in Haikou, focus on working adults, reliance on self-reported measures, and cross-sectional design, which restrict generalizability and causal inference. Future research should adopt more diverse samples, longitudinal or experimental designs, and objective indicators of environmental quality and psychological well-being.

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WHERE DO BIKE LANES WORK BEST? ALTERNATIVE PRIORITIES FOR IMPROVING BIKE LANE SERVICE PERFORMANCE IN URBAN AREA

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Abstract

As one of East Java's largest cities, Malang has significant potential for developing bike lanes and eco-friendly transportation. Although a bike lane has been installed on Jalan Besar Ijen, its use remains suboptimal due to several service issues. This study aims to identify priority recommendations for improving bike lane performance on Jalan Besar Ijen using questionnaire-based data collection. Importance Performance Analysis (IPA) is applied to assess service performance, followed by Quality Function Deployment (QFD) to formulate recommendations. The combined findings yield three priorities: (1) installing bicycle lane traffic signs at key locations, (2) establishing protected bike lanes, and (3) providing user-friendly bicycle parking spaces.

Keywords: Bike lanes, service performance, Importance Performance Analysis (IPA), Quality Function Deployment (QFD)

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INTRODUCTION

The Malang City Spatial Plan (2022–2042) calls for the construction of bike lanes in eleven Klojen and Lowokwaru subdistricts. There will also be other routes in Klojen, Lowokwaru, Kedungkandang, and Sukun. Future additions to ancillary amenities, such as bike parking, are included. Between 2019 and 2020, the city successfully erected bike lanes in eighteen locations; nonetheless, drivers' exploitation of these lanes as parking spaces has undermined their utility, highlighting the need for stricter enforcement and greater public awareness. (Mahmudan, 2023). In 2021, Jalan Simpang Balapan and Jalan Jakarta in the Ijen region were connected by a circular bike lane. The Jalan Besar Ijen corridor is well known for its colonial architecture and distinct urban character (Faisal & Adhitama, 2018), is already a popular route, especially on Car Free Day (Mahendra, 2023). Its central location and land use, which is dominated by commercial, educational, and public service buildings, make it an ideal place to encourage bicycle transportation (Malang City Government, 2020).

Numerous issues, including motorized vehicle parking, a lack of driver discipline, and the absence of supplementary amenities like bicycle parking and signs, are undermining the effectiveness of the cycling lane on Jalan Besar Ijen and lowering the safety and comfort of cyclists. In response, the Malang City Government established two bicycle lane designs under Regional Regulation No. 5 of 2015 on the Detailed Spatial Planning and Zoning Regulations for the North Malang Urban Area (2015–2035): (1) a bike lane with unique markings that is integrated with motorized vehicle roads; and (2) a bike lane with clear markings and physical separation, both of which are meant to more fully ensure cyclists' safety and comfort. This study develops evidence-based, strategic recommendations for improving bicycle lane services in Malang City by using Quality Function Deployment (QFD) and Importance Performance Analysis (IPA) to enhance the lane's performance.

LITERATURE REVIEW

Bicycle Infrastructure

The goals of transportation development are to minimize expenses, shorten travel times, and enhance user comfort and safety. Air pollution, traffic, and accidents are reduced via sustainable transportation (Ganiron et al., 2024), with non-motorized modes providing a greener substitute (Suryono et al., 2020). In particular, bicycles are marketed as an environmentally friendly everyday means of transportation (Romadhon & Murwadi, 2023) (Suryabrata & Suartika, 2025), cost-effective, health-promoting, emission-free, and fossil fuel-free (Márquez et al., 2021; Prasetyo et al., 2020) (Marditama & Santosa, 2022), and their increasing popularity as a public transportation alternative is indicative of

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Indonesia's larger transition to sustainable living (Enrico & Riani, 2021; Zaini et al., 2024).

The growing popularity of cycling highlights the need for the greatest bike lane infrastructure to promote comfort and safety (Dwi Ratnaningsih, 2022), foster an enduring culture of cycling (Praditya et al., 2021), to promote more environmentally friendly modes of transportation (Makatita et al., 2025). The Indonesian government has established a legal framework for this through Law No. 22 of 2009 and Government Regulation No. 59 of 2020. Dedicated bike lanes physically separate cyclists from motorized vehicles and are typically placed on routes with medium to high bicycle traffic levels (Fadly et al., 2020).

Bicycle Lane

A bike lane is a portion of the road designated for bicycles and other non-motorized, human-powered vehicles (Kurniasih, 2023), distinguished by signage that can be modified to fit the local context, colored lanes, or physical barriers (Delbosc et al., 2025; Harris et al., 2025). Bike lanes not only keep automobiles apart but also slow down traffic and lessen collisions (Younes et al., 2024), Both regional and local factors need to be taken into account. Bicyclists have a right to infrastructure that supports order, safety, security, efficient traffic flow, environmental sustainability, and conservation consciousness (Romadhon & Murwadi, 2023), rights that, when respected, encourage a full cycling network and a greater uptake of bicycles.

RESEARCH METHODOLOGY

The study area is situated in Malang City's Oro-Oro Dowo Village on Jalan Besar Ijen. The Malang City Spatial Plan (2022–2042) includes it. With two lanes in each direction, the Type C bike lane covers 136.96 hectares and connects the subdistricts of Oro-Oro Dowo and Klojen. Major problems include low bicycle usage the majority of residents mainly ride for fun or exercise rather than as a regular mode of transportation and frequent motorized vehicle blockage, which endangers cyclists' comfort, safety, and security (Figure 1).

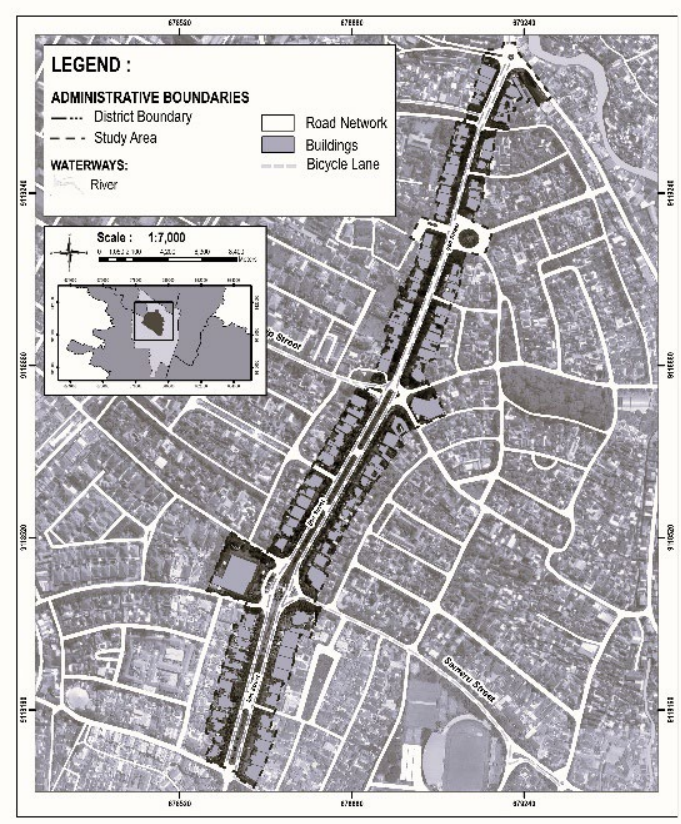


Figure 1: Study Area

Research methods are systematic procedures for obtaining data and information to address the objectives and problem formulation of a study. This study claims that "Where are bike lanes most effective? Quality Function Deployment (QFD) and Importance Performance Analysis (IPA), along with specific sample approaches and research variable selection, are the primary analytical methods employed in "Alternative priorities for improving bike lane service performance in urban areas" (Figure 2). When assessing bicycle infrastructure, IPA (Importance-Performance Analysis) and QFD (Quality Function Deployment) are frequently coupled because they work well together to bridge the gap between user views and the technical actions performed by legislators. The IPA is supposedly used to rank upgrades from the viewpoint of infrastructure users, such as bikers. How It Operates: The IPA evaluates a facility's actual performance in the field as well as its significance. Function: A four-quadrant matrix (such as the "Keep Up the Good Work" or "Concentrate Here" quadrants) is used to plot the results. In order to avoid wasting funds and

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resources, this aids planners in rapidly identifying which bike lane amenities are essential for cyclists but are still functioning poorly. Theoretically, QFD is utilized to convert user requirements into engineering blueprint technical specifications. How It Operates: QFD links "What the user wants" (Voice of the Customer, for example, a bike lane free from cars) with "How to technically achieve it" (Voice of the Engineer, for example, the thickness of the concrete road barrier or the width of the lane) through a crucial tool known as the House of Quality (HoQ). Function: QFD makes ensuring that modifications to the bike path's physical or geometric layout appropriately address the issues brought up by cyclists. While QFD acts as a technical solution to develop focused strategies for constructing or enhancing such infrastructure, IPA acts as a diagnostic tool to pinpoint the most urgent problems on bike lanes. QFD is designed to translate consumer needs and desires (Voice of consumer) into technical specifications so that every technical component is in line with user objectives and expectations (Sari, 2021). QFD is carried out by creating one or more House of Quality (HOQ) matrices, which are utilized to ascertain client needs (Margiandistira et al., 2023; Yuliana & Mayasari, 2022). (i) Voice of the Customer (VoC); (ii) Planning Matrix including Goal, Importance to Customer (IOC), Current Satisfaction Performance (CSP), Improvement Ratio (IR), Raw Weight (RW), and Normalized Raw Weight (NRW); (iii) Technical Response, (iv) Relationship Matrix, (v) Technical Correlation, and (vi) Technical Matrix with Contribution, Normalized Contribution, and Absolute Importance.

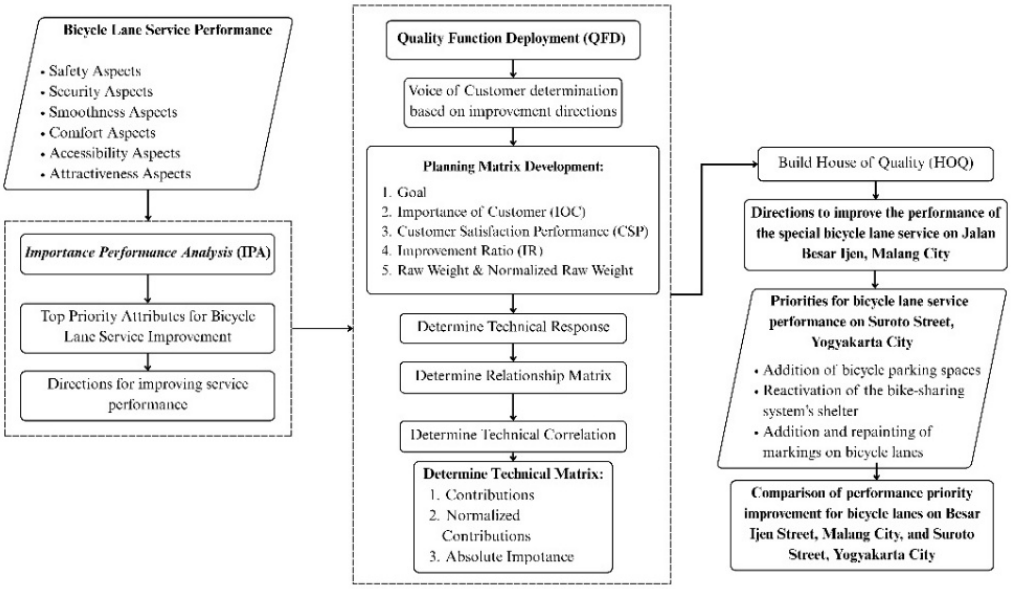


Figure 2: Research Framework

The study's participants are bikers who have used the bike lane on Jalan Besar Ijen in Malang City. Data was gathered using a Likert scale questionnaire that included the lane's service elements. Bicyclists who met predefined criteria and were observed at the research site were selected using accidental sampling, a non-probability technique. Even though there is a chance that some minority groups may be underrepresented, random sampling's strength is its capacity to reduce subjective selection bias and give every member of the population an equal chance of being chosen, guaranteeing that the research findings retain strong scientific validity for generalization. Since the total number of bicyclists using the lane is unknown, the sample size was determined using the Bernoulli formula (Amin et al., 2023).

$$n = \frac{(Z\frac{\alpha}{2})^2 p.q}{e^2}$$
$$= \frac{(1{,}96)^2.(0{,}5).(0{,}5)}{(0{,}1)^2}$$
$$= 96{,}04 \approx 100$$

The Bernoulli formula was used to get a sample size of 100 responders. Six criteria totaling thirteen factors were used to assess the service quality of the Jalan Besar Ijen bike lane: safety, security, smoothness, comfort, accessibility, and attractiveness (Table 1).

Table 1: Research variable

Aspect	Variable	References
Safety	- Condition of bicycle lane pavement - Bicycle lane height - Availability of traffic signs - Availability of bicycle lane markings	(Windarni et al., 2018)
Security	- Safe from motor vehicles - Safe from crime	
Smoothness	- Free from obstacles - Free from traffic jams	
Comfort	- Availability of bicycle parking - Availability of street lighting - Shade along the road - Availability of sufficiently wide lanes	
Accessibility	Land use affordability	
Attractiveness	Attractive bicycle lane design	

ANALYSIS AND DISCUSSION

The type C bicycle lanes on Jalan Besar Ijen are 1.2–1.34 meters wide and extend around 1.6 kilometers on both sides of the road. They run along the road surface and are divided from traffic by line markings. Marked by bicycle symbols and

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green line markings, with broken lines at intersecting openings, the lanes are in fair condition despite some fading, with characteristics further shaped by complementary facilities along the route (Figure 5).



Figure 5: Road Openings with Dashed Line Markings

The Ijen corridor's bike lane markings adhere to both the Directorate General of Highways' 2021 Guidelines for the Design of Bicycle Facilities and PM 59 of 2020 (Table 2).

Table 1: Comparison of Existing Marking Conditions with Standards

Existing Conditions	Policies/Standards
▪ Green lines and a green bicycle symbol are used to designate bicycle lanes along the important Ijen road corridor.	▪ According to PM 59 of 2020, bicycle lanes on the road must at the very least include markers that depict a white or green bicycle.
▪ At each road opening where it joins another road access, the area marking lines seem broken on both sides of the markings.	▪ According to the Directorate General of Highways Concerning the Design of Bicycle Facilities in 2021, bicycle lane markings are intended to be continuous in order to keep motorized vehicles out of the lane.
▪ Although the line color has faded in some places, the lane markings are still in generally good condition.	▪ Dotted lines are used on both sides to indicate area markers at road openings that connect to other road access points (Directorate General of Highways Concerning Design of Bicycle Facilities in 2021).

There are now only two bicycle lane signs, indicated by a cycling emblem, on the left side of Jalan Bandung on the northern stretch of the Jalan Besar Ijen corridor, and no warning signs on the southern portion at Jalan Kawi (Figure 6).



Figure 6: Bicycle lane sign distribution on Jalan Besar Ijen

The bicycle lane traffic signs on Jalan Besar Ijen, despite their scarcity, are in good condition and comply with PM 59 of 2020 and the Directorate General of Highways' Guidelines for the Design of Bicycle Facilities (2021).

Table 3: Characteristics of bike lane users in Jalan Besar Ijen, Malang City

No	Bike Lane Users	Criteria	Total
1	Gender	Male	80
		Female	20
2	Age	< 15 years old	1
		15-24 years old	7
		25-34 years old	27
		35-44 years old	35
		45-54 years old	19
		55-65 years old	9
		> 65 years old	2
3	Type of work	Not working	2
		Student	9
		Civil servant	15
		Housewife	9
		Private Employee	26
		Self-Employed	26
		Retiree	6
		Other	7
4	Travel intensity	Every Day	3
		Once a week	30
		2-5 Times a Week	17
		Once a Month	16
		2-5 Times a Month	10
		Once In 2-5 Months	24
5	Travel destination	School/College	1
		Work	5

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No	Bike Lane Users	Criteria	Total
		Medical Treatment	0
		Entertainment/Travel	35
		Exercise	84
		Home	6

According to study results, 80% of bikers on Jalan Besar Ijen are men, and the greatest age groups are 25–34 (27%) and 35–44 (35%). Cycling has not become a primary everyday form of transportation, as seen by the low usage frequency of 30% riding once a week, mostly on Car Free Day, and the remaining riding infrequently. Trip purpose data, which shows that 84% of cyclists ride for exercise, supports this. Cycling exercise here focuses more on cycling activities related to physical activity, and 27% for vacation or leisure. In general, the lane is utilized more for recreational purposes than for regular duties like traveling to work or school (Table 3). Theoretically, the main distinction between cycling as a sport and cycling as a method of transportation is that the former is more concerned with mobility than the latter. The goal of cycling as a mode of transportation is to get the rider from point A to point B quickly, safely, and without using too much energy so they won't feel worn out when they get there. As a result, the bikes utilized are city bikes, commuter cycles, or foldable bikes with fenders and luggage racks. Additionally, the route takes the safest or fastest urban routes, and riders wear work uniforms or informal everyday attire that emphasizes practical comfort. Cycling, on the other hand, is a sport that uses intense physical activity to increase cardiovascular fitness or performance, burn calories, and cause physiological changes in the body. In order to minimize wind resistance and avoid chafing, this sport uses lightweight, aerodynamic specialist bikes, such as road bikes or mountain bikes (MTBs), in conjunction with form-fitting athletic apparel, such as jerseys and padded shorts. In order to keep a constant pedaling rhythm, routes are purposefully selected for their physical challenges, such as steep climbs, off-road trails, or lengthy sections with little traffic.

Bike Lane Services' Performance on Jalan Besar Ijen in Malang City

The Importance Performance Analysis (IPA) qualities in this study were created from user perspectives and categorized into six service sections, which formed the basis for the questionnaire, based on prior research and bicycle lane regulations (Table 4).

Table 4: Important Performance Analysis Service Attributes

Aspect	Attributes	Notation
Safety	Bicycle lane pavement condition	A
	Bike lane height	B
	Availability of traffic signs	C
	Availability of bicycle lane markings	D
Security	Safe from motor vehicles	E
	Safe from crime	F
Smoothness	Free from obstacles	G
	Free from traffic jams	H
Comfort	Bicycle parking areas	I
	Street lighting	J
	Shade along the road	K
	Sufficiently wide lanes	L
Accessibility	Land use affordability	M
Attractiveness	Bicycle lane design	N

The Importance Performance Analysis (IPA), which plots the features onto a Cartesian diagram to determine priorities for enhancing bicycle lane services, is based on these service attributes (Table 5 and Figure 7).

