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GIS-BASED SPATIAL MODELLING TO ENHANCE TOURISM RESILIENCE AND CONSERVATION FOR SUSTAINABLE LEADERSHIP IN COASTAL COMMUNITIES

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Abstract

This study aims to create a spatial model for sustainable leadership in coastal communities to improve both tourism resilience and conservation efforts in those areas. The idea of this study stemmed from the need to better understand the importance of sustainable leadership in developing coastal communities and tourism. 366 respondents from the coastal areas in Kuala Terengganu and Marang answered the questionnaire. The statistical tool and geographical information system (GIS) were used to analyse the data. The findings show that critical thinking abilities, ethical and moral skills, and community involvement in tourism development have significant positive effects on sustainable leadership, making them vital elements in driving sustainable leadership forward. Cluster analysis groups the five sustainable leadership practices into three categories. Apart from certain domains like critical thinking, ethical and moral concerns, and sustainable leadership, the spatial analysis results show that sustainable leadership practices are typically strong in Kuala Terengganu and Marang. GIS analysis reveals a high density of sustainable leadership practices in coastal communities across different scales. The application of statistical analysis coupled with GIS can effectively identify the sustainable leadership that leaders in coastal areas adhere to.

***Keywords**:* Coastal Community, GIS, Spatial Model, Sustainable Leadership, Tourism

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INTRODUCTION

GIS has been welcomed as a crucial instrument for problem-solving and decision-making in many academic fields (Fazillah et al., 2018). GIS technology reveals geographic patterns that are not visible in traditional statistics by displaying data on the easily understandable maps (Toriman et al., 2015). GIS can be used for a variety of purposes, including in many fields of environmental management. Theoretically, GIS could also be used as a synthesizing tool for the management of interventions aiming at effective management. Furthermore, the development of GIS-based simulation models improves the accuracy with which environmental and planning problems are solved (Wang et al., 2019). A great deal of research places a strong emphasis on geographic visualization, which makes use of GIS tools to effectively present data and depict patterns.

Sustainable leadership is an innovative leadership strategy that improves organizational performance by addressing current and future environmental, economic, and social goals. Sustainable leadership is necessary in managing sustainability, of which is a constantly expanding and demanding area inside an organization, as its development is based on three pillars; social, economic and environmental factors (Abdullah et al., 2024; Abdullah et al., 2024). To achieve sustainability, leaders must be able to foster long-lasting behaviours in their communities and institutions, which will in turn stimulate economic growth (Iqbal et al., 2020). In 2003, Andy Hargreaves and Fink established the leadership strategy known as "Sustainable Leadership" (Phing & Karuppannan, 2022). Sustainable leadership is an effective leadership approach capable of influencing the entire organization as well as external groups to collaborate in order to achieve desired outcomes (Iqbal & Piwowar-Sulej, 2022).

RESEARCH PROBLEM AND LITERATURE REVIEW

Since sustainable development was first introduced into the field of organizational management by the Brundtland committee, the idea of sustainable leadership has evolved (Dzimińska et al., 2020). The existing body of knowledge on sustainable practices, sustainability principles and environmental leadership suggests that these leadership styles play an important role in achieving sustainability goals to attain long-term success of striking a balance between social responsibility and economic achievement (Suriyankietkaew et al., 2022). There is not a single, thorough definition of sustainable leadership in the body of current literature. The assessment does, however, draw attention to a number of important issues, such as the need for social and environmental responsibility, organizational preservation, shared accountability, moral and ethical behaviour, continuous development, and the impact of organizational culture on sustainability objectives (Boeske, 2023). Research on sustainable leadership has come a long way in the last few years with an abundance of study on sustainable

leadership in the literature, most of which focuses on studies conducted in the field of education (Liao, 2022). The concept of sustainable leadership just keeps evolving over time. Consequently, the attributes of sustainable leadership differ according to the particular role the leader plays within the company. Developing the operationalization of sustainable leadership presents future research opportunities across various contexts. This involves creating diverse theories tailored to the specific direction and context of each study.

Therefore, sustainable leadership is crucial in enhancing the quality of tourism development in coastal communities and realizing sustainability visions. Sustainable leadership in coastal communities and tourism entails good resource management and stewardship, both natural and human, to maintain the long-term viability and resilience of coastal destinations while still benefiting local communities. An effective sustainable leadership guides the vision and direction of tourism endeavours, ensuring that they match the community's needs and goals while simultaneously encouraging environmentally friendly practices. A series of research have indicated that GIS can be used as an analytical platform for studying tourism trends. Avdimiotis et al. (2006) used GIS applications as tools for tourism planning and education in Chalkidiki after discovering that coastal areas experience demand from May to October, peaking particularly in July and August, based on the analysis of tourism flows in various other regions. Foreign tourists are found to stay longer than domestic tourists, with Greek vacationers peaking between May and October while foreigners arrive steadily throughout the year. Chalkidiki is also discovered to primarily attract middle-class Central European tourists who prefer scheduled tour packages. In another study by Jovanović and Njeguš (2008) on the tourism potential of the Cajetina and Nova Varos municipalities, GIS was also continuously used, both theoretically and technically, providing tourism information in an integrated manner and being of immense benefit not only to the region but to Serbia as a whole. Another study by Rosa-Jiménez et al. (2016) presents a technique of using spatial data to map a mature destination in Benalmádena, Spain. The study concludes that the evolution in the destination's appeal from sun and beach to sun and water, the emergence of tourism hotspots, and the discovery of the public areas is what attracts the visitors the most.

Through GIS, this study seeks to identify the spatial distribution of sustainable leadership practices in the coastal communities and tourism in the study area and correlate the location data with the features. Spatial modelling of sustainable leadership and the identification of effective practices by leaders are essential for organizing and controlling changes in the environment, economy, society and population at different geographic dimensions (Alshuwaikhat & Aina, 2006; Avdimiotis et al., 2006). In Malaysia, Terengganu is regarded as an affluent state, mostly because of its copious marine resources. These resources

have helped Malaysia become one of the world's most popular travel destinations, and have promoted its economic growth, raising the living standards for the coastal communities (Masud et al., 2017). This study aims to identify the role of sustainable leadership practices in coastal communities and tourism in Kuala Terengganu and Marang, two districts in Terengganu. To that end, a suitable questionnaire was developed to explore the geospatial distribution of sustainable leadership practices in the study area. Spatial model allows more accurate and informative decision-making to assist sustainable leadership in managing changes and development within the coastal communities and the tourism sector.

RESEARCH METHODOLOGY

Study Area

This study was conducted in two districts (Marang and Kuala Terengganu) in Terengganu, Malaysia (Figure 1). The study area is located along the shore of the South China Sea. The coordinates are 5.3302 N, 103.1408 E for Kuala Terengganu and 5.207053 N, 103.205299 E for Marang. Marang district is located adjacent and 20 km from Kuala Terengganu. Historically, coastal towns have been filled with people who work as coastal fishermen. These areas were selected because they are located on the coastline and have currently been popular tourist destinations.

Research Design

The study used a quantitative research design, with questionnaires serving as the main methodological instrument for gathering data. This methodology has been proven effective since it enables the examination of sustainable leadership through the lens of societal perspectives. This approach allowed quantitative data collected from coastal communities in the research region to be consistently monitored and evaluated, making it easier to identify and investigate relevant issues. A pilot study was carried out by the researchers to verify the validity and reliability of the questionnaire items before conducting the actual study. The questionnaire used for this study is divided into six parts; Socio-demography, A, B, C, D and E, and contains 25 items on a 5-point Likert scale ranging from "strongly agree (5)" to "strongly disagree (1)".

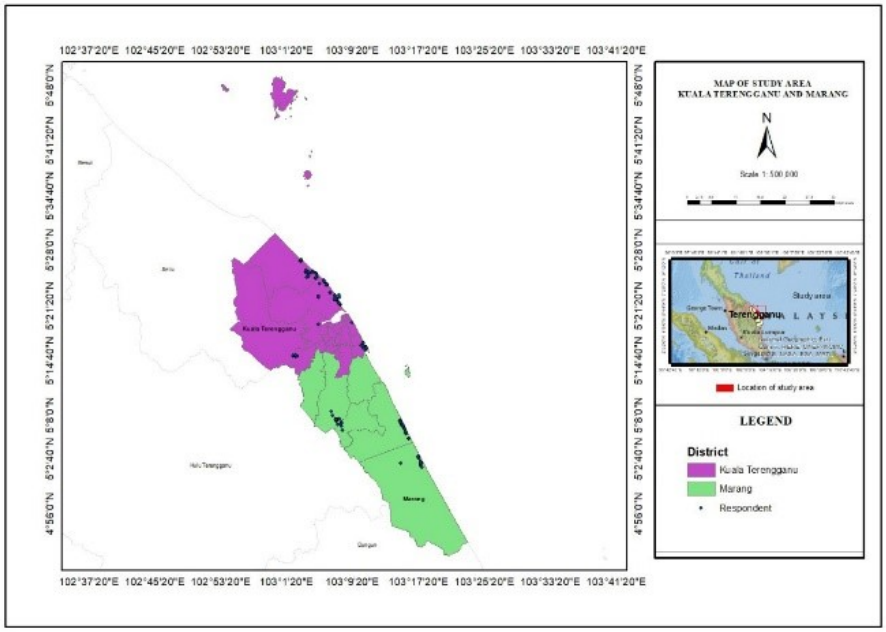

Figure 1: Map of Study Area, Showing the Location of Kuala Terengganu and Marang

Data Collection

Data collection for this study includes the creation of printed questionnaires, which were distributed to coastal communities in Kuala Terengganu and Marang by research assistants. Purposive sampling was used to select specific residents for questionnaire distribution. Notably, this method is a non-probability sampling technique. The questionnaire is divided into six sections, one for collecting the respondents' demographic information and others for identifying variables connected to sustainable leadership. In total, 366 survey questionnaires were distributed to coastal villages throughout the study area. Based on a preliminary study of 25 items assessed among 30 coastal residents in Kuala Terengganu, which does not include the data from the actual study's participants, the Cronbach's Alpha value is 0.782, with the range of all items between 0.753 and 0.793. The Terengganu topography map was digitized using ArcGIS 10. Once the pertinent portions of the map were extracted, the study regions were chosen using the "Select by Attribute" feature. During the process of gathering data, the GPS coordinates of the respondents were recorded. These coordinates were subsequently combined with the data gathered to create the attribute table for further process.

Data Analysis

The non-spatial data collected from the questionnaire surveys was re-entered into Microsoft Excel using sorting and coding techniques. The coded data were then analysed using the Statistical Package for Social Sciences (SPSS) version 26 for further statistical insights. It was used to run the following tests: Cronbach's alpha coefficient, general descriptive statistics, frequencies to assess the data, and representing the distribution and concentration of participant responses. Subsequently, the data was further analysed using the non-parametric tests, which are the Mann-Whitney test (U-test) and the Kruskal-Wallis H test. Multiple linear regression (MLR) was applied as well in this study to justify the relationship between the sustainable leadership practices with sustainable leadership itself. Using Ward's approach with squared Euclidean distances, Hierarchical Agglomerative Cluster Analysis (HACA) was performed on the standardized data.

The purpose of this investigation is to identify the differences between the coastal communities' sustainable leadership variables. A dendrogram was utilized to visually represent the results of the Cluster Analysis (CA) and provide insight into the homogeneity levels of the clusters (Fazillah et al., 2017). XLSTAT 2007 Microsoft statistical add-in was used to carry out the HACA procedure. Lastly, the GIS Arc Map 10.1 software was used to conduct graphical analyses aimed at identifying the spatial distribution of each sustainable leadership practice in the area. The interpolation method used was IDW (Inverse Distance Weighted) because of its excellent accuracy (Xu et al., 2020). The IDW approach, which assumes that anticipated values are comparable to those of neighbouring observation locations, is a simple yet efficient interpolation technique (Biswas et al., 2020). The IDW is a popular mathematical and geostatistical interpolation technique that is often used to predict target attributes. To calculate cell values, it uses a linearly weighted mixture of sample points (Yang et al., 2020).

ANALYSIS AND DISCUSSION

Socio-Demographic Profiles of The Respondents

366 respondents from coastal communities participated in this study. Descriptive frequencies were then used to evaluate the data. The respondents ranged in age of 25 – 34 (22.1%). The study involved about equal numbers of men (52.7%) and women (47.3%). Based on the participants' educational backgrounds, 89.3% had completed high school or a higher level of education. Additionally, the results reveal that the majority of the households (47.5%) have an average monthly income of below than RM1,500, while only 6.8% of them have a monthly income of more than RM4,500. It is also found that most households in the coastal areas generate income through a variety of occupations.

A Manne-Whitney test revealed a significant gender difference in responses to sustainable leadership practices. Males prefer that their leader have better communication skills ($z = -7.441$, $p = < 0.001$), critical thinking ($z = -3.553$, $p = < 0.001$), ethical and moral behaviour ($z = -3.254$, $p = 0.001$), sustainable leadership ($z = -1.972$, $p = 0.49$) and community involvement ($z = -5.053$, $p = < 0.001$), as compared to females. Next, to examine if there is a significant difference between sociodemographic factors of respondents which encompasses multiple classifications and sustainable leadership practices, Kruskal–Wallis H test was used. The Kruskal-Wallis H test was conducted on age, marital status, education level, occupation and monthly income. Out of the five sustainable leadership practices, the findings of the Kruskal–Wallis H test show that, there was a statistically significant difference among the four sustainable leadership practices according to these five sociodemographic factors (p value > 0.05), except for one particular practice (critical thinking) which did not differ regardless of the respondents' marital status, occupation and household income (p value > 0.05).

Sustainable Leadership Accelerators

MLR was employed to investigate the relationship of each sustainable leadership practice to the dependent variable (sustainable leadership). This enables the understanding of how each variable contributes to the larger construct of sustainable leadership. Table 1 shows an examination of the relationship between the constituents of sustainable leadership (communication skills, critical thinking skills, and ethical and moral behaviour) and the dependent variable of sustainable leadership. The findings confirm that the studied model is statistically significant ($sig = 0.000$; $F = 498.965$). The results indicate that critical thinking skills, ethical and moral behaviour, and community involvement in tourism development exert a significant positive impact on sustainable leadership, that they consequently act as the accelerators for sustainable leadership. Conversely, there is no support for communication skills, suggesting that it does not exert any statistically significant effect on sustainable leadership.

In this study, three variables meet the entry requirement to be included in the equation (critical thinking skills, ethical and moral behaviour, and community involvement in tourism development) with significant values of $p < 0.005$. The model's degree of predicting the dependent variable was found to be $R = 0.742$. The R-square of 0.551 implies that the three predictor variables make up about 55.1% of sustainable leadership, with ethical and moral behaviour shows the highest coefficients in multiple linear regressions, followed by critical thinking skills, community involvement in tourism development, and communication skills. These coefficients suggest that the model predicts the

dependent variable with a certain degree of skills or practices. Based on the multiple regression analysis results, the regression equation obtained is as below:

$$SL = 0.677 - 0.015\,\text{CS} + 0.311\,\text{CTS} + 0.425\,\text{EMS} + 0.117\,\text{CITD}$$

- *SL: Sustainable leadership
- CTS: communication skills
- EMS: ethical and moral skills
- CITD: community involvement in tourism development

Table 1: Coefficients for results of the multiple linear regression analysis for the dependent variable sustainable leadership

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	0.677	0.083		8.120	0.000
Communication skills	-0.015	0.015	-0.019	-0.982	0.326
Critical thinking skills	0.311	0.017	0.355	17.835	**0.000**
Ethical and moral skills	0.425	0.018	**0.448**	23.471	**0.000**
Community involvement in tourism development	0.117	0.015	0.153	8.068	**0.000**

Note: Dependent variable: sustainable leadership, *p < 0.05.

Similarities and the Grouping of Sustainable Leadership Practices

Cluster analysis was applied to the sustainable leadership practices according to the homogeneity of the observation, as stated in the questionnaire, to study the variation of sustainable leadership practices in the study area based on their similarity levels. When combining all the data from the two districts, the results show that the sustainable leadership practices are diversified into three significant groups in the hierarchical dendrogram at (Dlink /Dmax) × 100 (Figure 2).

In cluster 1, there are three variables that are clustered together, viz., critical thinking skills, ethical and moral behaviour, and sustainable leadership. These three variables are grouped together due to their similarities in emphasising on critical thinking-based decision-making as well as the effectiveness in ethical ideals and principles, in the context of leading and managing resources with sustainability as a goal. This cluster could be explained by its direction of

handling complexity and creating successful strategies; critical thinking requires analytical approaches and problem-solving techniques, while moral and ethical behaviour produces value-based and responsible decision-making that is advantageous to all parties involved. To promote resilience, adaptation, and ongoing development in tourism practices, sustainable leadership combines a strategic vision, evidence-based policies, and a balanced approach to economic, social and environmental goals. Researchers have discovered that sustainable leadership increases overall organizational effectiveness (Sezgin Nartgün et al., 2020), considerably improves environmental performance (Javed et al., 2021), and has a beneficial impact on organizational sustainability (Iqbal et al., 2020).

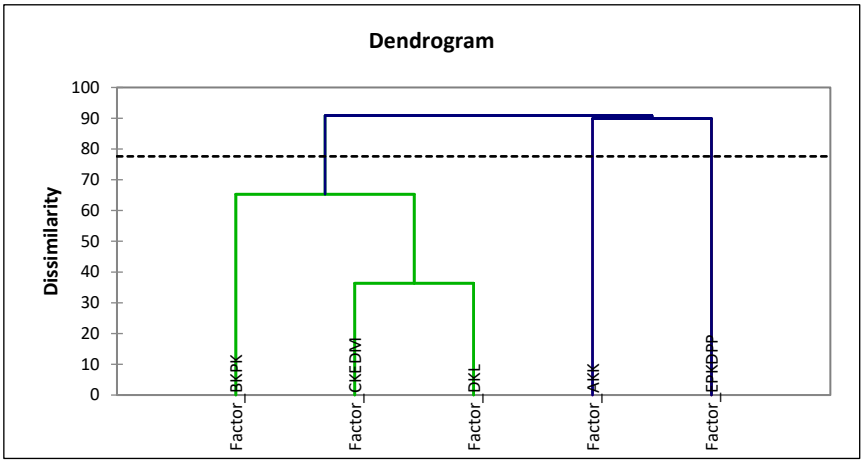

Figure 2: Sustainable Leadership practices dendrograms combining two districts

Cluster 2 demonstrates the importance of communication skills for sustainable leadership, which could boost self-efficacy. As a result, leaders are more equipped to inspire their communities, overcome challenges, and implement sustainable practices with assurance. This strategy contributes to the long-term profitability and sustainability of the tourism industry by improving organizational efficiency and guaranteeing a positive and sustainable experience for visitors. According to Armani et al. (2020), a leader who sets an example through their conduct and words will cause a ripple effect, which can influence the behaviour of others around them as well. Hanh (2023) asserts that proficient communication is a prerequisite for proactive community engagement, cultivation of trust and respect, and optimization of production. MacDonald and Shriberg (2016) also support this, claiming that communication skills are the most important skills in sustainable leadership.

Cluster 3 demonstrates the community's involvement in tourism development, which depends on its leader. It requires a deep commitment to the

well-being of others, and creating an environment conducive to the development of strength, resilience and vitality. It takes a holistic approach, focusing on human connections and ethical ideals to promote environmental and community concerns (Armani et al., 2020). In the context of the sustainability leadership criteria, cluster analysis can provide insights based on common traits. Furthermore, leaders can select ways or strategies appropriate to their situations from the peculiarities of various sets of criteria.

Spatial Distribution Pattern of Sustainable Leadership Practices

The five identified sustainable leadership practices in coastal communities and tourism were mapped spatially using the GIS mapping technique. This study demonstrates how the spatial model is able to group the distribution of sustainable leadership practices appropriately. This distribution visually represents the analysis results by focusing on regional variations and pinpointing the hotspots for these practices within the study area, as seen in Figure 3. From Figure 3 (a) to (e), it is clear that only two types of sustainable practices (communication skills and community involvement in tourism development) would indicate how good the leader is, without any disagreeing response from the respondents. The need for clear communication emphasizes the importance of these sustainable leadership practices. Enhanced communication between leaders and communities indicates a stronger understanding in their interaction, allowing leaders to deliver directives more easily (Bush et al., 2021). Leaders in the tourism industry who possess strong communication skills will be able to attract stakeholders, properly communicate sustainability goals, and create a collaborative environment. Responses vary merely from "strongly agree" to "agree " and mostly come from those living along the Marang shore and at the centre of Kuala Terengganu (for communication skills), and the southern part of Marang and the northern region of Kuala Terengganu (for both communication skills and community involvement in tourism development).

The community involvement in tourism boosts the tourism by providing unique cultural and historical contributions, creating local job possibilities, and encouraging entrepreneurship, hence reducing poverty and raising living standards (Ndivo & Cantoni, 2016). Nyaupane et al. (2006) highlighted that community involvement might as well promote environmentally conscious behaviour and the preservation of natural and cultural resources by coordinating tourism development with regional needs and sustainability objectives. Communities that are involved are also more prepared to adjust to changes in the industry, resulting in long-term sustainability and resilience. The three types of sustainable leadership practices (critical thinking, moral and ethical behaviour, and sustainable leadership skills) receive varying levels of responses, ranging from strongly agree to disagree. In terms of ethical and moral behaviour,

it was found that the majority of people in Marang and Kuala Terengganu strongly agree with the policies of their leaders, with very few expresses disagreement. Sustainable leadership, which covers the ability to attract stakeholders, socialize and be transparent, is fundamentally based on ethical behaviour. It is difficult to define ethical behaviour, but in order to safeguard and maintain their businesses, managers, especially those who are short-term goal-oriented, must operate with moral integrity and openness (Boeske, 2023). Suriyankietkaew et al (2022) also suggest that by highlighting virtues like restraint, caution, respect for one another and creativity, sustainable leadership will encourage the top management team to embrace sustainable practices. Hence, attaining sustainability across organisations actually depends on the integration of moral and ethical norms.

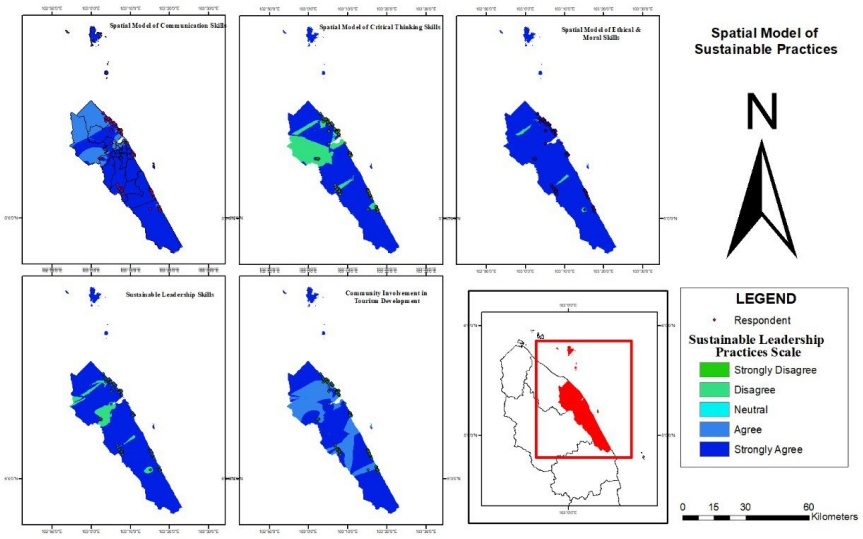

Figure 3: distribution of sustainable leadership practices in Kuala Terengganu and Marang (a) communication skills, (b) critical thinking, (c) ethical and moral skills, (d) sustainable leadership, and (e) community involvement in tourism development

High concentration (hotspots) and low concentration (cold spots) of sustainable leadership practices were found in areas specified by the interpolation technique. These variations in leadership philosophies between different coastal regions and tourism-related industries reveal to us the areas where leaders lack these practices as well as the areas where sustainable leadership is more common. By using the spatial model, it becomes clear on which locations should the strategic planning and policy making be stressed on. In a study by Wulung et al. (2021), who developed a spatial model for geotourism clusters in Bandung City,

Indonesia, it is used as a planning tool for tourism destinations, allowing for the integration of natural, social and economic environmental development while assuring its protection. This concept is especially useful given the long-term nature of tourism planning. In addition, policymakers and stakeholders can make evidence-based decisions to increase the sustainability within the coastal communities and tourism by using the insights collected from the geographical distribution maps. In line with the study by Al shawabkeh et al. (2023), this study would help to protect cultural and natural heritage places by offering the decision-makers a model along with a number of recommendations on how to achieve it.

Furthermore, comparing various locations can help find excellent practices and serve as a baseline for other regions to effectively implement sustainable leadership strategies. Examining the spatial distribution of sustainable leadership practices yields comprehensive insights that are necessary to advance sustainability in coastal communities and tourism. This strategy encourages focused interventions and well-informed decision-making while improving the overall effectiveness of sustainable leadership initiatives. The spatial model for the five sustainable leadership practices suggests that Marang leaders exhibit more sustainable leadership qualities than Kuala Terengganu leaders. Besides, it can be clearly seen that all sustainable leadership practices in coastal areas are better compared to those further inlands. Coastal areas are very desirable for tourism. Thus, in order to maximize these regions' potential for tourism, sustainable leadership is crucial. The spatial distribution pattern of sustainable leadership practices, when evaluated, indicates that leaders in coastal towns do employ sustainable leadership practices effectively.

CONCLUSION

Based on the MLR statistics for the dependent variable, this study examines the statistical relevance of the four independent factors in the standard model in determining the sustainable leadership score. The outcome demonstrates that moral and ethical behaviour, as well as community involvement in tourism development, significantly improve sustainable leadership and serve as key drivers of sustainable leadership advancement. Effective leadership is required to ensure that the coastal tourism development satisfies the current requirements while also laying the groundwork for resilient, inclusive, and sustainable tourism practices that benefit both current and future generations. The spatial analysis by GIS is practical and advantageous for formulating theories and identifying the areas that require attention. In order to build a database system of sustainable leadership, this study presents a visualization of the data that makes use of GIS features.