Table 5: Recapitulation of Science Results for the Bike Lane on Jalan Besar Ijen

No.	Quadrant	Notes	Variable	Attributes
1	I	Concentrate Here	Safety	C
			Security	E
			Safety	I
2	II	Keep up The Good Work	Safety	A, D
			Security	F
			Smoothness	G
			Comfort	J
3	III	Low Priority	Smoothness	H
			Comfort	L
			Accessibility	M
			Attractiveness	N
4	IV	Possible Overkill	Safety	B
			Comfort	K

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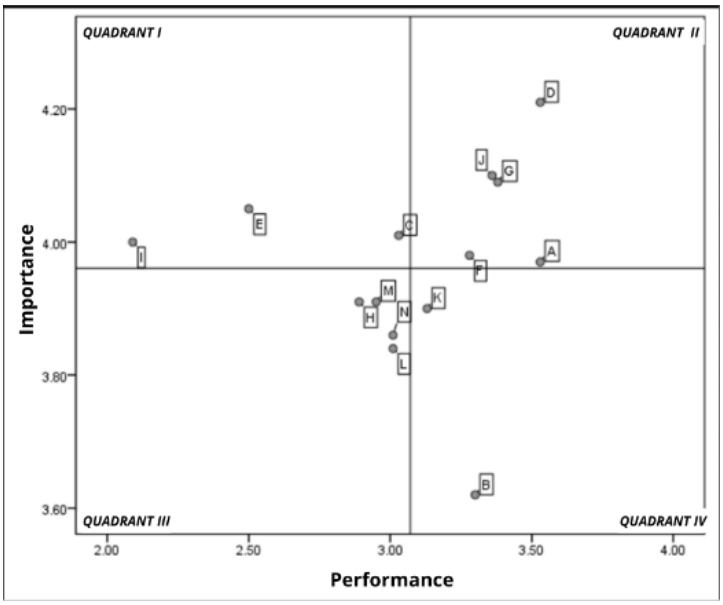
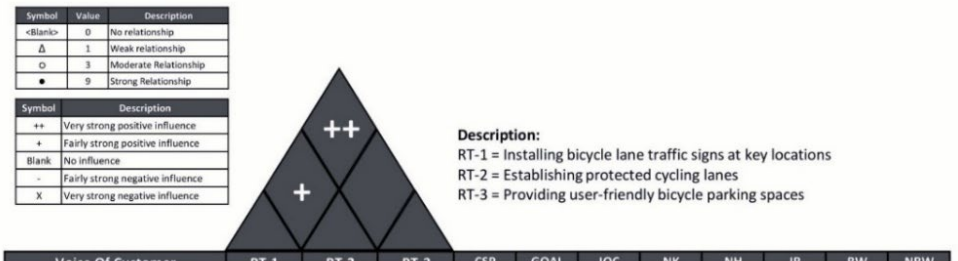


Figure 7: Cartesian Diagram of the Bike Lane Service Performance on Jalan Besar Ijen, Malang City

Bike Lane on Jalan Besar Ijen, Malang City: Quality Function Deployment (QFD) Service Performance

The IPA study's Quadrant I results, which cover the stages of Voice of Customer, Planning Matrix, Technical Response, Relationship Matrix, Technical Correlation, and Technical Matrix, served as the foundation for the QFD analysis for the bike lane on Jalan Besar Ijen. As shown in the House of Quality (HoQ) in Figure 8, three priority recommendations were identified: (1) putting up bicycle lane traffic signs at strategic locations; (2) creating protected riding lanes; and (3) offering user-friendly bicycle parking spaces.



Symbol	Value	Description
<Blank>	0	No relationship
Δ	1	Weak relationship
○	3	Moderate Relationship
●	9	Strong Relationship

Symbol	Description
++	Very strong positive influence
+	Fairly strong positive influence
Blank	No influence
-	Fairly strong negative influence
X	Very strong negative influence

Voice Of Customer	RT-1	RT-2	RT-3	CSP	GOAL	IOC	NK	NH	IR	RW	NRW
Lack of traffic signs on bicycle lanes	●			3,03	4,01	0,33	303	401	1,32	5,31	0,27
Lack of safety from motor vehicles	○	●		2,50	4,05	0,34	250	405	1,62	6,56	0,34
Absence of bicycle parking facilities			●	2,09	4,00	0,33	209	400	1,91	7,66	0,39
N	12	9	9								
Contribution	3,45	3,02	3,53								
Normalized Contribution	0,35	0,30	0,35								
Absolute Importance	48,24	36,45	36,00								
Target	1	2	3								

Figure 8: House of Quality: Jalan Besar Ijen, Malang City's Bike Lane Services Performance

A rational, planned, and financially feasible intervention strategy is shown in this priority of bicycle infrastructure upgrades. According to transportation planning theory, this progression starts with inexpensive interventions that have quick psychological effects, proceeds through the creation of auxiliary facilities, and ends with significant infrastructure investments that offer complete safety.

Installing bicycle lane traffic signs at key locations: This is a tactical intervention (legitimacy and visibility). The least expensive type of infrastructure is traffic signs, which are also the easiest to quickly and widely install. From a psychological standpoint, strategically placed traffic signs both provide bicycles a sense of legal recognition and inform other road users (motorized cars) that they are present in the area. Raising public awareness prior to the construction of extensive physical infrastructure is a critical first step.

Establishing protected cycling lanes: This is a structural intervention (long-term convenience and complete safety). The most expensive, time-consuming, and intricate traffic engineering is needed for protected bike lanes, which include physical barriers like bollards, concrete dividers, or median strips. This is the apex of the ecosystem for bicycle mobility. By keeping bicycles' speeds apart from those of cars, physical separation significantly lowers the number of fatal collisions. In order to draw in "beginner or hesitant" cyclists those who are interested but apprehensive who wouldn't dare ride if they had to share the road

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with vehicles or buses, this infrastructure is essential.

Providing user-friendly bicycle parking spaces: This reward program is focused on utilities (end-of-trip facilities). The next difficulty is making sure cyclists are secure when they arrive at their destination (end-of-trip amenities) when they start to feel acknowledged on the road (due to First Priority). The goal is to guarantee users' commitment by offering secure parking that satisfies their demands (e.g., close to train stations, office buildings, or shopping centers). Theoretically, people's interest in converting to bicycles as a daily mode of transportation is greatly increased when secure parking is available at destinations since worries about bicycle theft can be reduced.

Comparing the Bike Lane Priority Directions on Jalan Suroto in Yogyakarta City and Jalan Besar Ijen in Malang City

The main recommendations for Yogyakarta's Jalan Suroto corridor, which concentrated on bicycle parking, reinstating a bike-sharing scheme, and repainting lane markings, differ from those for Jalan Besar Ijen. Although both corridors have similar features, such as recreational and sporting use, different user needs highlight the importance of location-specific strategies to effectively address infrastructural requirements.

Implementation

In response to the HoQ analysis, two QFD priorities the availability of bicycle parking spots and the thoughtful placement of bicycle traffic signs are the main focus of implementation. PM 13 of 2014 about Traffic Signs mandates circular signs with a 45 cm diameter, a blue background, and a white bicycle icon. Figures 9 and 10 depict the recommended installation locations.

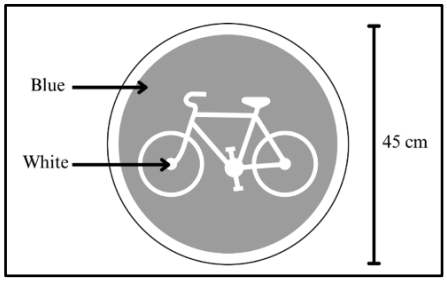


Figure 9: An example of a bike lane sign

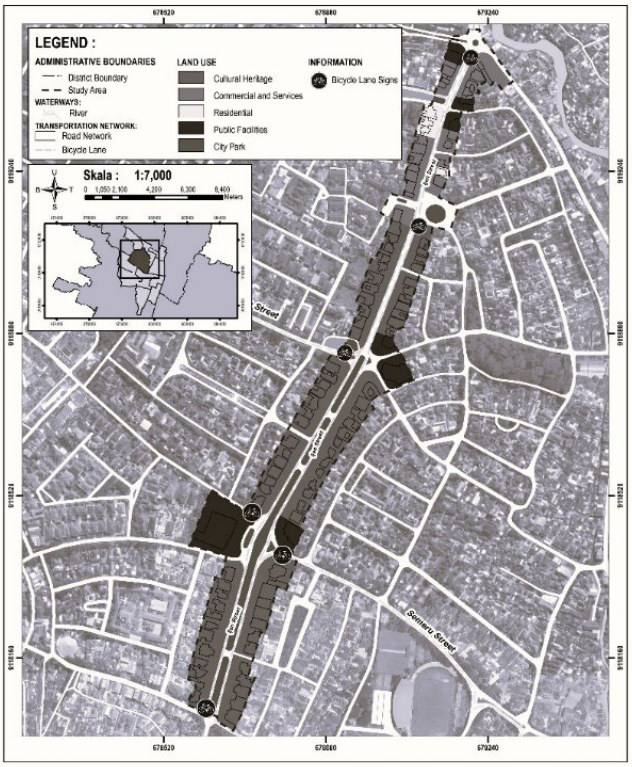


Figure 10: Bicycle Lane Sign Distribution on Jalan Besar Ijen, Malang City

The recommended bicycle parking option for Jalan Besar Ijen is the inverted U design, which has two locking hooks that simultaneously secure the frame and wheels. Its advantages include longevity, convenience of use, and compatibility with many bicycle types, according to international standards used by bicycle-friendly cities like Singapore (Figures 11 and 13).

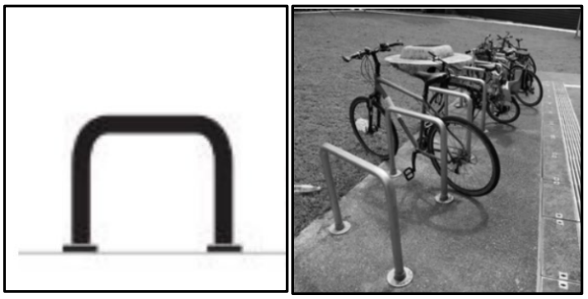


Figure 11: An Illustration of the Design and Execution of Bicycle Parking

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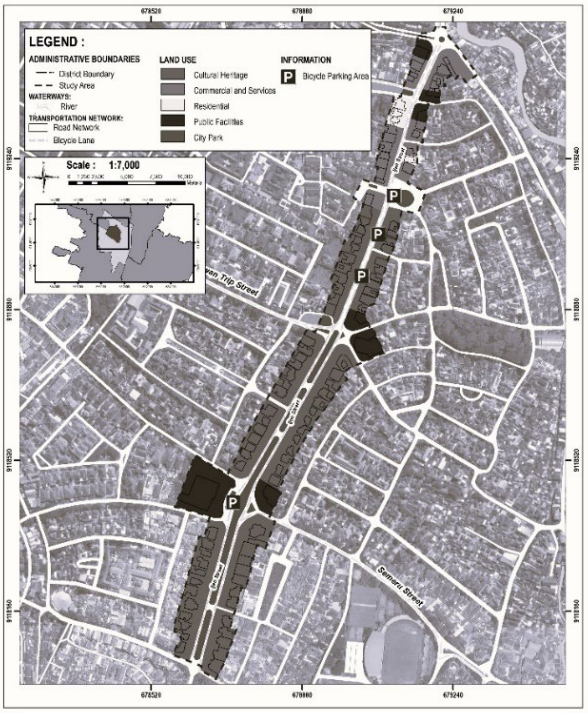


Figure 12: Distribution of Bicycle Lane Parking Points on Jalan Besar Ijen

At five strategic locations on Jalan Suroto in Yogyakarta, N-type bicycle parking racks with two locking points and security cameras were recommended (Figures 12 and 14). Bicycle parking should be introduced in each scenario in compliance with technical guidelines and any applicable laws.



Figure 13: Suroto Street Bicycle Parking Area

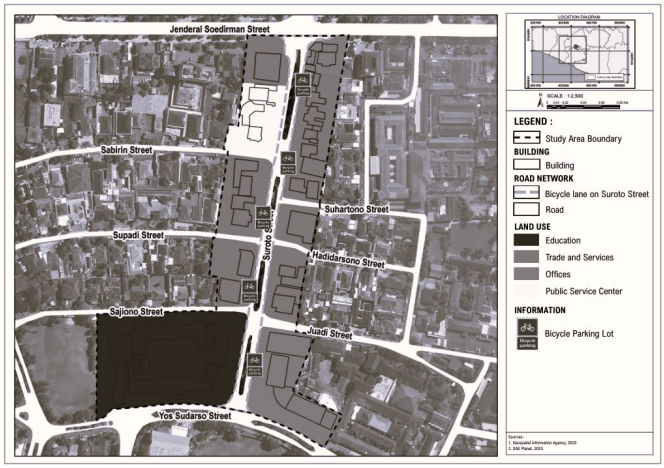


Figure 14: Strategic Locations for Adding Bicycle Parking Spaces

Jalan Suroto's second goal is to revive bicycle rental stations in public areas like parks and road medians through a bike-sharing system. This would encourage sustainable mobility and increase bicycle accessibility for residents and tourists (Figure 15).

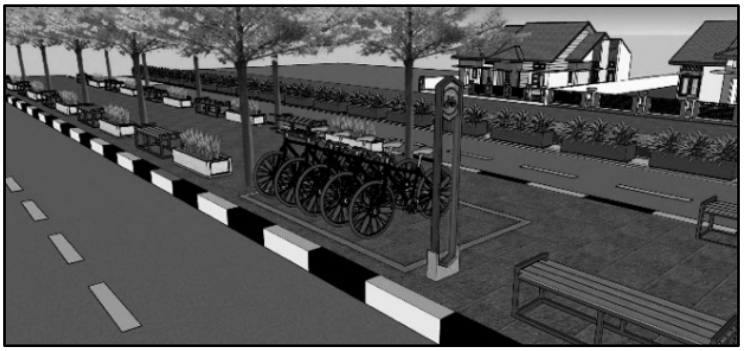


Figure 15: Bike-Sharing Jalan Suroto

The final goal for Jalan Suroto is to add area markings, arrow symbols, and "bike lane" inscriptions in addition to repainting the entire road with yellow thermoplastic paint and adding planter boxes. By increasing lane safety and clarity for both motorized vehicle users and bikes, these improvements are expected to lessen disruptions (Figure 16).

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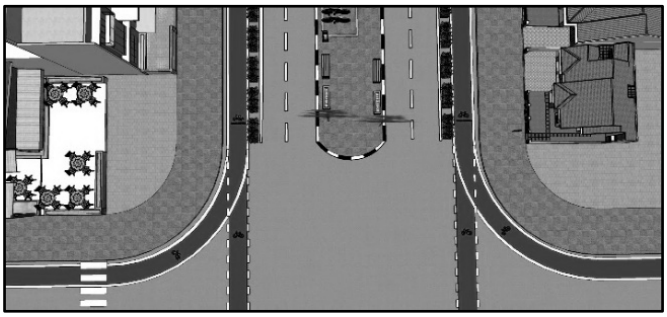


Figure 16: Better Markings for Bicycle Lanes on Jalan Suroto

Physical infrastructure is insufficient to establish a publicly accepted and safe cycling habitat. A legally binding framework of regulations and policies is required. The three key foundations for turning cycling from a "recreational option" into a "legally recognized primary mode of transportation" are laws pertaining to network integration, lane protection, and law enforcement.

More robust policies for law enforcement (strong enforcement)
Without legal certainty, even the best infrastructure will be useless. Ensuring the rule of law for vulnerable road users and addressing road space infractions are the goals of strict law enforcement measures.

1. Enforcement Against Lane Occupation: A regulation that penalizes motor vehicles that park or drive in bike lanes with severe fines, automatic towing, or electronic traffic tickets (ETLE).
2. Strict Liability Rules: Adopting a legal principle that, unless the cyclist is proven to have committed a purposeful and fatal violation, larger and faster vehicles carry higher legal culpability in the case of an accident involving a cyclist.
3. Urban Speed Limit Regulations: In order to lower fatalities, motor vehicle speed limits in heavily populated regions or mixed-use bicycle-pedestrian zones should be lowered to 30 km/h.

Track Protection & Design Requirement
This regulation requires physical barriers in place of the road design standards that were previously based on road markings (standard bike lanes).

1. Physical Protection Mandate: An urban planning rule requiring bike lanes with structural barriers (such concrete curbs, median strips, or variations in road elevation) rather than just white painted lines to be included in any significant road construction or rehabilitation.

2. Exclusive Access Rights: Laws that declare bike lanes to be barrier-free, exclusive areas (e.g., barring the establishment of utility poles, trash cans, or street vendors on bike lanes).
3. Safe Intersection Design (Protected Intersections) is a regulation that mandates the installation of specific bicycle markings and traffic signals at intersections, which are the locations where accidents occur most frequently, in order to give cyclists an earlier start time than cars (bike boxes/advanced stop lines).

Guidelines for Network Integration (Integration into the Wider Network)
The goal of this strategy is to guarantee that bike lanes are integrated into a coherent and interconnected urban transportation system rather than being dispersed (disconnected).

1. Policies requiring connectivity between bike lanes and major public transit hubs (train stations, bus terminals, MRT/LRT) are known as multimodal integration. Regulations permitting folding bikes to be loaded aboard train cars or the availability of sufficient "Park and Ride" facilities for bicycles facilitate this.
2. Land-use regulations that forbid the construction of bike lanes that are broken up in the middle of the road are an example of a cohesive and continuous network. Every route must be planned to go straight from residential neighbourhoods (origin) to hubs of activity like workplaces, educational institutions, and commercial districts (destination).
3. The 15-Minute City Concept is an urban design strategy that incorporates land use and places amenities for everyday requirements within a 15-minute walking or bicycling distance.

Together, these three policies form a cycle: designated bike lanes provide a sense of physical safety, legal enforcement ensures comfort and equity on the roads, and network integration provides the practical functionality needed for bicycles to be truly effective for daily movement.

CONCLUSION

Three Quadrant I priority attributes are identified by the IPA analysis: traffic sign availability (C), motor vehicle safety (E), and bicycle parking (I). Three associated improvement solutions are identified by QFD research: (1) putting bicycle lane traffic signs at strategic locations; (2) creating protected riding lanes; and (3) offering bicycle parking spots that are easy to use. Different priorities can be seen when comparing Yogyakarta's Jalan Besar Ijen and Jalan Suroto. Even though both routes need extra parking, Jalan Suroto prioritizes parking above

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Jalan Besar Ijen. These variations highlight the significance of context-specific approaches to bicycle lane building since they represent unique user characteristics and desires.

A coherent and thorough urban planning strategy for creating a sustainable transportation ecosystem is formed by these three key areas for enhancing bike infrastructure. Through the construction of traffic signs, the first phase aims to increase public awareness and create legal legitimacy for bikes on the road. In order to guarantee complete safety against the possibility of motor vehicle accidents along the route, this step is subsequently structurally reinforced by the installation of protected bike lanes. In order to guarantee the provision of end-of-trip amenities and to make the public feel comfortable, safe, and eventually motivated to convert to bicycles as their daily method of transportation, it is ideal to finish this sequence of actions by offering secure bicycle parking at destination locations.

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GIS-BASED ENVIRONMENTAL RISK ASSESSMENT IN INDUSTRIAL CITIES: METHODOLOGICAL FRAMEWORK AND APPLICATION TO ALMALYK, UZBEKISTAN

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Abstract

Industrial cities are characterized by the coexistence of intensive production, dense settlement patterns, transport infrastructure, and long-term anthropogenic pressure on environmental systems. Under such conditions, environmental risk is not confined to a single medium but emerges through the interaction of atmospheric pollution, groundwater and soil contamination, ecological degradation, and human exposure. This study develops a geoinformation-based methodological framework for assessing environmental risks in industrial urban territories and applies it to Almalyk, Uzbekistan, as a representative mining and metallurgical city. The framework integrates remote sensing, spatial interpolation, buffer analysis, thematic layer overlay, and multi-criteria evaluation within a unified GIS environment. Environmental indicators related to air quality, groundwater contamination, land use, vegetation condition, industrial proximity, and population vulnerability are standardized and combined to derive a composite environmental risk index. The results show that environmental burden in Almalyk is unevenly distributed and is concentrated in industrial zones and adjoining residential territories, especially those influenced by mining and metallurgical activity, waste disposal areas, and pollutant transport pathways. The resulting risk map provides a practical analytical basis for environmental monitoring, urban planning, zoning control, and public health protection in industrial cities.

Keywords: Geographic information systems; Environmental risk assessment; Industrial city; Almalyk; remote sensing; Spatial analysis; AHP; Environmental monitoring.

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INTRODUCTION

Industrial urban systems are important for economic growth and jobs, but they also create heavy environmental pressure because industrial, residential, transport, and waste areas are often close together (Pupentsova et al., 2019). This proximity increases emissions, dust, noise, waste buildup, soil and groundwater pollution, and habitat fragmentation. Beyond environmental control, urban sustainability also depends on how public and religious spaces support social cohesion and community identity (Baydoun, Bin, et al., 2025). Traditional Uzbek Islamic architecture and calligraphy reflect sustainable design that integrates cultural and ecological contexts, offering insights for mitigating industrial impacts (Baydoun et al., 2024; Baydoun, Baydoun, et al., 2025)

Environmental risk in such territories cannot be understood adequately through isolated measurements alone (Mehta et al., 2025). Industrial cities display strong spatial heterogeneity, and the intensity of environmental pressure can vary substantially over short distances depending on source location, land-use pattern, topography, meteorological conditions, and urban morphology (He et al., 2020). Consequently, analytical approaches that can integrate multiple spatial datasets into a unified system are essential for effective environmental assessment and decision-making (Dong et al., 2025).

Geographic information systems have evolved from cartographic support tools into advanced analytical platforms that enable the collection, storage, management, analysis, modeling, and visualization of heterogeneous environmental information (Janarthanan et al., 2023). GIS is widely used to identify pollution hotspots, map exposure, integrate remote sensing with ground data, and support planning in urban and industrial areas (Mohammed Hamud et al., 2019). The literature shows that GIS-based environmental risk assessment is now standard, especially when integrated with interpolation, remote sensing, and multi-criteria analysis (Calka & Szostak, 2025).

Industrial cities in Uzbekistan provide a particularly important context for such work. Cities such as Almalyk, Navoi, Angren, and Fergana function as major economic centers but also experience elevated environmental stress arising from mining, metallurgy, thermal energy production, transport activity, and historical pollution legacies (Perez-Lancellotti et al., 2025). Almalyk is especially significant because of its association with large-scale mining and metallurgical operations and because residential districts occur in proximity to industrial infrastructure and waste-related facilities.

The novelty of this study is the development of an integrated GIS-based environmental risk framework for industrial cities that combines multiple hazard and vulnerability indicators in one spatial model. This goes beyond earlier GIS-AHP studies by linking remote sensing, interpolation, buffer analysis, and weighted overlay for practical urban risk mapping.

This study develops a GIS-based methodology for environmental risk assessment in industrial cities, demonstrated in Almalyk. It identifies key indicators, integrates them in a geospatial framework, classifies risk zones, and interprets results for planning and governance, offering a practical approach that combines hazard and vulnerability.

LITERATURE REVIEW

GIS in environmental assessment

Environmental risk assessment has shifted toward integrated spatial analysis, as urban-industrial degradation arises from interconnected processes. GIS supports this by combining monitoring data, satellite indicators, regulatory thresholds, infrastructure, and socio-demographic variables in a single platform (Chen et al., 2022; Mojaddadi et al., 2017). In environmental applications, GIS supports the creation of thematic maps, detection of risk concentrations, comparison of multiple indicators, and communication of results to planners and decision-makers. The reviewed material indicates that GIS is especially valuable in industrial settings where environmental hazards are spatially concentrated and where population exposure depends strongly on location. Through GIS, environmental observations can be transformed from isolated records into continuous surfaces and then interpreted in relation to land use, urban structure, and sensitive receptors (Benza et al., 2016). This makes GIS suitable not only for mapping but also for environmental diagnosis and planning support.

Weighted overlay and multi-criteria methods

One of the most common approaches in environmental GIS studies is the use of multi-criteria decision analysis, especially the Analytic Hierarchy Process (Cegan et al., 2017). AHP integrates expert judgment with quantitative environmental indicators to assign weights and build a composite index. In industrial assessments, it captures the combined effects of pollutants, ecological sensitivity, settlement patterns, and socio-economic vulnerability. Studies show that AHP-based GIS models effectively classify ecological vulnerability and pollution risk using weighted overlay (Artat et al., 2025; Wen et al., 2026). Their advantage lies in methodological transparency, since each criterion can be justified and weighted explicitly. When properly validated, this approach provides interpretable outputs that are suitable for planners and environmental managers.

Statistical integration and PCA

Another important line of research links GIS to multivariate statistical analysis, particularly principal component analysis. PCA is useful when large environmental datasets contain correlated variables that must be reduced into a smaller set of meaningful dimensions before interpretation (Gewers et al., 2022).

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Studies summarized in the source text show the use of PCA in groundwater quality assessment, pollution source discrimination, and health-risk-related environmental mapping (Balamurugan et al., 2020; Ncibi et al., 2023). Principal components represent key pollution patterns mapped in GIS, reducing redundancy and highlighting the most important environmental factors across multiple pollutants and sites.

Remote sensing and interpolation

Remote sensing has become an essential companion to GIS-based environmental risk assessment because it enables regular and wide-area observation of land surface conditions, vegetation cover, water-related features, surface temperature, and atmospheric conditions. The reviewed material identifies Landsat, Sentinel, MODIS, ASTER, and other sources as suitable inputs for industrial environmental analysis (Acar & Zengin, 2023; Song et al., 2021). Remote sensing, GIS, and interpolation are effective for mapping pollution patterns in industrial cities, especially where field data are limited. They help estimate continuous contamination surfaces and capture spread along wind, terrain, drainage, and land-use gradients.

Research Gap

Existing studies provide valuable methodological components, but many remain fragmented by focusing either on a single pollutant, a single analytical technique, or a single environmental medium. There is a continuing need for a coherent GIS-based framework that can integrate atmospheric, hydrological, ecological, and socio-demographic dimensions of risk in industrial cities and translate them into planning-relevant outputs. This study addresses that need by presenting an integrated methodological structure and illustrating its application to Almalyk.

STUDY AREA

Almalyk, in Uzbekistan’s Tashkent region, is a major industrial city shaped by mining and metallurgical activities, transport systems, waste facilities, and nearby residential areas. These factors create a complex environment with risks from emissions, dust, heavy metals, blasting, and groundwater contamination. Its overlapping industrial and residential pressures make it a representative case for environmental risk assessment.

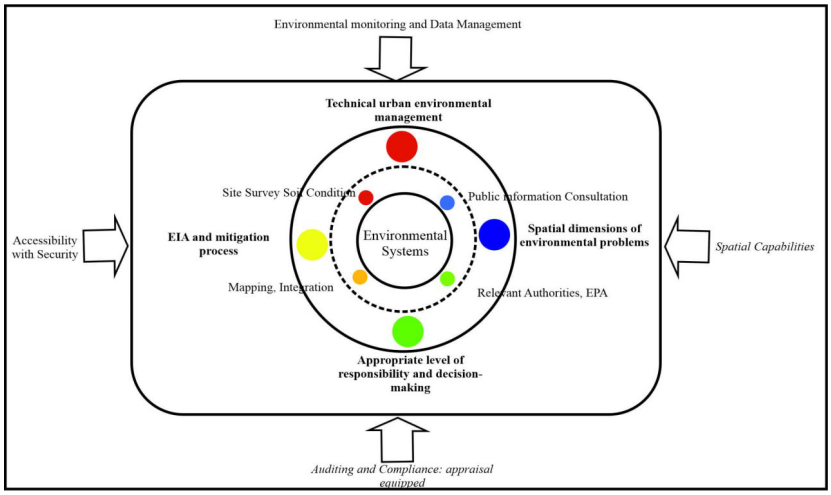


Fig. 1: GIS as a vital tool for environmental impact assessment and mitigation.

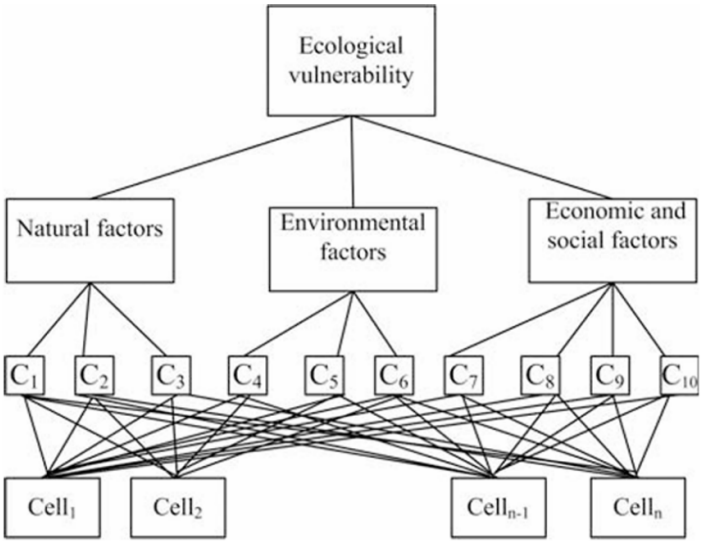


Fig. 2: Integrated evaluation criteria system used in GIS-based ecological vulnerability assessment.

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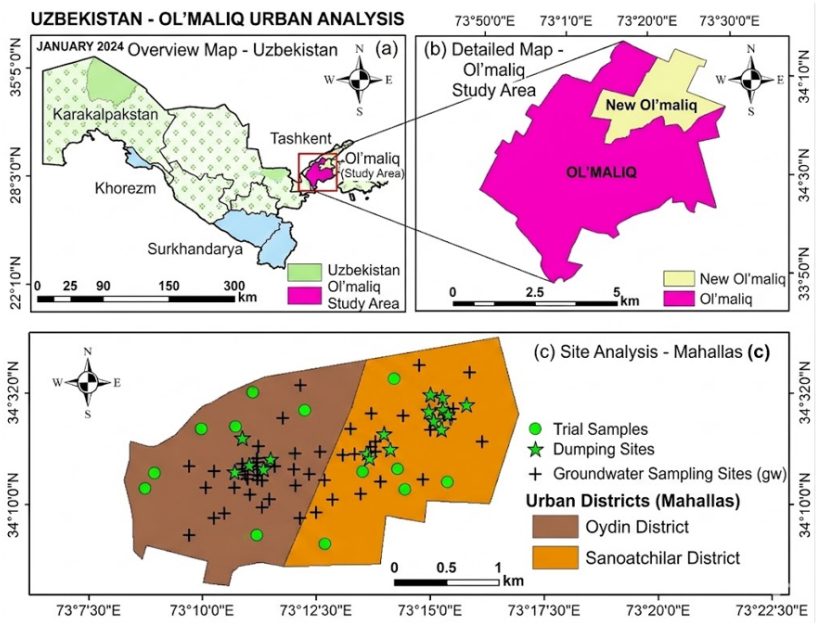


Fig. 3: Location of Almalyk city, industrial zones, and groundwater sampling sites.

RESEARCH METHODOLOGY

Conceptual basis of the model

The study conceptualizes environmental risk as the interaction between environmental hazard and territorial vulnerability. Hazard is the intensity and extent of industrial environmental pressure, while vulnerability is the exposure and sensitivity of people, infrastructure, and ecosystems. This distinction matters because pollution alone does not define risk; it becomes critical where it overlaps with vulnerable or sensitive areas.

Data Categories

A comprehensive environmental risk assessment in an industrial city requires integrating several data groups. The study uses atmospheric pollution, water and groundwater quality, soil contamination, meteorological, land-use/land-cover, and socio-economic or demographic data to build hazard and vulnerability layers in GIS. Atmospheric indicators include PM2.5, PM10, NO2, and SO2; water and groundwater indicators include heavy metals and related quality parameters; soil contamination is assessed through heavy metals and residual pollutants. Ecological indicators include NDVI, NDWI, land cover classes, and landscape fragmentation, while vulnerability is represented by population density, proximity to industrial objects, and the location of critical urban facilities.

Geospatial data sources

The framework is compatible with open-access geospatial data such as Landsat 8/9, Sentinel-2, Sentinel-5P, MODIS, and SRTM, which provide multispectral, atmospheric, topographic, and land-surface information. Additional layers can come from OpenStreetMap and official databases for roads, boundaries, built-up areas, industrial facilities, and infrastructure. In GIS, raster data represent continuous features and vector data capture discrete elements; formats are converted as needed for overlay and mapping.

Preprocessing and quality control

All input data must be standardized before analysis. Satellite imagery is atmospherically corrected, geometrically rectified, and reprojected to a common coordinate system, while spatial layers are clipped, checked for consistency, and matched in scale and resolution. Monitoring data are checked for missing values, outliers, and coordinate errors, and interpolation is used where observations are incomplete. This is necessary because monitoring often provides point data, while risk modeling needs continuous territory-wide surfaces.

Technical parameters used in GIS and AHP analysis

Table 1 summarizes the key technical parameters used in the GIS and AHP workflow to improve methodological transparency and reproducibility.

Table 1: Methodological matrix of GIS-based environmental risk assessment approaches, data sources, and indicators

Technical parameter	Value/specification
GIS software	QGIS 3.34 (LTS, Prizren) with GDAL 3.8.4; secondary verification in ArcGIS Pro 3.2
Coordinate reference system	WGS 1984 UTM Zone 41N (EPSG:32641)
Spatial resolution	30 × 30 m
Raster cell size	30 × 30 m
Buffer distances	0–500 m, 500–1,000 m, 1,000–3,000 m, 3,000–5,000 m
Interpolation method	IDW (power = 2) for air/water; ordinary kriging with spherical variogram for soil
Expert respondents (AHP)	N = 18
AHP consistency ratio	CR = 0.047
Study period	Environmental data: 2018–2023; satellite imagery: 2021–2023

Spatial interpolation and environmental surfaces

Interpolation methods turn sampled values into continuous environmental surfaces for joint analysis with other spatial variables. In this framework, inverse distance weighting is preferred for its simplicity and interpretability, while kriging may be used when observations are denser and geostatistical assumptions

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are stronger. These interpolated surfaces are applied to air pollution, groundwater contamination, and other sampled parameters to reveal hotspots, gradients, and likely exceedance zones. They are then reclassified and integrated into the composite risk model.

Remote sensing indicators

Remote sensing provides an important source of information for environmental conditions and land-surface characteristics. The Normalized Difference Vegetation Index is used to assess vegetation status and green cover conditions, while the Normalized Difference Water Index supports the interpretation of surface moisture and water-related features. Land use and land cover classification derived from satellite imagery is further used to distinguish industrial land, residential areas, open land, green spaces, and water-related surfaces. The standard expression for NDVI is given by:

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

This indicator is particularly useful in industrial cities because vegetation conditions may reflect ecological stress and may also influence dust retention and microclimatic regulation. Remote sensing, therefore, supplements field monitoring with territorial continuity and repeated observation capacity.

Indicator standardization

Because the environmental indicators used in the study differ in scale, unit, and interpretation, standardization is required before weighted integration. A common min-max normalization procedure is applied to convert all indicators to a comparable dimensionless scale. For direct risk indicators, the normalization can be expressed as:

$$X_i' = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

For inverse indicators, where higher values correspond to lower environmental stress, the transformation direction is reversed. Standardization ensures that heterogeneous data can be integrated meaningfully in subsequent multi-criteria analysis.

AHP-based weighting

The Analytic Hierarchy Process assigns weights to risk criteria through pairwise comparison of expert judgments. It is useful because it transparently combines

scientific and local knowledge, with matrix normalization, priority vectors, and a consistency check to ensure logical judgments. Indicators with the strongest expected impact, such as air pollution, groundwater contamination, and proximity to industrial sources, can therefore receive higher weights than secondary factors. Table 2 presents the AHP pairwise comparison results, final criterion weights, eigenvector priorities, and overall consistency ratio used in the analysis.

Table 2: The AHP pairwise comparison results.

Criteria	Weight	Eigenvector	CR value
Air Quality (AQ)	0.282	0.291	0.047
Water Quality (WQ)	0.201	0.208	0.047
Soil Contamination (SC)	0.148	0.153	0.047
Noise Pollution (NP)	0.102	0.105	0.047
Health Risk Index (HR)	0.074	0.076	0.047
Proximity Buffers (PB)	0.110	0.113	0.047
Land Use Compatibility (LU)	0.083	0.054	0.047

Composite environmental risk index

After indicator standardization and weighting, the final environmental risk index is computed using weighted overlay analysis. The general form of the model is:

$$ERI = \sum_{i=1}^{n} w_i x_i$$

where w_i represents the weight assigned to the i-th criterion and x_i represents its standardized spatial value. This procedure produces a composite index surface that can be classified into environmental risk categories. In conceptual terms, the index integrates hazard and vulnerability, allowing the analyst to identify places where environmental pressure and human exposure overlap most strongly. The classified output can then be represented using a low-medium-high risk scheme and visualized through thematic GIS mapping.

Buffer and overlay analysis

Buffer analysis defines influence zones around industrial facilities, waste sites, mines, and other major sources, helping identify direct exposure and priority management areas. In blasting and vibration zones, concentric buffers help distinguish levels of disturbance. Overlay analysis then combines the reclassified

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hazard and vulnerability layers in GIS to produce final risk zones. This is the key step that turns separate datasets into an integrated territorial risk model.

Example of integrated indicator structure

The study framework may be summarized through a methodological matrix linking approach, data sources, and principal indicators as shown in Table 3.

Table 3: Methodological matrix of GIS-based environmental risk assessment approaches, data sources, and indicators.