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AGROPOLITAN PLANNING AS A STRATEGY FOR PROMOTING SUSTAINABLE LIVING AMONG RURAL POOR COMMUNITIES: EMPIRICAL EVIDENCE

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Abstract

Although Malaysia's poverty rate has decreased, there are still people who suffer from extreme poverty, especially in rural areas. The agropolitan project aims to eradicate extreme poverty and accelerate development in rural areas. The achievements of agropolitan projects are evaluated through the extent to which they help participants to get out of extreme poverty and are measured using Poverty Line Income (PLI). A study using the Sustainable Livelihood Framework (SLF) was conducted at the Gahai Agropolitan Project, Lipis, Pahang, and involved 45 participants. Research data was obtained through the distribution of questionnaires and analyzed using Statistical Package for the Social Sciences (SPSS) version 22 software and Microsoft Excel. Studies indicate that the Gahai Agropolitan Project can eradicate poverty and contribute to sustainable livelihoods. From the aspect of sustainable living, the study results show that the participants of the Gahai Agropolitan Project experience high vulnerability. Moreover, asset ownership analysis reveals that the Gahai Agropolitan Project participants have good asset ownership.

Keywords: Agropolitan; rural; sustainable livelihood; poverty

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INTRODUCTION

The development of agropolitan projects in Malaysia aims to eradicate extreme poverty in rural areas (Amriah et al., 2011; Amir et al., 2014). It is an integrated program to eradicate poverty through increasing income and quality of life and accelerating rural development. The implementation of the agropolitan project indicates the government's meticulous efforts to eradicate extreme poverty and increase rural development. Although rural areas are often associated with backwardness, isolation, and abandonment, they have high economic potential (Ismail et al., 2018). This economic potential can be achieved through increased agricultural, tourism, and industrial activities. For the agropolitan project, the main activity is agriculture, which can contribute to the economic development of the participants. This economic activity is crucial in increasing income and helping participants escape poverty. Currently, there are 11 agropolitan programs implemented by the government under the supervision of the Ministry of Rural and Regional Development (KKLW) (Ismail et al., 2019).

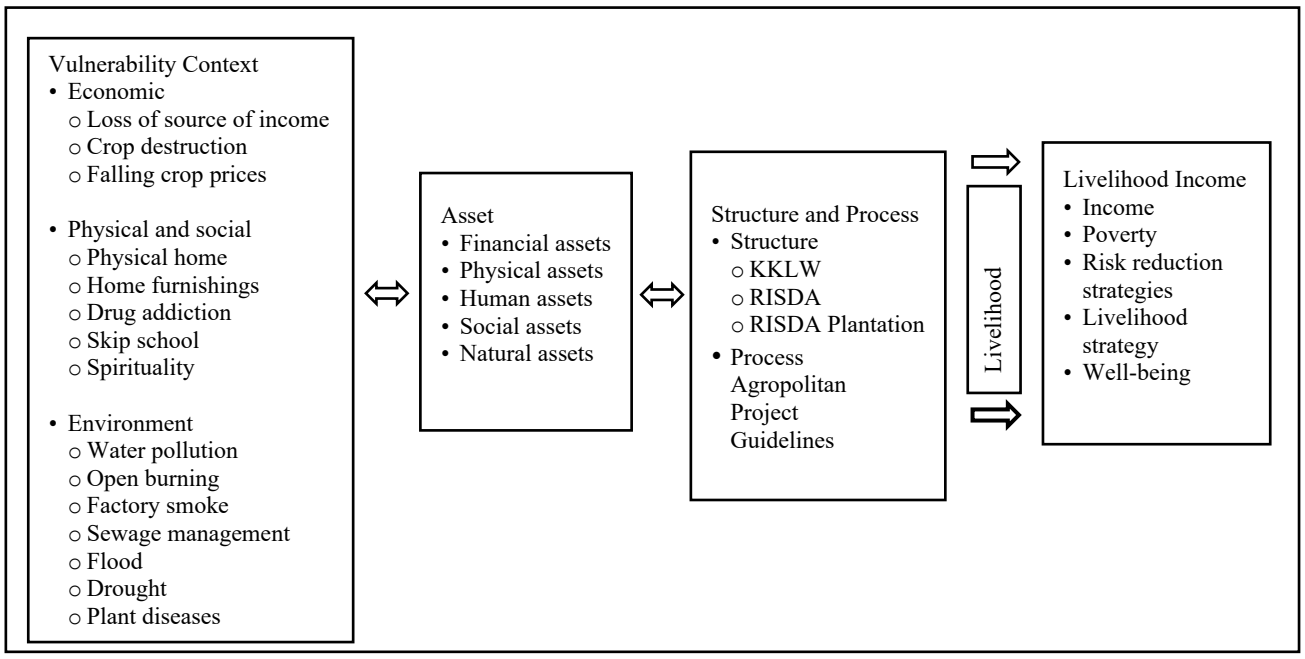
In addition, existing studies indicate no empirical study related to the impact of implementing agropolitan projects toward sustainable livelihoods in Malaysia. Recent studies such as Ahmad et al. (2019) focused more on the condition of the participants before and after participating in the Agropolitan program. Consequently, the absence of studies on the impact of the implementation of agropolitan projects results in no information capable of explaining the achievements of agropolitan projects in Malaysia. This type of study needs to be conducted to determine the project's achievement in achieving its development goals. For agropolitan projects, the impact of project implementation needs to be evaluated in the context of sustainable livelihoods. Therefore, based on empirical evidence, this study discusses agropolitan planning as a mechanism for sustainable living in poor rural communities.

CONCEPTUAL FRAMEWORK OF THE STUDY

Figure 1 reveals the conceptual framework of the study modified based on the Department for International Development (DFID) (1999). The conceptual framework contains five main components: vulnerability context, assets, structures and processes, strategies, and livelihood outcomes. In the context of vulnerability, it involves three aspects, namely economic, social and physical, and environmental. Economic threats include the loss of sources of income or employment, the destruction of crop yields, and the fall in crop prices. Meanwhile, social and physical threats involve the physical condition of the home, lack of home furnishings, lack of basic facilities, relationship network problems, drug addiction problems, school truancy problems, and spirituality. At the same time, environmental threats include water pollution, open burning, the

release of factory fumes, foul odours from septic tanks, floods, droughts, harvests, and plant disease attacks.

Institutional elements refer to institutions that ensure the implementation of legislation and policies and provide services, exchanges, and certain functions that affect individuals or households. These institutions determine and influence the way individuals or households interact. This institutional context affects the vulnerability faced by individuals and access to life assets. This study has identified several institutions that are closely related to the study respondents, namely the KKLW, the Economic Planning Unit (UPE), the Rubber Industry Smallholder Development Authority (RISDA), the state government, and RISDA Plantation Sdn. Bhd and other agencies related to rural communities are either involved in providing assistance or services to rural communities and the poor.



Source: Modified from DFID (1999)

Figure 1. Conceptual Framework of the Study: Sustainable Livelihood Framework of the Gahai Agropolitan Project

In this study, livelihood strategy refers to the economic activities conducted by individuals, whether they are a main job or a side job. Livelihood income is an aspect that affects household well-being and long-term growth prospects. This study considers three criteria as elements of livelihood outcomes, namely income, well-being, and the reduction of vulnerability faced by individuals referring to the strategy of vulnerability reduction.

RESEARCH METHODOLOGY

For this study, the research design combines qualitative and quantitative design. There is a difference between qualitative and quantitative methods. Qualitative methods tend to use deep analysis techniques (in-depth analysis), that is, using case studies to study problems. In this study, the study population is the participants of the Gahai Agropolitan Project, Lipis. Based on statistics from the Ministry of Rural & Regional Affairs, 80 Heads of Households are participating in the Gahai Agropolitan Project, Lipis. Based on the number, a total of 50 participants with settlements and 30 participants without settlements. Only settled Gahai Agropolitan Project participants are defined as the study population. This study used simple random sampling, which is justified because the study has a clear population definition and information. After identifying the sampling technique, the next study determines the sample size required for the study. In this study, the total number of samples (n) was determined based on the 90% confidence limit and 10% error, and it was based on the Yamanei (1964) formula. Since the number for the population group is the same, which is 50, the calculation is demonstrated using 45 samples only. Regarding the type of question, two categories of questions, open questions and closed questions, were used in the questionnaire for this study. In addition, a five-point Likert scale was also used for perception questions. This study uses several types of software to analyze the data obtained, namely Statistical Package for the Social Sciences (SPSS) Version 22.

Vulnerability Index

The Vulnerability Index of this study is a composite index approach proposed by Hahn et al. (2009). The Vulnerability Index for the study involves three types of vulnerability, namely economic, social and physical, and environmental. The questions for each indicator are in the form of a dichotomy, which is 1 (facing/ ever facing) and 0 (not facing). The selection of this indicator for the types of vulnerability is based on the Sustainable Livelihood Framework (SLF) DFID (1999), which has been adapted according to the context of this study. All vulnerability indicators are standardized (composite) and used to calculate this index. The Vulnerability Index calculation uses the same weighting value for

each type of vulnerability and the indicator that represents it. This same weighting consideration is based on Sullivan et al. (2002), where each indicator contributes equally to each type of vulnerability. Based on Hahn et al. (2009), index calculation should use a method that is easy to understand, and placing the same weights is one of the recommended methods. However, the researcher can change it according to the needs of the study. This study uses nominal data, which is 1 (facing/ever facing) and 0 (not facing). The nominal data for each indicator will be calculated in the form of a percentage and converted into an index value using the 92 conversion method found in the Human Development Index, which takes into account three main values, namely the actual data value, the minimum value and the maximum value (Hahn et al., 2009).

Asset Ownership Index

The Asset Ownership Index of this study is a composite index approach proposed by Hahn et al. (2009). The Asset Ownership Index for this study contains five types of assets, namely financial assets, physical assets, human assets, social assets, and natural assets. These five assets are represented by 20 indicators. The selection of these indicators for these assets is based on the SLF DFID (1999), which has been adapted according to the context of this study. For the calculation of this index, only asset indicators that can be standardized (composited) are considered and used to calculate the asset ownership index. Asset indicators that cannot be standardized for calculation will be discussed descriptively only. The calculation of the Asset Ownership Index uses the same weighting value for each asset and the indicator that represents it. This same weighting consideration is based on Sullivan et al. (2002), where each indicator contributes equally to each type of asset. Based on Hahn et al. (2009), the use of calculating the Asset Ownership Index requires a method that is easy to understand, and placing the same weights is among the recommended methods. However, the researcher can change it according to the needs of the study.

Since each asset indicator has a different measurement scale, researchers can decide whether to use the original scale or select items that have a uniform measurement. This study considers only uniform asset indicators when forming the asset ownership index. This study uses nominal data, which is 1 (have) and 0 (does not have). The nominal data for each indicator will be calculated in the form of a percentage and converted into an index value using the conversion method found in the Human Development Index, which measures three main values, namely the actual data value, the minimum value, and the maximum value (Hahn et al., 2009).

The calculation of the index

The calculation of an index involves a systematic process to ensure a precise and standardized assessment. The initial step is to identify the indicators or constructs to be included in the index, such as land, housing, vehicles, livestock, savings, and other relevant factors. Since these indicators often have varying units of measurement, it is essential to normalize them to a common scale for comparability. Normalization adjusts the values of each indicator to a uniform range, typically between 0 and 1, ensuring consistency and alignment across all components.

Following normalization, equal weights are allocated to each asset and its associated indicators. This method, inspired by the work of Sullivan et al. (2022), ensures that every asset and indicator contribute equally to the overall index. For instance, if there are several assets, each is assigned an identical weight. Likewise, the indicators within each asset are weighted uniformly, promoting balance and fairness in their contribution to the composite index. The normalized values for each indicator are then aggregated to compute an overall score for each indicator, representing the average level of ownership or access associated with it.

After determining the scores for all indicators, the overall index is computed by combining the scores of all assets according to their assigned weights. While equal weighting is a common approach for simplicity, researchers can adjust the weights to reflect the relative significance of specific assets within the context of their study. The resulting index provides a single composite value, typically ranging from 0 to 1, where higher values indicate greater levels of asset ownership. This method, as advocated by Hahn et al. (2009), is both straightforward and flexible, enabling researchers to adapt the calculation process to meet their specific research goals and requirements.

EMPIRICAL ANALYSIS OF SUSTAINABLE LIVELIHOODS OF AGROPOLITAN PROJECT PARTICIPANTS

Table 1 tabulates the Vulnerability Index for participants of the Gahai Agropolitan Project. According to Table 1, the highest threat vulnerability is Economic Threat, with a value of 0.689. Social and Physical Threats, as well as Environmental Threats, also occur, but their index values are small, namely 0.187 and 0.352, respectively.

Table 2 illustrates the Asset Ownership Index for participants of the Gahai Agropolitan Project. Based on the analysis of participants' asset ownership, it is high for human assets, social assets, financial assets, natural assets, and physical assets. This indicates that the asset ownership among participants of the Gahai Agropolitan Project is at a commendable level.

Table 1: Vulnerability Index of Participants in the Gahai Agropolitan Project

Construct	The value of the index according to the indicator	Type of Vulnerability	The value of the index is according to the type of vulnerability
Loss of the main source of income/job	0.600	Economic	0.689
Destruction of crops (rubber, vegetables, livestock, etc.)	0.533		
Fall in crop/commodity prices (rubber etc.)	0.933		
Physical condition of the house (cramped/bad house)	0.2	Social and Physical	0.187
Lack of home furnishings	0.133		
Lack of basic facilities (prayer, kindergarten, shop lot)	0.044		
Communication network problems (tarred roads, etc.)	0.022		
Drug addiction problem	0.111		
The problem of skipping school	0.778		
Spirituality	0.022		
There is a polluted river/source of water	0.089	Environment	0.352
There is open burning from agricultural activities	0.089		
Floods that damage crops and property	0.044		
Drought affecting agricultural production	0.933		
Storms that damage crops and property	0.289		
Plant disease attack (e.g., rubber tree disease, etc.)	0.667		

Source: Field Study (2022)

Table 2: Asset Ownership Index of Gahai Agropolitan Project Participants

Asset component	Index value according to indicator	Asset type	The value of the index depends on the type of asset
Respondent's highest education	1	Human assets	0.606
Current work experience	0.267		
Health	0.778		
Knowledge gets help	0.378		
Water source	1	Physical assets	1
Toilet	1		
Home conditions	1		
Home ownership	1		

Asset component	Index value according to indicator	Asset type	The value of the index depends on the type of asset
Vehicle ownership	1		
Association position	0.289	Social assets	0.75
PIBG	0.911		
Society	0.800		
Cooperative	1		
Land ownership	0.244	Natural assets	0.466
Agricultural input assistance	0.244		
Fertility	0.911		
Income (PGK)	0.966	Financial assets	0.630
Acceptance of financial aid	1		
Loan	0.244		
Savings	0.311		
Overall			0.690

Source: Field Study (2022)

Sustainable Livelihood Results

Increased Income

Table 3 displays the income of participants in the Gahai Agropolitan Project, indicating an increase in 2022 compared to 2018. This demonstrates an improvement in the income of participants in the Gahai Agropolitan Project and signifies a positive outcome in achieving sustainable livelihoods as a result of their participation in the project.

Table 3: Income of Gahai Agropolitan Project Participants in 2018 and 2022

Year	**2018**		**2022**
	n = 45		
Income	**Percentage (%)**	**Income**	**Percentage (%)**
RM500 and below	11.1	RM500 and below	0.0
RM501-RM1000	64.4	RM501-RM1000	8.9
RM1001 – RM1500	17.8	RM1001 – RM1500	31.1
RM1501 – RM2000	4.4	RM1501 – RM2000	42.2
RM2000 and above	2.2	RM2000 and above	17.8

Source: Field Study (2022)

Poverty reduction

The poverty analysis of the Gahai Agropolitan Project participants uses the Poverty Line Income (PLI). The results reveal that a total of 43 respondents, or 96.6%, are not poor. It indicates that 43 of these respondents earn a monthly income of more than RM940. A total of two respondents, or 4.4%, are poor since they earn less than RM940 per month. In addition, 4.4% of these respondents did not earn enough income to meet basic needs, such as food and clothing, amongst others, to continue their lives. According to Ravallion (1995), individuals who earn a low income from PLI have constraints in obtaining a comfortable life since they face problems in meeting the needs of life.

Vulnerability Reduction

Vulnerability reduction analysis refers to the resilience strategies taken by the participants of the Gahai Agropolitan Project in the face of vulnerability. It refers to the resilience strategies taken by the study respondents for economic, social, physical, and environmental.

Economic vulnerability

Table 4 provides the reduction strategy or resilience strategy against the economic vulnerability faced by the participants of the Gahai Agropolitan Project. Economic vulnerability refers to the loss of the main source of income or employment, the destruction of crops (rubber, vegetables, livestock, and others), and the fall in prices of crops or commodities (rubber and others). For losing the main source of income or job, the risk reduction strategy of doing a side job is the highest for both categories of respondents. Meanwhile, for the destruction of crops (rubber, vegetables, livestock, and others), resilience strategies are used more by the participants of the Gahai Agropolitan Project. A total of 22.2% of the participants of the Gahai Agropolitan Project implemented the strategy of planting or rearing and seeking help or compensation from related agencies.

In order to cope with the threat of a fall in the price of crops or commodities (rubber and others), as many as 68.9% of Gahai Agropolitan Project participants do side jobs.

Table 4: The reduction strategy or resilience strategy against economic vulnerability

Type of Vulnerability	Strategy for reducing vulnerability	Percentage (%) n = 45
Loss of primary income/source of employment	Seeking new employment	8.9
	Taking on side jobs	37.8
	Borrowing money	13.3
Destruction of crops (rubber, vegetables, livestock, etc.)	Replanting/rearing crops or livestock	22.2
	Seeking assistance/compensation from relevant agencies	22.2
	Taking out loans to restart enterprises	8.9
Drop in crop/commodity prices (rubber, etc.)	Seeking new employment	8.9
	Taking on side jobs	68.9
	Borrowing money	11.1
	Seeking assistance/compensation from relevant agencies	2.2

Source: Field Study (2022)

Vulnerability to social and physical threats

Analysis of social and physical vulnerability reduction strategies involves resilience strategies in facing the vulnerability of the physical condition of the home, lack of home furnishings, lack of basic facilities, relationship network problems, drug addiction problems, school truancy problems and spirituality. In the face of the vulnerability of the physical condition of the house, many resilience strategies are implemented by the participants of the Gahai Agropolitan Project. Home renovation is a resilience strategy preferred by 13.3% of Gahai Agropolitan Project participants (Table 5). In order to overcome the lack of home furnishings, buying home furnishings by yourself is the strategy most used by participants of the Gahai Agropolitan Project.

Table 5: Comparison of social and physical vulnerability reduction strategies

Types of vulnerability	Vulnerability reduction strategies	Percentage (%) n = 45
Physical condition of the house (cramped/bad house)	Self-improvement of the house (continued)	13.3
	Repair the house yourself	4.4
	Apply for home help from the responsible party	2.2
Lack of home furnishings	Buy your own home furnishings	11.1
	Ask for help from the responsible party	2.2
Lack of basic facilities (prayer, kindergarten, shop lot)	Make reports and complaints to relevant agencies	4.4
	Ask for help from the responsible party	0
Communication network problems (tarred roads and others)	Using the existing road (unpaved)	0
	Making reports and complaints from responsible parties	0
	Actions from responsible parties	2.2
Drug addiction problem	Advice to individuals involved	4.4
	Awareness program	0
	Actions from responsible parties	4.4
The problem of skipping school	Advice to individuals involved	20.0
	Awareness program	2.2
	Actions from responsible parties	55.6
Spirituality	Advice to individuals involved	8.89
	Organize spiritual programs	0
	Asking for help/action from the responsible party	0

Source: Field Study (2022)

Threats such as lack of basic facilities, relationship network problems, drug addiction problems, and spirituality are low threats faced by both categories of respondents. Therefore, the threat-friendly strategy only involves a small part of the respondents. However, for the ease of school truancy, it reveals three resilience strategies taken by the participants of the Gahai Agropolitan Project, which are advice to the individuals involved, the implementation of awareness programs, and actions from the responsible party.

Ease of environmental threats

The ease of environmental threats such as floods, droughts that affect agricultural yields, storms that damage crops and property, and plant disease attacks demonstrate a high number of resilience strategies for the participants of the Gahai Agropolitan Project. The analysis suggests that there are two resilience strategies for overcoming the threat of flooding that damages crops and property,

namely renovating houses and reclamation of higher land and getting help or compensation from related agencies (Table 6). A total of 4.4% of the participants of the Gahai Agropolitan Project renovated their houses and raised the land higher. In order to face the problem of drought affecting agricultural products, a total of 60% of respondents for the participants of the Gahai Agropolitan Project prioritize actions to do side jobs.

Table 6: The resilience strategies to ease environmental threats

Types of vulnerability	**Vulnerability reduction strategies**	**Percentage (%)** n = 45
There is a river or source of polluted water	Do not engage in polluting activities	6.7
	Implementation of awareness programs	0
	Actions from responsible parties	2.2
There is open burning from agricultural activities	Implementation of awareness programs	2.2
	Actions from responsible parties	4.4
Floods that damage crops and property	Renovating the house, raising the land higher	4.4
	Getting help/compensation from related agencies	0
	Build drainage/deepen ditches and drains	0
Drought affecting agricultural production	Do side jobs	60.0
	Borrow money	24.4
	Getting help/compensation from related agencies	6.7
Storms that damage crops and property	Repair damage	15.6
	Buy new equipment	2.2
	Getting help/compensation from related agencies	11.1
Plant disease attack (e.g., rubber tree disease and others)	Control of poisons and fertilizers	62.2
	Replant	0
	Getting help/compensation from related agencies	6.7

Source: Field Study (2022)

As for the vulnerability of storm damage to crops and property, the mitigation strategy only involves the participants of the Gahai Agropolitan Project through the strategy of repairing the damage, buying new equipment, and getting help or compensation from related agencies. Analysis of resilience strategies for plant disease attacks, such as rubber tree disease, indicates that a total of 62.2% of respondents from the participants of the Gahai Agropolitan Project opt for poison control measures. There are many responses to this vulnerability strategy since it is one of the main vulnerabilities faced by the respondent group.

Well-being

Table 7 provides the analysis of the welfare of the participants of the Gahai Agropolitan Project for the economic, social, and physical dimensions, as well as the environment. This well-being analysis uses a Likert scale (value 1 to 5). Mean analysis reveals that the participants of the Gahai Agropolitan Project have high well-being in all dimensions.

Table 7: Well-being Analysis

Dimensions	Agropolitan Project Participants
Economic	4.203
Social and physical	3.902
Environment	3.839

Scale: 1 = Strongly disagree; 2 = Disagree; 3 = Medium; 4 = Agree; 5 = Strongly agree
Scale: *Score: 1.00 – 2.39: Low; 2.40 – 3.79: Medium; 3.80 – 5.00: High

Source: Field Study (2022)

SUMMARY

This study contributes to the study of existing literature related to agropolitan projects both in the country and abroad. Through the study of the impact of agropolitan projects in Malaysia, especially in the Gahai Agropolitan Project, this study can fill the research gap in studying the impact of agropolitan projects to eradicate poverty and contribute to the study of sustainable livelihoods in Malaysia. This study also contributed to the discovery of evidence of the impact of the Gahai Agropolitan Project on sustainable livelihoods. Furthermore, this study uses the Sustainable Livelihoods Framework, which discusses and links poverty, the role of agropolitans, and sustainable livelihoods.

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EXAMINING MALAYSIA'S LOW-INCOME HOUSING ENVIRONMENT: A QUANTITATIVE STUDY OF THE LOW-INCOME HOUSING ENVIRONMENT'S IMPACT ON RESIDENTS' ATTITUDES AND QUALITY OF LIFE

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Abstract

In Malaysia, the burgeoning population has increased the demand for affordable housing, leading to the establishment of Low-Income Housing Programs (PPR) to assist the B40 income group. Despite the noble intentions, PPR communities face challenges, especially with residents' behaviours such as improper waste disposal, which exacerbate cleanliness and safety issues. These behaviours negatively affect living conditions and contribute to an increase in crime rates within these areas. Numerous studies have investigated how the PPR environment impacts residents' quality of life, highlighting the prevalence of detrimental living conditions. Although extensive research has been conducted on the structural and operational aspects of PPR housing, more studies are needed to explore the direct impact of residents' attitudes on their quality of life. This study aims to bridge this gap by examining the intermediary role of residents' attitudes towards their environment and its subsequent effect on their quality of life. Utilizing data from a survey conducted in five states with PPR residents and employing the Partial Least Squares (PLS) method, the study found significant correlations between the PPR environment, residents' attitudes, and their quality of life, underscoring the crucial role of attitude in shaping the living experiences of PPR inhabitants.

Keywords: PPR Environment, B40, Attitude and Quality of Life

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INTRODUCTION

The quality of life (QoL) for residents, particularly those with low income, is critical (Riazi & Emami, 2018). This demographic often cannot afford alternative housing options, making it essential to provide high-quality public housing (Ghezelseflou & Emami, 2023). Achieving a high standard of QoL is challenging, especially in developing countries like Malaysia. To tackle this, the Malaysian government initiated a public housing scheme under the Eighth Malaysia Plan to address squatter issues and provide affordable housing for lower-income groups. The National Housing Department, part of the Ministry of Local Government Development, manages these People's Housing Program (PPR) projects nationwide. PPR is divided into PPR-rented and PPR-owned, with guidelines set by the National Housing Standard for Flat Low-Cost Housing. PPR homes, typically multi-story buildings ranging from five to eighteen storeys, are located in major cities, while terrace houses are more common in suburban areas. Each unit, mandated to cover 700 square feet, includes three bedrooms, a living room, a kitchen, and two bathrooms. Standard amenities in every PPR include public spaces, prayer rooms, food stands, kindergartens, accessible facilities, playgrounds, and garbage disposal areas, ensuring that every citizen has access to suitable, well-designed housing with basic amenities. However, challenges remain in providing decent housing environments at reasonable costs. Issues such as substandard construction, lack of maintenance, and inadequate infrastructure result in poor living conditions, including leaky roofs, insufficient ventilation, improper sanitation, and overcrowding. Additionally, public housing management faces problems like vandalism, rubbish disposal, and rent arrears. Despite adherence to the National Housing Policy, no study has assessed the behaviour and QoL of B40 PPR residents (Leung et al.,2019; Firdaus et al., 2016; Ismail et. al., 2015). Research has primarily focused on residential satisfaction with housing design and the effectiveness of Performance Measurement systems in PPR. More evidence is needed on how experiential value impacts residents' QoL. In Kuala Lumpur, 69 crime cases were recorded in PPR in 2019, with 1001 arrests for drug-related offenses, highlighting security issues (Dzulkifly, 2019). The Department of Statistics Malaysia reported that, among 52,344 crime index cases in 2020, break-ins and theft, with 14,040 cases, were the second highest crime category. This underscores the low security and deteriorating QoL for residents. The media often highlights the poor attitudes and criminal involvement of B40 PPR residents, raising national concerns. The future of these residents, surrounded by a detrimental environment and uncertain academic prospects, is at risk. Addressing these issues is crucial for the nation's future.

This study will focus on how the PPR environment impacts the quality of life of B40 PPR residents, including factors like income, education level, military control, and health. It will also explore how the PPR environment

influences residents' quality of life by mediating their attitude, a previously unmeasured aspect. Investigating whether environmental factors such as unit features, public facilities, neighbourhood environment, and support services affect the QoL of PPR residents is essential. Yet, very few housing programs track QoL as an outcome that can be used to tailor service provision. At the same time, gaps remain in understanding what matters most to emerging low-income groups regarding their QoL. The general understanding of the QoL explains that an individual or social group should work to fulfil physiological needs.

LITERATURE REVIEW

RESEARCH METHODOLOGY

This study utilized a cross-sectional and quantitative research design, employing a survey questionnaire distributed among PPR residents in Malaysia. The research focused on urban areas, specifically major cities such as Johor Bahru, Kuala Lumpur, Kuantan, Penang, and Kota Kinabalu, which were chosen for their concentration of PPR flats. 704 participants were selected via purposive sampling, facilitated through coordination with PPR block leaders in July 2022. Before distributing the survey, the researchers sought and received approval from the Ministry of Local Government Development to conduct the study within the PPR framework. Following this approval, the researchers obtained an official authorization letter and arranged meetings with PPR block leaders to organize the survey distribution.

A. Measurement of the Constructs

Table 1 demonstrates that a survey questionnaire was developed based on the indicators linked to each proposed research model’s constructs.

Table 1: Measurement of the Constructs and Sources

Constructs	Items	Source(s)
Quality of Life (QoL)	13	Streimikiene (2015)
PPR Environment	5	Arabi et al. (2020), Cozens & Sun (2019) and Olanrewaju & LeeA (2022).
Attitude	8	Zanna & Rempel (2008)

Table 1 shows the measurements of the constructs and their sources. The respondents were asked to indicate their perception levels on a 6-point Likert scale, ranging from Strongly Disagree (1) to Strongly Agree (6). A pre-test was carried out by two experts in research methodology, and, after further corrections, the final survey draft was piloted to 30 respondents. A preliminary analysis of the data was performed and a reliability assessment of the constructs was carried out

by calculating the values of Cronbach's alpha for each construct separately. The results of Cronbach's alpha were 0.852 for QoL, 0.848 for PPR environment, and 0.901 for Attitude. Hence, the internal consistencies of all constructs were considered acceptable since each reliability test exceeded the threshold (>0.70) suggested by Hair, et. al., (2019).

Modelling Approach

The conceptual framework could be explored based on the theoretical perspectives and arguments related to the corresponding relationships above.

The Conceptual Framework

Figure 1 below is the graphical view of the conceptual framework in this study.

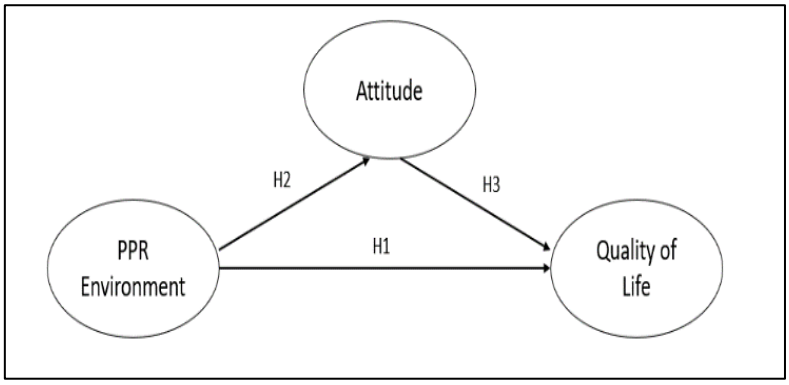

Figure 1: The Conceptual Framework

In this study, PPR Environment (PPRE) of the residents is considered as an independent or exogenous latent construct of the study. Correspondingly, Quality of Life of the PPR residents is considered as the dependent or endogenous latent construct, which is useful in measuring the perception of the residents. Meanwhile, Attitude of the PPR residents is considered as a mediating factor in the relationship between the PPRE and Attitude of the residents with the interrelationships between the three constructs, the following hypotheses are to be tested;

H1: PPRE has a significant influence on Quality of Life of the PPR residents.
H2: PPRE has a significant influence on Attitude of the PPR residents
H3: Attitude of the PPR residents has a significant influence on their Quality of Life
H4: Attitude of the PPR residents mediates significantly in the relationship between PPRE and the residents' Quality of Life

Data Analysis

Partial Least Squares Structural Equation Modeling (PLS-SEM) (Rigdon et al., 2014) was adopted to analyse the conceptual framework. The model has two parts, i.e., measurement and structural models, and has direct and indirect relationships, which have been hypothesized earlier. PLS-SEM was the most appropriate method for certain data conditions, such as small sample sizes and non-normal data (Hair et al., 2016). The key criteria for the goodness of fit are the size, sign, and significance of path coefficients, the R2 values, and the effect size f2 (Ali et al., 2018). The procedure developed by Nitzl et al. (2016) was used to test the mediation effects of Human Resources and Technology in the framework.

ANALYSIS AND DISCUSSION

Results of PLS-SEM Analysis

Assessment of the Measurement Model

The research model (Figure 2) was analyzed using SmartPLS 4.0, a PLS structural equation modeling software. The measurement model in PLS is assessed in terms of item loadings and reliability coefficients (composite reliability), as well as convergent and discriminant validity. Individual item loadings greater than 0.7 are considered adequate (Fornell & Larcker, 1981). The average variance extracted (AVE) measures the convergent validity via the variance captured by the indicators relative to measure error, and it should be greater than 0.50 to justify using a construct (Barclay et al., 1995). Table 2 shows the result of the reflective measurement model that presents the values of indicators loadings, composite reliability, Cronbach's alpha, and AVE.

Table 2: Reliability and Discriminant Validity of the Constructs

Construct and Items	Loadings	CA	CR	AVE	Discriminant Validity
PPRE		0.846	0.896	0.683	Yes
Attitude		0.797	0.880	0.710	Yes
QoL		0.904	0.922	0.567	Yes

As shown in Table 2, the CA values of all constructs were between 0.801 and 0.906, which are all above 0.7, as Hair et al. (2016) recommended. While CR values were between 0.866 and 0.922, which are higher than 0.7 and indicate adequate internal consistency (Gefen et al., 2000). Thus, the constructs are considered reliable. The values of AVE for all the constructs ranged from 0.567 to 0.710, and therefore, all the constructs achieved convergent validity.

Discriminant validity assessment must be accepted to evaluate relationships between latent constructs. Traditionally, two discriminant validity measures are commonly used in SEM-PLS: cross-loadings and the Fornell-Larcker criterion (1981). Cross-loadings are attained by relating each construct

score to the other items (Chin, 1998). If each indicator's loading is higher for its allocated construct than for any of the other constructs, and each of the constructs put in highest with its assigned items, it can be concluded that the dissimilar constructs' indicators are not substitutable. In the case of SEM-PLS, each indicator loading on associated constructs should be greater than all of its cross-loadings, as illustrated in Table 3.

Table 3: Heterotrait-Monotrait Ratio (HTMT) for Discriminant Validity

	PPRE	**Attitude**	**QoL**
Attitude	0.616		
QoL	0.830	0.784	

Evaluation of the Structural Model

To assess the structural model, R2, beta, and t-values via a bootstrapping procedure with a resample of 5000 and the effect sizes (f2) suggested by Hair et al. (2016) were performed. The results in Figure 3 and Table 6 indicated that the three relationships turned out to be highly significant. The two predictors (PPRE and Attitude) had significant relationships with Quality of Life.

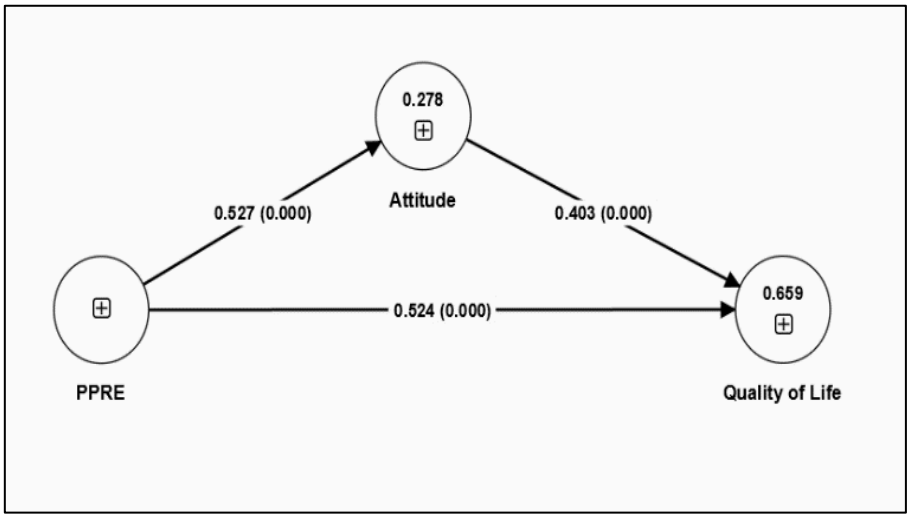

Figure 3: The Estimated Structural Model

For the relationship between PPRE and QoL (H1) $\beta = 0.524$ ($p < 0.01$), PPRE and Attitude (H2) $\beta = 0.527$ ($p < 0.01$), and Attitude and QoL (H3) $\beta = 0.403$ ($p < 0.01$) had highly significant positive relationships. Thus, for H1, H2, and H3 were supported.

Table 4: The Structural Model Path Coefficients

Relationships	Path Coefficients	t-values	p-value	Hypothesis supported by Data?
H1: PPRE -> QoL	0.524	17.074	0.000***	Yes
H2: PPRE -> Attitude	0.527	13.936	0.000***	Yes
H3 Attitude -> QoL	0.403	12.802	0.000***	Yes

Note: *** Significant at 0.01 level

The R2 value for QoL is 0.659, above the 0.26 value that Cohen (1988) suggested, indicating a substantial model. Hair et al. (2016) have suggested an extra step by examining the change in the R2 value through the value of f2. The step involves the omission of a specific exogenous or independent construct from the model and seeing the change in R2. It can be used to evaluate whether the omitted construct has a substantive impact on the endogenous construct. Tables 5-6 show the R2 and adjusted R2 results, respectively.

Table 5: R2 and Adjusted R2

	R^2	R^2 Adjusted
Attitude	0.278	0.277
QoL	0.659	0.658

Table 6 shows the results of f2. Following the Cohen (1988) guideline, the effect sizes of 0.02, 0.15, and 0.35 represent small, medium, and large effects. The results showed that while Attitude has a small effect on QoL, PPRE has a large effect on both Attitude and Quality of Life of the PPR residents.

Table 6: Effect Size (f2)

	Attitude	PPRE	QoL
Attitude			0.343
PPRE	0.385		0.580
QoL			

In this study, Attitude's role in enhancing the residents' Quality of Life was the main focus. Therefore, its role as a mediator was examined accordingly. Table 7 illustrates the significance of the mediating factor (via its indirect effect) in the relationship between PPRE and Quality of Life. The results showed that Attitude was a significant mediating factor ($\beta = 0.212$) was significant at 0.01 level, and therefore, H4 was supported. This confirmed the significant role of Attitude in enhancing the Quality of Life of the PPR residents, as shown by the indirect relationship between PPRE and QoL in Table 7.

Table 7: Mediating Effect

Indirect Relationship	Indirect Effect	t-Statistic	p-values	Hypothesis Supported by Data?
H4: PPRE -> Attitude -> QoL	0.212	9.016	0.000***	Yes

Note: *** Significant at 0.01 level

CONCLUSIONS

This paper presented the link between the influences of the PPR Environment on the Quality of Life of the PPR residents in Malaysia. The proposed model included another factor, i.e., the Attitude of the residents, that was expected to influence their Quality of Life. The empirical evidence from the study seems to be congruent with the argument made by Muianga et al. (2021). The residents indicated they were most happy with QoL5 (I hang out with my neighbours in this PPR quite often) and QoL10 (I am satisfied with legitimate support for my health activity in this PPR). The study also indicated that the attitudes of the residents concerning their PPR environment were dominated by ATT1(I am afraid to act silly around PPR residents), ATT2(I have a positive attitude about my PPR residence), and ATT3 (I care about living in privacy in my PPR residence)

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BEHAVOURIAL ASPECTS IN PLACEMAKING WITHIN TRANSIT-ORIENTED DEVELOPMENT

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Abstract

Transit-oriented development (TOD) has attracted significant attention globally for its effective role in promoting pedestrian-friendly environments. Recent implementations have focused on urban redevelopment, with the goal of enhancing walkability and TOD placemaking. The significance of TOD is evidenced by public behaviours within the TOD area. Hence, this research aimed to comprehend the significance of the behavioural aspects in building sense of place within public space in relation to TOD. The study evaluates literature spanning from 1993 to 2021, drawing from various disciplines such as architecture, urban design, environmental geography, psychology, and sociology. The studies incorporate multiple sources including reviews, case studies, and theoretical works. The findings of this study suggest that people's behaviour and daily routines are influenced by their needs. Understanding the psychological patterns and needs of the public is crucial to effective placemaking in TOD neighbourhoods.

Keywords: Placemaking, TOD, Sense of Place, Behavioural Aspect, Public Space

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INTRODUCTION

Public transit projects, in conjunction with transit-oriented development (TOD) plans, are a popular instrument for urban revitalization (Aranda, 2006). TOD planning means incorporating transportation and land use planning in a way that encourages the utilization of public and active transit instead of relying on the private automobile (Gomez et al., 2019; Jacobson & Forsyth, 2008; van Lierop et al., 2017). These are integrative projects that include residential, offices, commerce, and places for people to go about their everyday lives (Rahmat et al., 2016). TOD policies are implemented by municipal and regional governments in order to offer more socially, ecologically, and financially viable communities (van Lierop et al., 2017). The concept of TOD is broadly known in Malaysia due to both regional and local plans, and as well as state structural plans (Gomez et al., 2019).

A TOD is typically described as a region with an 800m radius around a transport station, as compared to Peter Calthorpe's definition of 600m radius, which equates to a maximum 10-minute walk from a transportation hub for the average person (Lang et al., 2020). A "secondary area" associated with a TOD may arise at a maximum distance of 1.6 kilometres from the city centre. This area might include low-density dwellings, huge park spaces, institutions, as well as other community amenities (Ibraeva et al., 2020). This is strongly related to the concept of the "pedestrian pocket," which refers to the concept of a neighbourhood plan that encourages walking excursions by providing a choice of possible routes and minimizing travel times for walkers (Ibraeva et al., 2020). A TOD is an attempt to integrate a neighbourhood with features of a town centre, potentially resulting in a less crowded, congested, and hectic place which remains vibrant and functioning (Ibraeva et al., 2020). Implicitly, it can boost the economy and overall quality of life by making an area much more pleasant and structured according to their specialized amenities (Rahmat et al., 2016).

Practitioners' opinions are critical factors impacting TOD implementation (van Lierop et al., 2017). A regional viewpoint should consider TOD as a carefully planned initiative encompassing multiple cities that are economically and culturally intertwined (Aranda, 2006). Collaborative planning is required for the development of socially balanced TODs (van Lierop et al., 2017). Countless planners and urban designers have turned their attention away from the vehicle and toward the pedestrian, in a response to the detached suburban environment (Aranda, 2006). The seven most widely discussed TOD characteristics are spatial layout, mobility, environment, sociocultural, economy, cooperation, and accessibility (van Lierop et al., 2017).

This research, however, will not just focus entirely on TOD world at large, but rather on the psychological patterns of the general public that are affected in constructing placemaking when TOD plans are properly integrated in the neighbourhood. To fully utilise the TOD approach in a selected region,

professionals must first understand the minds of the people that will significantly influence the results of this method, in order to assure that benefits accrue to both government and society in general.

This paper provides a summary of studies on place-making in transit-oriented development (TOD) from 1993 to 2021. The purpose of this research is to comprehend the significance of the behavioural aspect role in building a sense of place in a public space. The fundamental subject addressed in this research is what influences community behaviour in public places? Sub questions related to the primary result of this research have been separated into two sections for additional debate. To begin with, how do an individual's needs impact their attitude? How does a person's sensory experience influence their behaviour? Understanding the applicable terms will help answer both questions. Both concerns may be answered by understanding the reason behind human needs using Maslow's Hierarchy of Needs. Second is to thoroughly comprehend the critical features of placemaking when developing public places in the context of how they may impact people's behaviour. Three questions have been proposed: a) what are the needs that drive behaviour; b) why accessibility and security are essential in placemaking and c) how does sensory effect people's daily routines? These three issues may be answered through understanding society's aspirations and requirements, as well as how the environment impacts individuals in general.

LITERATURE REVIEW

Public spaces are one of the most essential features of Transit Oriented Development (TOD), since they serve as links between buildings and transit stations, and therefore in a mixed-use development (Mehta, 2014). They are spaces which have the ability to incorporate different sets of activities, behaviours and functions would be the main justification that fixates the focus of the public towards public spaces (Jalaladdini & Oktay, 2012). Public spaces are defined as essential as a part of the public's life because they are capable of offering paths for circulation, a way for interaction and a base for recreation and leisure, and also have the ability to provide experiences and insight depending on the role that the spaces portrayed (Aghostin-sangar, 2007, Peimani & Kamalipour, 2020). Public spaces should be celebrated, whether consisting of streets, public building or an open area through placemaking to form appreciation on their societal beliefs (Fisher et al., 2017, Harun et.al, 2021). Fundamentally, public spaces that are located in a mixed-use area would have the privilege of attracting more people, as compared to the public spaces in a one-land use type (Jalaladdini & Oktay, 2012). Basically, such a space that can be enjoyed by the community's despite of their cultural or social preferences (Aghostin-sangar, 2007).

In general, a majority of society has spent their public life in public grounds, indicating that most of the societies would likely agree that public places should comprise some major needs of what it takes to be a fully functional realm

(Jalaladdini & Oktay, 2012). Good public places must be able to build a popular network for people to stroll and enjoy themselves. For example, the width of walkways would allow people to mingle socially and therefore creates social interactions among themselves (KARACOR, 2014). The community should be able to freely access and use these spaces without enforcing biased difficulty towards the class of people who can be allowed in them, or even the intentions for the spaces (Aghostin-sangar, 2007). Streets, parks, squares, and other common areas in a city can be viewed as symbols of communal possibility and well-being, as well as expressions of success and ambitions by urban leaders and visionaries, as well as places for civic culture formation, public interaction, and significant spaces for political debate and conflict (Amin, 2008). Buildings themselves are also an important element of the environmental experience, serving a variety of roles ranging from simple shelter to a myriad of symbolic and ceremonial activities. As a result, successful design can be defined as a balance between functional utility and aesthetic excellence (Burgess, 2012).

Placemaking is a broad notion which spans multiple disciplines (Strydom et al., 2018). Placemaking is a lengthy process that involves future expectations; it must address not only the needs and aspirations of today's people, but also those of future generations (KARACOR, 2014, Setiawan, 2022; Stojanovski, 2019). According to Ellery et al. (2021) and Fincher et al. (2016), placemaking has multiple substantial concepts and definitions; however they are nonetheless widely considered within the same context, as they describe placemaking as a phase either in moulding people or shaping environments (Ali et al., 2020; Schneekloth & Shibley, 1993; Toolis, 2017; Wyckoff & A, 2014). According to Finlaw (2013), Poerbo et al., 2022; the dynamic of the society can be completely transformed through placemaking. Placemaking is not created for the sole of the design or the project, but rather focuses on the collaborative of the whole community with the function of the space (KARACOR, 2014, Raj, 2022). It has evolved as a rising trend in which the residents engage in constructing and altering the environments, they reside with the intention of improving the bond amongst individuals and the locales they shared (Toolis, 2017). Every placemaking effort should represent the unique character of a space, while also taking into account the demands and potential of both society and the location (KARACOR, 2014).

Needs Influence Behaviour

Based on McLeod (2018), humans have congenital needs that encourage our behaviours. Individuals are driven to meet specific wants, and some needs take priority over others. Human behaviours, social interactions and experiences are the consequences of the mind development that are affected by various characteristics of the spaces, either it be physically, socially and sensory (Aghostin-sangar, 2007, Lam et al. 2021). Most response is multi-motivated, and

"any conduct likely to be influenced by several or even all of the basic requirements concurrently rather than simply by only one of them," according to the study (McLeod, 2018).

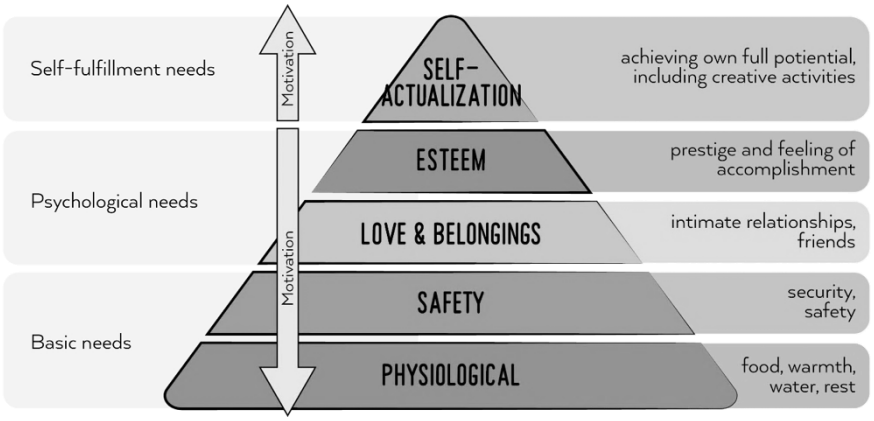

Figure 1 Maslow's hierarchy of needs

Maslow's Hierarchy of Needs stacks different needs according to their respective necessities. McLeod (2018) stated that, individuals must first achieve lower-level deficiency needs before moving on to higher level growth needs but later clarified that satisfying a need is not a "all-or-nothing" phenomenon but rather a choice that individuals would pick first to satisfy partially. To put it another way, individuals would try to fulfil any needs first either way, according to their preferences. Certain human behaviours can be facilitated, modified, or hampered by the built and natural environments (Aghostin-sangar, 2007, Abu Bakar, A. (2023). Maslow's pyramid serves as a prime guide followed by many designers in terms of creating quality spaces for the society (Aghostin-sangar, 2007; Jalaladdini & Oktay, 2012; Tandogan & Ilhan, 2016). To achieve great standards of place-making in public places, we must first understand the importance of each need according to their respected tiers.

Referring to Figure 1, the basic needs that covers the first tier, physiological, also refers to accessibility, and second tier, safety, comprehensively influence and inspire human behaviours, and are capable of shifting the individual in seeking to meet those needs (Tandogan & Ilhan, 2016). A good quality of placemaking must be accessible especially by the public and offer both safeties, not only in design of the architecture, but also are able to create the feeling of safe in the mind of the public (Tandogan & Ilhan, 2016, Afzali et al., 2022). It is understandable that a part of human behaviours may be affected by the surroundings and physical characteristics of the public spaces (Aghostin-sangar, 2007). This fear is due to feeling of unsafe has indirectly strict the access to the social interactions between the community therefore reducing the value of

life (Tandogan & Ilhan, 2016). Due to this realisation, street life has been rejuvenated, and numerous functions for the formation of social interactions have been created (KARACOR, 2014), because city design is an important factor in moulding human attitudes and preferences (Lew, 2017). The second and final needs, which are the psychological and self-fulfilment needs, are both covered by the activities happening around the individuals. Activities are one of the essential reasons for communities to travel to their destination where their needs can be meet.

Vitality and Equity in Accessibility and Security

The dynamics of people congregating in and moving through streets, squares, parks, libraries, and cultural and recreational facilities are more likely to be understood in terms of their influence on consumer cultures, strategies for navigating in the urban environment, and social reactions to unidentified others than in terms of their central role in forming civic and political culture (Amin, 2008, Afzali et.al, 2021). Physiological needs, on the first tier from the bottom of the pyramid, are also known as basic needs in the state of place-making. This refers to the main key of what a public place should offer, which is accessibility to fulfilling the basic needs of the humans. Without accessibility, a space cannot be called a place, since there would be no entities allowed in those areas, which is why having access to a space is considered as one of the basic needs in a public place (Jalaladdini & Oktay, 2012). The accessibility of a public area itself can be both an effective element and a hindrance to higher use and the attainment of social interaction in a public place (Pasaogullari & Doratli, 2004, Peimani, & Kamalipour, 2020). The building density and the standard of having circulation for pedestrian is so much higher than vehicular in providing vitality in a place, making it rather important (Jalaladdini & Oktay, 2012; Mouratidis & Poortinga, 2020). Accessibility to a place comes in two types, visually and physically, which balance all the senses that are needed for the public's interest.

Public open areas are essential in promoting fairness and inclusiveness in towns and cities (Attia & Ibrahim, 2018). Equity and inclusion are major elements that form urban life and the public sphere in neighbourhoods (Attia & Ibrahim, 2018). Environments that can be equally shared by all societal groups are said to be equitable. They offer all the characteristics that a wide range of users need, and they accommodate the requirements of many groups without jeopardising the well-being of others (Jalaladdini & Oktay, 2012). In terms of daily activity, urban vitality is a requirement for a secure and thriving city (Mouratidis & Poortinga, 2020), while equity creates a safe, vital public arena in which various people from different socioeconomic structures can engage without conflict (Jalaladdini & Oktay, 2012). Access to streets and building density are both required for urban vitality (Mouratidis & Poortinga, 2020).

On the second tier from the bottom is the need of safety, where this covers both safety and security physically and mentally as in being safe from any form of harm or being able to handle any situation particularly in the scope of security (Jalaladdini & Oktay, 2012). The word 'safe' according to Hornby (2015), defines numerous meanings, but to specifically depicts what is safe in this context is to not likely to lead to any physical harm or danger. According to Figure 2, safety is one of the most vital necessities when establishing placemaking, as shown in the second tier of the Maslow's Hierarchy of Needs, which represents the basic needs of humans (Tandogan & Ilhan, 2016). Thus, making 'safety' as a positive quality in a city and the spaces within it (Jalaladdini & Oktay, 2012). Feelings of fear could easily happen when one does not feel safe in any condition and when it is discussed about as a topic that is related to public spaces, 'crime' would always be mentioned beforehand (Tandogan & Ilhan, 2016).