Approach/method	Primary data sources	Indicators
GIS + AHP (MCDA)	Industrial facilities, road maps, population density, climate, and landscape data	Air quality, water pollution, socio-economic indices, population, and health-related exposure.
PCA + GIS	Multidimensional pollution data in air and water samples, demographic indicators	Principal pollution components and dominant contamination structures.
GIS interpolation (IDW, Kriging)	Monitoring stations for air, water, soil, and meteorological data	Continuous pollution maps, pollutant concentration gradients, and hotspot zones.
Remote sensing	Landsat 8/9, Sentinel-2/5P, MODIS, ASTER, GEE platform	NDVI, NDWI, surface temperature, land cover, dust-related or atmospheric indicators.
Machine learning	Large environmental databases, sensor outputs, social and spatial datasets	Risk classes, prediction outputs, feature importance, and uncertainty estimates.

Illustrative environmental risk index example

An example of normalized territorial values and resulting risk indices is presented below as part of the integrated assessment frameworks in Table 4.

Table 4: Illustrative example of normalized territorial values and environmental risk index calculation.

Territory	Air value	Water value	Population	Normalized air	Normalized water	Normalized population	Risk index
A	80	50	100	1.00	0.625	1.00	0.85
B	30	80	80	0.375	1.00	0.80	0.69
C	50	30	60	0.625	0.375	0.60	0.52

The illustrative values indicate that Territory A has the highest environmental risk, followed by Territory B, whereas Territory C has comparatively lower risk. In operational environmental zoning, values above 0.80 may be interpreted as high-risk conditions requiring priority intervention.

Validation of the environmental risk map

Validation was performed by comparing the GIS-derived risk map with existing monitoring and documentary data available for Almalyk. Specifically, high-risk zones were checked for spatial coincidence with groundwater and soil monitoring points reporting elevated heavy-metal concentrations and with mapped industrial sites, waste areas, and known pollutant sources. No new field campaign was conducted for this study; therefore, the validation is qualitative and limited to these available measurements and official records.

RESULT AND ANALYSIS

General spatial pattern of environmental risk

The GIS-based analysis of Almalyk indicates that environmental burden is spatially uneven and is concentrated in zones directly or indirectly affected by industrial activity. The source material identifies elevated air pollution and heavy metal contamination in areas adjacent to industrial enterprises and mining-related facilities. This concentration pattern confirms that environmental pressure follows the geography of industrial infrastructure and associated transport and waste systems. Table 5 summarizes the quantitative distribution of environmental risk classes, including area, percentage of land, exposed population, and affected neighbourhoods in Almalyk city.

Table 5: Illustrative example of normalized territorial values and environmental risk index calculation

Risk Class	Color	Area (km^2)	Area (%)	Population Exposed	Neighborhoods
Very High Risk	Red	47.3	12.4	~145,000	18
High Risk	Orange	89.6	23.5	~210,000	27
Moderate Risk	Yellow	124.8	32.7	~180,000	23
Low Risk	Green	98.2	25.7	~85,000	11
Very Low Risk	Light Green	22.1	5.7	~15,000	3
TOTAL	—	382.0	100.0	~635,000	82

The quantitative summary shows that 35.9% of the study area falls within the Very High- and High-Risk categories, affecting approximately 355,000 residents and 45 neighbourhoods. The highest-risk zones are concentrated near the AGMK smelter complex, cement manufacturing areas, and associated industrial corridors, indicating strong overlap between environmental pressure and population exposure.

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Air pollution and industrial influence

The analysis suggests that particulate pollution and related atmospheric stress are highest near industrial production zones and along areas influenced by transport activity. Spatial mapping of air-quality-related indicators shows that pollutant load does not remain confined to the industrial core but extends toward inhabited urban territories. This is particularly important because exposure risk increases when polluted zones overlap with residential and service functions. The source material further indicates that prevailing winds and the structural configuration of the city influence the direction and reach of pollutant transport. As a result, districts beyond the immediate industrial footprint may also experience elevated environmental burden. This demonstrates the value of spatial modeling in identifying indirect impact zones that conventional site-based assessment may underestimate.

Groundwater and heavy-metal contamination

Groundwater quality constitutes a major component of environmental risk in Almalyk. The study area includes groundwater monitoring points and waste-related locations that allow contamination to be interpreted spatially in relation to industrial influence. According to the source material, elevated concentrations of copper, zinc, lead, cadmium, and arsenic are associated with industrially affected zones. To support the interpretation of groundwater contamination, the following exceedance relationship may be used:

$$Excess_{GW} = Measured$$

This expression quantifies the degree to which observed groundwater values exceed accepted regulatory or health-based standards. In the source material, arsenic contamination is interpreted using a WHO-based threshold of 0.01 mg/L. The supporting conceptual structure is presented below in Table 6.

Table 6: Conceptual framework for groundwater exceedance assessment and comparison with WHO standards.

Concept	Definition
Excess (GW)	Portion of groundwater quality indicators exceeding the normative value
Measured values (GW)	Laboratory results obtained from Almalyk and its industrial zones
WHO standards (GW)	Maximum permissible concentrations recommended for groundwater interpretation

Population exposure and urban vulnerability

Environmental risk in Almalyk is shaped not only by pollutant concentration but also by the distribution of people and urban functions. Population density and proximity to industry help identify areas of higher human exposure, with nearby residential zones facing greater environmental pressure. Particular attention is drawn to populated sectors located close to the industrial perimeter and central urban areas influenced by pollution transport pathways. In such areas, environmental vulnerability is increased by the overlap of exposure, settlement concentration, and infrastructure use. This reinforces the need for risk zoning that incorporates both source intensity and territorial sensitivity.

Buffer zones, blasting effects, and disturbance corridors

Industrial and mining activities in the study area generate disturbances beyond chemical contamination, including blasting vibrations, noise, and dust transport affecting nearby residential areas. Analysis identifies concentric buffer zones around mining sites, with the innermost 500–1 km zone showing the strongest impact and requiring strict geodynamic regulation for safe construction. Including these stressors broadens environmental assessment beyond air and water pollution metrics.

Spatial extension of risk beyond the industrial core

The mapped risk structure indicates that elevated environmental pressure extends from the central industrial sectors of Almalyk toward adjacent districts. This pattern is associated with the interaction of stationary industrial emissions, transport activity, and regional wind regimes. It shows that environmental management in industrial cities must be planned at the metropolitan or city-region scale rather than only within fenced industrial parcels.

Development indicators and planning context

The planning relevance of environmental risk assessment becomes clearer when interpreted alongside the broader development trajectory of the city. The source material provides the following urban development indicators for Almalyk as shown in Table 7.

Table 7: Current and projected urban development indicators for Almalyk city.

Indicator name	Unit of measurement	Current status (estimated)	Plan / Prospect
Population	Thousand people	190.5	215.0
Volume of industrial output	Trillion soums	35.0+	50.0+
Export potential	Million USD	900+	1,200+
Share of green areas	%	8.5	15.0
New jobs	Number	4,500	12,000

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Indicator name	Unit of measurement	Current status (estimated)	Plan / Prospect
Housing stock (new)	m²	120,000	250,000

These indicators show that environmental risk assessment is directly relevant to ongoing and future urban development. As industrial output, employment, housing, and population continue to increase, the need for environmental zoning and exposure-sensitive planning becomes more urgent.

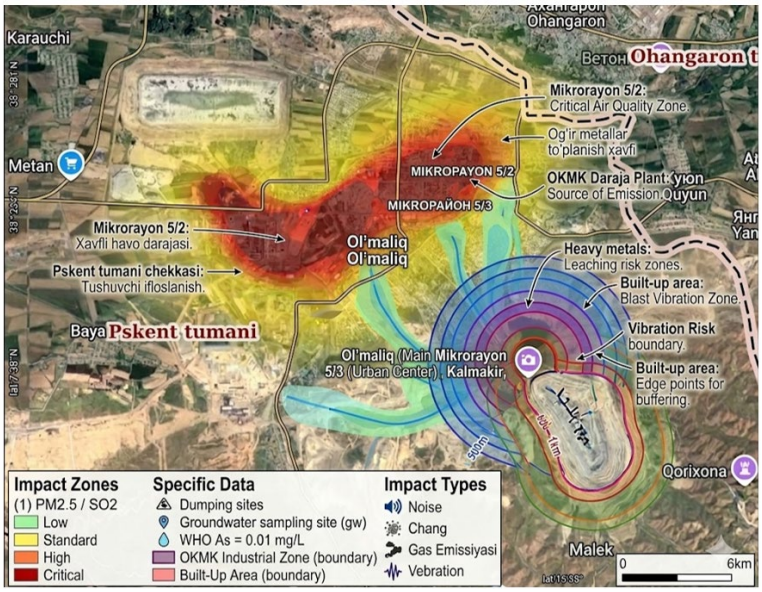


Fig. 4: Impact of the industrial zone in Almalyk on the population.

DISCUSSION

The results confirm that environmental risk in industrial cities is a cumulative and spatially differentiated phenomenon. In Almalyk, environmental pressure peaks where industry, waste, and population intersect, highlighting the need for integrated territorial assessment rather than isolated pollutant control. The GIS-based framework used in this study provides several advantages for such assessment. First, it enables the integration of diverse environmental datasets that would otherwise remain analytically separate. Second, it converts point-level observations and remote-sensing indicators into interpretable territorial patterns. Third, it supports prioritization by showing where environmental burden is greatest and where human exposure is most significant.

From a planning perspective, the identification of high-risk zones near industrial-residential interfaces is especially important. These areas should receive priority attention in the form of stronger monitoring systems, stricter land-use regulations, green-buffer development, and public health safeguards. Groundwater-sensitive zones and areas influenced by waste disposal should also be monitored more intensively because contamination in these areas may persist and spread through subsurface pathways.

The study also demonstrates the value of remote sensing as a complement to field-based environmental monitoring. Vegetation condition, land cover, terrain, and atmospheric indicators improve the interpretation of ecological stress and help explain the territorial differentiation of risk. In rapidly transforming industrial cities, such tools can support repeated observation and long-term environmental management at relatively low cost. At the same time, the effectiveness of the framework depends on the quality and completeness of input data. A robust implementation requires a reliable sampling design, accurate spatial coordinates, justified weighting, clear classification rules, and validation against observed environmental patterns. Continued refinement may include stronger use of PCA, fuzzy approaches, uncertainty analysis, and machine-learning-based prediction where sufficient data are available.

The results support spatial planning in industrial cities through industrial buffer zoning, environmental protection corridors, targeted green infrastructure, and stricter development control near high-risk areas. The risk map can also guide environmental monitoring priorities and be integrated into local structure plans to support land-use regulation, pollution mitigation, and public health protection. This study is limited by the availability and completeness of environmental and spatial data, and the analysis reflects the specific time period for which those data were collected. Some uncertainty remains in the AHP weighting process because expert judgments are inherently subjective. In addition, while the framework is transferable in principle, its application to other industrial cities will require local data and context-specific adjustment.

CONCLUSION

This study presents a GIS-based methodological framework for environmental risk assessment in industrial cities and demonstrates its application to Almalyk, Uzbekistan. By integrating environmental hazard indicators and vulnerability indicators within a unified geospatial environment, the framework provides a practical basis for identifying high-risk zones and supporting spatially informed environmental governance. The results indicate that environmental risk in Almalyk is not distributed evenly across the urban territory. The most significant pressures are concentrated in industrial zones, nearby residential sectors,

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groundwater-sensitive areas, and corridors influenced by pollutant transport and mining-related disturbance. These findings confirm the need for environmental management strategies that are spatially targeted and linked directly to urban planning and public health protection. The methodological structure developed in this study is applicable beyond the specific case of Almalyk. With appropriate local data, it can be adapted to other industrial cities experiencing overlapping environmental pressures from production, urban growth, and ecological degradation. The integration of GIS, remote sensing, spatial interpolation, and multi-criteria analysis, therefore, offers a strong foundation for sustainable urban environmental assessment in an industrial region.

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INTEGRATED GIS AND DIGITAL TWIN–BASED FRAMEWORK FOR SCENARIO-BASED SEISMIC VULNERABILITY ASSESSMENT OF URBAN BUILDINGS: CONCEPTUAL ARCHITECTURE AND CASE STUDY OF TASHKENT

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Abstract

Urban areas located in seismically active regions are exposed to complex multi-factor risks arising from the interaction between seismic hazards and structural characteristics of the built environment. This study proposes an integrated analytical framework for scenario-based seismic vulnerability assessment of urban buildings that combines structural engineering analysis, multivariate regression modeling, geospatial information systems, and digital twin concepts, formulated here as a conceptual architecture that links structural databases, probabilistic simulations, and GIS visualization in an updateable decision-support loop. The methodology incorporates a structured building inventory including geometric, material, structural, and condition-related parameters to calculate a quantitative vulnerability index for each building under defined seismic loading scenarios. The proposed model was applied to a representative sample of buildings in Tashkent, where vulnerability levels were classified using a five-tier risk scale. Results demonstrate that the calculated vulnerability index effectively captures the combined influence of structural attributes and allows identification of buildings with elevated seismic susceptibility. Spatial visualization within a GIS environment revealed pronounced heterogeneity of risk distribution, highlighting localized clusters of structurally vulnerable buildings. The findings confirm that integrating engineering-based evaluation with data-driven modeling significantly improves predictive accuracy compared to traditional deterministic assessment approaches. The developed framework represents a scalable and transferable decision-support tool suitable for urban resilience

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planning, seismic risk mitigation, and prioritization of structural strengthening measures in earthquake-prone regions.

Keywords: Seismic risk assessment, urban infrastructure, structural vulnerability, GIS modelling, digital twin, regression analysis, earthquake resilience.

INTRODUCTION

Seismic risk is an increasingly critical issue for urban territories located in tectonically active zones. The ability of urban infrastructure to withstand seismic events is determined not only by geological and seismic characteristics but also by the resilience of the built environment. The consequences of seismic events can span from structural collapse to widespread socio-economic disruptions. This necessitates a comprehensive, multidisciplinary approach to evaluating and mitigating these risks. In recent decades, the convergence of civil engineering, geoinformatics, and data science has enabled the development of more sophisticated frameworks for seismic risk assessment (Boje et al., 2020; Gürdür Broo et al., 2022). These frameworks are no longer limited to static analyses but incorporate real-time monitoring, probabilistic modeling, and dynamic simulation.

Urban territories located in seismically active regions are increasingly exposed to complex and multidimensional risks resulting from the interaction between natural seismic hazards and the characteristics of the built environment. Rapid urbanization, population growth, and the expansion of critical infrastructure have significantly increased the potential consequences of seismic events (Lei et al., 2023; Weil et al., 2023). In densely developed cities, even earthquakes of moderate intensity may lead to substantial structural damage, disruption of essential services, and long-term socio-economic losses. Therefore, the assessment of seismic risk has become a fundamental task in modern civil engineering, urban planning, and disaster risk management.

Seismic risk is not determined solely by the magnitude or frequency of earthquakes. The vulnerability of buildings, infrastructure systems, and urban layouts plays a decisive role in shaping potential damage scenarios. Aging building stock, outdated construction practices, and insufficient seismic upgrading further aggravate the problem, particularly in cities with long development histories. As a result, there is a growing need for comprehensive assessment frameworks capable of addressing the complexity of urban systems under seismic loading (Guo et al., 2024; Heresi & Miranda, 2022; Macatulad & Biljecki, 2024; Wang et al., 2024).

The originality of this research lies in developing a unified framework that integrates structural inventory, probabilistic vulnerability modeling, GIS, and Digital Twin technology for dynamic seismic risk assessment and decision

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support. Its regional applicability is demonstrated through a scenario-based assessment of Tashkent, combining GIS with national seismic regulations and EMS-98 to classify buildings by structural characteristics, age, height, material, and condition under defined earthquake scenarios (Jahangir et al., 2025; Kookalani et al., 2026; Sianko et al., 2023; Zhai et al., 2026).

The integration of geospatial analysis with regulatory-based vulnerability assessment allows identification of spatially concentrated high-risk zones within the urban territory. Such scenario modeling improves predictive accuracy of potential earthquake consequences and supports prioritization of structural retrofitting, urban resilience planning, and civil protection strategies in seismically active regions.

METHODOLOGY

Technical inventory of urban structures

The Technical passportization of urban buildings is a fundamental procedure for assessing the seismic safety of urban environments (Alemdar, 2025; Douglas et al., 2024; Guardiola-Víllora et al., 2023; Oleng et al., 2025). To address the complexity of urban seismic risk, assessment methodologies must be structured in a clear and logical sequence (Ghaffarian, 2025; Rosvold & Buhaug, 2021; Tulaganov et al., 2021). This sequence should ensure a consistent transition from general risk concepts to detailed engineering analysis and, ultimately, to practical implementation.

$$R_{urban=}\frac{1}{N}\sum_{i=1}^{N} I_f\,(i) \quad (1)$$

Spatial information for the buildings and urban zones was obtained from municipal cadastral maps and existing GIS layers of the city's building stock and infrastructure, which were harmonized within a common coordinate system for analysis. The sampling procedure focused on ensuring coverage of the main structural typologies and construction periods rather than on statistical representativeness in a probabilistic sense. Buildings were selected to represent typical combinations of height, material, configuration, and condition that are characteristic of the urban fabric, enabling scenario-based interpretation of model behaviour across a realistic range of vulnerability drivers.

The inventory covers the principal built-up districts of Tashkent, representing the city's dominant structural patterns. Data quality was ensured through consistency checks, removal of incomplete records, and expert review. Buildings with missing key attributes were excluded. A purposive engineering sampling approach was used to capture representative combinations of structural

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system, material, height, construction period, and condition, ensuring coverage of the main regional vulnerability characteristics.

A comprehensive structural database is established through systematic collection, verification, and standardization of building attributes. The inventory includes structural system typology, primary construction material, number of stories, construction year, geometric irregularities, maintenance condition, and retrofitting history.

Let each building be represented by a feature vector:

$$x_b = [S_b, M_b, H_b, Y_b, Q_b, R_b I_b] \quad (2)$$

Where;
S_b — structural system type
M_b — material class
H_b — height/stories
Y_b— construction year
Q_b— condition index
R_b— retrofit indicator
I_b— irregularity indicator

A fragmented approach, in which individual components of risk are analyzed independently, limits the applicability of results for urban planning and decision-making.