Public life in the streets helps in providing safety in cities, encouraging small businesses or shops to become the eyes on the street, especially in residential areas (KARACOR, 2014). Researchers are particularly interested in the interactions between people and their surroundings (Burgess, 2012). A vibrant street life can provide safety and security while also contributing to the development of social sustainability (KARACOR, 2014). Creating a safe public environment will help in creating more engaging public spaces where people can gather and communicate in a psychologically normal behaviour (Finlaw, 2013). However, although a space can be safe from any physical danger done by the space itself, the behaviours of human being are also capable in initiating the feeling of fear in an individual, resulting in bad impacts towards the liveability and growth of the city (Tandogan & Ilhan, 2016).

Experiences Affect Interest in Activities

Public spaces that have vitality in them may succeed in acting as a breeding ground of social relationships in the community (Jalaladdini & Oktay, 2012). The discipline focuses on the ways in which surroundings influenced behaviour of the people, individual comprehensions and perceptions of environments, and the impact of environmental changes on people's feelings and activities (Burgess, 2012). Another supporting factor that helps in creating quality public spaces the number and kind activities that these places can hold in a time. People tend to spend more of their public life in a place where they can do most of their day or night activities there, especially when it comes to creating and strengthening social relationships among themselves (Jalaladdini & Oktay, 2012).

Activities are influenced by the ambient of the place. The term "ambient environment" refers to the non-visual and non-physical characteristics of the constructed environment such as sound, smell, temperature, and lighting and these are perceived by sensory organs such as the ears, nose, skin, and eyes (Aghostin-sangar, 2007). Direct sensory experiences result from the combination

of stimuli such as sight, smell, sound, touch, and taste. The majority of studies have focused on visual perception and standards of visual quality (Burgess, 2012). The sense of sight has a much broader functional range, which allows individuals to notice a subject from afar (Gehl, 2011). People's decisions on where they will travel and what they will avoid doing are also influenced by weather changes such as rain, wind, cold, and heat (Aghostin-sangar, 2007). This is because there are two types of sensory apparatus: distance receptors (eyes, ears, nose) and proximate receptors (skin, membranes, muscles). These receptors differ in terms of specialisation and functional domains (Gehl, 2011). As an example, the sense of smell detects odour differences only within a relatively narrow range (Gehl, 2011). This implies that people's interactions with their surroundings are tri-dimensional, involving emotions, thought or cognitive processes, and physiology (Aghostin-sangar, 2007). Appropriate surroundings are those that make culturally appropriate emotions and feelings visible (Burgess, 2012).

Environmental perception studies are based on the idea that an individual's view of the world is constructed using direct sensory experiences that are ordered in major ways by processes of perception and cognition and are impacted by social and cultural norms (Burgess, 2012). As with other ambient factors, there is significant evidence that noises can 'arouse' or distract individuals, to the level which they are regarded bothersome, a nuisance, or pleasurable is determined by individual sensitivity (Aghostin-sangar, 2007). This is due to the auditory sense, which has a wider functional range (Gehl, 2011). Uncomfortably noisy surroundings are associated with increased arrest rates, hostility, decreased environmental care, decreased social engagement, and errors in judgement (Aghostin-sangar, 2007). Because sight and hearing are associated with the most comprehensive of outdoor social activities - seeing and hearing interactions - how they perform is, of course, a critical planning consideration (Gehl, 2011).

Experience is obtained by action and interaction with the environment, and is represented in the individual's ability to change settings of a place for their own purposes that contrast with its true function or to interpret cues for acceptable behaviour in public places (Burgess, 2012). The diverse purposes portrayed in the streets offer various objectives that allow the public to create both active and semi active edges. This allows a space to be build outside their region to encourage the presence of the people into that space (Jalaladdini & Oktay, 2012). Activities that occur in outdoor spaces can be categorized into different specification, which include the function of a space and the recurrence pattern of events (Hanzl & Ledwoń, 2017). All activities that take place at certain locations are distinct and intriguing enough to keep people coming back (KARACOR, 2014).

RESEARCH METHODOLOGY

The literature evaluation was drawn from a variety of disciplines, including architectural, urban design, environmental geography, psychology, and sociology. This study has already been confined to publications published between 1993 and 2021 in order to condense the research, which includes reviews, case studies, and theoretical work. Literature was gathered to highlight the significance of understanding behavioural aspect in placemaking and its success as a technique.

ANALYSIS AND DISCUSSION

Public spaces offer physical and psychological links between individuals and their surroundings. It is a space that can host a wide range of activities depending on its functions, which makes it ideal as a gathering venue for social activities. Any vacant location that is accessible to the public, yet serves no purpose or meaning, lacks the essence of place-making. As a result, establishing place-making in a public area can enhance a city's strength of its rich and diverse communities that are active in social interactions. According to the literature assessment, placemaking represents either moulding the place via the people, or perhaps shaping the individuals themself through the function of such public spaces. In any case, the participation of both parties-communities and practitioners-is critical in generating high-quality placemaking. It is comprehensible that a public place could influence people's attitudes; for example, the presence of a pond in a public park can draw users to go fishing; but even so, individuals also are capable of altering the character of a place simply by throwing trash in that specific pond, likely to result in poor behaviour, and the capacity to prevent other individuals from entering that particular park with said pond.

It is true how both communities and the environment have such a role in creating high-quality placemaking. People's behaviour and attitudes become crucial in the process of placemaking because they can impact the overall goal of placemaking. However, before individuals may engage with one another in a public space, they must first be able to access it. This is when the Maslow's hierarchy of needs comes into play, as a guideline for basically all practitioners to better understand people's behaviour so that they may design out spaces and functions wisely and comprehensively. According to Figure 2, Maslow's Hierarchy of Needs includes five stages, with the first and second tiers classified as basic needs which are fundamental requirements, the third and fourth tiers classified as psychological needs, and the top layer classified as self-fulfilment needs. These requirements differ depending on their position, with the bottom position indicating the most desirable wants to be met first, and the top position indicating the final one to be met.

Public places must be easily accessible to the public in order to function efficiently to meet basic and additional needs. Streets and parks are considered

public places; thus, in order for them to properly operate as a location for activity to occur, everybody must be able to use them without difficulty, including the disabled. One of the most important factors in creating vitality and equity in a community is accessibility. Vitality is important in marketing public spaces in order to bring in more people, whereas equity provides equitable service, which implies that the public space and its functions really are available to all segments of society.

A public area not only needs to be inclusive, but it also needs to be safer in terms of physical architecture as well as the surroundings which other individuals creates at a place. Such sites may be secure in terms of design; however if they contain crimes, they are still deemed hazardous and would automatically induce dread in the population. As a result, people will have fewer social encounters with strangers, because they will be hesitant to trust them. This is why some urban designers believe that effective place-making requires mixed-use density, such as placing housing, retail, and transit hubs next to one other, in order to ensure that these places are not left unoccupied or vacant for crime to occur.

Aside from accessibility and safety, which can affect an individual's behaviour, sensory experience is able to influence people's attitudes toward a location, whether it looks appealing or resistant to visitors. Human senses normally refer to the senses of sight, smell, taste, touch, and smell, but it genuinely means to somewhat more beyond just five basic senses. The significant meanings behind such perceptions create reasons for an individual to travel from one location to another. There are several sensory experiences that a person might experience in the setting of public areas. Humans utilise their senses of sight and hearing the most, especially when they are too far away for other senses, such as smell and touch, to pick up. This is because the human vision field is significantly broader and therefore can detect an entity from such a distance. People are compelled to travel because of visual and auditory stimulus. These senses also play a part in the enjoyment of activities, for instance when a person sees colourful canopies or hears people laughing, that person would undoubtedly rush over to whichever his eyes locate and as to why and where the sound comes from. Not only may senses lure individuals to an object, but they can also drive them away if the entity causes unpleasant inputs to the human sensory system. Bad odours from rubbish bins behind shop lots in alleyways might deter people from utilising those pathways, and even unclean sidewalks due to spilt food and drink are reason enough for people to avoid that location. In theory, less activity will occur in these sorts of situations, but in such areas where bad behaviour has become the norm, portions of the senses will be disregarded to maintain the activities going. This is the part during which the demands of self-fulfilment are met.

In this study, it is obvious that not only physical characteristics are significant in producing a sense of place in placemaking, but behavioural components are also key in giving the place a purpose and allowing it to completely operate. The sensory experience plays a vital role in placemaking, and experts may

quickly discern what is ideal for the community with the aid of Maslow's Hierarchy of Needs.

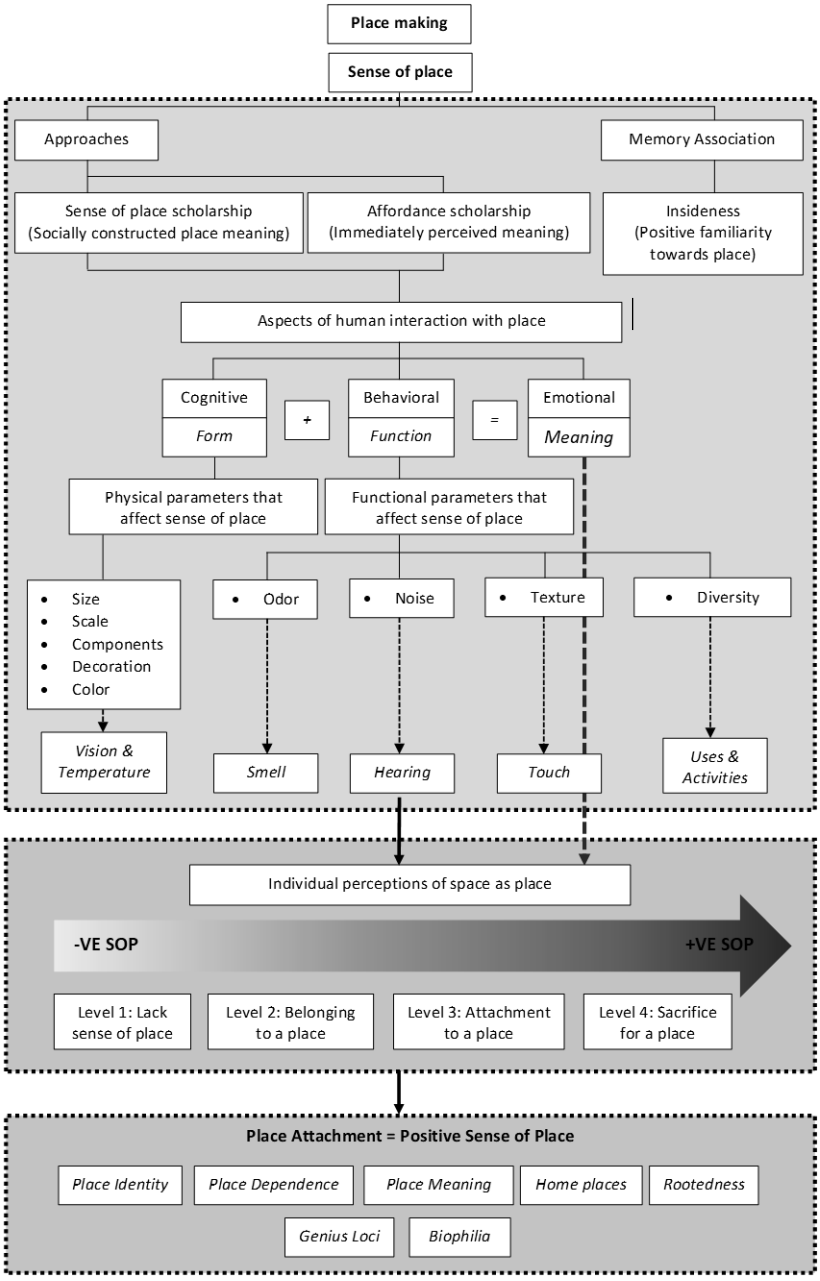

Figure 2 Theoretical framework of placemaking

CONCLUSION

In transit-oriented development (TOD), how does the behavioural component impact the methods of placemaking in a public space? People's attitudes and daily routines are definitely influenced by their needs. These requirements may be identified and met with the aid of Maslow's Hierarchy of Needs, which indicates how important each need is based on its stage.

The behavioural element, on the other hand, might vary based on the environment and the individuals themselves. This happens because the type of behaviour is sometimes unexpected, and it may be challenging to keep proper behaviour in society. Nonetheless, while all human wants are the same, what distinguishes one person from another is the desire to fulfil that need. Maslow's Hierarchy of Needs identified the major categories of human needs and ranked them according to their significance. Access to a public space is one of the most important aspects of placemaking since it is the preliminary stage as to what gives the public space value. When activities occur in a public space, this already portrays the purpose of the space and carries its own significance based on the cultural rationale for the activity. Safety, on the other hand, is what makes individuals feel at ease being in a given location. Apart from being able to access public space easily, safety is also important, and it is what makes individuals feel secure being at that location. Sensory experiences involving the five sensory organs are essential for initiating social and recreational connections. The surroundings, which comprise the environment as well as the events taking on around them, primarily excite all of the senses. Accessibility, safety, sensory stimulation, and activities are all important factors which influence people's actions in public places. All of these factors must be considered in order to create high-quality placemaking and to prevent spaces from becoming unoccupied or vacant.

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ANTICIPATING LOCAL ACCEPTANCE OF SOLAR FARM DEVELOPMENT IN BATANG KALI, SELANGOR, MALAYSIA: ASSESSING POTENTIAL IMPACTS

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Abstract

To restructure the country's economy towards a high-value economy, the government has placed the transition to a green economy as one of the main targets of its economic restructuring efforts. This transition will create a significant positive impact on every level of society, in addition to guaranteeing the continuity of the country's energy. Nonetheless, every planned development must minimise its impacts on the communities that it will affect. The main objective of this study is to explore the impact of solar farm development on a local community in the dimension of sustainability. This study employed a quantitative research methodology to evaluate the level of impact that the community may experience. The study's primary findings revealed that the community involved in the proposed development project would be significantly affected, both positively and negatively, across social, environmental, and economic dimensions. The community anticipated that the solar renewable energy generation would have a significant positive impact, and the establishment of a solar-based community would improve the quality of life. The implications of this study will facilitate policy makers, decision makers and practitioners in developing solar farms in a sustainable manner while safeguarding the interests of local communities.

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INTRODUCTION

Sustainable Development Goals (SDG) 7 is a global energy goal that includes three main objectives: guaranteeing universal, affordable, and dependable access to modern energy services, significantly increasing the proportion of renewable energy (RE) in the world. Moreover, energy plays a crucial role in achieving all SDGs, including alleviating poverty and hunger, improving healthcare and education, promoting gender equality, ensuring access to clean water and sanitation, driving economic growth, fostering full and productive employment, reducing inequalities, encouraging sustainable production and consumption, and building sustainable cities and communities (United Nations, 2021). As the energy industry advances, the production of clean, efficient, and low-carbon energy focusses on renewable energy production. However, in Malaysia's energy industry, fossil fuel generation continues to dominate the national installed capacity mix. Malaysia's percentage of renewable energy remains below the world and regional averages. In 2020, RE made up 23% of the national installed power capacity, compared to the global average of 37% and the Southeast Asia regional average of 30%. Malaysia must accelerate renewable energy deployment to meet climate targets. This can be achieved by strengthening existing programmes, introducing new approaches, and future-proofing electricity market regulations and industry practices (SEDA, 2021). Solar energy is one of the renewable energy sources, where the use of solar photovoltaics (PV) can generate electricity for the benefit of the country's energy production. The main idea of solar PV is the conversion of sunlight into electricity. The use of PV technology in conjunction with mini grids allow for the generation of electricity and its distribution throughout the country. The decreasing cost of solar panels has made power not only more affordable but also more accessible to a broader population. As a result, solar PV installations have expanded significantly in Malaysia (Vaka et al., 2020).

While the expansion of the PV projects has positively impacted energy production, it is equally important to assess potential negative impacts to ensure the well-being of local communities. According to PLANMalaysia (2023), the quality of life and well-being of the community must be prioritised in the pursuit of economic progress. A nation's prosperity is linked to societal well-being, which encompasses all aspects of life including economics, living standards, health, and safety. If certain areas of development are ignored, the quality of life will suffer. Against this backdrop, this paper aims to investigate the anticipated impacts of a proposed solar farm development project on the local community of Batang Kali, Selangor, Malaysia.

LITERATURE REVIEW

Sustainability Concept and Sustainability Variables for Solar Farm Development

Sustainability has been a major conceptual paradigm for urban development since 1987 when the call for sustainable development gained traction. The World Commission on Environment and Development (WCED) presented sustainable development in the Brundtland report, also known as Our Common Future. The purpose was to launch a global agenda to tackle the degradation of social and ecological ecosystems, which has intensified since the Industrial Revolution (Taiwo et al., 2021). According to Ozili (2022), sustainability can be defined as the capacity to allocate resources to economic and non-economic activities responsibly to attain specific social, economic, and environmental goals. There are three interwoven subjects of sustainability that describe how our world's environmental, economic, and social components interact. These circles are linked concepts that, when combined, can provide a firm foundation for key decision-making activities. Examples of such decisions include land use planning, project management, building design and construction, and even legislation (Wanamaker, 2022). Figure 1 illustrates three pillars that serve as the foundation for sustainability: economy, society, and environment. The figure also depicts the connection between the three pillars.

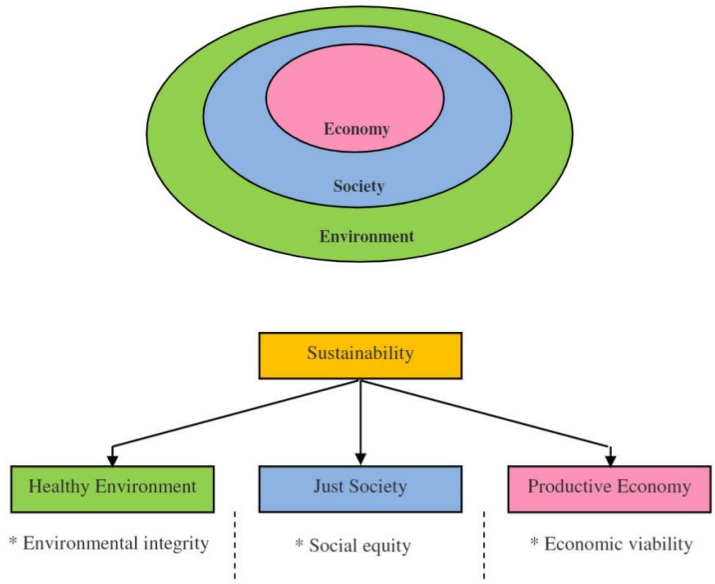


Figure 1: The Three Pillars of Sustainability
Source: Abu-Goukh et al. (2013)

The three pillars of sustainability are thought to be highly significant, particularly in the context of research for the development of sustainable solar farms. Therefore, to evaluate the impact of solar farm development on the local community from this sustainability perspective, an important group of variables was identified based on the literature from previous studies on the development of solar projects. The following are the dimensions and variables that are important for this study (refer to Table 1):

Table 1: Sustainability Dimensions and Variables for Solar Farm Development

Dimensions	Variables
Social Sustainability	Accessibility to facilities
	Safety and health
	Road and traffic risk
	Quality of life
	Cultural values & norms
Environmental Sustainability	Land use change and conservation
	Noise and solar glaring
	Air and water quality
	Carbon emissions and climate change
Economic Sustainability	Efficiency and reliability of the energy system
	Effects on business opportunities and productive diversification of the area
	Economic benefits for local community
	Employment in renewable energy sector
	Improvement of property value
	Advancement of surrounding development

Source: Adapted from Gupta (2001); Modotti et al. (2015); Mutatkar (2017); Roddis et al. (2018); Lassio et al. (2021); Hamed et al. (2022); PLANMalaysia (2023)

Local Community Acceptance of Renewable Energy Developments

According to Yiridoe (2014), the development of new renewable energy technology requires social acceptance. Lack of social acceptance among local population can hinder the adoption of renewable energy in a country. Renewal energy transitions have had both positive and negative impacts on equity and community cohesion. The current change is influenced by complicated authority and experience matrices among major stakeholders and actors. To address the needs of local communities, governance structures and organisational formats should be participatory, inclusive, and reflective of their lived experiences (Lennon et al., 2019). Based on previous research on the development of solar farms in developed nations, the researchers discovered that local support for utility-scale solar was highly influenced by perceived positive outcomes, such as employment growth and improved property value. They also discovered that, contrary to previous research, place-based beliefs (e.g., level of agreement regarding whether the place they lived was beautiful, had a great community of people, etc.) and perceived negative impacts had no significant influence on

support for utility-scale solar when controlling for other factors, such as perceived positive impacts. Other characteristics, such as perceived severity of climate change and the belief that solar development would reduce property value, were not significant predictors of local acceptance. These findings indicated that the anticipated individual and community benefits of a local solar power system are particularly significant influences on local acceptability (Scovell et al., 2024). Additionally, Bishoge et al. (2020) found that involving the community at all levels of a project leads to increased legitimacy, community ownership, and reduced conflicts during implementation, resulting in community acceptance. Other relevant components of community acceptance that may result in project resistance or lack of support include failing to consider the political context as well as local perceptions of economic, social, and environmental impacts when planning and implementing the project. All these elements are necessary for project sustainability (Tsoeu-Ntokoane et al., 2024).

STUDY AREA

According to the Selangor Structure Plan 2035, Batang Kali, Selangor, Malaysia is included in category 1 of development priority area, which includes growth centres outside the Greater KL urban hub, such as Kuala Selangor, Banting - Telok Panglima Garang, Batang Kali, Bernam Jaya and Sabak Bernam. In addition, under the MP31 policy, the development of green technologies in the energy and water supply sectors, as well as in building, waste management and transport systems, will be promoted and facilitated. There is a special initiative to promote the use of environmentally friendly power generation technologies and the use of RE, especially solar energy, as an alternative to conventional electricity systems (PLANMalaysia Selangor, 2017). Specifically, an open tender programme for solar developers has been placed under the Sustainable Energy Development Authority (SEDA) to promote the development of solar farms to support the transition towards clean and green energy.

Figure 2: Study Area: Batang Kali, Selangor, Malaysia

Figure 2 shows a 61-acre oil palm agricultural land proposed for solar farm development by a solar developer. The site is being evaluated to assess its feasibility and anticipated impact of the development before the proposal is fully implemented as a future development.

METHODOLOGY

This study employed a quantitative approach, using a questionnaire designed based on sustainability dimensions and variables. Primary data were collected through a survey of households using physical and online questionnaires. Data from the questionnaires were then analysed to assess the social impact of the proposed development. It was found that within the Zone of Influence (ZOI) of one (1) kilometre from the proposed site, there were 165 residential units: 36 units in Kampung Idaman, 107 units in Perumahan Sime Darby Ladang Tennamaram (A), and 22 units in Perumahan Sime Darby Ladang Tennamaram (B). From the sample size calculation using formulas from Rea and Parker (1997) with a confidence level of 95%, it was determined that the number of housing sample units required for this study was 116. For data analysis and storage, SPSS software was used. Each impact variable in this study was subsequently evaluated using measures of central tendency and the severity of impact based on the

median value categorised by the sustainability dimensions (refer to Table 2 below). This analysis focuses on the anticipated impact on the local community once the solar farm project is completed and becomes operational.

Table 2: Levels of Impact Severity Used in the Study

Severity of Impact						
Scale	No Impact	Very Little	Minor	Moderate	High	Very High
Score	0	1	2	3	4	5

Source: PLANMalaysia (2017)

DATA ANALYSIS AND FINDINGS

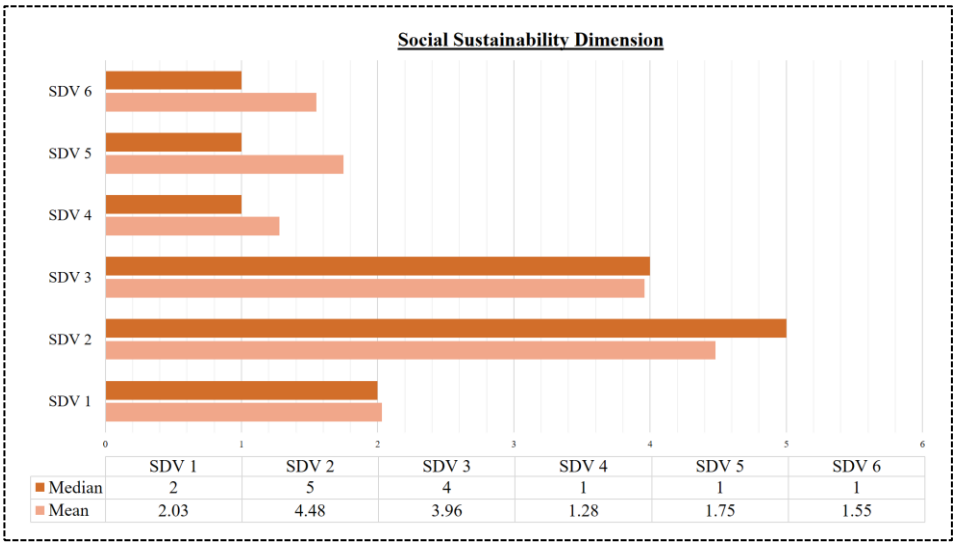
A.Social Sustainability Dimension

As indicated in Table 3 and Figure 2 below, six (6) variables were tested to assess the severity of the expected impact on the local community from the social sustainability dimension. The most significant expected positive impact was observed in variable SDV 2, with a mean score of 4.48. However, variable SDV 1 was rated unsatisfactory, with a mean score of 2.03. Regarding anticipated negative impacts, variable SDV 3 had the highest mean score of 3.96, followed by SDV 5 (1.75), SDV 6 (1.55), and SDV 4 (1.28).

The analysis revealed that SDV 1 had very little impact on the accessibility of facilities from the perspective of the local community. However, the improvement of the quality of life was expected to have a very high level of impact, with the formation solar-based communities anticipated in the future. Regarding the negative impact, the local community anticipated that the development of this solar farm would lead to overcrowding by foreigners within the local community (SDV 3), which was assessed at a high impact level.

Table 3: Dimensions, Variables and Impact Types for Social Sustainability

Dimension	**Variable**		**Impact**
Social Sustainability	*SDV 1*	Solar farm development will create and improve accessibility to the facilities around the neighbourhood.	*Positive*
	SDV 2	The quality of life will increase with the formation of a solar-based community.	*Positive*
	SDV 3	Solar farm development will overpopulate the local community with foreigners.	*Negative*
	SDV 4	Solar farm development will cause social problems which can disrupt cultural values and societal norms.	*Negative*
	SDV 5	The safety of the population will be affected (crime, road accident, natural disaster, neighbourhood safety etc.).	*Negative*
	SDV 6	Health problems and infectious diseases will increase due to solar farm development.	*Negative*



	SDV 1	SDV 2	SDV 3	SDV 4	SDV 5	SDV 6
Median	2	5	4	1	1	1
Mean	2.03	4.48	3.96	1.28	1.75	1.55

Figure 2: Result of Social Sustainability Dimension According to Local Community

B.Environmental Sustainability Dimension

EDV 1 had the highest anticipated positive impact in the environmental dimension, with a mean score of 4.22. On the other hand, EDV 2 had the highest predicted negative impact, with a mean score (3.53), followed by EDV 3 (3.14), EDV 5 (3.09), and EDV 4 (2.72). Figure 3 shows that, based on the median score for this dimension, the level of impact was high to moderate. For the expected positive impact in general, the local community expected that the solar farm development would have a good impact on the environment, particularly in reducing carbon emissions compared to conventional methods in energy production. In addition, they foresaw negative impacts on land use, with this development likely to result in future land use conflicts. They anticipated that the conversion of agricultural land to infrastructure would undoubtedly have an impact on development in the surrounding area, particularly in neighbourhoods near the proposed site. This was followed by other environmental impacts, such as influence on land degradation, habitat loss, noise, air, and water quality, and the impact of solar glare.