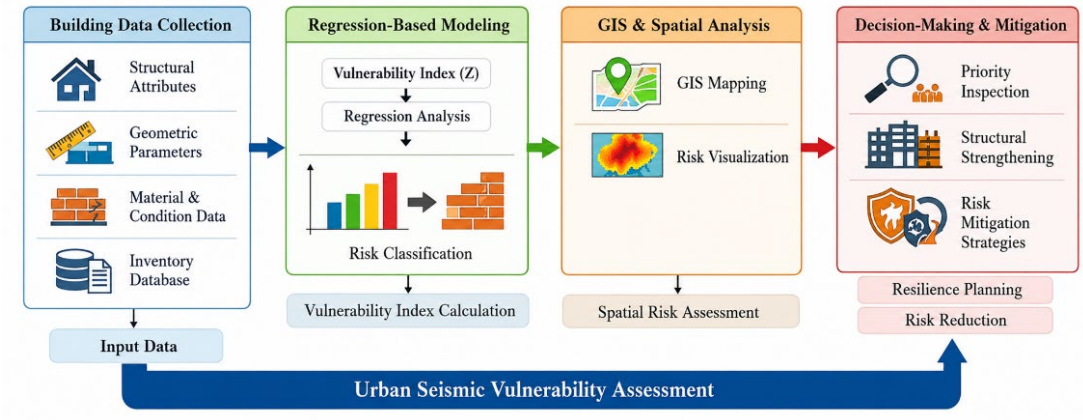


Figure 1: Integrated seismic vulnerability assessment framework for urban buildings

Within this (Figure 1) framework, technical inventory and structural vulnerability assessment constitute the core analytical stages. These stages provide the necessary link between theoretical seismic risk concepts and applied engineering evaluation, enabling the integration of empirical data, analytical models, and digital tools within a unified assessment process.

Table 1: Simulation Tools for Urban Seismic Risk Assessment

Tool	Description	Use Case
HAZUS	FEMA's loss estimation tool	Earthquake impact modeling
CAPRA	Probabilistic risk platform	Urban risk estimation
OpenQuake	Seismic hazard modeling	Scenario-based loss mapping
InaSAFE	Disaster impact tool	Planning emergency services

A technical building inventory is fundamental to city-scale seismic risk assessment, providing data on structural system, materials, height, construction period, condition, and retrofitting. Beyond documentation, it enables quantitative analysis of building typologies, spatial distribution, and vulnerable structures, forming the basis for large-scale urban risk assessment.

In many cities, incomplete or outdated building records require supplementary data from field surveys, archives, and geospatial sources. Digital inventories support efficient large-scale spatial analysis. Structural vulnerability depends on factors such as structural system, materials, construction quality, design, and seismic code compliance, causing buildings to perform differently under similar earthquake conditions. Structures with similar mechanical properties are grouped into classes, allowing statistical representation of expected damage behavior. This grouping significantly reduces computational complexity while preserving structural realism at the urban scale.

Probabilistic classification may also be implemented:

$$VC_b = \text{argmaxP}(VC = k \mid x_b) \tag{3}$$

Vulnerability assessment enables the classification of buildings into groups with comparable seismic performance. Such classification forms the basis for estimating expected damage levels, potential economic losses, and functional disruptions under different earthquake scenarios. At the urban scale, vulnerability mapping provides valuable insight into the spatial distribution of risk and allows

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for the identification of priority areas where mitigation and retrofitting measures are most urgently required.

Building inventory and data collection

The seismic vulnerability assessment is based on a structured inventory of urban buildings compiled from technical passport records, regulatory documentation, and field verification. The inventory covers multistory residential and public buildings across Tashkent, representing the city's main structural types and construction periods. For the regression analysis, representative buildings were selected to capture variations in structural system, height, materials, and condition. Each building was described by geometric and structural attributes, construction year, condition, retrofit status, and irregularity indicators. Data consistency was verified through cross-checking of records and expert review.

Probabilistic Simulation Module

Uncertainty in seismic input, structural parameters, and material properties is propagated through stochastic simulation. Monte Carlo sampling is employed to evaluate failure probability;

$$P_f = \frac{1}{N}\sum_{i=1}^{N} I_f\,(i) \quad (4)$$

Where;
N — number of simulations
If(i) — indicator of structural failure in simulation iii

Adaptive sampling strategies are used to ensure convergence while minimizing computational cost. This probabilistic framework captures variability in structural performance that deterministic methods cannot represent.

It is essential to recognize that vulnerability assessment must be adapted to local construction practices and regulatory conditions. The direct application of generalized vulnerability models without regional calibration may lead to inaccurate or misleading results. Therefore, vulnerability classification should be aligned with national design standards, historical construction practices, and observed damage patterns from past seismic events.

Spatial Risk Mapping

Building-level risk indices are aggregated spatially within a geographic information system. The spatial risk indicator for a region is computed as:

$$RI_{zone} = \frac{\sum w_b RI_b}{\sum w_b} \qquad (5)$$

Where;
RI_b— risk index of building
w_b — weighting factor (population, area, importance)

Spatial clustering identifies vulnerability hotspots where structural risk is concentrated. These results are integrated into a Digital Twin environment that combines structural databases, probabilistic models, GIS visualization, and monitoring data into a dynamic virtual representation of the urban infrastructure.

The architecture operates as a bidirectional information loop consisting of three functional layers:

1. Data Layer — consolidates structural inventory records, GIS spatial datasets, hazard parameters, and monitoring inputs.
2. Modeling Layer — executes probabilistic simulations, vulnerability analysis, and risk calculations under varying seismic scenarios.
3. Interface Layer — provides interactive visualization dashboards and decision-support outputs for planners and engineers.

In the present study, this digital twin environment is introduced as a conceptual architecture that defines how structural inventory data, probabilistic simulation results, and GIS-based risk layers can be organized within an updateable decision-support system. The Tashkent case study demonstrates the operation of the data and modeling components and their integration with GIS visualization, while full real-time synchronization and implementation of all monitoring interfaces are identified as future development steps.

Linear Regression–Based Vulnerability Assessment Model.
To quantify structural vulnerability at the building level under a defined seismic scenario, a predictive model based on multivariate linear regression was developed. The model evaluates the influence of geometric, structural, and material attributes on the seismic vulnerability index.

Each building is represented by a feature vector:

$$X=[x_1,x_2,x_3,\ldots,x_n] \qquad (7)$$

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where the attributes include building length, total area, height, structural system type, construction material, number of stories, structural configuration, construction period, maintenance condition, and retrofitting status.

The vulnerability index is computed using the linear regression model:

$$Z=XW \tag{8}$$

For transparency, the regression equation can be written explicitly as;

$$\begin{aligned} Z = \beta_0 + \beta_1 \cdot \text{Height} + \beta_2 \cdot \text{Number of stories} + \beta_3 \cdot \text{Structural system type} \\ + \beta_4 \cdot \text{Material class} + \beta_5 \cdot \text{Building area} + \beta_6 \\ \cdot \text{Construction period} + \beta_7 \cdot \text{Maintenance condition index} + \beta_8 \\ \cdot \text{Retrofit indicator} + \beta_9 \cdot \text{Geometric irregularity indicator} \end{aligned}$$

where the coefficients $\beta_i$represent the contribution of each attribute to the vulnerability index. Positive coefficients for deterioration-related variables (older construction periods, weaker maintenance condition, absence of retrofit, presence of irregularity) increase Z, indicating higher vulnerability, whereas favourable conditions (recent construction, good maintenance, presence of seismic strengthening measures, regular configuration) are associated with lower Z values.

Where;
X — matrix of building attributes;
W — vector of weight coefficients determined through normal equation estimation;
Z— predicted seismic vulnerability indicator.

The weight coefficients are obtained by minimizing the least squares error:

$$W = (X^T X)^{-1} X^T Y \tag{9}$$

where *Y* represents observed or calibrated vulnerability values derived from seismic performance data and regulatory thresholds.

This approach enables evaluation of the relative contribution of each structural parameter to the overall vulnerability level. The model produces a continuous vulnerability score for each building, which can subsequently be classified into discrete risk categories. For the scenario simulation, a seismic intensity corresponding to a magnitude of 6.5 was adopted and normalized for

integration into the regression framework. This allows consistent comparison of buildings under identical seismic loading conditions.

The regression-based vulnerability index was calibrated on a representative set of urban buildings characterized by structural, geometric, and condition-related attributes. The model specification and parameter values were selected to ensure consistency with established seismic design regulations, observed damage tendencies in the region, and expert engineering judgment, rather than to exhaustively report all possible statistical diagnostics.

Vulnerability Level Classification Scale.
To interpret the calculated vulnerability indicator *Z*, a five-level classification scale was introduced. The intervals are defined as follows:

- Level 1 (Very Low Risk): $Z < 1.5$
- Level 2 (Low Risk): $1.5 \leq Z < 2.5$
- Level 3 (Moderate Risk): $2.5 \leq Z < 3.5$
- Level 4 (High Risk): $3.5 \leq Z < 4.5$
- Level 5 (Very High Risk): $Z \geq 4.5$

Each level is associated with a corresponding visualization color code to facilitate GIS-based spatial interpretation of seismic risk distribution. This classification system provides a structured basis for prioritizing detailed structural assessment, retrofitting interventions, and urban seismic risk mitigation planning.

RESEARCH METHODOLOGY

The obtained results demonstrate that integrating structural engineering parameters with data-driven predictive modeling substantially improves the reliability of seismic vulnerability assessment at the urban scale. Unlike conventional deterministic approaches that rely primarily on generalized structural typologies, the proposed regression-based method incorporates multidimensional building attributes, allowing a more realistic representation of structural behavior under seismic loading conditions.

The spatial analysis showed that seismic vulnerability is unevenly distributed across the city, with localized high-risk clusters driven by differences in construction materials, structural systems, maintenance, and building age. These results highlight the importance of accounting for local building characteristics rather than relying on citywide averages. Integrating GIS visualization with predictive modeling improves interpretation by converting numerical results into spatial decision-support tools, helping planners prioritize

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inspections, retrofitting, and risk mitigation measures while supporting urban resilience planning.

Another important outcome of this study is the demonstration that combining engineering-based assessment with digital modeling technologies creates a scalable analytical framework suitable for complex urban systems. The developed methodology can be adapted to other seismically active regions by recalibrating structural parameters, regional building practices, and local regulatory requirements. This adaptability indicates that the proposed framework represents a transferable analytical tool rather than a location-specific case study.

It should be noted that, in this initial application, the digital twin component is implemented at the level of an analytical and visualization framework linking structural inventory, regression-based vulnerability estimation, probabilistic interpretation, and GIS-based mapping, rather than as a fully operational real-time monitoring system.

Despite its advantages, several limitations should be acknowledged. The predictive accuracy of the model depends on the completeness and reliability of structural inventory data. In many urban territories, technical documentation may be outdated or incomplete, which introduces uncertainty into vulnerability estimation. Future research should therefore focus on integrating real-time monitoring data, remote sensing inputs, and automated data acquisition systems to enhance model robustness and reduce uncertainty.

Overall, the results confirm that the proposed integrated methodology provides a scientifically grounded and practically applicable approach for assessing urban seismic vulnerability, supporting evidence-based decision-making, and improving the resilience of built environments exposed to seismic hazards.

Scenario-Based Seismic Vulnerability Assessment.

The developed regression-based model was applied to a sample dataset consisting of fifteen representative buildings characterized by ten structural and geometric attributes. This sample size was chosen to provide a clear illustration of how the vulnerability index differentiates buildings with contrasting structural systems, material classes, height ranges, construction periods, and maintenance conditions within the considered urban context. For the detailed scenario-based regression demonstration, a sample of fifteen representative buildings was used to illustrate how the vulnerability index differentiates objects with different structural and condition-related characteristics. Using the calibrated weight coefficients, vulnerability index values were computed for each building under a simulated seismic scenario corresponding to intensity level 6.5. The calculated indicator $\boldsymbol{Z}$ reflects the integrated influence of structural configuration, material properties, geometric parameters, and technical condition on seismic performance.

In this study, Table 2 defines the classification scale used to interpret the calculated vulnerability index Z. To support the results more transparently, Table 3 presents anonymized building-level model outputs for the fifteen representative objects analyzed under the 6.5 scenario. Higher values of Z indicate increased susceptibility to seismic damage, while lower values represent more stable structural behavior.

Table 2: Classification of Buildings According to Seismic Vulnerability Index

Vulnerability Level	Color Code	Vulnerability Index (Z) Range	Color
Level 1	Green	0 – 1.5	
Level 2	Light Green	1.5 – 2.5	
Level 3	Yellow	2.5 – 3.5	
Level 4	Orange	3.5 – 4.5	
Level 5	Red	> 4.5	

Table 3. Anonymized building-level scenario results for the representative sample

ID	Structural profile	Dominant vulnerability driver	Z	Level	Recommended action
B01	RC frame, 4 stories	recent construction / good condition	1.25	Level 1 (Very low)	Routine monitoring
B02	RC frame, 5 stories	Good maintenance condition	1.42	Level 1 (Very low)	Routine monitoring
B03	RC frame, 6 stories	Moderate height effect	1.63	Level 2 (Low)	Periodic inspection
B04	Masonry, 2 stories	Older material class	1.81	Level 2 (Low)	Periodic inspection
B05	RC frame, 7 stories	height and plan configuration	2.05	Level 2 (Low)	Screening inspection
B06	Masonry, 3 stories	maintenance condition	2.22	Level 2 (Low)	Screening inspection
B07	RC frame, 8 stories	geometric irregularity	2.38	Level 2 (Low)	Screening inspection
B08	Panel building, 5 stories	construction period	2.46	Level 2 (Low)	Screening inspection
B09	Masonry, 4 stories	material and age effects	2.71	Level 3 (Moderate)	Detailed inspection

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ID	Structural profile	Dominant vulnerability driver	Z	Level	Recommended action
B10	RC frame, 9 stories	height and irregularity	2.84	Level 3 (Moderate)	Detailed inspection
B11	Panel building, 6 stories	maintenance condition	3.07	Level 3 (Moderate)	Detailed inspection
B12	Masonry, 4 stories	absence of retrofit measures	3.26	Level 3 (Moderate)	Detailed inspection
B13	RC frame, 10 stories	irregular configuration	3.41	Level 3 (Moderate)	Detailed inspection
B14	Masonry, 5 stories	age, condition, and material	3.62	Level 4 (High)	Engineering assessment
B15	Mixed system, 7 stories	Irregularity and lack of retrofit	3.88	Level 4 (High)	Priority strengthening review

The individual building names and coordinates are anonymized in Table 3 to avoid disclosing exact object locations, while preserving the analytical value of the calculated vulnerability results. The behaviour of the calibrated model was examined by comparing predicted vulnerability levels with the structural characteristics and spatial patterns of the analyzed buildings. Objects classified in higher vulnerability categories predominantly correspond to older construction periods, less favourable material classes, weaker maintenance conditions, irregular configurations, and absence of retrofit measures, and they form spatial clusters rather than appearing randomly across the study area. This agreement between model outputs, engineering expectations, and GIS-based risk patterns indicates that the regression-based index provides a consistent and practically meaningful representation of seismic vulnerability for the considered scenario.

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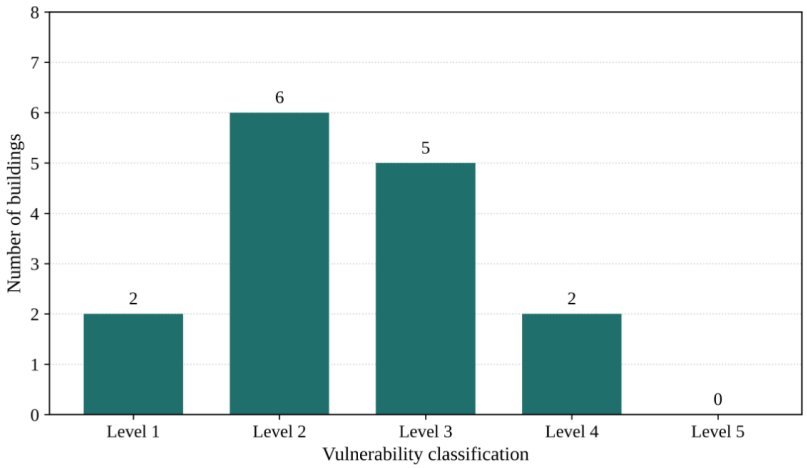


Figure 2. Distribution of buildings by seismic vulnerability level under the scenario seismic loading

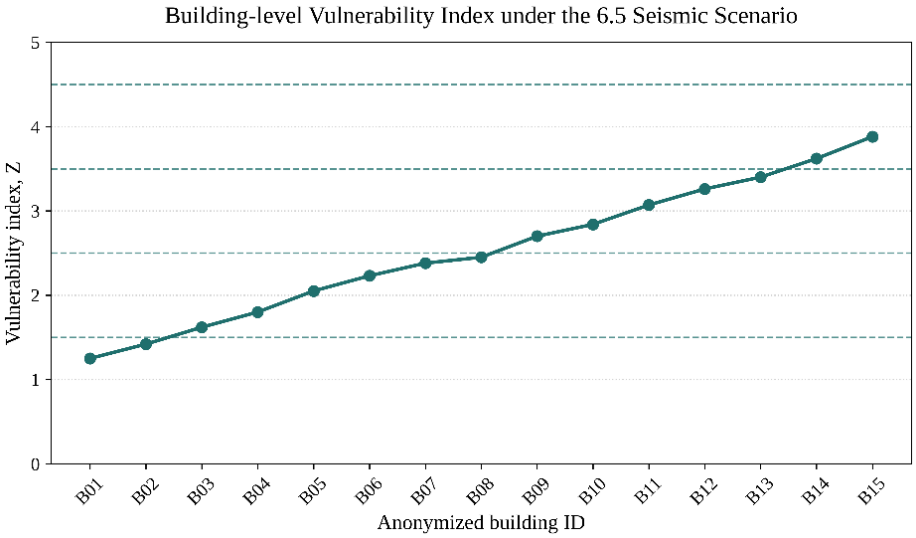


Figure 3. Building-level vulnerability index profile for the anonymized representative sample

As shown in Figures 2 and 3, most buildings fall within low-to-moderate vulnerability levels, with none classified as very highly vulnerable. The continuous vulnerability index (Z) distinguishes buildings within similar structural groups, highlighting localized weaknesses that may affect seismic performance during stronger earthquakes.

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Spatial Visualization of Vulnerability Distribution.
The calculated indices were further integrated into a GIS environment to enable spatial interpretation of seismic risk distribution. Figure 4 illustrates the geographic allocation of buildings according to their vulnerability classification levels. The visualization reveals spatial heterogeneity of seismic risk, highlighting zones where structural vulnerability is concentrated rather than uniformly distributed across the study area.

From a practical implementation perspective, the framework can be deployed as a city-scale decision-support tool in which regularly updated technical passport data are fed into the regression-based vulnerability index, the resulting risk levels are visualized in the municipal GIS system, and the Digital Twin architecture is used to explore alternative retrofitting, evacuation, and resource allocation scenarios without interrupting real-world operations.

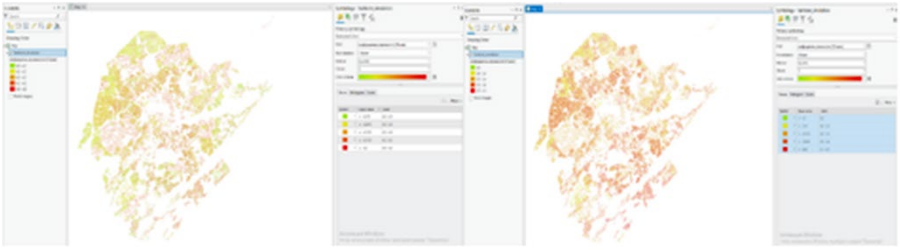


Figure 4. GIS-based visualization of building seismic vulnerability levels for Tashkent under scenario seismic loading

Such spatial analysis allows identification of priority areas requiring detailed structural inspection, retrofitting measures, and risk mitigation planning. The integration of predictive modeling with geospatial visualization significantly enhances interpretability of results and supports evidence-based decision-making in urban seismic risk management.

The reliability of the proposed vulnerability index was assessed qualitatively by comparing model outputs with expert judgment and established regional damage patterns. Buildings classified as highly vulnerable were generally older masonry structures with poor maintenance, irregular configurations, and no retrofitting, while newer reinforced concrete buildings in better condition consistently showed lower vulnerability. These results agree with engineering expectations and previous seismic risk studies, providing indirect validation of the model despite the absence of large historical damage datasets or extensive field validation. Although a formal uncertainty analysis is beyond the scope of this study, imperfect documentation and variability in structural

condition are recognized as key sources of uncertainty. The observed trends, higher vulnerability for older masonry buildings and lower vulnerability for newer reinforced concrete structures—are consistent with regional earthquake damage patterns and established typology-based vulnerability models. This agreement indicates that, despite data limitations, the proposed regression-based index is consistent with accepted seismic vulnerability concepts.

Findings and Practical Implications.

The expanded scenario analysis provides four main findings that strengthen the empirical contribution of the study. Compared with conventional approaches based on generalized building typologies or single-parameter screening, the proposed regression-based framework offers two key advantages. It combines multiple building attributes, structural system, material, geometry, construction period, condition, and retrofit status into a single vulnerability index, enabling more accurate differentiation between buildings. In addition, integration with GIS and Digital Twin technologies converts numerical results into spatial decision-support information, helping planners identify priority areas and optimize strengthening strategies. From an urban planning perspective, the proposed framework supports zoning, land-use planning, and development control by identifying areas that require stricter planning standards or strengthening measures. Integrating the vulnerability index into GIS enables seismic risk to be incorporated into local plans, emergency preparedness, and resilience strategies, making the framework both an engineering assessment and an urban planning tool.

The regression-based vulnerability index provides a consistent building-level ranking, distinguishing buildings of similar typology based on age, condition, geometric irregularity, and retrofit status. The results show that seismic vulnerability is governed by multiple factors rather than a single structural attribute, supporting the use of a multidimensional inventory over simplified typology-based screening.

The normalized contribution plot in Figure 5 supports this interpretation by showing the normalized contribution of the main input parameters to the vulnerability score. The largest effects are associated with maintenance condition and construction period, followed by geometric irregularity and material type. The normalized contributions indicate the relative importance of each variable in the vulnerability index. Structural condition and construction period have the greatest influence, followed by geometric irregularity and material type, while geometric parameters such as area and height have comparatively smaller effects. The regression model assigns higher vulnerability scores to buildings with poor maintenance, older construction, and geometric irregularities, while better-

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maintained, newer, and structurally regular buildings receive lower scores. This confirms that the model behaves consistently with engineering expectations.

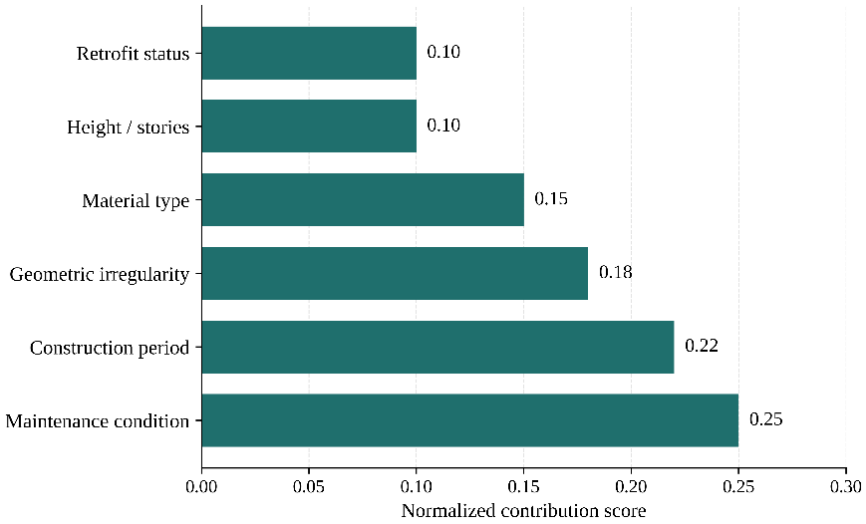


Figure 5. Normalized contribution of key structural and condition-related parameters to the vulnerability score

Third, the GIS analysis shows that vulnerability is spatially clustered, enabling priority districts to be identified for inspection and mitigation. Fourth, the Digital Twin framework supports continuous updates, allowing new building and monitoring data to be incorporated without repeating the entire assessment process.

Table 4: Number Summary of additional findings derived from the scenario-based assessment.

Analytical finding	Evidence from the scenario-based assessment	Practical implication
Building-level differentiation	The calculated vulnerability index Z assigns each building to a risk level and allows comparison of buildings with different geometric and structural attributes	Supports ranking of buildings for detailed engineering inspection and strengthening programs
Dominance of low-to-moderate categories	The analyzed sample is mainly represented by low-to-moderate vulnerability levels, while very high vulnerability is not observed in the considered scenario	Indicates that general structural performance is acceptable, but selected vulnerable buildings still require attention

Analytical finding	Evidence from the scenario-based assessment	Practical implication
Influence of structural condition and configuration	Higher vulnerability is associated with weaker maintenance condition, older construction period, irregular geometry, less favorable material type, and lack of retrofit measures	Confirms the need to include technical passportization and structural condition data in seismic risk models
Spatial clustering of vulnerability	GIS visualization reveals localized concentrations of elevated vulnerability rather than uniform risk distribution across the study area	Enables identification of priority urban zones for inspection, retrofitting, evacuation planning, and resource allocation.
Digital twin applicability	The framework links inventory data, regression-based calculation, probabilistic interpretation, and GIS visualization in one updatable system	Provides a scalable tool for future monitoring, model recalibration, and evidence-based urban resilience planning

The current implementation is limited by the size and completeness of the structural inventory, the use of a single normalized seismic scenario, and the lack of large-scale statistical calibration, which constrain uncertainty analysis and broader generalization. Nevertheless, the framework goes beyond producing a vulnerability score by generating spatially interpretable results, identifying key vulnerability drivers, and supporting the prioritization of seismic mitigation measures in Tashkent and other earthquake-prone cities.

CONCLUSION

This study developed an integrated framework for scenario-based seismic vulnerability assessment of urban buildings that combines structural engineering analysis, probabilistic modeling, geospatial technologies, and digital twin concepts. The proposed methodology enables systematic evaluation of building performance under seismic loading by incorporating multidimensional structural attributes and predictive modeling techniques.

The results demonstrate that regression-based vulnerability estimation provides a reliable quantitative indicator reflecting the combined influence of structural configuration, materials, geometry, and technical condition. The classification system derived from the calculated vulnerability index allows buildings to be grouped into standardized risk levels, facilitating interpretation and practical decision-making.

Spatial integration of calculated indicators within a GIS environment revealed pronounced heterogeneity in vulnerability distribution across the analyzed urban area. This confirms that seismic risk is strongly influenced by localized structural characteristics and cannot be accurately represented by generalized or averaged indicators. The spatial visualization approach therefore

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provides a powerful tool for identifying priority zones requiring structural strengthening, inspection, or preventive mitigation measures.

The proposed framework extends beyond a single case study and provides a scalable approach that can be adapted to other earthquake-prone regions through regional calibration of structural parameters and regulatory conditions. By integrating engineering assessment with digital modeling and GIS, it transforms seismic risk evaluation into a dynamic decision-support tool for urban resilience and disaster risk reduction. Its vulnerability index is based on standard structural attributes, making the model reproducible and transferable to other cities after calibration. Future work should expand the structural database, incorporate real-time monitoring and machine learning, and develop a fully operational urban Digital Twin. Larger datasets will also enable more comprehensive validation, regression diagnostics, and improved predictive accuracy while maintaining practical interpretability.

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THE KHATABA VENTILATION METHOD: ENHANCING FOUNDATION DURABILITY IN KHIVA'S ARCHITECTURAL MONUMENTS

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Abstract

This article examines the importance of the Khataba method in the restoration and preservation of architectural monuments, especially in the historic regions of Ichan Qala and Deshon Qala in Khiva. The study explains Khataba as a traditional ventilation technique applied to foundations, walls, and roof structures to reduce moisture, salt migration, and capillary absorption, which damage historic materials. Based on historical sources, field observations, and restoration practice, the paper discusses the scientific basis of the method and its application in several monuments. The findings show that the Khataba system improves durability, reduces the harmful effects of groundwater, and contributes to the long-term conservation of monument structures.

Keywords: Architectural monuments, restoration, Khataba, foundations, ventilation, groundwater, capillary absorption, Ichan Qala, Deshon Qala, Khiva

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INTRODUCTION

The Architectural monuments in Central Asia face significant threats from environmental factors that compromise their structural integrity and longevity (Hejazi, 2008). Groundwater rise, capillary moisture ascent, and salt crystallization are primary deterioration mechanisms affecting porous materials such as fired brick and gypsum plaster, leading to foundation instability, wall cracking, and surface degradation (Afif-Khouri et al., 2025; Bochen et al., 2021; Cheema & Bell, 2013). Traditional restoration practices, therefore, emphasize moisture management strategies to enhance durability without compromising historical authenticity (Ehteshami & Soltaninejad, 2020). The importance of moisture management, humidity, and ventilation has been emphasised by (Baydoun et al., 2025).

Restoration efforts worldwide have increasingly adopted ventilation-based techniques to mitigate these issues (Mousavi et al., 2025; Rubulotta et al., 2024). For instance, cavity walls and air gaps in historic masonry structures allow moisture evaporation and reduce salt migration, as demonstrated in European heritage conservation projects (d'Ambrosio Alfano et al., 2023; Proietti et al., 2021). Similarly, in arid regions, passive ventilation systems have proven effective in stabilizing foundations by promoting airflow and drying (Ayoobi et al., 2024; Chohan & Awad, 2022). These approaches align with sustainable conservation principles, minimizing invasive interventions while extending service life.

The Architectural monuments in Central Asia are highly vulnerable to deterioration caused by groundwater, capillary moisture rise, salinity, and poor ventilation in lower structural zones (Arefyeva et al., 2022). To address these challenges, traditional construction and restoration knowledge developed several techniques, among which the Khataba method holds a special place (Durán-Suárez et al., 2018). Khataba is essentially a ventilation-based construction and restoration approach in which an air passage is deliberately left between structural or finishing layers. This air gap allows moisture and salts to dissipate, helps maintain dryness in walls and surface finishes, and ultimately slows the decay of bricks, plaster, and tiles. Historically, master builders in Khorezm and other regions applied this method in foundations, walls, roof spaces, and finishing interfaces. However, over time, many aspects of the technique were forgotten or simplified, and modern repair works often replaced it with direct adhesion methods, which, in many cases, accelerated deterioration.

Previous studies and restoration literature confirm that Khataba has deep historical roots and functioned as a natural ventilation strategy in traditional architecture. Several researchers have also highlighted its significance in restoration practice, including investigations of the Chor-Bakr complex in Bukhara (Anvarovna Nazarova, 2020). In addition, scientists have emphasized

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that foundation failures often require careful soil examination, staged repair processes, and structurally sensitive interventions, principles that strongly support the logic of Khataba-type systems when dealing with weak or moisture-affected foundations.

Abdugaffor Hakkulov further explained how roof-related Khataba devices improved ventilation, reduced dampness, and extended the service life of traditional buildings, linking restoration practice with long-term structural performance (Shynu & Steffi, 2023). Similarly, Azizova et al. argue that the Khataba ventilation method represents an important traditional restoration technique that was largely forgotten as architectural knowledge declined. Their research highlights that in Uzbekistan, particularly during the independence period, scholars have increasingly attempted to recover such historical construction practices to improve monument preservation and reconstruction efforts (Azizova, 2017).

The purpose of this article is therefore to systematize the available information on the Khataba method and demonstrate its importance in the ground and foundation zones of the architectural monuments, particularly those restored in Khiva. This study is novel in that it systematically documents the Khataba method as applied to Khiva's architectural monuments, provides a scientific explanation of its moisture-control mechanism, and synthesizes multiple restoration case studies from Ichan Qala and Deshon Qala. By combining historical review, field observation, and semi-quantitative comparison, the paper clarifies both the practical and conservation value of this traditional technique.

THEORETICAL BASIS OF THE KHATABA METHOD

The Khataba method operates on the principle of ventilation and separation. By creating an air chamber between the original wall and a newly formed protective layer, the system reduces direct contact between the monument fabric and moisture-bearing soil or finishing material. This technique is particularly relevant for porous materials such as baked brick and tile, which are susceptible to capillary absorption. In porous media, water rises through small voids, transporting salts upward; this leads to dampness, cracking, plaster failure, and loss of decorative surfaces. The use of a ventilated cavity helps release moisture and harmful salts into the atmosphere. It limits the destructive effect of aggressive groundwater on both underground and above-ground sections of the monument.

Moisture movement in porous masonry materials is primarily governed by capillary action, where water rises through fine pores due to surface tension forces. This process depends on pore size, material composition, and environmental conditions. In historic brick and plaster systems, smaller pore radii lead to higher capillary rise, allowing groundwater to migrate upward and carry dissolved salts. When evaporation occurs, salts crystallize within pores,

generating internal stresses that cause cracking and material loss. This mechanism explains the effectiveness of the Khataba method in interrupting moisture pathways.

Use in Building elements

Traditional Khataba solutions were strategically applied across multiple building elements to create ventilated separations that mitigate moisture accumulation and enhance material longevity. Each application targets specific deterioration risks associated with environmental exposure and material properties.

Foundations of buildings and structures:

Khataba in foundations involves excavating trenches or creating air gaps adjacent to the base, often filled with permeable materials to promote airflow. This prevents capillary rise from groundwater, reducing salt crystallization and foundation settlement in moisture-prone soils common to Khiva's historic sites.

Walls of buildings and structures:

Wall applications feature ventilated cavities between the original masonry and protective layers, such as brick or plaster facings. These gaps facilitate moisture evaporation and salt dissipation, protecting porous fired bricks from efflorescence and cracking while maintaining structural breathability.

Under-roof and upper covering elements:

In roof zones, Khataba forms air channels beneath tiles or coverings to improve circulation and prevent condensation. This technique counters dampness from roof leaks or humidity, extending the lifespan of timber supports and mud-based insulations in traditional Central Asian designs.

Between the roof and wall finishing layers:

Here, thin air passages separate decorative plasters, tiles, or paintings from underlying walls or roofs. This isolation shields ornate surfaces from rising damp and thermal fluctuations, preserving aesthetic and cultural value without direct adhesion that could trap moisture.

Applications in the Khiva monuments

The newly proposed and practically implemented Khataba style was used in the restoration of several monuments in the Ichan Qala and Deshon Qala areas of Khiva. These include the Sayyidniyoz Sholikorboy complex, Bikajon Bika madrasa, Muhammad Amin Inaq madrasa, Mamat Mahram madrasa, Sayyid Mohi Roi Jahan complex, Palvan Qori madrasa, Sayyid Muhammadkhan madrasa, Shergozikhan madrasa, and the Shikhnazar rich house.

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RESEARCH AIM AND METHODOLOGY

The aim of this study was to evaluate the scientific and practical significance of the Khataba method and its role in reducing moisture-related deterioration in the architectural monuments. The research combined analysis of historical and scientific sources, review of restoration literature, interviews with traditional master builders, field observations, and direct examination of restoration works carried out in Khiva between 2010 and 2020. The study focused on selected monuments in Ichan Qala and Deshon Qala where Khataba-based interventions were implemented. Fieldwork included observation of foundation conditions, dampness, wall deterioration, and the restoration solutions applied on site. The case study monuments were selected because they represent restored historic structures in Ichan Qala and Deshon Qala where the Khataba method was applied and where visible moisture-related deterioration was documented. Selection was based on the presence of foundation dampness, salt crystallization, structural risk, and the availability of restoration records. In addition, interviews were conducted with traditional master builders and restoration practitioners involved in the works to clarify construction details and practical application of the method. Field observations were recorded through site notes, photographs, and direct visual inspection, and the observed conditions were compared by examining the same deterioration indicators before and after intervention. The before-and-after assessment focused on visible moisture, salt damage, and surface deterioration, using a semi-quantitative scale to classify each condition consistently across the selected monuments. Figure 1 and Table 1 present the monuments examined in this study.

To support comparison across case studies, a semi-quantitative assessment framework was used. Each monument was evaluated using three observable indicators: moisture presence, salt crystallization, and surface deterioration. Moisture was classified as low, moderate, or high according to visible dampness. Salt damage was categorized as none, moderate, or severe based on efflorescence. Surface deterioration was recorded in terms of cracks, plaster detachment, and brick erosion. This framework made it possible to compare conditions consistently before and after the intervention.

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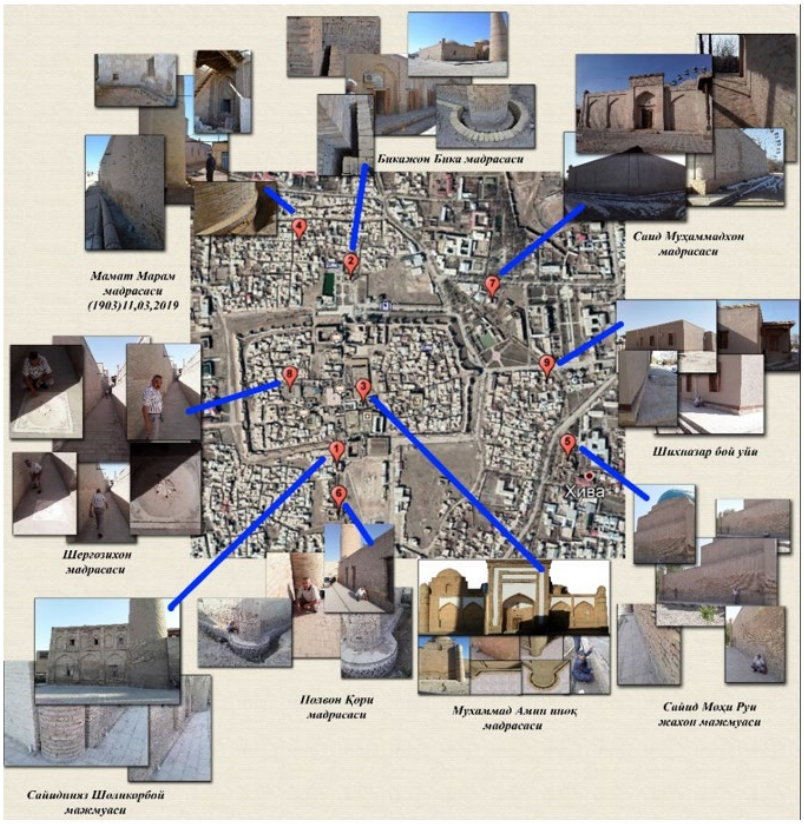


Figure 1: Objects in Ichan Qala and Deshon Qala where the Khataba method was used and their location on the scheme.