Table 4: Dimensions, Variables and Impact Types for Environmental Sustainability

Dimension	Variable		Impact
Environmental Sustainability	*EDV 1*	Solar farm development will reduce carbon emissions compared to conventional energy use.	*Positive*
	EDV 2	Solar farm development will cause land use conflicts.	*Negative*
	EDV 3	Solar farm development will cause land degradation and habitat loss.	*Negative*
	EDV 4	Solar farm operation will cause solar glaring.	*Negative*
	EDV 5	Solar farm development will have a significant impact on noise, air and water quality.	*Negative*

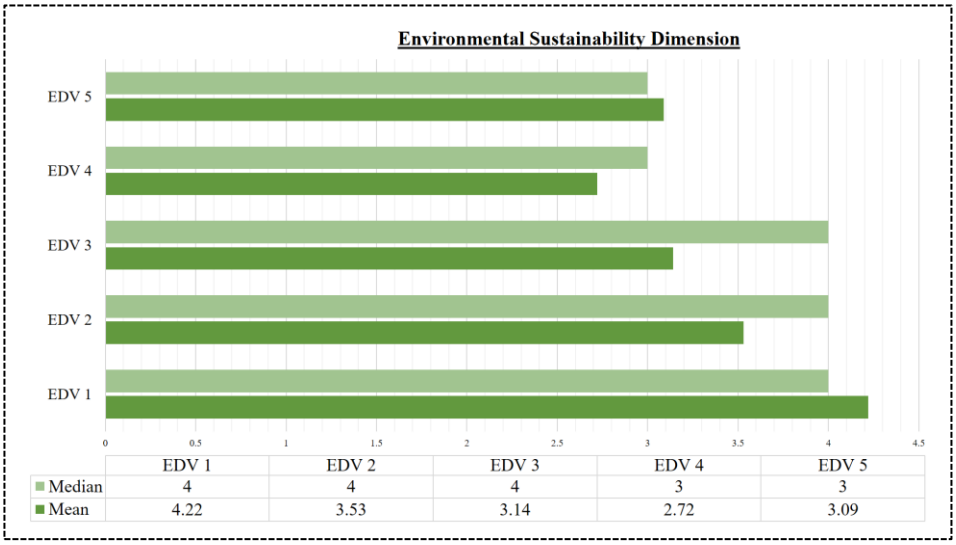


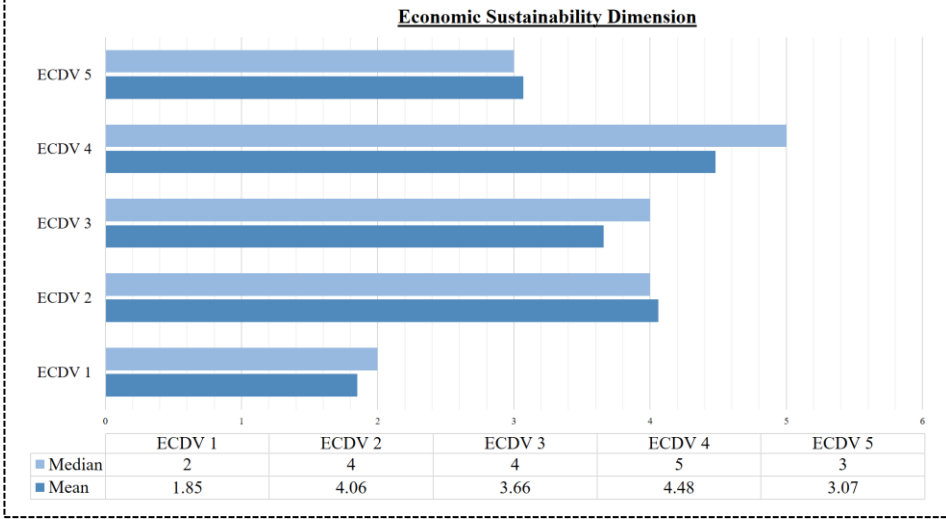
Figure 3: Result of Environmental Sustainability Dimension According to Local Community

C.Economic Sustainability Dimension

All the economic sustainability impacts were positive. Table 5 and Figure 4 show that the variables with the highest mean score were ECDV 4 (4.48) and ECDV 2 (4.06). These were followed by ECDV 3 (3.66), ECDV 5 (3.07), and ECDV 1 (1.85). A noteworthy result regarding this economic dimension is the anticipated high impact from solar farm development, which would help the local community by generating sustainable energy. Another significant impact concerned the development of surrounding neighbourhood. The local community believed solar farm development would accelerate the development of the surrounding neighbourhood. However, the local community did not expect the solar farm development to create job prospects for them; they believed this variable would have a minor impact.

Table 5: Dimensions, Variables and Impact Types for Economic Sustainability

Dimension	Variable		Impact
Economic Sustainability	*ECDV 1*	Solar farm development will provide employment opportunities to the local community.	*Positive*
	ECDV 2	Solar farm development will advance the development of the surrounding area.	*Positive*
	ECDV 3	Solar farm development will improve the socio-economy of the local community.	*Positive*
	ECDV 4	Solar farm development will benefit the community with renewable energy generation.	*Positive*
	ECDV 5	Solar farm development will increase property value.	*Positive*



	ECDV 1	ECDV 2	ECDV 3	ECDV 4	ECDV 5
Median	2	4	4	5	3
Mean	1.85	4.06	3.66	4.48	3.07

Figure 4: Result of Economic Sustainability Dimension According to Local Community

DISCUSSION

The main outcome of this study was derived from the social dimension, where the local community expected their quality of life to be boosted as a result of the development of a solar-powered community. They believed that the development of this solar farm would improve the environment by lowering carbon emissions compared to conventional energy production. In terms of the economic dimension, the community anticipated that the surrounding development would accelerate, as would the socioeconomic development of the local population, who would profit from the RE generation. However, negative effects were also expected to occur in each dimension and measured variable. The local community's attention was specifically focused on the impact of an overpopulation of foreigners, land use conflicts, land degradation and habitat

loss. This indicates that the local community had a deep awareness of sustainability in terms of the importance of protecting the environment. The findings also indicate that each dimension and variable is essential in protecting the community's interest in the proposed development in a sustainable manner. Consequently, the findings could assist policymakers and developers in considering appropriate mitigation measures for minimising the impact on the community, particularly for solar development projects. Furthermore, research associated with the development of solar farms, especially in Malaysia, is considered to be less thorough than in developed nations that utilised solar energy as their main energy production. As confirmed by a study conducted by Sahid et al. (2021), promoting solar energy generation has led to multiple challenges, particularly in terms of solar farm development, which is still in its early stages and lacks sufficient guidance. This study also serves as the foundation for solar farm development projects by assessing their impacts on the local community as well as contributing to the body of knowledge and practices of impact assessment practitioners specifically in managing solar farm development within the local context.

CONCLUSION

Malaysia's energy sector requires significant support at all levels of stakeholders in infrastructure development. RE is an endeavour that contributes to the achievement of national energy development goals and strategies while also moving the country towards energy efficiency and low carbon emissions. However, dealing with the impact on the local community in a sustainable manner is vital to the project's development and defines its success factor. The development of solar farms based on project size also has a significant impact on the local community and surrounding environment. In contrast to this case study, the development of large-scale projects is expected to generate a greater impact.

Although the approach taken in this study is quantitative, a qualitative method may also assist in the deeper meaning and interpretation of issues, particularly in analysing the impact on the community and stakeholders involved in solar farm development. This study recommends that further research be conducted, particularly in urban planning and project management, to ensure that solar farm project development mechanisms are sustainable and comprehensive.

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THE DELAY OF PLANNING PERMISSION APPLICATION OF TAHFIZ INSTITUTION IN SELANGOR

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Abstract

This paper investigates the delays in planning permission applications for Tahfiz institutions in Selangor. Malaysia experiences a significant number of illegal constructions that are built without the required planning licences, primarily due to insufficient monitoring and enforcement by local authorities. The absence of supervision results in unapproved constructions that can potentially endanger safety and hinder urban planning initiatives, and this includes the illegal construction of Tahfiz Institutions. There is no proper regulation on the development of Tahfiz Institution in terms of its Planning Permission until the year 2020. In 2021, the Selangor state has established a guideline on the Legalisation of Private Religious Schools (Tahfiz Institution) after the wake of the tragic incident of a deadly fire at Tahfiz Darul Quran Ittifaqiyah in September 2017. A purposive sampling method is chosen for expert interviews. Through interviews with two professional town planners responsible for preparing submissions, two town planning officers from the local authority involved in evaluating planning permissions, and an owner of a Tahfiz institution who has experienced the submission process, as well as a review of secondary data, several key factors were identified: regulatory complexity, a lack of awareness and understanding of technical requirements, inefficiencies in government initiatives, resource constraints, and extended timelines due to technical requirements. The study highlights the significant implications of these findings for the development and operation of Tahfiz institutions. Simplifying regulatory processes, enhancing awareness and educational efforts, improving implemented guidelines, providing financial support, and strengthening coordination among agencies are recommended to address these challenges. Correspondingly, the study acknowledges its limitations, including its focus on the planning permission process. By addressing the identified factors, policymakers can create a more supportive environment for the growth and sustainability of Tahfiz institutions in Malaysia.

Keywords: Urban planning, planning permission, one-stop centre, illegal construction, regulatory process

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INTRODUCTION

Development control is one of the crucial components of urban and regional planning as it helps to regulate and manage the land development and buildings in an area. In Malaysia, development control is submitted through a planning permission process at the respective local authority. It is a mechanism to maintain standards and processes laid down by legislation, which regulates the development of land and buildings (Ifediora, 2019; Marzukhi et.al., 2019). It is a legal procedure that has provided local authorities with the power of jurisdictions' responsibilities to access the ideas and policies and implement town planning concepts to actual development. The way authorities in Malaysia control development is through the Planning Permission application. Tasantab (2016) highlights that planning permission or construction permits are crucial for systematic urban development. Any development project or construction must first obtain planning permission and go through the whole process until it receives a Certificate of Completion and Compliance (CCC). This is done to verify that the premises are suitable and secure for the occupancy of people.

Tahfiz institutions in Malaysia have experienced extensive growth and development over the years, and they have played an invaluable part in the preservation and education of the Quran. Tahfiz schools are institutions that are accountable for educating students who can memorise and recite the whole Al-Quran (Hassan et. al., 2015). In recent years, the Malaysian government and private organisations have strengthened their support for these institutions, acknowledging their significance in the development of religious scholars and the promotion of Islamic education in the nation. Furthermore, the government and pertinent authorities have initiated the process of prioritising safety concerns in the construction of Tahfiz institution buildings to ensure a secure and conducive learning environment, especially in terms of safety measures.

In order to ensure the safety of Tahfiz institution buildings, all construction projects must undergo a comprehensive development procedure. The government is particularly concerned about the planning permission for Tahfiz institutions, especially in Selangor. PLANMalaysia@Selangor established a comprehensive guideline in 2021 to address the issue of illegally constructed Tahfiz schools in the state. The objective of this paper is i) to study the process and procedure of submission for planning permission for Tahfiz Institution, and ii) to investigate the delay factors in preparation of planning permission for Tahfiz Institutions, with the focus on ensuring compliance to safety established standards and regulations.

The outcome of this paper will identify different issues which may linked to the submission of planning permission such as the competency of submitting person, land ownership issues, related policies and requirements by authorities, financial challenges and other core issues that affect the owner of Tahfiz institution from submitting the planning permission.

LITERATURE REVIEW

Development Control

Based on the Town & Country Planning Act 1976 (Act 172) "development" means the carrying out of any building, engineering, mining, industrial, or other similar operation in, on, over, or under land, the making of any material change in the use of any land or building or any part thereof, or the subdivision or amalgamation of lands; and "develop" shall be construed accordingly. Development encompasses any activities related to construction, engineering, mining, or industrial operations on land, as well as alterations in land or building use, and dividing or amalgamation of land. Development control is the process of controlling and regulating how land, buildings, and other physical structures are built and used so that the public interest is served and protected. The goal of development control is to ensure that new buildings fit in with the area around them and meet the standards needed to protect the health, safety, and the environment. Rabe (2011) stated that development control is a legal procedure that has provided local authorities with the jurisdiction and responsibility to translate ideas and policies of town and country planning into reality. The process includes preparing and implementing development plans such as the local plan and granting or objecting to planning permission in the area under its localities.

Planning Permission

Planning permission is a crucial step in the development control process, ensuring that new developments are in line with the intended purpose of the area. Planning permission is the written approval granted by a local government or planning authority to permit the development or use of land, buildings, or infrastructure in accordance with the provisions of local planning policies and regulations. Based on the Town and Country Planning Act 1976 (Act 172) as stated in section 19(1): "No person, other than a local authority, shall commence, undertake, or carry out any development unless planning permission in respect of the development has been granted to him under section 22 or extended under subsection 24(3)". In the context of Malaysia, planning permission is a legal process which will be granted by local authorities where the process will be through the One Stop Centre (OSC) at each respective local authority (Marzukhi et al., 2019). The latest OSC 3.0 Plus manual (2019) has classified planning permissions into three categories which are small, medium, and large-scale planning permission. The categorisation of planning permission categories according to the level of intensity and risk associated with development is essential in establishing the approaches used in processing the planning permission approval. This includes the number of days needed by the local authority for processing and the list of necessary documents to be submitted with the application.

The classification of planning permission for a Tahfiz institution may be classified as either small or medium scale, depending on the size and scale of

the project. This is because a small-scale Tahfiz school may need the construction or conversion of a structure to accommodate a limited number of students. This aligns with the requirements for the small category, which includes residential projects of up to 4 units or the development of a single residential unit. An example of a small-scale project would be the creation of a Tahfiz centre in a residential area, which can accommodate less than 10 students and does not cause substantial changes to land use or infrastructure. In contrast, a medium-scale Tahfiz institution would include the construction of a more extensive complex with many buildings that can accommodate a greater number of students. This may also require incorporating public facilities and enhancements to the surrounding infrastructure. An example of this would be the construction of a Tahfiz school comprising dormitories, classrooms and recreational spaces on a land area of less than 100 hectares. This development would have a population effect of fewer than 10,000 and would need the approval of a layout plan. Consequently, it would fall within the medium category. A project of this type may also include vital public amenities and comply with the minimum plot ratio and density standards set by the local planning authority. The planning permission is the initial phase in the development process, which is preceded by the approval of building plans, engineering plans for roads and drainage, and landscape plans. This critical phase is to ensure that the proposed development adheres to all pertinent regulations and standards prior to the submission of more detailed and technical plans for review. The authority and technical agencies will give feedback during the approval process and the local authority has the right to approve, reject or postpone the decision.

One Stop Centre

In Malaysia, the process of obtaining planning permission for all types of developments or construction projects is streamlined through the latest One-Stop Centre 3.0 PLUS (OSC 3.0PLUS) system (Kamaruddin et. al., 2020). This system is managed by the Department of Local Government under the Ministry of Housing and Local Government (KPKT). The One-Stop Centre (OSC) system in Malaysia is a dynamic process that responds to current development situations and advancements in information technology which is continuously evolving. The objective of this development is to improve the efficacy and responsiveness of the planning permissions submission and approval processes. The transition from manual to entirely digital submissions, the reduction in approval periods, and the reduction in the number of agencies involved are all significant improvements. The Prime Minister announces improvements to one-stop centre procedures efforts to expedite the development approval period are believed to be able to indirectly improve the investment environment in addition to increasing the country's competitiveness (Bernama, 2023). The objective of these updates is to enhance the country's competitiveness and establish a more

favourable investment environment by expediting the approval process for development. Based on Manual 3.0 PLUS (2019) on 25 Processes and Procedure of Development and Implementation of OSC, there are six main processes, as shown in Figure 1.

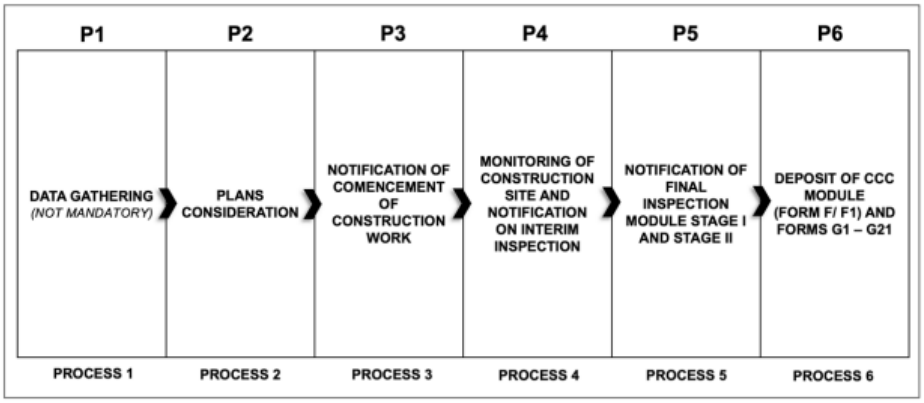

Figure 1: Six (6) main processes of OSC 3.0 PLUS Process
(Source: OSC 3.0 PLUS Manual, 2019).

Factors Influencing the Delay of the Planning Permission Process

Delay is the act of postponement or prolonging the expected timeframe for something to occur or to be completed. In line with Tariq and Gardezi (2023), delay is defined as the period of time that goes beyond the designated contract date. It refers to circumstances in which activities, processes, or events do not occur as planned, causing a delay or interruption. Delay in construction projects is one of the most recurring issues in construction projects worldwide where it can be defined as the lateness of completion, either exceeds the date specified in the contract or the date decided by the parties for delivery of the project (Tawfek & Bera, 2018). Delays may arise from a variety of variables including unexpected events, lack of resources, complicated procedures, or reliance on external factors.

Most researchers have highlighted several factors that can influence the delay, including financial difficulties, poor coordination between clients and consultants, incomplete submissions, and incompetence of consultants. The planning permission process is a critical component of urban development and infrastructure projects, as it serves as the gateway for the implementation of necessary initiatives. Based on past research, delays in the development that include in designing, planning and construction stages are common and can significantly hinder the progress of a project. To address this challenge, it is essential to identify the key factors that contribute to the delay in this stage. By identifying and addressing the key factors that contribute to the delay in the planning permission process, stakeholders can facilitate the timely implementation of necessary urban development and infrastructure projects,

ultimately supporting economic growth, community well-being, and environmental sustainability.

RESEARCH METHODOLOGY

This study conducts qualitative research, which involves an in-depth interview with the local authority's professional town planners and planning consultants. The interview is described as an information-gathering device that is normally conducted face-to-face or through a phone call interview. The interviewing mode can be defined as a conversation with the purpose of specifically gathering information (Berg, 2004). To get at the essence or basic underlying structure of the meaning of an experience, the narrative interview or people's story or experience is the primary method of data collection. Prior to interviewing those who have had direct experience with the process, the researcher usually explores his or her own experiences, in part to examine dimensions of the experience and in part to become aware of personal prejudices, viewpoints, and assumptions (Berg, 2004; Merriam, 2009). Therefore, the in-person interview is chosen to be one of the methods to collect data from the professional town planners who are experienced in the process of planning permission for Tahfiz Institution. The two primary types of interviews are structured and semi-structured, each with its unique characteristics and applications.

To ensure the integrity of all data and information during the interview session, voice recording and note-taking techniques are used. The two techniques are used to enhance the reliability of the data and to ensure that there is no missing data throughout the information-gathering session. The researcher used an interview method to obtain information about the factors that influenced the delay of planning permission application of Tahfiz institutions, to align with the study goals and objectives. Therefore, five interviewees who were involved in the planning permission application were selected, as well as the professional town planner who prepared the submission, the town planning officer at the local authority responsible for the evaluation of planning permission, and the principal or owner of Tahfiz institutions who went through the submission process. During the course of the interview session, several questions need to be modified in order to align with the interviewees' expertise and understanding.

For the data analysis, a thematic analytic technique is used to investigate the perspectives and experiences of different stakeholders. The aim is to understand the elements that impact the efficiency of planning approval. This paper aims to gain a comprehensive understanding of the perception and impact of the various parts of the planning permission process on its delay factors through a thorough analysis and identification of themes. This thematic analysis will provide in-depth and precise insights into the complexity of the planning permission process, emphasising important areas that should be improved and informing policy and practice. According to Kiger and Varpio (2020) the

thematic analysis process typically consists of six key steps, they are: 1) Familiarisation with Data; 2) Generating Initial Codes; 3) Searching for Themes; 4) Reviewing Themes; 5) Defining and Naming Themes; and 6) Producing the Report/ Manuscript.

The goal of analysing qualitative data from interview sessions is to identify patterns, themes, and relationships in the data that can help answer the research questions. The method that will be used to analyse the qualitative data from the interview session is content analysis which involves identifying the interview transcripts. This will be done using the computer-assisted qualitative data analysis software Nvivo, which will identify and categorise themes, and summarise the data to identify patterns and relationships.

ANALYSIS AND DISCUSSION

Planning permission is a critical step in the construction process, and delays in obtaining it can have significant consequences for the overall project timeline and budget. This chapter presents the findings from an expert interview with town planners at the local planning authority. These planners are responsible for preparing submissions, while others at the authority evaluate and investigate the factors that contribute to delays in obtaining planning permission. Five primary themes were identified, each consisting of subthemes that describe the elements that contribute to these delays. These main themes are summarised in Figure 2. The objective of this review was to understand specific components of the planning permission procedure that experts had identified as the cause of delays and to examine how these variables impacted the approval process for Tahfiz institutions. Additionally, a comprehensive qualitative commentary is included in the findings section.

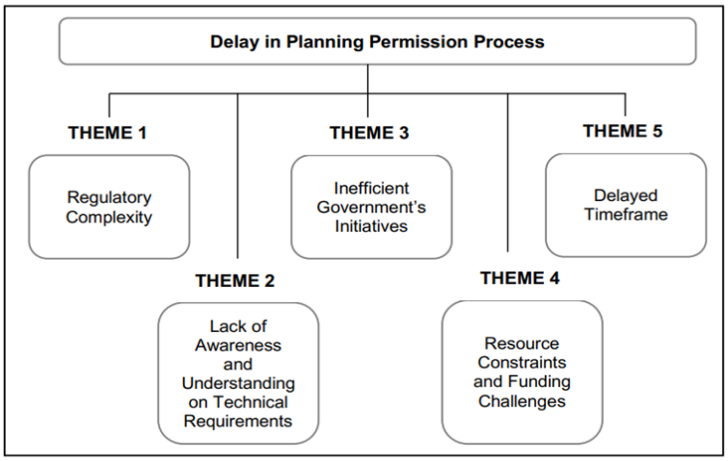

Figure 2: The illustration of the main theme of factors influencing delay in the planning permission process

Theme 1: The Regulatory Complexity

The subject matter explores the complex and extensive layers of legislation and administrative processes that are responsible for causing delays in obtaining planning permission for Tahfiz institutions. Applicants often face a hard environment due to the need to adhere to several requirements from various agencies, which often results in extended approval periods. Tahfiz institutions must navigate through an extensive number of processes, each with its own distinct needs and norms, due to the complex structure of the regulatory framework and process.

Theme 2: Lack of Awareness and Understanding of Technical Requirements

The efficient implementation of the Tahfiz submission procedure often faces significant challenges because of an extensive absence of knowledge and understanding among Tahfiz owners about technical requirements. Many of these owners, who are usually non-experts or are laymen with no experience in development processes, have challenges in understanding and dealing with the complex requirements and regulations of the authority. This challenge of lacking knowledge not only hinders their ability to adhere to fundamental requirements but also leads to delays and inefficiencies in the submission procedure.

Theme 3: Inefficient Government Initiative in the Legalisation of Tahfiz Institution

For the legalisation of the Tahfiz program in Selangor, there are two levels of involvement, they are the state government, which acts as the policy maker, and the local government, which serves as the implementer. The state government of Selangor has implemented specific guidelines through PLANMalaysia@Selangor to standardise Tahfiz institution submissions. These guidelines have been in place since 2021.

After the implementation of the guidelines, feedback from town planners- consultants and the local authorities, indicates that these rules have not been helpful, as the submission process still requires adherence to the same standards as other types of submissions. It can be said that the guidelines are too general, and most requirements are stated as being subject to the local authority. Relating to this, government initiatives should include the establishment of specific, clear guidelines to streamline the planning process, ensuring that all stakeholders have a transparent and consistent framework to follow, thereby reducing uncertainties and delays. Gallent et al. (2019) emphasised that identifying the key drivers of delays is crucial, as it would enable policymakers and stakeholders to implement targeted measures to enhance the planning system's efficiency and expedite project delivery.

Theme 4: Resource Constraints and Funding Challenges

Most Tahfiz institutions encounter significant financial challenges and resource constraints. These institutions frequently operate on very limited budgets, relying substantially on community support and donations. This financial instability could hinder their capacity to improve facilities, deal with very important consultants and professionals for compliance and submissions or meet regulatory requirements.

It shows that Tahfiz Institutions may have difficulty covering the expenses associated with the preparation of detailed plans and documents that are required by the authorities, which can result in delays in project implementation due to a lack of sufficient funding. Furthermore, the infrastructure and services that are offered by Tahfiz institutions may be compromised by resource constraints, which may impact their overall quality and sustainability. This shortage or insufficiency of resources can be related to financial challenges, which can delay the planning permission process. Toor and Ogunlana (2008) highlighted that delays in construction projects were primarily caused by shortages or insufficiencies in the industry's infrastructure, particularly in terms of resource supply. Financial challenges can impede various stages of a construction project, including the crucial planning permission process. When the Tahfiz owners face financial insufficiency, they may struggle to pay the consultant fees, and planning permission fees to the authority, and to comply with the regulatory requirements in ensuring safety standards.