Table 1: Monuments in Khiva where the Khataba method was applied

Monument	Location	Main problem observed	Khataba application
Sayyidniyoz Sholikorboy complex	Deshon Qala	Rising groundwater, tilt, structural risk	Ventilated foundation-zone device with protective brick wall
Bikajon Bika Madrasa	Deshon Qala	Dampness and salt damage in lower walls	Trench-type Khataba along wall perimeter
Muhammad Amin Inaq madrasa	Ichan Qala	Foundation moisture and deterioration	Trench-like Khataba on all four sides

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Monument	Location	Main problem observed	Khataba application
Mamat Mahram madrasa	Khiva	Moisture-related monument protection	Khataba-based restoration mentioned in the study
Sayyid Mohi Roi Jahan complex	Khiva	Monument preservation intervention	Khataba-based restoration mentioned in the study
Palvan Qori madrasa	Khiva	Monument preservation intervention	Khataba-based restoration mentioned in the study
Sayyid Muhammadkhan madrasa	Khiva	Monument preservation intervention	Khataba-based restoration mentioned in the study
Shergozikhan madrasa	Khiva	Monument preservation intervention	Khataba-based restoration mentioned in the study
Shikhnazar rich house	Khiva	Monument preservation intervention	Khataba-based restoration mentioned in the study

CASE STUDY: SAYYIDNIYOZ SHOLIKORBOY COMPLEX

A comparative evaluation was conducted to assess the performance of the Khataba method across selected case studies. The analysis focuses on changes in moisture levels, salt crystallization, and surface condition before and after intervention. Although precise measurements were not available, consistent improvement patterns were observed. The Sayyidniyoz Sholikorboy complex, located in the eastern part of Deshon-Kala near the Polvan Gate, experienced serious structural risk due to rising groundwater, traffic-related dynamic effects, and failures in water and sewage systems. The tower had a height of 30.5 meters and a tilt of 1.07 meters toward the northwest, indicating an emergency condition. To reduce these threats, the Khataba method was applied to the foundation zone. A trench was excavated along the wall, and on the opposite side, a protective brick wall was constructed while leaving a ventilated space near the original foundation. Buttresses were introduced at intervals to improve the stability of the added structure. Figure 2 presents the cantilevered Khataba device used in the Sayyidniyoz Sholikorboy complex, together with the related foundation settlement diagram and construction details. The main types of Khataba application and their functions are listed in Table 2.

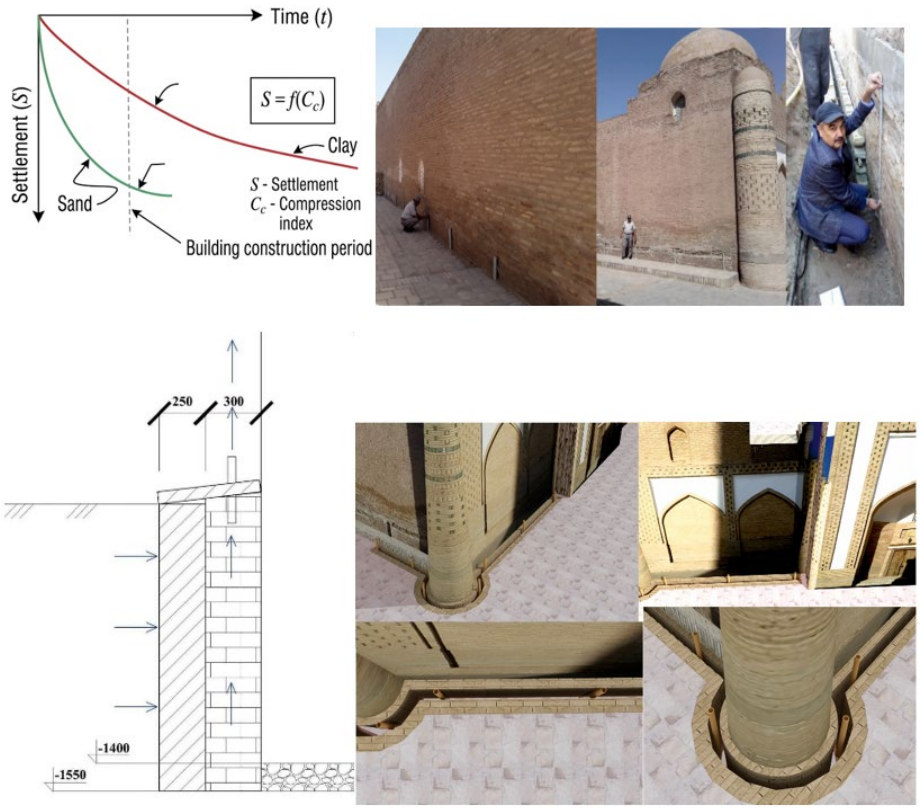


Figure 2: Cantilevered Khataba device used in the Sayyidniyoz Sholikorboy complex, including the foundation settlement diagram and construction details.

Table 2: Types of Khataba application and their functional purpose

Khataba type	Structural location	Main purpose	Expected effect
Foundation Khataba	Foundations and plinth zones	Reduce direct moisture contact	Limits capillary rise and dampness
Wall Khataba	Wall layers	Create a ventilated separation layer	Improves drying and salt release
Roof Khataba	Under-roof and upper cover elements	Improve air circulation	Reduces condensation and dampness

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Khataba type	Structural location	Main purpose	Expected effect
Finishing-layer Khataba	Between the roof and wall finishes	Separate decorative layers from moisture sources	Protects plaster and tile surfaces
Trench-type Khataba	Along perimeter walls	Provides a ventilated protective trench	Helps stabilize moisture-prone foundations
Cantilevered Khataba	Foundation-adjacent protective structure	Strengthen foundation protection	Improves durability under settlement risk

CASE STUDY: BIKAJON BIKA MADRASA

The Bikajon Bika madrasa and minaret, restored in 1894 and located in Deshon Qala, showed visible dampness and salt-related brick damage in the lower wall and plinth zones. The general view of the Bikajon Bika madrasa from the north-east is shown in Figure 3. In this monument, two Khataba variants were used depending on the local structural and environmental conditions. A trench 50-60 cm wide was dug along the wall, and baked brick was laid opposite the monument wall while maintaining a ventilated gap of about 25-30 cm from the foundation. The trench-type Khataba system applied to the eastern wall of the Bikajon Bika madrasa is illustrated in Figure 4. On the northern facade, which faced the roadway, the ventilation shaft was filled with rubble stone to improve resistance to dynamic vibration caused by heavy traffic. The ventilation shaft in the northern wall, filled with rubble stone for added stability, is shown in Figure 5. Restoration views of the northern facade, including pre- and post-intervention details, are presented in Figure 6. Application of the trench-type Khataba system on the northern and northeastern walls is depicted in Figure 7.



Figure 3: General view of the Bikajon Bika madrasa from the north-east.



Figure 4: Application of the trench-type Khataba system on the eastern wall of the Bikajon Bika madrasa.

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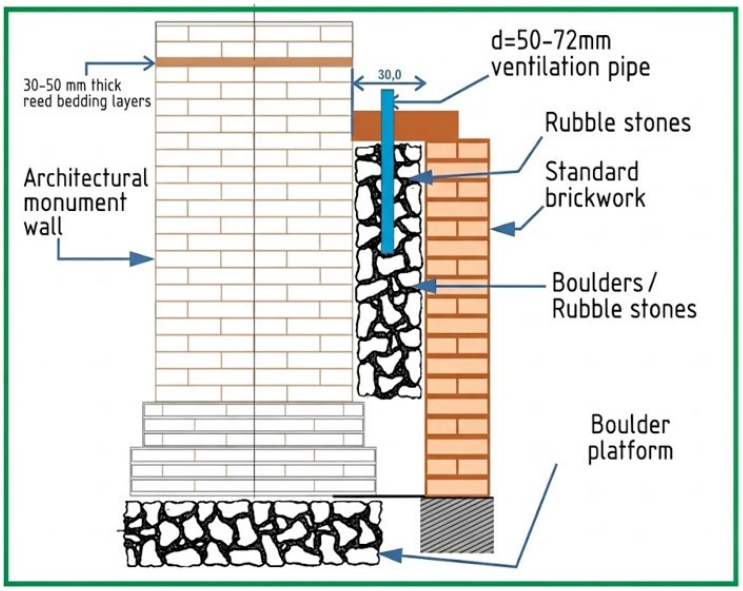


Figure 5: Ventilation shaft in the northern wall of the Bikajon Bika madrasa filled with rubble stone.



Figure 6: Northern facade of the Bikajon Bika madrasa and related restoration views.



Figure 7: Application of the trench-type Khataba system on the northern and northeastern walls of the Bikajon Bika madrasa.

CASE STUDY: MUHAMMAD AMIN INAQ MADRASA

The Muhammad Amin Inaq madrasa in Ichan Qala was built in 1780-1785 and later underwent several repairs, including interventions in the foundation, plinth, roof, and dome areas. In this monument, the foundation was treated with a trench-like Khataba system along all four sides. A 50-60 cm wide trench was dug along the walls, and ordinary baked bricks were laid opposite the original monument wall using a cement-sand mixture. The spacing between the new brickwork and the original foundation was maintained to preserve ventilation and reduce moisture accumulation.

SUMMARY OF RESULTS

Table 3 summarizes the observed condition of the selected monuments before and after application of the Khataba method. The comparison shows a general reduction in moisture level, salt crystallization, and surface deterioration after intervention.

Table 3: Summary of Before-and-After Condition Assessment for Monuments Treated with the Khataba Method

Indicator	Before Khataba	After Khataba
Moisture level	High	Moderate
Salt crystallization	Moderate to high	Low to moderate
Surface deterioration	High	Moderate

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DISCUSSION

Field observations and restoration practice indicate that the Khataba method effectively reduces the adverse effects of groundwater and capillary moisture on monument foundations and lower walls. By ventilating the foundation perimeter, it helps preserve both finishing layers, such as plaster and tiles, and the structural body of the monument by limiting dampness, corrosion, and salt accumulation. This also has an economic benefit, as preserving the original fabric and reducing the need for repeated repairs can lower restoration costs over time. In this sense, Khataba functions not only as a conservation technique but also as a sustainable maintenance strategy.

The effectiveness of the Khataba system is related to its influence on moisture transport. The ventilated cavity interrupts capillary continuity between the soil and the wall and promotes evaporation through airflow, thereby reducing moisture retention and limiting salt crystallization. These processes help explain the improved condition observed in the treated structures.

Compared with other traditional moisture-control strategies reported in heritage conservation, such as cavity walls or passive ventilation systems, the Khataba method offers a similar benefit of allowing moisture to dissipate while preserving material breathability. Its advantage is that it is closely adapted to the construction logic of historic masonry in Khiva, where ventilated gaps are created in foundations, walls, and roof interfaces without relying on impermeable barriers. Unlike chemical damp-proofing or rigid membranes, Khataba is more compatible with original materials and is easier to integrate into traditional restoration practice. At the same time, it should be viewed as a complementary strategy rather than a complete substitute for modern waterproofing when severe groundwater pressure is present.

Compared with modern damp-proofing methods such as chemical barriers and impermeable membranes, Khataba is better aligned with traditional materials, reversible in principle, and more environmentally sustainable. At the same time, its performance depends on construction quality and local environmental conditions, and it does not completely prevent moisture ingress. For this reason, it should be regarded as a complementary conservation solution rather than a full replacement for modern waterproofing systems.

LIMITATIONS

This study is based on qualitative and semi-quantitative observations without instrument-based measurements. The findings are specific to the environmental conditions of Khiva and may not be fully generalizable. Future research should include sensor-based monitoring and laboratory validation.

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CONCLUSION

The study shows that moisture, groundwater, and capillary absorption remain among the main threats to the preservation of the architectural monuments in Khiva. These processes lead to damp foundations, salinity, swelling, and cracking of walls, and the deterioration of plaster and tile surfaces. The renewed Khataba method provides an effective response to these problems by introducing ventilation around the foundation perimeter and between structural layers. Its practical use in several monuments of Ichan Qala and Deshon Qala confirms that it can improve structural durability and support long-term preservation. Therefore, the Khataba method should be recognized as an important traditional restoration principle that deserves further study and wider use in the conservation of architectural heritage. This study provides a structured validation of the Khataba method as a passive moisture-control strategy suitable for sustainable heritage conservation. For conservation practitioners and heritage authorities, the Khataba method can be used as a low-intervention moisture-control strategy in monuments where preserving traditional fabric is a priority. Future studies should include quantitative monitoring with moisture sensors and longer-term performance evaluation to verify durability under different environmental conditions.

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SMART CITY INITIATIVES IN ENHANCING THE QUALITY OF LIFE FOR URBAN POPULATION

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Abstract

Smart cities are widely accepted worldwide as an important component of the modernisation initiatives. The use of technology offering an alternative way to tackle complex and dynamic problems in urban studies. As urban areas progressively adopt intelligent and interconnected technologies, the rapid urbanisation and population expansion has adversely affected human health and their quality of life due to living in heightened densities area, worsened traffic congestion, and deteriorated pollution levels. Smart cities are not just about integrating technology into urban life. It also involves a comprehensive and holistic approach to city administration and planning authorities that includes multiple systems that lead to a good quality life. Therefore, the goal of this article is to explore the integration of smart city technologies as a strategic framework for enhancing quality of life of urban dwellers. The aim of this article is to increase the understanding of how smart cities may facilitate urban planning processes that grappling with a range of urbanization challenges with a focus on smart living and smart environment. A questionnaire survey was distributed to residents who work or live in the urban area. A total of 220 respondents living in Seremban City have participated in this study. The findings that have been identified are in line with the quality of life model which highlighted the relationship between the implementation of smart city technology and the well-being of the community. Hence, a collaboration between stakeholders and community involvement is vital to increase awareness and improve the quality of life of urban community in Seremban.

Keywords: Smart cities, quality of life, urban planning, smart living, smart environment

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INTRODUCTION

In the rapidly evolving landscape of urban development, smart cities have emerged as a pioneering model that integrates advanced technology, data analytics and innovative infrastructure to enhance the quality of life for urban populations. As cities become more interconnected and data driven, there is growing recognition of the potential for smart city interventions to shape and improve well-being. The term smart city is said to have first appeared in the middle of the 1990's and the core idea is to introduce smartness in every entity of the ecosystem that the people life in and interact (Shamsuzzoha et al., 2021).

LITERATURE REVIEW

Smart Cities

The concentration of housing in urban areas and the strong population growth imply that cities must adapt to improve the quality of life for their residents. Therefore, smart cities offer a viable solution by bringing together public resources, human capital, social capital and information and communication technologies (ICT) to promote sustainable development. The growing urbanisation has had a severe negative impact on the environment, this increasing the demand for sustainable development in urban planning. Smart cities are urban areas that use advance technologies and data driven strategies to enhance the quality of life for their residents, improve environmental sustainability and optimise the efficient of urban services and infrastructure. Different authors defined smart cities differently, where Batty et al., (2012) state that smart cities are instruments for improving competitiveness in such a way that community and quality of life are enhanced. Other than that, Chen & Chan (2023) defined smart city as a city that is integrated with high level of smartness, gained from the utilisation of available intelligent systems and services. These systems and services either improve or automate city functions, thereby generating jobs and increasing citizens' satisfaction. It is the automation of managing transportation, water energy, security and safety, traffic services, wastage, communications and other resources (Sharida et al., 2020). Therefore, it can be highlighted that smart cities are intelligent system that integrates different devices and hardware to enable automation.

Smart cities are increasingly important as they offer innovative solution to the challenges that is posed by rapid urbanisation and resource constraints. By leveraging advanced technologies such as Internet of Things (IoT), big data and artificial intelligence, it enables to enhance the efficient of urban services, reduce energy consumption and improve public safety. It plays an important role in economic growth in terms of production, resource efficiency, job opportunities, new investors and tourism (Sharida et al., 2020).

The framework of a smart city typically includes the integration of internet of things (IoT) devices, data analytics and digital platforms to monitor and manage urban systems. This interconnected network enables real time data collection and analysis, allowing city administrators to make informed decisions, reduce resource consumption and address challenges such as traffic congestion, pollution and emergency response more effectively. They are built upon a set of components that work together to enhance urban living through integration of technology, data and innovative solution. It includes smart digital infrastructure, smart government, smart environment, smart mobility, smart economy, smart people and smart living (Refer Figure 1).

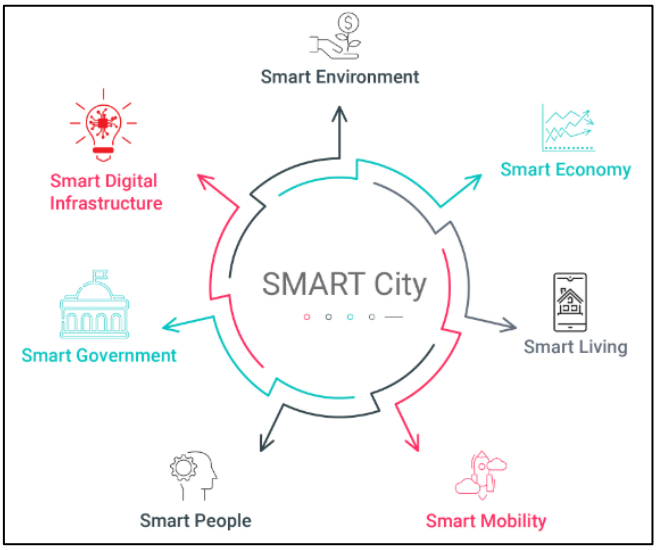


Figure 1. Smart City Components
Source: https://smart.cidb.gov.my/article/future-of-smart-cities-444

Smart City Components

In this article, smart city components have been selected to be used as a reference. These components were chosen based on a comprehensive review and summary of study from various scholars and researchers on smart city. The selection process focused on identifying the characteristics that have the most significant impact on the public and community in order to address the relevant aspects of urban living. Moreover, those components will be as a guide and indicators to conduct this study smoothly. The key components considered for this study will be smart living and smart environment as described below:

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a) Smart living

Smart living refers to a lifestyle that incorporates technology and connected devices to improve the convenience, efficiency and overall quality of everyday life. It involves the use of smart technologies such as internet of things (IoT), automation and artificial intelligence (AI) to manage various aspects of daily activities. When focusing on smart living, citizens are the key users (Axelsson et al., 2024). According to a study conducted by (Sharida et al., 2020), safety and security is one of the main concerns in urban development, where violence, accidents, hazard will affect greatly on quality of life. Hence, by using smart devices such as automated systems, wearable health monitors and energy efficient appliances, individuals can streamline tasks, optimize their environment and improve the health and lifestyle.