Theme 5: Delayed Timeframe of Planning Permission

The timeline for the planning permission process is typically related to the category of the planning permission. As explained in the Manual OSC 3.0 PLUS, which was reviewed in the literature, planning permissions fall into three main categories- small scale, medium scale, and large scale. Each category is assigned a recommended timeframe for the duration of the procedure, starting with the submission of the application until its approval. Based on expert interviews, most Tahfiz institutions fall under the medium-scale category, which includes free-standing buildings such as bungalows on individual lots.

The timeline for obtaining planning permission for Tahfiz institutions varies greatly depending on multiple factors. In a seamless preparation process, when documentation is completed and the owner is prepared to engage and appoint professionals, plans and reports can be completed around two months. However, land ownership issues may greatly increase the timeframe of project approval. Additionally, the issues of right of way, such as passing through an Orang Asli village might cause the procedure to be delayed by up to a year. This is because the planners and Tahfiz owners need to coordinate with other agencies to resolve the land matters or legal right of way to the site.

The findings reveal several key factors contributing to the delay in planning permission applications for Tahfiz institutions. These factors are as follows: 1. The submission procedure is complicated by the extensive and complex regulatory framework, which includes several requirements and involves different technical agencies even though it has special guidelines on the legalisation of the Tahfiz programme. This complexity often leads to bureaucracy and delays in obtaining the necessary approvals; 2. Numerous Tahfiz owners and operators have insufficient knowledge and comprehension of technical requirements, resulting in delays in the preparation of documents for the submission of planning permissions. The lack of awareness emphasises the need for focused outreach efforts to provide Tahfiz owners with the necessary information regarding the planning permission process from preparation to endorsement of plans; 3. Despite efforts to streamline the legalisation process for Tahfiz institutions, the Tahfiz guidelines that are provided have not effectively simplified the submission process. Many requirements remain subject to local authority discretion, resulting in the typical submission of planning permission that causes further delays since Tahfiz cannot comply with the technical requirements; 4. Financial limitations and resource constraints also hinder Tahfiz institutions' ability to appoint professional consultants and meet regulatory requirements. These constraints contribute to delays as institutions struggle to allocate the necessary resources for compliance; 5. The timeline for planning permission approval is often extended due to technical requirements and development issues such as land ownership and the need for special additional permits. These delays are exacerbated by bureaucratic inefficiencies and a lack of coordination among the relevant agencies.

Furthermore, the findings have significant implications for the development and operation of Tahfiz institutions in Selangor. The regulatory complexity and lack of awareness among Tahfiz owners highlight the need for simplified processes and increased educational efforts to ensure compliance. The inefficiency of government initiatives suggests that clearer and more streamlined guidelines are necessary to facilitate the legalisation process. Resource constraints and funding challenges underscore the need for financial support and innovative funding mechanisms to help Tahfiz institutions meet regulatory requirements.

CONCLUSION

In conclusion, this paper has identified several factors contributing to delays in the planning permission process for Tahfiz institutions in Selangor. By addressing these factors through simplified regulations, increased awareness, clearer guidelines, financial support, and improved coordination, the development and operation of Tahfiz institutions can be significantly facilitated. However, this paper has several limitations. First, it focuses solely on the

planning permission process, excluding the post-approval stages. Second, the study relies on qualitative data from expert interviews, which may not fully represent the situation in other local authorities in Selangor. Thus, future research can explore the post-approval stages of the development process and expand the study to include local authorities to provide a more comprehensive understanding of the issues that are faced by Tahfiz institutions across Malaysia.

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DIGITAL TWIN APPLICATION IN CONSTRUCTION COST MANAGEMENT

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Abstract

In line with the current construction revolution, it is time for the construction industry to embrace innovation and technology. This is corresponding with the National Construction Policy 2030 (NCP 2030) that comes out with the aim to digitalize the entire construction industry towards the IR 4.0. The focus is to boost the nation's construction industry's competitiveness and recognition worldwide. The construction industry has undergone a significant transformation in recent years such as BIM, IoT including Digital Twin due to the incorporation of digital technologies. A digital twin is a virtual representation of a physical asset. It is still a relatively new concept in the construction industry, but it offers an innovative method for improving cost management strategies in construction projects. Applications of the digital twin in construction cost management have the potential to revolutionize conventional methods. Therefore, this study seeks to determine the level of understanding of construction industry players on the concept of digital twin applications in construction cost management by providing the concept and to explore the challenges and strategies in implementing the digital twin applications in construction cost management. This research employed a mixed-method approach by means of questionnaire survey and interview for data collection. 35 samples that consist of construction industry players from different organizations participated in this study. The data collected from the survey and interview are analyses through descriptive and content analysis. Overall, the findings find out the understanding of digital twin applications with its challenges and strategies to overcome it. This research contributes to the body of knowledge regarding digital twin applications and construction cost management.

Keywords: construction cost management, challenges, digital twin, strategies

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INTRODUCTION

In the early stages of the construction industry, conventional methods like manual progress tracking were used to manage projects. These outdated approaches negatively impacted productivity and quality, largely due to reliance on unskilled manual labor (Santi Edra et al., 2021). With the increasing complexity of projects and the demand for reduced timelines, improved quality, and lower costs (Garcia de Soto et al., 2019; Cristóbal et al., 2018), adopting modern technologies has become essential for maintaining competitiveness.

The Fourth Industrial Revolution (IR 4.0) marks a significant technological leap, with digital twin technology playing a pivotal role. A digital twin involves a digital model, a physical twin, and a connection between them, using real-time data and IoT connectivity (Khajavi et al., 2019). This technology enhances operational efficiency, enabling predictive maintenance and better decision-making. It streamlines traditional construction processes, covering economic conditions, physical environments, and project execution (Reja and Varghese, 2022).

This research focuses on the application of digital twin technology in construction cost management. Cost management spans from initial cost estimation to ensuring project completion within budget and on schedule. Success in construction projects hinges on the balance between cost, time, and quality, where any change in one affects the others (Albtoush et al., 2020). Effective cost management prioritizes efficiency, client satisfaction, and profitability. The study explores how digital twin technology can optimize cost management by improving accuracy, reducing inefficiencies, and ensuring better control throughout the project lifecycle. By leveraging digital twin technology, construction projects can achieve greater alignment with budgets, schedules, and quality standards, ultimately driving project success.

LITERATURE REVIEW

Digitalisation Revolution in Construction Industry

A digital twin is a virtual representation of a physical object or system that simulates its behaviour in real time. In the construction industry, digital twin pertains to a computer-generated replica that incorporates both the design and construction phases offering a full and up-to-date perspective on the project's advancement. A digital twin can be used in project cost management to produce a virtual version of a construction project that can be used to analyse and manage expenses. Khajavi et al., (2019) said the usage of a digital twin for performance is crucial, and it has proven to be successful in terms of cost savings and reliability improvements for capital-intensive equipment such as jet engines. Bademosi et al. (2019) found that these technologies have been associated with improved employee skill development, reduced task redoing, enhanced safety perception, lower labour costs, and improved project deadline outcomes. This is achieved

through the integration of simulations with experts' domain knowledge, enabling the use of digital twin in the construction sector. In contrast, Shen (2022) said that the construction sector has historically seen limited uptake of technological advancements in the execution of projects. This phenomenon may be attributed to the prevalent practice of extensive planning and execution in the building industry, sometimes spanning many years.

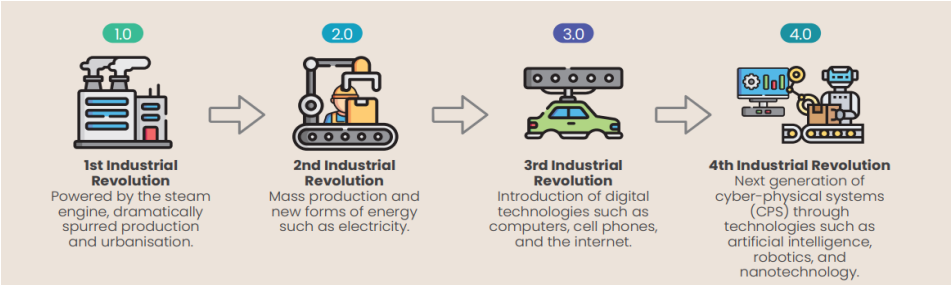

Figure 1: Revolution of Industry
Source: CIDB, 2020

Industrialization has progressed through several key revolutions. Figure 1 illustrates the paradigm shift in the technological revolution. The First Industrial Revolution marked the shift from manual labor to mechanized production. The Second Revolution brought major technological advancements in steel, electricity, communication, and transportation. The Third Revolution transitioned from mechanical to digital technologies, paving the way for the Fourth Industrial Revolution, which enables the digital transformation of industries. This transformation is largely driven by the exponential growth in computational power and the increased accessibility of electronic data (Reischauer, 2018). The COVID-19 pandemic significantly accelerated digitalization, resulting in a marked increase in the use of mobile and cloud computing. According to the McKinsey Global Institute (2020), this surge led to a twofold increase in revenue compared to pre-pandemic projections. This trend is expected to continue as industrialized nations strive to recover economically. Cyber-physical systems, which integrate physical processes with digital technologies, have the potential to save both time and costs, contributing to long-term economic recovery.

Digital Twin

A digital twin is a virtual replica of a physical object that captures and transmits real-time data from the actual asset, creating a digital version. It allows for feedback from the digital world to the physical entity (Madubuike et al., 2022; Fu et al., 2022; Attaran and Celik, 2023). Figure 2 shows how the real space and virtual space are connected by digital twin technology. The technology connects

real and virtual spaces, simulating complex processes and behaviors interacting with the environment (Magomadov, 2020). Digital twins can be used in various contexts and are built with data from tools like Building Information Modeling (BIM) and sensor systems. By integrating data through machine learning algorithms, they offer insights across different project phases, enabling real-time monitoring, simulations, and quality assessments.

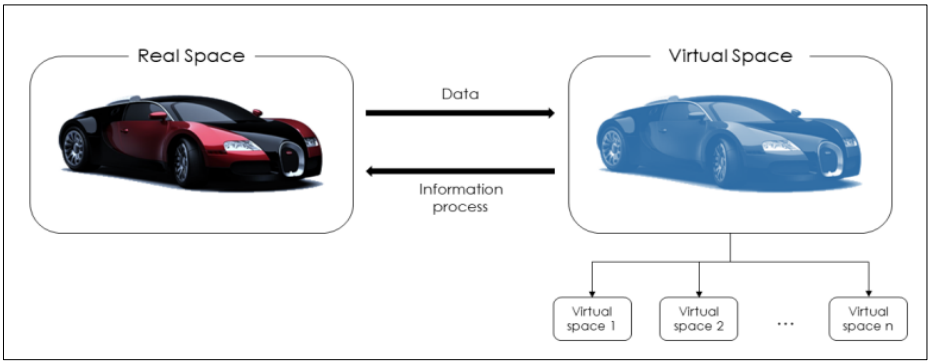

Figure 2: Implementation of Digital Twin
Source: Barricelli et al., 2019

Digital Twin in Construction Industry and Other Sectors

Digital twins enable the simulation and visualization of complex systems, with growing applications in the construction sector. El Jazzar et al. (2020) highlight that digital twin, evolving from Building Information Modeling (BIM), can help transform the construction industry. Liu et al. (2020) note that digital twins could improve safety in construction by integrating AI, sensors, video cameras, and mobile devices to create a comprehensive safety framework. Digital twins allow for real-time monitoring of construction processes and project managers to simulate scheduling scenarios, assess resource utilization, and identify potential conflicts. Lydon et al. (2019) suggest that digital twins can support different construction methods and enhance risk management by modeling various scenarios. By capturing real-time data, digital twins improve decision-making compared to static BIM data, offering better oversight for construction managers, designers, and clients (Tang et al., 2019).

Construction Cost Management

Herszon (2017) says that cost management is the systematic estimation of costs related to the various activities and endeavours necessary for the successful completion of a project. According to Verbeeten (2011), the scope of cost estimation extends beyond just financial considerations and involves the utilisation of management accounting principles, techniques for gathering and analysing data, and methods of presenting information. The implementation of

effective project cost management practises guarantees the successful completion of a project within the allocated budget and in accordance with the predetermined scope. Girma and Alemu, (2018) states that the need of efficiently managing construction costs is widely acknowledged as a crucial element in attaining project success and is a significant task that needs to be done with accuracy. The total cost management process encompasses all stages of development, as depicted in Figure 3. During each step, the execution of cost management activities should be carried out by professionals like Quantity Surveyors (QS) or cost managers.

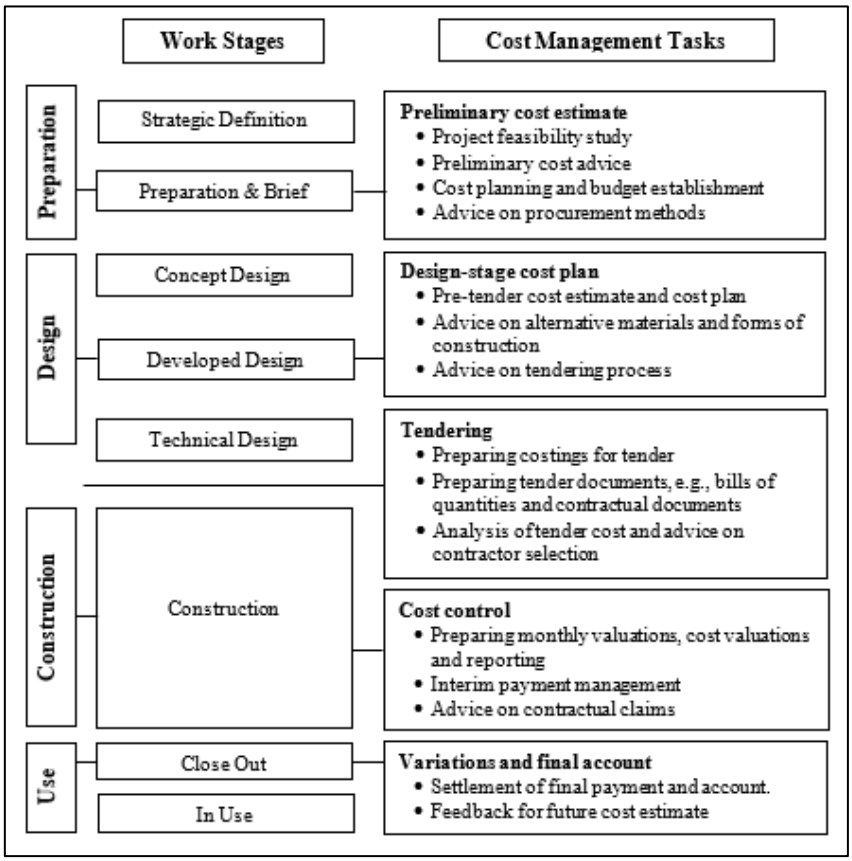

Figure 3: Cost Management Activities by following RIBA Plan of Work
Source: Weisheng et al. 2019

Digital Twin in Construction Cost Management

Challenges and Strategies for Implementing of Digital Twin in Construction Cost Management

Digital twin technology, which creates virtual representations of physical objects or structures, supports informed decision-making in cost estimation, streamlines construction coordination to reduce time, and improves risk management. However, its implementation can face challenges unforeseen by clients, consultants, contractors, and stakeholders. Despite the benefits of digital twins, challenges arise from factors such as knowledge, technology, governance, and economic issues, particularly in Malaysia's construction sector. To overcome these challenges, it is essential to analyze and implement effective strategies, supported by four key enablers: people, integrated technology, governance, and economy.

RESEARCH METHODOLOGY

This study uses questionnaires and interviews to collect data from construction industry participants, both directly and indirectly involved in the construction process. Questionnaires, which include both closed and open-ended questions, are distributed via email, Google Forms, and social media platforms like LinkedIn, targeting 70 respondents. The data is analyzed using the Statistical Package for the Social Sciences (SPSS), with frequency distribution and central tendency measurements to identify key patterns. A Likert scale is used to gauge the extent of agreement with digital twin applications in construction cost management, categorized into low, medium, or high based on mean values. Additionally, four experienced respondents are interviewed to provide insights on challenges and strategies for implementing digital twin technology. Content analysis is employed to examine and categorize responses from the interviews.

ANALYSIS AND DISCUSSION

Questionnaire Survey

The first part of the questionnaire is to know the level of understanding and agreement of respondents on the concept of digital twin applications in construction cost management. This section aims to achieve the main objectives.

Table 1: Result of Digital Twin Application in Construction Cost Management

Digital Twin Application in Construction Cost Management	Mean
Analysis and Optimization - Digital twins can be used to analysis by simulating and evaluating cost projection in virtual environments, this is to avoid loss, cost overruns, minimise the risk and helps in decision making.	3.8857
Real-Time Cost Tracking - Digital twins allow real-time tracking and costing of construction projects through the use of sensors, Internet of Things (IoT) and project management tools to track labour productivity, materials and equipment used for projects.	3.8571
Risk Management - Digital twins facilitates construction project manager in risk management related to cost, i.e.: risk identification, risk mitigation, risk allocation etc.	3.8571
Cost Estimation - Digital twins facilitate accurate cost estimation using data provided from architectural and engineering designs, material, labour and machinery rates and others.	3.8000
Lifecycle Cost Analysis - Digital twins analyse the lifecycle of a building, including maintenance, operational, energy consumption, and cost data for cost management.	3.7714

The analysis of Table 1 shows that all concepts of digital twin application in construction cost management received high scores, with mean values above 3.50. The majority of respondents agreed that digital twin technology helps with analysis, optimization, and cost projection in virtual environments, minimizing risks and cost overruns (mean value of 3.89). The lowest mean value, 3.77, relates to digital twins analyzing a building's lifecycle, including maintenance, operations, energy consumption, and cost data. The research also aims to identify the challenges faced by Malaysian industry players in adopting digital twin technology for cost management and to recommend efficient strategies for overcoming these challenges. Respondents shared their opinions using a Likert scale, with a focus on identifying obstacles and potential solutions. Although digital twins are widely used in aerospace, manufacturing, and industrial engineering, their implementation in construction remains limited (Madubuike et al., 2022). Respondents strongly agreed that digital twins integrate multiple software types, facilitating the creation of virtual models and linking them to real-world objects. This aligns with Madubuike et al.'s (2022) research, which emphasizes that digital twins optimize services and operations through data from the Internet of Things (IoT) and physical assets.

Table 2: Result of Challenges and Strategies of Digital Twin Application in Construction Cost Management

Challenges	Mean	Strategies	Mean
Lack of experience with Digital Twin application in construction industry	4.3714	Providing training to industry players of Digital Twin application	4.3143
Lack of government incentives i.e.: training centre	4.3143	Enhanced skills programme for Digital Twin technology application in construction	4.3143
Lack of knowledge of Digital Twin technology	4.2857	Create a blueprint for digital twins to give clear standard approach	4.2571
Lack of Digital Twin experts	4.2571	Government to infuse emerging technologies in construction practices	4.2571
Lack of awareness regarding Digital Twin technology	4.2286	Strengthen partnerships between the public and private sectors to joint venture in the implementation of digital twin technology	4.2286
Lack of confidence in successfully implementing Digital Twin technology	4.2000	Educate and giving awareness on the implementation of Digital Twin technology	4.2000
Limited Digital Twin technology implementation in construction project	4.2000	Partnering with a trusted provider to avoid making cost mistakes	4.2000
Poor collaboration among construction players in incorporating new technology	4.1714	Government to developing a privacy policy to secure the data information and privacy	4.2000
Lack of investor in technology application that includes Digital Twin application	4.1714	Government to enforce rules that the usage of data must be in accordance with privacy policy	4.1714
Lack of training provided related to Digital Twin	4.1429	Government to analyse and strengthen existing legislation, rules, and standards to create a comprehensive digital construction environment.	4.1714
Lack of government support i.e.: funding	4.1429	Increase local stakeholders' expertise through knowledge transfer by collaboration with international organisations.	4.1429

Challenges	Mean
High cost of Digital Twin implementation	4.1429
Digital twin is a new technology in construction industry	4.0571
Resistance to change to the new technology	4.0571
No clear blueprint to use Digital Twin	4.0571
Require higher financial obligations	4.0571
Unreadiness of financial institution to fund in Digital Twin technology	4.0286
Readiness of stakeholders in adopting Industry Revolution 4.0 (IR 4.0)	3.8857
Complexity of data sharing	3.8857
Readiness of stakeholders in IT investment	3.8571
Complicated use of Digital Twin technology	3.8571
Lack of information security and data privacy	3.7143
Legal and ethical issues	3.6571

Strategies	Mean
Develop understanding of using Augmented Reality (AR) as it helps to give information about the visualisation of digital twin	4.1429
Governments to provide funding to support research and development of digital twin technologies	4.1143
Use and improve the integration of the current data platform for construction data sharing	4.0857
Benchmarking programme to identify technological gaps with the Construction 4.0 leading countries.	4.0857

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Table 2 shows that the challenges associated with digital twin application in construction cost management have high mean scores, with all challenges exceeding a moderate level of 3.50. The most significant challenge, with a mean of 4.37, is the lack of experience with digital twin technology in the construction industry. The least significant challenge, with a mean of 3.66, relates to legal and ethical issues. For strategies, the mean scores range from 4.31 to 4.09, indicating strong support for strategies promoting digital twin adoption. The highest-rated strategy is providing training and enhancing skills for industry

players, with a mean score of 4.31. The lowest-rated strategy is conducting benchmarking programs with leading Construction 4.0 countries, scoring 4.09. The top challenges include lack of experience, government incentives, knowledge, experts, awareness, and confidence in implementing digital twin technology. These challenges align with findings by Santi Edra et al. (2021), highlighting issues like limited talent, lack of training, and resistance to change. The most significant challenges relate to knowledge and governance. Regarding strategies, all received mean scores above 4.00, indicating strong support. The highest-ranked strategy is providing training for industry players, with the government identified as a key enabler. Research by Mazumder et al. (2023) emphasizes the importance of training and upgrading skills to fully leverage digital twin technology, suggesting that universities could incorporate digital tools into relevant courses to prepare future professionals for the construction industry's digital transformation.

Interview

In order to strengthen the research objectives, semi-structure interview is also conducted after questionnaire survey is done. The targeted respondents are construction industry players that had involve in construction process directly or not. The names of the interviewees were abbreviated as Respondent 1 (R1), Respondent 2 (R2), Respondent 3 (R3), and Respondent 4 (R4) that are contractor, executive in contract, quantity surveyor and researcher respectively.

Table 3: Result of Digital Twin Application in Construction Cost Management

Concept	No. of Respondents Agree
Digital twins provide accurate cost estimates by utilizing data from architectural models, engineering designs, material quantities, and labour rates.	R1, R2, R3, R4
Digital twins enable real-time monitoring and accounting of construction project costs, incorporating sensors, IoT devices, and project management systems to track labour productivity, material consumption, and equipment usage.	R1, R2, R3
Digital twins enable scenario analysis by simulating and evaluating cost scenarios in virtual environments, enabling stakeholders to optimize cost management strategies and make cost-conscious decisions.	R1, R2, R3
Digital twins help construction project managers identify and manage cost-related risks, develop risk mitigation strategies, and allocate contingency budgets by analysing historical data.	R1, R2, R3
Digital twins analyse building lifecycle, integrating maintenance, operational, energy, and cost data for cost optimization.	R1, R2, R3

The Table 3 shows that respondents R1, R2, and R3 agreed with all statements regarding digital twin application in construction cost management. However, R4 did not provide an answer, as they believe the technology is complex and requires more research before implementation. During interviews, participants initially expressed confusion about the term "digital twin." However, after receiving a detailed explanation from the researcher about its definition and practical applications, they realized they had encountered similar technology before, but in a different context. Their responses were based on theoretical knowledge, and they found it difficult to provide practical answers without further experience.

Table 4: Result of Challenges and Strategies of Digital Twin Application in Construction Cost Management

Challenges	No. of Respondents
Reluctance of players	R1, R2, R3, R4
Lack awareness	R1, R2, R3, R4
Funding/Money issues	R1, R2, R4
Ecosystem – the IT facilities and software	R3, R4
Lack of knowledge	R2, R3
Lack of expertise	R1, R4
Industry players still use traditional method	R1, R2
Long Return of Investment (ROI)	R1, R2
Server – connection/internet	R3
No demand for new technology	R2

Strategies	No. of Respondents
Enhance awareness	R1, R2, R3
Initiatives from government	R1, R2
Financial incentive from government	R3
Collaboration with expertise	R3
Training	R3
Enforce guidelines and policies	R4
Build the capacity	R4

The interviews revealed that the main challenges in adopting digital twin technology for construction cost management are related to knowledge, technology, governance, and economics. Key issues include a lack of awareness and reluctance among industry players, which aligns with the questionnaire findings. Respondents noted that limited knowledge and awareness of digital twin technology hinder its application in Malaysia's construction sector. Additionally, reluctance to adopt new technologies poses a significant barrier. Funding for the necessary hardware and software also remains a challenge. Successful implementation of digital twin technology requires overcoming these barriers through technological innovation, organizational commitment, and effective

change management. The majority of interviewees emphasized the importance of increasing awareness and knowledge to address these challenges. They suggested that awareness could be raised by governmental bodies, universities, and industry stakeholders. Respondents highlighted the government's crucial role in promoting awareness, offering incentives, and providing training before requiring the adoption of new technology in construction projects, as outlined by CIDB (2020).

CONCLUSION

This research successfully achieved its aim and objectives using a mixed-method approach for data collection. The study concludes that the application of digital twin technology in construction cost management within the Malaysian construction industry is currently low. A majority of respondents lack awareness and knowledge about digital twin technology. However, they recognize the challenges hindering its adoption in the industry and fully agree with the recommended strategies to overcome these challenges. The key challenges identified relate to knowledge gaps, including a lack of awareness, confidence, and hesitance to adopt the technology, as well as cost concerns. The questionnaire findings also highlight the need for government and large organizations to provide training programs to industry players to facilitate the adoption of digital twin technology. For future research, it is recommended to explore the perspectives of IT experts on their readiness to adopt digital twin technology in the Malaysian construction industry. Further research in this area could improve understanding and raise awareness of digital twin technology.

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RESERVOIR SEDIMENTATION MANAGEMENT: A SUSTAINABLE DEVELOPMENT CHALLENGE IN THE KENYIR LAKE BASIN, MALAYSIA

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Abstract

Reservoir sedimentation poses a significant challenge to the sustainable development of water resources, with profound implications for ecosystem health and water management. These lead to cause changes and challenges for rivers, such as floods, river erosion, sedimentation processes, and anthropogenic interference, which contribute to problems for humans and specifically for river basin ecosystems. This research examined the issue of sedimentation, a critical water body for the region's hydrology and socio-economic activities and proposed a multi-faceted management strategy that integrates sediment control measures, regular monitoring, and community involvement to enhance the sustainability of reservoir operations and safeguards the ecological integrity of the Kenyir Lake Basin. Through a combination of field surveys and sedimentation problem analysis, we assessed the current state of sediment accumulation and its impact on reservoir capacity, water quality, and downstream ecosystems. There are several aspects of processes such as erosion, sedimentation and the overflow of the river that have been found. The sedimentation problem in the Kenyir Lake Basin is caused not only by the flow rate of water but the land use activities also contribute to the increasing sediment levela. The implementation of recommendations should be carried out more specifically for reservoir sedimentation problems to avoid and minimise various other problems.

Keywords: Reservoir sedimentation; Kenyir Lake Basin; sedimentation problem; reservoir operation; velocity flow

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INTRODUCTION

Reservoirs are vital for water resource management, supporting a range of activities including water supply, irrigation, hydropower generation, and recreation. However, sedimentation in reservoirs poses a significant challenge, threatening their long-term sustainability and efficiency. Sediment accumulation reduces storage capacity, impacts water quality, affects aquatic habitats, and increases maintenance costs, ultimately reducing the lifespan of reservoir infrastructure. These issues are prominent in tropical regions, where high rainfall and steep topography accelerate erosion and sediment transport (Lee et al., 2018; Hogeboom et al., 2018; Fulazzaky et al., 2023). Kenyir Lake Basin in Malaysia exemplifies these challenges. As the largest man-made lake in Southeast Asia, Kenyir Lake is crucial for the region's hydrology and socio-economic activities, including water supply, flood control, hydropower generation, fisheries, and tourism. However, sedimentation is jeopardizing the sustainability of these services. The sedimentation problem in Kenyir Lake is driven by multiple factors such as land use changes, deforestation, agricultural activities, and natural erosion processes. Additionally, climate change and extreme weather events exacerbate these issues by altering precipitation patterns and increasing the frequency of heavy rainfall which leads to higher rates of soil erosion and sediment transport. The main objective of this research is to examine the issues of sedimentation in Kenyir Lake Basin and to propose a multi-faceted management strategy to address them. Uncontrolled river management can cause the water level raise, allowing it to be tapped and directed into the intake channel. The drainage system is built up as a network of rivers with settling basins positioned between 250 to 300 metres apart to maintain the high standards of the river water. To prevent basic and high sediment transport, particularly the sand fraction into the irrigation network, the concept of creating sedimentary pockets is a supplementary component of the main building. In addition, if the effectiveness of the sediment pockets declines, some buildings may not be able to be cleaned up for optimal work, which could lead to fewer incorrect operation plans and field maintenance (Uca et al., 2018; Wahab et al., 2019). It was also discovered that in certain instances, the building's poor design concepts made them difficult to operate and required expensive upkeep. By addressing these objectives, the study seeks to enhance the sustainability of reservoir operations and safeguard the ecological integrity of Kenyir Lake Basin. The proposed multi-faceted management strategy involves implementing sediment control measures to reduce sediment influx, establishing regular monitoring programs to track sedimentation trends, and engaging the local community in sediment management efforts. These comprehensive approaches aim to provide a framework for managing sedimentation challenges in tropical reservoir systems and contribute to a broader understanding of reservoir sedimentation issues.

LITERATURE REVIEW

Sedimentation is a process whereby deposition of the soil, gravel and sand is transported by the river flow and eventually settles as mud and reshapes the riverbed geometry. This process will leave a noticeable effect on the change in the geometry of the river, especially the downstream, where the velocity is low. After a few years of this process, the formation of the land following the sedimentation process will become clearer from the aerial view (Kamarudin et al., 2019). Sedimentation is a deposition event or process that occurs in several abiotic components that exist in the environment such as soil and sand. This sedimentation process is caused by several factors such as water flow or wind gusts which can move small particles from the soil or sand to other places until they are deposited and form the new land. The sedimentation process can occur in various places such as on soils, at the sea or in river ecosystems. These degrading materials are residual materials from weathering or erosion which last for a long time so that they are easily transported. The geological sedimentation process is the accumulation of sediments at a normal rate. This refers to the deposition process that occurs within the limits allowed, remaining or within the natural balance of the the degradation process. The rate of sedimentation process or total transport rate and reservoir life expectancy are very important for a sustainable ecosystem. The river flow and discharge are important in relation to the sedimentation production level and sediment movement (Kamarudin et al., 2017; Wahab et al., 2019). The accelerated sedimentation process is a sedimentation process that occurs in a relatively shorter time. This process is different from the geological sedimentation process (Chang & Liao, 2016). The accelerated sedimentation process has a detrimental effect, causing harm or damage, and disrupting the natural balance of the environment (Ismail et al., 2023). Besides that, the accelerated sedimentation process creates magnetic particles which enhance the sensitivity through the concentration process. The rapid immunological reaction on the walls by the magnetic field leads to a higher sedimentation rate. The sedimentation process is the direct result of erosion and sediment deposition from other aquatic areas or land-based areas. Based on previous hydrological studies, the sedimentation process can be detrimental and degrade the river ecosystem (Rendana al., 2017; Hossain et al., 2019). According to Ismail & Amin (2020) and Wahab et al. (2019), the natural physical processes such as deposition, transportation and erosion always will continue regardless of whether they are influenced by human activities or anthropogenic and natural factors along the river basin. According to Gasim et al. (2013), morphological or river planform changes (physical changes over a large area) in large river basin systems can also be major factors contributing to changes in natural sediment erosion and consequently, sediment production in the river basin (Lee et al., 2018; Hogeboom et al., 2018; Fulazzaky et al., 2023).

STUDY AREA AND RESEARCH METHODOLOGY

Study Area

Using a global positioning system (GPS), the latitude and longitude coordinates for every sampling point were recorded during the fieldwork. The massive development that has been carried out has had a significant impact on the environment. The development of the areas, including buildings, parking spaces, and roads, has led to the loss of the land's ability to absorb rainfall. Poor ability to absorb rainfall contributed to the surface runoff. The surface runoff became faster and the river faced difficulties in controlling the flow of water entering it. Table 1 and Figure 1 display the sampling locations along the Terengganu River Basin, which includes the districts of Kuala Terengganu, Kuala Nerus and Hulu Terengganu, representing areas from the upstream to the downstream. The Kenyir Dam controls the water capacity in the Terengganu River, and the hydroelectric project in Kenyir Lake involves a large area and provides various benefits. Water discharge activities from the Kenyir Dam affects the flow of lake water, making it less dynamic and triggering disruptions in the sedimentation process as well as the equilibrium of environmental flow assessment. These hydro resources create a socio-economic overflow effect and serve as flood mitigation, especially in Terengganu. This study included 19 sampling stations during dry season and 21 sampling stations during wet season which are Sungai Siput (ST1), Sungai Petuang (ST2), Sungai Tembat (ST3), Sungai Terengganu (ST4), Sungai Ketiar (ST5), Sungai Besar (ST6), Sungai Lepar (ST7), Sungai Lawit (ST8), Sungai Cenan (ST9), Sungai Bewah (ST10), Sungai Cicir (ST11), Sungai Perepek (ST12), Sungai Terenggan (ST13), Sungai Cacing (ST14), Sungai Pertang (ST15), Sungai Lasir (ST16), Sungai Leban Terengganu (ST17), Sungai Sauk (ST18), Sungai Mandak (ST19), Sungai Kenyir (ST20) and Sungai Berangan (ST21).

Table 1: The sampling station in Kenyir Lake Basin, Terengganu, Malaysia

Station	Longitude	Latitude	Station	Longitude	Latitude
ST 1	102° 42'42.602"E	05°11'01.064"N	ST 11	102°44'30.707"E	4° 47'42.302"N
ST 2	102°39'49.705"E	5° 17'42.360"N	ST 12	102°44'31.9"E	4° 47'16.9"N
ST 3	102°38'19.879"E	5° 12'57.393"N	ST 13	102°45'00.244"E	4° 46'28.235"N
ST 4	102°37'46.486"E	5° 11'24.258"N	ST 14	102°42'32.595"E	4° 48'17.089"N
ST 5	102°33'17.735"E	5° 03'30.462"N	ST 15	102°48'00.5"E	4° 55'26.2"N
ST 6	102° 34'15.044"E	04°58'03.613"N	ST 16	102°50'22.510"E	4°57'54.633"N
ST 7	102° 33'09.379"E	04°56'16.506"N	ST 17	102°45'03.621"E	5° 02'21.528"N
ST 8	102°35'13.374"E	4° 54'38.067"N	ST 18	102° 46'42.443"E	05°04'58.079"N
ST 9	102° 42'04.9"E	04°52'32.0"N	ST 19	102° 20'6.25"E	05°07'34.463"N
ST 10	102°41'24.427"E	4° 50'36.340"N	ST 20	102°54'5.18"E	05° 0'40.01"N
			ST 21	102°54'40.34"E	05° 1'2.36"N

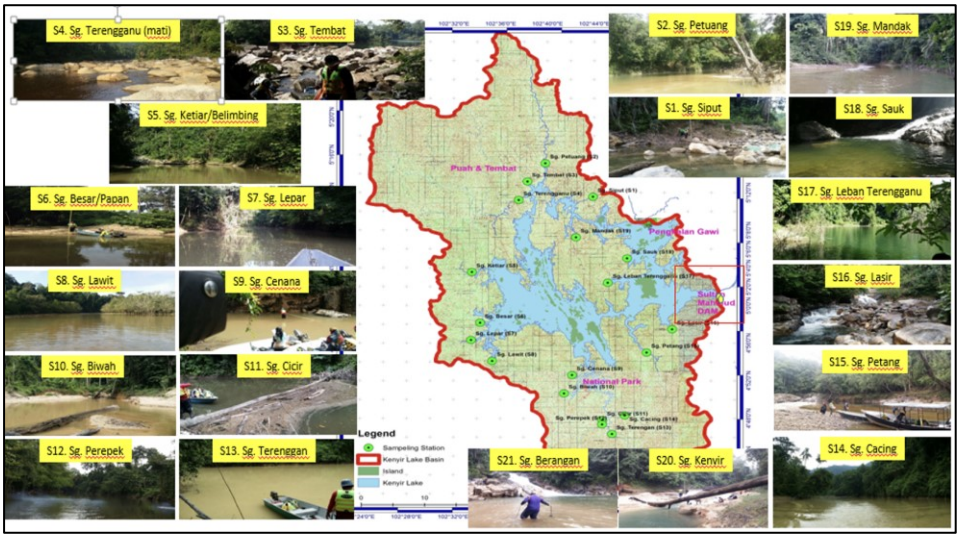


Figure 1: The Ilustration of Sampling Station in Kenyir Lake Basin, Terengganu, Malaysia

Research Methodology

Sedimentation is a critical environmental issue affecting water bodies worldwide, and the Kenyir Lake Basin in Hulu Terengganu, Malaysia, is no exception. Effective management of sedimentation problems requires a comprehensive understanding of various hydrological and sediment-related parameters. Table 2 shows the basic indicators used to measure the level of sedimentation in the Kenyir Lake Basin, providing essential data for environmental monitoring and management strategies. Monitoring these indicators provides valuable insights into the dynamics of sedimentation in the Kenyir Lake Basin. The indicators outlined in Figure 2 are essential tools for understanding and managing sedimentation problems in the Kenyir Lake Basin.

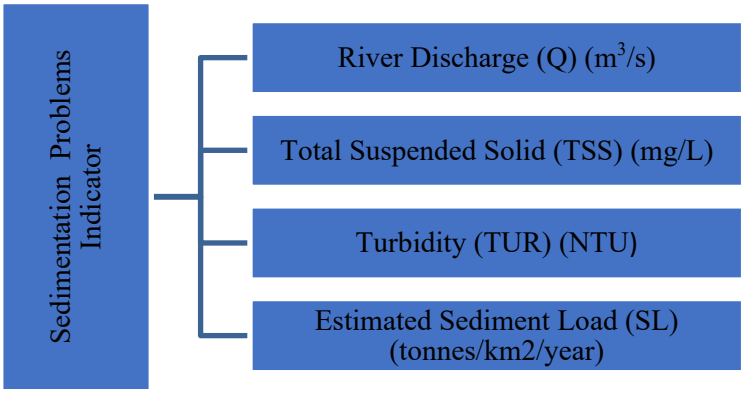
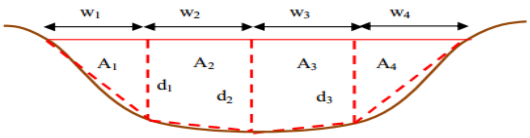
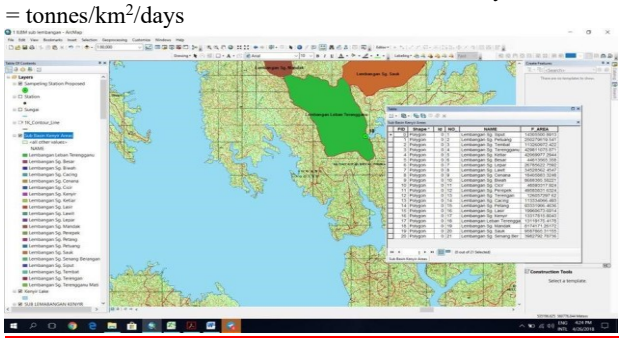


Figure 2: The Basic Indicators in Measuring the Level of Sedimentation in Kenyir Lake Basin, Hulu Terengganu, Malaysia

Table 2: The sediment problems indicator applied in this research and scientific used in measurement for each indicator

Sedimentation Problems Indicator	Scientific Method
River Discharge (Q) (m^3/s)	The discharge value (Q) is the product of velocity and cross-section area (A). The cross section area is derived from the product of depth (d) and width (w), the cross-section area is trapezium or triangular shaped and the value is half the product which is due to imprecision of the current meter, variability of the river flow velocity over the cross section and uncertainty in the estimation of the cross section geometry (**Figure 3(a)**).  **Figure 3(a)**: The Theory of Discharge Measurement By River Cross-Section
Total Suspended Solid (TSS) (mg/L)	The United States Environmental Protection Agency (USEPA) and the American Public Health Association (APHA) provide standard procedures for sample processing and preservation, which were followed in all cases. Using the gravimetric method, the laboratory evaluation was conducted in accordance with the standard analytical process to measure the precise values of TSS (Wahab et al., 2019).
Sediment Load (SL) (tonnes/km^3/year)	The calculation of annual sediment load production (MS) is based on the discharge value (Q) (m^3/s), TSS value (mg/L) and area of the sampling basin (km^2). The analysed data will be used to determine the changes in the concentration of suspended sediment and its relationship with hydrological and geomorphological factors and other variables. **Equation 1** shows the formula used in the measurement of MS (tonneskm^2/year). **Figure 3(b)** shows the Fundamentals of the Georeferencing of the ArcGIS method to determine the area of each sub-catchment (area sampling basin) (Kamarudin et al., 2020). **Equation 1** Annual sediment load production (MS) = (Q x TSS)/ Area of sampling basin

Sedimentation Problems Indicator	Scientific Method
	= (L/day x tonnes/day)/ km^2 = tonnes/km^2/365 days = tonnes/km^2/days  **Figure 3(b)**: Fundamental of Georeferencing of ArcGIS to Determine the Area of Each Sub Catchments in Kenyir Lake Basin, Hulu Terengganu, Malaysia
Turbidity (TUR)	The measuring tool used to identify the TUR values is the HACH 2100Q portable turbidimeter. This tool is equipped with a copper carrying case so that it can be easily carried to the field (Wahab et al., 2019).
Total Dissolve Solid (TDS)	To measure Total Dissolved Solids (TDS) using a TDS meter, the meter is firstly clean and calibrated. A water sample was collected in a clean container, and the TDS meter was turned on. The probe was then immersed into the sample, ensuring it was fully submerged to the indicated level. The reading is allowed to stabilise, which may take a few seconds, and then displayed TDS value, typically in parts per million (ppm) or milligrams per litre (mg/L), was recorded. Finally, the probe was cleaned with distilled water, the meter was turned off and stored appropriately.

ANALYSIS AND DISCUSSION

River Discharge

The observed value (Q) at Sungai Petuang (Station 2) showed the highest value at 10.48 m^3/sec and the lowest value (Q) at Sungai Bewah was at 0.07 m^3/sec during the dry season. During the wet season, the maximum value of discharge was recorded at 28.436 m^3/sec and the minimum is at 0.809 m^3/sec **(Figure 4)**. This is a normal reading for a river, where the observed value (Q) or water velocity in the elevated upstream is higher than the downstream. In flat areas, excess water flows out from Kenyir Lake into Sungai Terengganu and the difference in depth and width of the river significantly influences the flow of the river. The processes of erosion, transport, and sedimentation occur along the river to the estuary to influence deposition. The speed of water flows is the main factor, affects the capacity of the sediment transportation and movement. The processes of deposition of sediment indeed depends on the river discharge and the speed of the river flow. The theory of hydrology describes that when the discharge value is high and the water velocity is low, the amount of sediment load deposited in the downstream area is higher. The action involves the normal process of erosion,

transport, and sedimentation along the river. Rivers are important sources of water for humans and other organisms as they are essential for sustaining life. The sedimentary content and quality of water influence the condition of the river. The frequency and intensity of rainfall influence the water level flow and the rates of the erosion process (Wahab et al., 2019).

JPS River Index (JRI)

JRI is based on the flow (discharge), turbidity, TSS, and TDS parameters, with the main focus on monitoring the physical changes in polluted rivers as a result of land use development, logging, tourism, and the opening of agricultural land along the Lake Kenyir Basin. Based on the results obtained (refer to **Figure 5**), it is evident that increased velocity and volume of water would also increase the rate of erosion, leading to increased production of TSS, water turbidity and eventually the river becoming shallower. This harms the benthic ecosystem, and flora and fauna in the area surrounding the river and lowers the water quality. The advantage of using JRI which takes into account the area of the river basin catchment area at the station location when the flow is high, medium and low makes JRI suitable for monitoring the quality of river water in rural areas because the classification of river water index JRI is more oriented towards the physical shape of the river and not to the quality of life in the river water (JPS, 2012; Hasan et al., 2015; Shafii et al., 2018; Wahab et al., 2019).

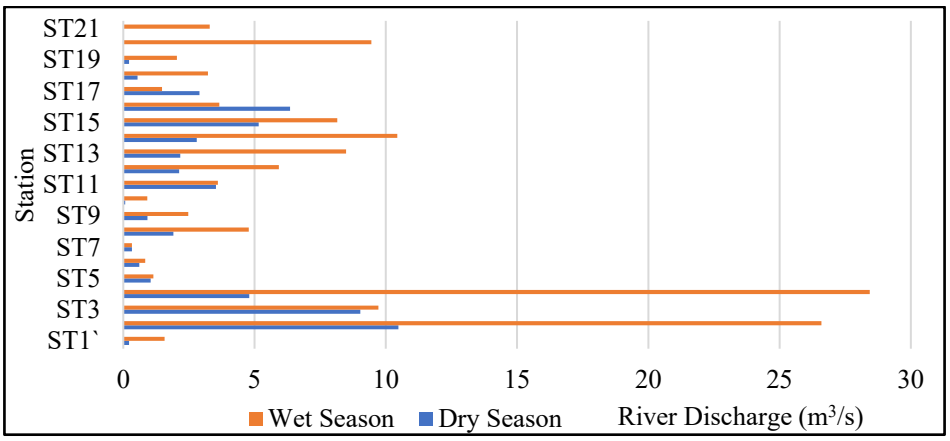


Figure 4: The Estimated of River Discharge (Q) at Kenyir Lake Basin, Hulu Terengganu, Terengganu During Dry Season and Wet Season

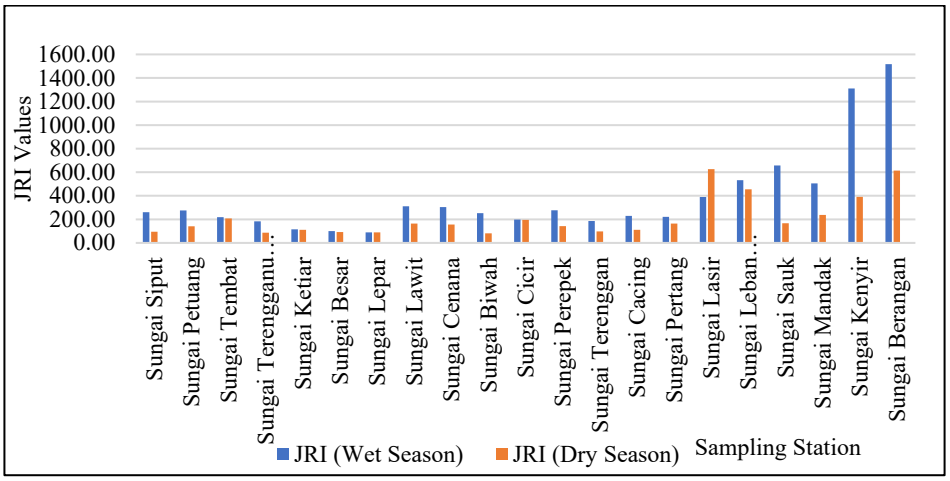


Figure 5: The JPS River Index (JRI) at Kenyir Lake Basin, Hulu Terengganu, Terengganu During Dry Season and Wet Season

Table 3(a) and **Table 3(b)** show the leave-one method or analysis of the importance of inputs to determine hydrological parameters that significantly affect water quality status using JRI. Sediment mobilisation processes in a semi-arid tropical river system state that river water flow has been proven to influence the flow pattern peaks in the wet season compared to the dry season. The low flow rate recorded in the sub-basin that has a small basin area is proven in this study through linear analysis with the highest percentage contribution value for the Specific Flow parameter compared to other parameters which are 99.97% (wet season), 94.19% (dry season) and 99.95% (normal season). The tendency of the Specific Flow condition depends on the rapid water velocity and the river receives a high intensity of rain during the wet season. In general, high water speed and volume result in a tendency to increase the erosion rate and water speed is the main factor that affects the Specific Flow trend (Toriman et al. 2015). In addition, TSS is one of the most important parameters that affect the production of sediment load each year. The concentration of TSS is higher in the wet season compared to the dry and normal seasons because the erosion process is more active and facilitates the deposition of suspended solids. This theory also describes that water flow during the wet season has more energy to transport TSS in larger amounts than during slow water flow (Wahab et al., 2019).

Table 3(a): Important variables in the linear relationship between water quality parameters and JPS River Index (JRI) in Kenyir Lake Basin in the wet season

R-Square Reference = 0.9989			
Leave Variable	**R-Square Leave Variable**	**R-Square Difference**	**Percent Contribution**
Specific Flow(SF)	0.0606	0.9383	99.97
Total Suspended Solid (TSS)	0.9988	1E-04	0.01
Turbidity (TUR)	0.9988	1E-04	0.01
Total Dissolve Solid (TDS)	0.9988	1E-04	0.01
TOTAL	**3.057**	**0.9386**	**100.00**

Table 3(b): Important variables in the linear relationship between water quality parameters and JPS River Index (JRI) in Kenyir Lake Basin in the dry season

R-Square Reference = 0.9891			
Leave Variable	**R-Square Leave Variable**	**R-Square Difference**	**Percent Contribution**
Specific Flow(SF)	0.0512	0.9379	94.19
Total Suspended Solid (TSS)	0.9601	0.029	2.91
Turbidity (TUR)	0.9703	0.0188	1.89
Total Dissolve Solid (TDS)	0.979	0.0101	1.01
TOTAL	**2.9606**	**0.9958**	**100.00**

Estimated Sediment Load (SL) Production

The highest value of MS during the wet season was recorded at 348968.41 kg/km^2/year in the Sungai Kenyir Sub Basin and the lowest value of MS during the wet season in the Sungai Lepar Sub Basin was 6993.35 kg/km^2/year. In addition, the highest MS value in the dry season was recorded in the Terengganu Leban River Sub-Basin which was 36249.93 kg/km^2/year and the lowest value in the Siput Sungai Sub-Basin was 581.96 kg/km^2/year (refer to **Figure 6(a)** and **Figure 6(b)**). The value of MS production in the dry season was relatively high in some sub-basins compared to the wet, possibly due to the geographical position of most of the sub-sub-basins in the Kenyir Lake Basin, especially the sub-basins in the upper part located near the forest area near the border of the National Park. During the wet season, the rapid flow of water facilitates the absorption of foreign substances by trees, resulting in clearer water and fewer suspended particles flowing into the river compared to the dry season. This is also the main reason why MS production is higher during the dry season compared to the wet season throughout the research. Sediment load rates were found to be relatively high at the beginning of the wet season because observations were made after rainfall, when the accumulated river flow provided sufficient energy to transport sediment in large quantities, especially in the river basin with an area of only 13,318 km^2.

The comparison of the sediment load value for the Sungai Kenyir Sub-Basin area with other rivers that have similar basin areas is very high. For example, the sediment load value for the Siput River Sub-Basin with a basin area of 14,306 km² recorded a sediment load concentration of 55409.54 kg/km^2/year during the wet season and 581.96 kg/km^2/year during the dry season. On the other hand, the Kenyir River Sub-Basin recorded a sediment load value 10 times higher with a basin area of only 13,318 km². This shows that the amount of sediment production in this basin area is high compared to the selected river sub-basins that have been studied in the Lake Kenyir Basin. It was found that the sub-basin in the downstream part is more vulnerable to soil erosion due to the construction carried out near the banks of the river, causing soil erosion to easily occur when it rains. The estimated value of Sediment Load (SL) in the lower and middle parts of Tasik Kenyir Basin is higher than the upper part. This study proves that sediment production is the result of geomorphological factors, hydrology, the development of anthropogenic factors and climate change that occur in the Kenyir Lake Basin. It shows a clear relationship whereby the wider the basin, the higher the annual sediment load that can be produced, based on hydrological theory. However, most studies in Malaysia cannot be fully applied without considering the external environmental factors surrounding the basin and the uncertain impacts of climate change in recent years. Taken together, changes in the activity within the entire river basin will impact sediment production in the river (Aweng et al., 2016; Saad et al., 2023).