As highlighted in the Executive Summary of Smart City Framework Malaysia (2018), smart living can be described as a component that focuses on high quality of life especially in residential areas and is closely related to healthcare services. This includes examples like smart devices integrated in the house, healthcare systems and eco-friendly infrastructure that boost safety, convenience and comfort to residents. Besides, researchers have emphasized how important cultural infrastructure, smart healthcare systems, and energy management are in creating a living environment that is both efficient and interconnected, helping to improve the overall quality of life in cities. By integrating advanced technology into homes, workplaces and public spaces, the smart living component may help to create a more sustainable and comfortable way of life in the cities as well as enhances the daily experience for residents while promoting long-term sustainability.

b) Smart environment

Environment plays an important major role in smart cities as in the strong population growth, many agreed that cities have high pollution and will affect the quality of life in cities (Sharida et al., 2020). The smart environment component refers on prioritizing the environmental sustainability of resource management which maximizes the use of natural resources as well as reduces the urban ecological footprint. It can also be concluded that this component integrates renewable energy, efficient waste management and having green area to promote to protect the environment. Plus, this component also plays a role in protecting the environment, keeping the environment clean, as well as adopting a green lifestyle and a low-carbon city. Hence, smart environment refers to a physical space that is equipped with advanced technologies and interconnected systems designed to monitor, manage and enhance various environmental aspects in real-time. These technologies such as sensors, internet of things (IoT) and data analytics, work together to monitor, manage and enhance various environmental

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aspects in real-time. The goal of smart environment is to improve the sustainability, efficiency and livability of the space by optimizing resource usage, reducing waste and minimize environmental impact. The key features of smart environment include energy efficiency, water management, air quality monitoring, waste management, sustainable transportation and climate adaptation. Additionally, it helps cities toward more resilient to future challenges and may contributes in order to maintain a healthy urban ecosystem, creating a balanced environment that enhances the quality of life for residents.

Smart cities have the potential to significantly enhance the quality of life for their residents by leveraging technology and data driven solutions to address urban challenges. Accordingly, from this study, adaptation strategies and decision makers can make the right decisions and also minimise the impact of mental health by integrating technology in urban land dynamics domain to enhance peoples' quality of life.

Relation Between Smart City and Urban Planning

The concept of smart city in this era is increasingly relevant in the context of modern and advanced urban development. Smart cities play an important role in shaping future urban planning towards more efficient, sustainable and inclusive. According to Lim & Malek (2022), the development of smart cities in Malaysia focuses on a citizen-based approach where digital technology is used to improve the quality of life of residents and at the same time encourage active community participation in the planning process. The application of technology nowadays makes a city more responsive and advanced including to prevent the issues of urbanization. Moreover, integrating technology into urban planning benefits not only the community but also the city itself. These benefits include improvements in sustainable mobility and transportation where a transport system with smart technology can help to solve the traffic issues that often occur (Narain, 2024). In addition, environmental sustainability is also ensured with the support of smart city technology by increasing energy efficiency and helping to reduce carbon emissions into the air while being able to preserve the nature (Narain, 2024). Therefore, the smart city concept was created to introduce a certain extent in order to help solving mainly urbanisation issues with the latest technology.

Quality of Life

Quality of Life (QoL) refers to the overall well-being and satisfaction that individuals experience in their daily lives. In recent years, QOL has gained relevance in the fields of city planning and governance (Lim et al., 2020). According to World Health Organisation (2021), QOL is defined as an individual's perception of their position in life in their context of the culture and value systems in which they live and in relation to their goals, expectations,

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standards and concerns. According to Centre on Quality of Life (2017), QoL can be distinguished into objective domain and subjective domain, where objective domain refers to income, education, healthcare, life expectancy, public security, employment, transportation and residence quality. On the other hand, subjective domain refers to life satisfaction, happiness and perceive QoL. Additionally, it also includes standard of living, achievements, safety and security. QoL encompasses a wide range of factors, including physical health, mental well-being, economic stability, access to education, safe living conditions and a clean environment. It is also influenced by social relationships, cultural opportunities and the availability leisure activities. In broader sense, it reflects how well a society meets the needs and aspiration of its people.

The impact of smart cities on quality of life is significant and multifaceted, that influences various aspects of urban living, including mental health of urban population. Smart cities leverage technology, data and digital infrastructures to improve efficiency, sustainability and liveability of urban environments. One of the positive impacts of smart cities in improving quality of life is through the improvement of health and wellbeing, in which the integration of technology into healthcare systems. Hence, QoL in the context of smart cities is directly related to government actions to encourage interaction between public and private entities, with the goal of promoting sustainable development (De Guimarães et al., 2020). Ultimately, smart cities significantly enhance the quality of life of urban population in establishing liveable and sustainable urban environment.

RESEARCH METHODOLOGY

A primary and secondary data was used to gain comprehensive insights on how smart cities may facilitate urban planning processes towards achieving a good quality of life on urban population. A case study of Seremban City was selected. Seremban City is central area that has various types of land use such as commercial, transport systems, green spaces, residential and more, which can make it easier for this study to be carried out (Table 1). Additionally, Seremban is also one of the areas that has already begun implementing smart city initiatives.

Table 1: Background of Study Area

Content	**Description**
Site Location	Seremban Town Centre
State	Negeri Sembilan
District	Seremban City
Mukim	Seremban
Planning Block	Planning Block 1 : Seremban City
Local Authorities	Seremban City Council (MBS)
Population of Negeri Sembilan	1,207,900 (Year 2022)

Content	Description
	Source: (Department of Statistics Malaysia, 2024)
Population of Seremban District	696,900 (Year 2022) Source: (Department of Statistics Malaysia, 2024)
Total Area of Seremban District	95,363.79 hectares
Total area of study area	2,324.09 hectares

Source: Malaysia Vision Valley Local Plan 2045

The primary data was collected through questionnaires distributed to residents who work or live in the city. A total of 220 respondents have participated in this study by providing the valuable insights on the awareness of smart city technology on urban living in Seremban. The determination of sample was based on Krejcie and Morgan, in which the confidence level used is 90% due to the needs of balance precision and resources like time and available population. The questionnaire survey was divided into four (4) sections which consist of respondents' demographics, the level of awareness of the respondents regarding the implementation of smart city in the Seremban city, relationship between age group and level awareness on smart city initiatives, the use of smart city service, and the components and strategies of smart city that will enhance the quality of life. For the secondary data, the study referred to the existing policies, articles, journals or reports related to smart cities, urban planning and study areas, such as Smart City Framework Malaysia and Seremban Smart and Low Carbon City Special Action Plan 2027 for deeper understanding on smart cities. Relevant documents assist to enriching the important information and data that can be extracted to provide insight into the relevant smart city components.

ANALYSIS AND DISCUSSION

The influence of smart cities initiatives on QoL was studied based on the conceptual framework (Figure 2). The QoL was affected by awareness of respondents and perceptions of urban dwellers on the quality of life as a result of using smart city technologies, particularly the smart living and smart environment initiatives.

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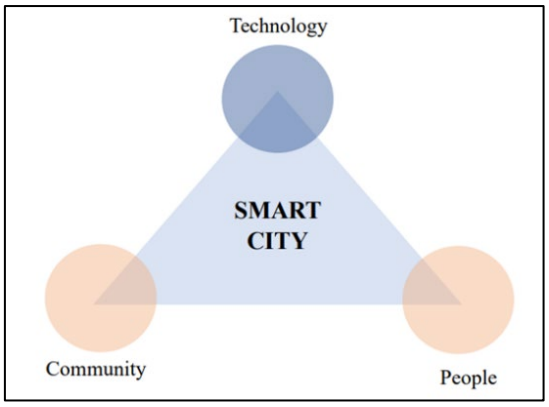


Figure 2. Smart City Elements
Source: Adapted from (Arroub et al., 2016)

The demographic profile is divided into three (3) sections, including age group, occupation and the period the respondents staying in Seremban (Table 2).

Table 2. Demographic Profile

Age Group	**Frequency (F)**	**Percentage (%)**
18 – 24 years old	85	38.6
25 – 34 years old	24	10.9
35 – 44 years old	64	29.1
45 – 54 years old	47	21.4
55 years old and above	0	0
TOTAL	**220**	**100.0**
Occupation	**Frequency (F)**	**Percentage (%)**
Student	77	35.0
Employed	88	40.0
Self-Employed	49	22.3
Unemployed	6	2.7
Retired	0	0
TOTAL	**220**	**100.0**
Period of Staying in Seremban	**Frequency (F)**	**Percentage (%)**
Less than 1 year	22	10.0
1 – 3 years	52	23.6
3 – 5 years	37	16.8
5 years and above	109	49.5
TOTAL	**220**	**100.0**

Table 2 shows that, out of a total of 220 respondents, the age group of 18-24 years old has dominated in answering this questionnaire with a total of 85 respondents (38.6%). Next, the second highest age group consists of the 35 – 44 years old group which represents 64 respondents (29.1%). The lowest age group is 55 years and above because there is no representative from that age group. This shows that the highest group answering this question is from the teenage group while the lowest group is from the old group. Furthermore, there are five (5) employment statuses in the demographic profile. The highest results are from respondents who are working, which is a total of 88 respondents (40.0%) while the lowest employment status is from the retired group. The retired group represents 0 respondents and shows that no respondent from a retired. While the second highest occupation is from the student which are represented by 77 respondents (35.0%). The result shows that the respondents who answered the question consisted of working people and a student.

Finally, for the demographic analysis is the period of staying in Seremban city. This is important as it will affect the level of respondents' exposure to smart city technology. The highest group is from a period of 5 years and above, with a total of 109 respondents (49.5%) while the lowest group is from the less than 1 year group, which represents a total of 22 people (10.0%). Furthermore, the second highest group is from 1 – 3 years old represented by 52 people (23.6%). Respondents who have been settled in Seremban for a long time can provide insight into the changes that have taken place since the start of the smart city implementation in the city of Seremban.

Level of awareness on Smart City Technology

This section identifies the factors influencing the level of respondents' awareness and understanding of smart cities as well as the information gap that exists among respondents.

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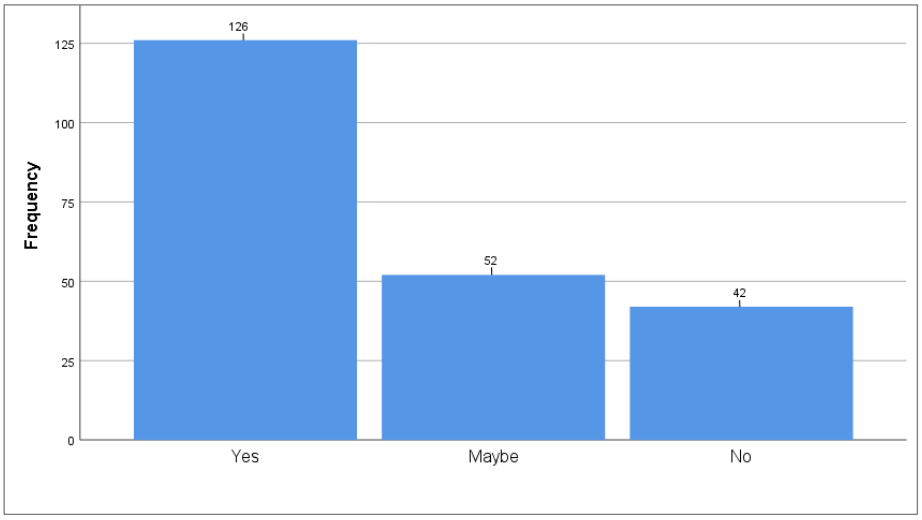


Figure 3. Frequency Level of Awareness on Smart City Technology

Figure 3 shows the level of awareness of the respondents regarding the implementation of smart city in the Seremban city. A total of 126 respondents (57.3%) are aware of the smart city implementation in Seremban city while a total of 42 respondents (19.1%) is not aware of the smart city implementation in Seremban city. The following are the highest and lowest numbers chosen by the respondents. The number of respondents who chose not to be aware is likely due to a lack of knowledge about smart cities. Moreover, the remaining number of respondents have chosen answers that show the respondents are not sure and have doubts about smart city knowledge. This is due to, 52 respondents (23.6%) are not confident and have a little knowledge regarding the smart city initiatives. This shows that there is a need to increase awareness and promotion of smart city initiatives to the public especially to those who are unaware or unsure about the smart city.

Perception of the Influence of Smart Environment on Quality of Life

Smart environment is one of the components of a smart city which combines advanced technologies such as sensors, IoT, environmental monitoring based on AI and green infrastructure, which has been shown in this study. For the context of urban living in Seremban city, smart environment aims to optimize waste management and promote sustainable energy use. With the implementation of smart city initiatives, the city can reduce its carbon footprint, even improve the quality of life of residents and will ensure environmental resilience in the long term.

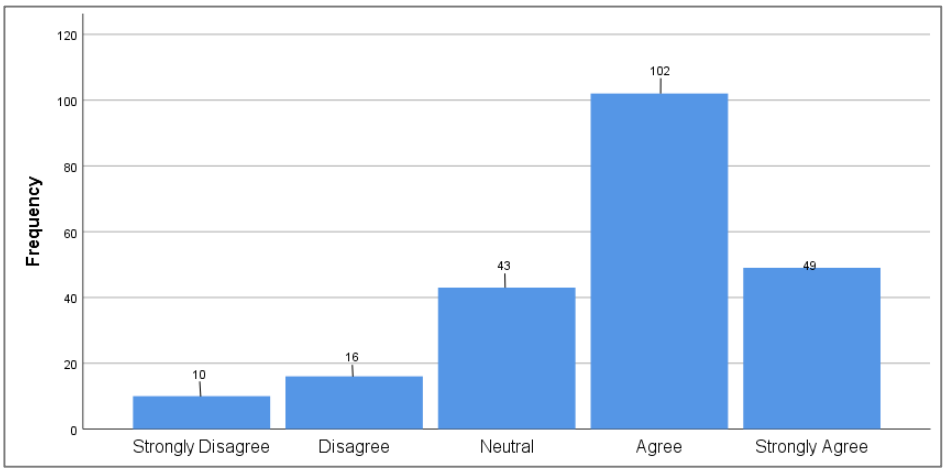


Figure 4. Frequency Perception on the Influence of Smart City Technologies on Quality of Life

Figure 4 shows the frequency of respondents' perceptions regarding the influence of smart city technology on quality of life in Seremban. Based on the results obtained from the respondents, a total of 49 respondents (17.8%) were reported strongly agreed that smart city technology will improve sustainability and environmental conditions in Seremban. In addition, 102 respondents (54.5%) who are the majority group also agreed that smart city technology will improve quality of life from the aspect of smart environment. This shows that the majority of respondents have a positive perception of the impact of smart environmental technology. According to a study by Arroub et al. (2016), the authors believes that environmental technology, especially smart environment such as waste management and renewable energy systems, can improve the sustainability of a city and help reduce negative impacts on the environment. This is similar to the positive opinions of the respondents regarding the smart city technology in Seremban.

Furthermore, there is also a group of respondents who disagree, with 16 respondents (7.3%) and 10 respondents (4.5%) strongly disagree, which shows a negative view on the impact of smart city technology from the smart environment aspect. In conclusion, the majority of respondents show a view that smart city technology in the smart environment has a positive impact and vice versa.

Perception on the Influence of Smart Living on Quality of Life

Smart living is one of the main components in the development of smart cities which includes various aspects of quality of life such as culture, health, safety, housing, tourism, and many more (Giffinger et al., 2007). In addition, it is not just introducing technology into daily life but also functions as changing the

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environment of homes, neighborhoods, workplaces, energy systems and environmentally friendly transportation (Trincă, 2023).

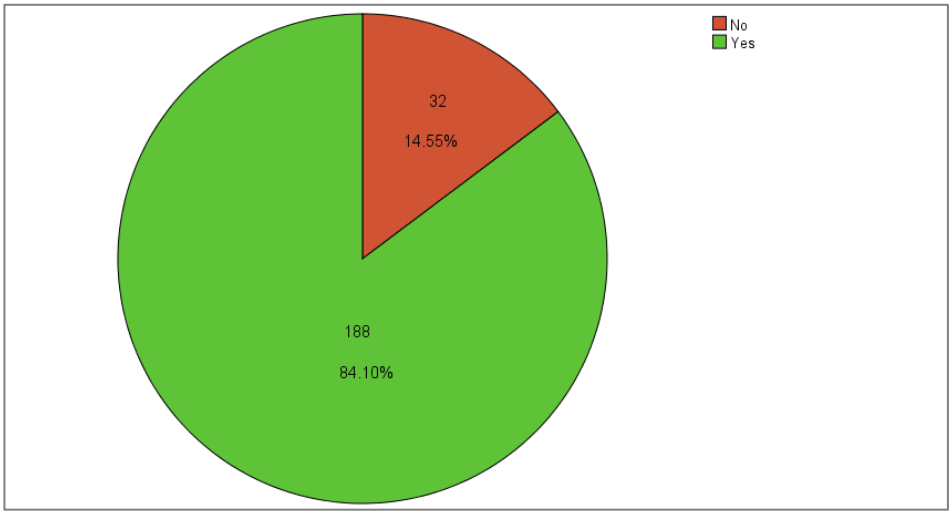


Figure 5. Frequency of Perception on the Needs of Smart Living initiatives

Based on the data findings, figure 5 above measures the level of acceptance of residents regarding the implementation of more smart living initiatives such as garbage separation systems, smart parking in Seremban and so on. The results of the data findings show that the majority of the respondents, namely 188 respondents (84.10%) support the implementation of more smart living initiatives in Seremban while 32 respondents (14.55%) disagree with the proposal. This result reflects that the majority of respondents see smart city technology as a positive step to improve the comfort and efficiency of urban life. To sum up, the findings that have been identified are in line with the quality of life model that shows the positive impacts of smart cities in improving quality of life of urban population through two main key components, smart living and smart environment.

CONCLUSION

The concept of smart city is increasingly relevant in the context of modern and advanced urban development. Smart cities play an important role in shaping future urban planning towards more efficient, sustainable and good quality of life in urban living. In summary for each smart components section, captured the awareness of respondents and perception that revealed the influence of using the smart city technologies towards achieving a good quality of life of urban dwellers in Seremban city. Thus far, the analysis concludes that the majority of

respondents demonstrates awareness and usage of smart city services in Seremban by showing that more than half of them use these services regularly. Whereas, based on the document analysis, the most significant components of smart city that can enhance quality of life is smart living and smart environment.

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