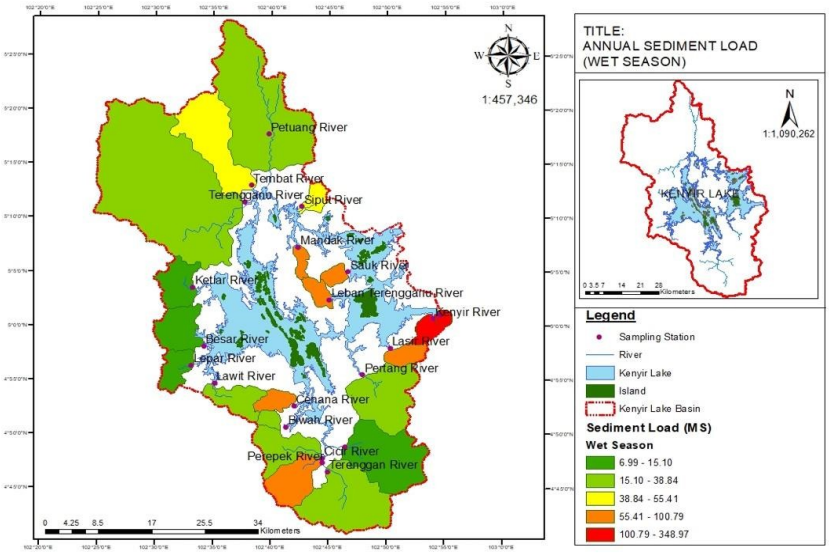


Figure 6(a): The Distribution of Estimated Sediment Load (SL) Production During Wet Season Along Kenyir Lake Basin

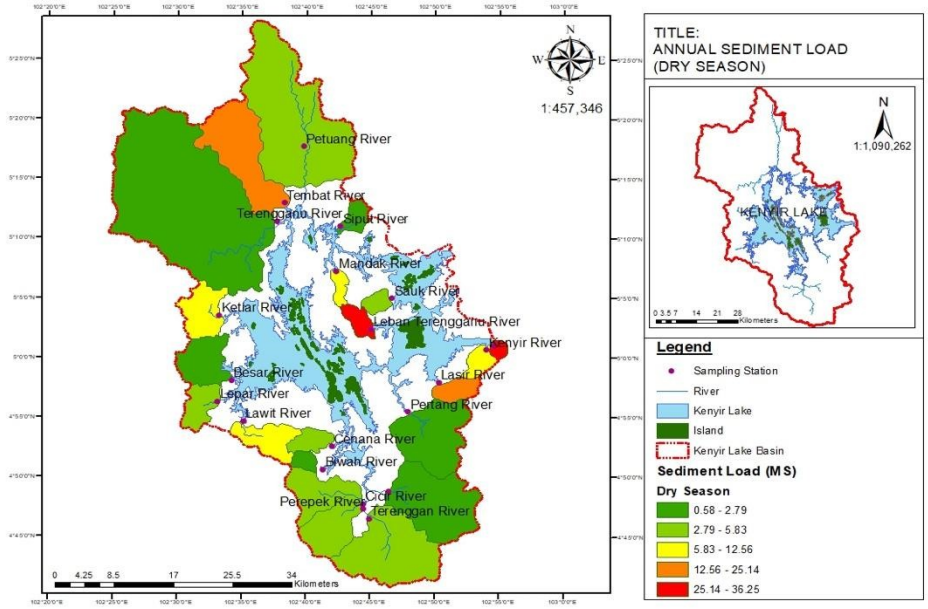


Figure 6(b): The Distribution of Estimated Sediment Load (SL) Production During Dry Season Along Kenyir Lake Basin

Reservoir Sedimentation Mitigation Management

The land use changes around the Kenyir Lake Basin, such as agriculture, tourism, domestic development, animal husbandry and cage fishing, have resulted in the creation of certain areas suffering from deteriorating water quality and critical sedimentation along the basin. Through the "Regional Local Plan (RTD) Kuala Terengganu 2008-2020", several environmental management methods have been implemented, including aspects of environmental quality control, biological diversity protection and the management of environmentally sensitive areas (*Kawasan Sensitif Alam Sekitar*) (KSAS), to achieve progress in the environmental management development by 2020. **Figure 7** shows a structured approach to manage reservoir sedimentation mitigation in the Kenyir Lake Basin, highlighting three primary strategies. The first strategy, land use management along the Kenyir Lake Basin, involves the implementation of sustainable land-use practices to minimise soil erosion and reduce sediment influx into the reservoir. The second strategy to address bank erosion along the Kenyir Lake Basin, focuses on controlling erosion of the reservoir's banks through various erosion control measures, thereby preventing sediment from degrading water quality and reservoir capacity. The third strategy involves mitigation management based on the concept of Integrated Water Resources Management

(IWRM) in the Kenyir Lake Basin, utilising comprehensive and coordinated water resource management practices. This strategy integrates various sectors and stakeholders to develop and implement effective solutions for managing and mitigating sedimentation in the reservoir, ensuring long-term sustainability (Wahab et al., 2023).

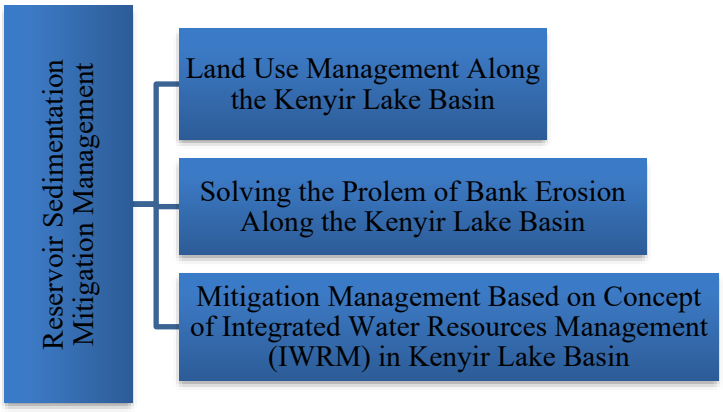


Figure 7: The Ilustration of reservoir sedimentation mitigation management in Kenyir Lake Basin

CONCLUSION

The management of reservoir sedimentation in the Kenyir Lake Basin presents a complex yet critical challenge for sustainable development in Malaysia. This study highlights the multifaceted nature of sedimentation issues, including environmental, social, and economic dimensions. Effective sedimentation management is essential not only to preserve the reservoir's capacity and prolong its lifespan to protect the surrounding ecosystems and support the livelihoods of local communities. Community involvement is paramount in ensuring the success of sedimentation management initiatives. Engaging local stakeholders in decision-making processes and promoting awareness about sustainable practices can foster a sense of responsibility towards the lake's health. Moreover, interdisciplinary collaboration among government agencies, research institutions, and non-governmental organisations is crucial to developing and implementing comprehensive sediment management plans. The findings from the Kenyir Lake Basin can serve as a valuable reference for other reservoir systems facing similar challenges. Future research should focus on long-term monitoring and evaluation of sediment management practices to adapt and refine strategies as needed. By prioritising sustainable sedimentation management to the broader goals of environmental sustainability and socio-economic development in Malaysia.

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PLANNING FOR COMMUNITY ADAPTATION TO THE RISK OF FOREIGN SHIP TRAFFIC ON INTERNATIONAL SHIPPING LANES IN THE INDONESIAN ARCHIPELAGO SEA ROUTE

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Abstract

The International Convention Law on the Sea, which was adopted by the United Nations in 1982, granted foreign-flagged ships the right to pass safely and smoothly through the Indonesian Archipelago Sea Route/Alur Laur Kepulauan Indonesia (ALKI). The density of the shipping lanes has triggered risks such as accidents and environmental pollution caused by ship exhaust carbon emissions. Therefore, this qualitative research aimed to determine the possibilities of coastal communities to adapt to the risk in accordance with the policy of ship traffic regulation with international shipping lanes through the Traffic Separation Scheme. There is still limited research on the community's adaptation due to ship exhaust carbon emissions and the lack of adaptation actions taken in response to environmental pollution from foreign ship exhaust emissions. Adaptation efforts recommended include the preparation of collaborative measures and strategies to ensure the carbon management has a net zero emission value on foreign ship traffic in ALKI. The result showed that adaptation effort can be used to ensure Indonesians Nationally Determined Contribution (NDC) can prevent global temperature rise from the shipping sector through carbon management, decarbonization, and energy transition programs.

Keywords: Indonesian Archipelago Sea Route, Ship Emissions, Carbon Management, Nationally Determined Contribution, Net Zero Emission.

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INTRODUCTION

Indonesia is an archipelago characterized by 17,001 islands and a water area of 6,400,000 km^2 functioning as a unifier thousands of cities (Geospatial Information Agency, 2023). As a result, the transportation network in these domestic waters unites with those on land and overseas routes (exports and imports). In addition, there are also international shipping lines in Indonesian territorial waters that globally permit the legal crossing of foreign-flagged ships from various countries (Hidayat, *et, al*, 2019). These ships cross through an international shipping lane called the Indonesian Archipelago Sea Route/Alur Laur Kepulauan Indonesia (ALKI) agreed on during the United Nations Convention on the Law of the Sea (UNCLOS) session of the International Maritime Organization (IMO) in 1982. There are three international shipping lanes, and based on data from the Directorate General of Sea Transportation of the Ministry of Transportation of Indonesia in 2019, 53,068 ships belonged to the countries passing through ALKI I. Meanwhile, 36,773 and 18,028 foreign-flagged ships passed through ALKI II and III, annually (Alamsyah & Sikumbang, 2023).

Hundreds of ships that passed through the ALKI daily posed a risk to coastal communities and the environment (Hadi, 2023). These oil-fueled foreign ships cause traffic, alongside thousands of red and white flagged ships for domestic and inter-island transportation (INCAFO, 2014). A review of the preferred adaptation efforts in responding to the risks of foreign ship traffic density on the community and coastal environment adjacent to the international shipping lane has never been carried out in depth. Therefore, this research adopted a descriptive qualitative method (Denzin, 2009) to investigate the obligations of foreign shipping in protecting the environment and coastal areas while freely crossing the ALKI, as mandated by the Indonesian government.

LITERATURE REVIEW

The Indonesian Archipelago Sea Route as an International Shipping Route

The review on maritime data acquired in 2023 by the United Nations Conference on Trade and Development (UNCTAD), stated that the use of this transportation mode to convey various world trade commodities covered approximately 91% of other transportation modes (UNCTAD, 2023). Indonesia, characterized by the strategic position between the Asian and Australian continents as well as the Indian and Pacific Oceans, plays an important role in influencing international shipping lanes to support world trade (INSA, 2023).

This led to the implementation of the UNCLOS agreement for traffic regulation in 1982. Additionally, the IMO maritime safety committee approved the proposal submitted in respect to the three ALKI lanes on May 19, 1998 to regulate the rights and obligations of ships and aircraft that would crossing it as stated in the Indonesian Government Regulation Number 37 of 2002 (Simanjuntak, 2018). This was aimed to support the smooth traffic of foreign ships in the three channels (Hutagalung, 2019), namely ALKI I, II and III. Furthermore, the Indonesian government set the following geographical coordinates, latitude and longitude as the connecting axis of the archipelago flow depicted on the map as a reference for ship crews during voyage as shown in Figure 1.

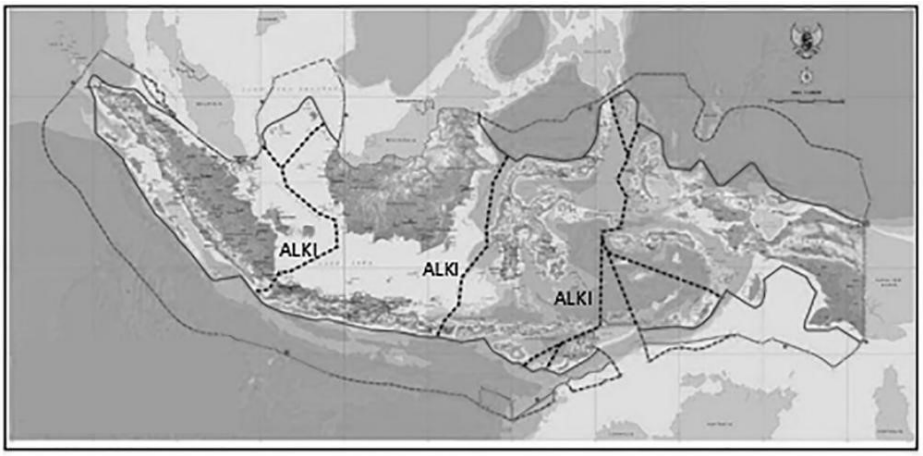

Figure 1. Map of the Indonesian Territory and the Indonesian Archipelago Sea Route (ALKI)
Source: BAKORSURTANAL-Indonesian Navy,2003

Adaptation of Coastal Communities on the ALKI Line

The main problem caused by the density of traffic along the ALKI was accidents consisting of collisions, fire outbreak, sinking, and ships running aground. Based on data from the Indonesian National Transportation Safety Committee (NTSC) in 2022, approximately 108 cases of accidents were reported in Indonesian waters. The lack of regulatory policy, and increased traffic proved risky for the community, including certain activities carried out along the ALKI coast, which intersects with domestic shipping lanes.

Table 1: Number of shipping accident investigations Based on Type of Accident 2018-2022

No.	Description	Year					
		2018	**2019**	**2020**	**2021**	**2022**	**Total**
1	Drowning	10	6	3	5	5	29
2	Burned	12	6	2	6	5	31
3	Collision	3	9	2	4	1	19
4	Grounding	7	0	4	2	2	15
5	Miscellaneous	7	4	1	2	0	14
Total		39	25	12	19	13	108

Source: NTSC, 2022

The risk of accidents caused by the density of traffic, especially on international shipping lanes in ALKI, motivated people to embrace various adaptation options for the purpose of survival, including avoiding detrimental risks. Several adaptation options are preferred by the community, government, and business actors as a form of strategy in responding to environmental changes associated with the trigger factor, namely the risks caused by the density of international ships (Siswono, 2015). Furthermore, these options can be in the form of awareness or knowledge, attitude, and action or practice (Notoadmodjo, 2012).

The reaction to a risky phenomenon leads to a variety of responses (Adger & Vincent, 2005). Some people do not respond despite being aware of the risks or careless about the impact on survival. Certain adaptation options carried out included actions taken through policy initiatives. These could be in the form of regulatory and supervisory actions, as well as field activities to anticipate or reduce the risks that occur in Indonesian waters due to shipping traffic in ALKI (Bakti & Sukartono, 2022; De Araujo Pereira Babo Martins, 2022). This research focused on the phenomenon of traffic density in Indonesian waters caused by the thousands of foreign ships passing through the ALKI route, in relation to the adaptation options preferred by the community in addressing the associated risks.

Ship Exhaust Gas Emissions

CO_2 emission is urge issue in the transportation sector (Yola et all., 2024).The research on IMO greenhouse gas conducted in 2020, reported that CO_2 emissions from the shipping sector increased by 9.6%, amounting to a total of 1,076 million tons compared to 977 million tons recorded in 2019. Furthermore, this figure reportedly increased from 2.76% to 2.89% of total global carbon emissions (IMO, 2020). The condition became a concern when the United Nations Framework

Convention on Climate Change (UNFCC) published a review of the Sustainable Development Goals in 2023. In respect to climate change, a significant increase in global temperature of 1.1℃ was recorded for the past 10-years and is expected to continue increasing from 1.5℃ to 2℃ if proper initiatives are not adopted (MPEC, 2023).

The adopted strategies to reduce gas emissions from the shipping sector worldwide referred to the Marine Pollution Regulation Annex VI and the resolution of the 80th IMO Marine Environment Protection Committee - MPEC session held in 2023 (MEPC, 2023). These included 1) reducing the carbon intensity of shipping, 2) and emissions by 40% by 2030 compared to 2008, 3) increased initiatives towards zero to low emission with the support of substitute technologies, fuels or energy sources by 5% to 10% by 2030, and, 4) the implementation of strategies towards emission-free shipping by 2050 was in line with the targets of reducing greenhouse gas emissions by 30% by 2030 and 70% to 80% by 2040.

Carbon Management Toward Emission Reduction Targets in International Shipping

In 2020, the Institute of Environmental Management and Assessment (IEMA) submitted a review on the Carbon and GHG Management Hierarchy relevant to the IMO 2023 strategy towards sustainable low and emission-free shipping. Furthermore, the carbon and greenhouse gas governance/management were explained through the following stages. First, reduce or abstain from using ship fuel, this effort is aimed to prevent the generation of carbon and greenhouse gas emissions such as the use of energy supply from the port (Onshore Supply Power). Second, reduce the generation of carbon emissions (decarbonization) and greenhouse gases through operational excellence efficiency strategies both technically and on board. Third, substitute with low-emission energy such as non-fossil fuels including LNG, Biodiesel, Hydrogen, and Ammonia. Fourth, compensate the remaining carbon produced by the ship through offset mechanisms, and development of carbon markets (carbon tax), (EIMA, 2020).

The carbon and greenhouse gas governance is in line with the adaptation efforts embraced by stakeholders in archipelagic countries. This is in anticipation of the risk associated with coastal and marine environmental damages caused by the density of foreign ship traffic in ALKI.

RESEARCH METHODOLOGY

The research was conducted using qualitative methods supported by data obtained quantitatively. This included the exploration of information through interviews held with communities along ALKI and other resourceful people that influence the objective. Data from field observations in the Lombok Strait on the

ALKI II route were obtained from February to March 2024. This was combined with quantitative data, constituting information on ships passing through ALKI II in 2022 captured by satellite based on the Marine Traffic and other applications at the Directorate General of Sea Transportation of the Ministry of Transportation of Indonesia. Furthermore, the ministry is authorized to regulate ship navigation in Indonesian waters. The analyzed ship specification data focused on type, size, fuel consumption, and flag. In order to ensure accurate results, various information was extracted from several literatures as well as comparative research in different countries, reviews from IMO and from previous scientific evaluations that supports the implemented objectives (Denzin, 2009).

ANALYSIS AND DISCUSSION

The processed data in table 2 showed that 35 foreign ship units passed through ALKI II daily, with a total of 2,189 ships recorded in 2023. These foreign ships whose passage is legally protected and authorized by Indonesia are mostly commercial. The vessel types included bulk and liquid cargos for conveying commodities such as coal iron ore, and processed palm oil. Additionally, the passenger and special ships supported the conveyance of offshore oil work supply equipment.

Bulk and liquid transport ships, including passenger ships are generally large with dimensions of 175 meters to 360 meters, and depth of approximately 12 meters. These were categorized as supramax and panamax ships with a fuel tank capacity of relatively 1800 metric tons. The fuel tank capacity enabled the seaworthiness requirements for undergoing voyages with lengthy intercontinental and interoceanic shipping routes (Seithe, 2020). The enormous dimensions of the large cargo tend to be in line with the fuel consumption capacity as the ships pass safely and smoothly along the relatively 800 nauticalmiles of ALKI II (Listiyono et al., 2022).

Table 2. Recapitulation of Monitoring of Ships Crossing ALKI II in the Lombok Strait on December 31, 2023

Ship Type/Vessel Length	Number of Ships	Estimated Ship Daily Consumption	Ship Flag
Bulk carrier (150-350m)	30	27-31 KL	• English, Panama, Liberia, Malta, Bahamas, Marshalles, Hong Kong, Greece, Madeira, Cyprus, China, Singapore
Liquid cargo ship/tanker (150-350 m)	1		
Passenger Ship/Cruise Ship (250-330m)	2		
Specialized ships supporting offshore Activities	2	3-5 KL	
Total	35	Minimum 945 KL	

Source: Processed Data of the Directorate of Navigation of the Ministry of Transportation of the Republic of Indonesia, 2024

The large size of foreign ships with dimensions less than 150 meters affected the traffic order in Indonesian water. Moreover, fishing boats owned by coastal communities encountered difficulties in dealing with sea waves caused by large ships. The ship flag was also used to identify the country where it was registered, binding all rights and responsibilities of the owner to that nation. Foreign-flagged ships passing through ALKI II are registered in diverse countries ranging from those in Asian Continent such as China, Hong Kong, Singapore, and European nations, namely the United Kingdom, Malta, and Cyprus. This also included nations around Panama and Liberia, regarded as the alliance members of convenience flag countries. Additionally, Indonesian waters, especially ALKI II offered safety, smooth traffic, and economical rights, without passage payment for more than 40 years since the UNCLOS convention in 1982. In accordance with processed data through direct observation (*emic*) at the port, review of IMO ship satellite and criticized information from interviews held with community members, business actors, and government, it was proven that the biggest risks posed by the density of international ship traffic in ALKI II, included accidents and environmental pollution by carbon emissions. These tend to adversely affect marine ecosystems and coastal environments.

Community Adaptation to the Risk of Ship Accidents in ALKI

Foreign ships report and transmit data to VTS officers at coastal radio stations or ports located in the straits of the ALKI, through predetermined frequency as well as AIS. The information which constituted ship type, IMO identity number, type of cargo categorized as either dangerous and risky to the environment or not, and other facts related to the condition. This navigational information assistance from the government proved helpful for foreign ships that only passed the ALKI route through nautical charts available on board as shown in Figure 2. The regularly updated manual and electronic charts provided virtual coordinates that monitor the movement of ships in the ALKI. These virtual or geographical coordinates connect the axis lines of the ALKI channel in Government Regulation of Indonesia Number 37 of 2002, including areas where Indonesian domestic sea transportation ships cross the Lombok Strait.

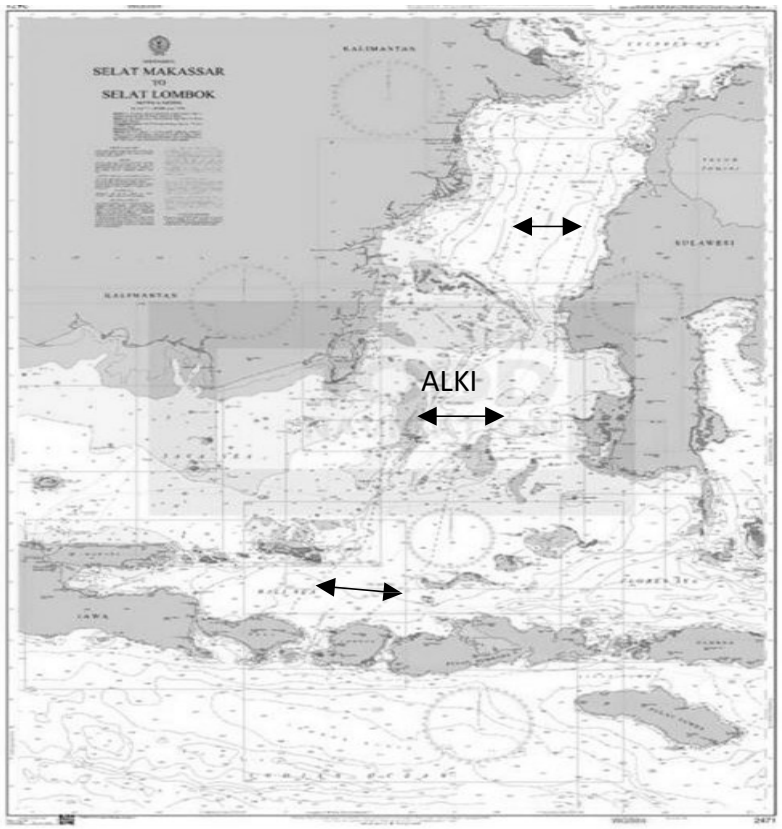

Figure 2: *Admiralty Chart* 2471: ALKI Line from Makassar Strait to Lombok Strait
Source: *Toddchart*, 2024

In situations where there are problems, disturbances or needs from foreign ships along the ALKI, the captain independently contacts the nearest port authority through the VHF radio or communicates with the nearest Indonesian-flagged ships. Similarly, if the public witnesses any foreign ships causing problems or disturbances in coastal waters and environments, these people are expected to manually use the telephone network without a system to report to the nearest port authority. The disturbances include discharging waste and excess emissions, leaving the permitted 25 nautical mile width of ALKI and entering territorial waters without permission, as well as various other acts violating the jurisdiction.

Community Adaptation to the Risk of Environmental Pollution in ALKI

Another concern felt by coastal communities was the risk of environmental pollution caused by exhaust emissions in the form of smoke produced by foreign-flagged ships when passing through ALKI. This carbon emission has a Global Warming Potential (GWP) value of one, due to the adverse impact on climate change and global warming (Winebrake, *et.al*., 2007). In addition, another pollutant of concern to the IMO is sulfur detected in the fuel of large ships due to the high risk to the environment, especially the occurrence of acid rain. This tends to have a negative impact on the environment and human health, including acting as disturbance to plants (Nevers, 2000). Both pollutants are components of Marine Fuel Oil with High or Low Sulfure, consumed by large foreign ships. The IMO stated that limited sulfur content of fuel was released into the environment (Chatzinikolaou, *et.al.*, 2015).

Based on data from the Cosco Shipping Heavy Industry Design and Research Institute in 2023, the specification for inter-oceanic and country ships with a dimension of 200 meters was equipped with a fuel tank of approximately 1800 m^3. This ensured the cruising area for shipping lines was approximately 22,000 nautical miles with speed and fuel oil consumption of 13.5 knots and 21 to 27 kilo liters/day (COSCO, 2023). The fuel consumption was greatly influenced by the dimensions of the ship, the capacity of the cargo, type and size of the main engine adjusted to suit the actual measurement of the vessel. From the average of 35 international ship per day in December 2023 that crossed ALKI II, the fuel consumption of the MFO type was approximately 945 kilo liters per day, equivalent to the consumption rate of relatively 47,250 cars. Therefore, the amount of fuel needed by ships to cross ALKI II within a period of three days was approximately 2,895 kiloliters of MFO. The amount of greenhouse gas, especially carbon emissions generated by ships, can be calculated using the following formula (IPPC, 2007):

$$E\ (CO2) = DA \times FE$$

Where:
E = Emissions tons of CO_2
DA = Activity Data (TJ)
= Fuel (Kilo liter) x Fuel specific gravity x Fuel net calorific value
FE = Emission Factor (tons/TJ)

Table 3. Potential Carbon Emissions of International Ships in ALKI II
As of December 31, 2023

Ship Fuel Consumption Details	**Consumption (tons @27 kL/day)**	**Emission Factor (tons CO_2/ton)**	**CO_2 Emissions (tons)**
Ship Daily Consumption (35 ships/day)	945	3,15	2.976
Consumption while crossing ALKI II (Three Day Voyage)	2.835	3,15	8.930
Consumption of 12,189 ships in 2023 for three shipping days in ALKI	987.309	3,15	3.110.023

Source: Data Processed by Researchers, 2024

The total emissions generated by 12,189 units of foreign ships in 2023, when passing through international shipping lanes in ALKI II was 3.11 million tons of CO_2. This is equivalent to 0.28% of the total carbon emissions from all international ships generated in 2020, amounting to 1,076 million tons of CO_2. The process does not include the 53,000 and 18,000 foreign ships passing through ALKI I and III per year, respectively.

The total carbon emissions from the ship exhaust tend to be in line with the sulfur emitted (Nahlik, 2016). Therefore, the safe limit of 0.5% or normal requirement of sulfur content in MFO fuel according to IMO refers to the Marine Pollution Convention Annex VI, regulation 14, effectively adopted by all international ships since January 1, 2020 (European Commisions, 2022). This policy also needs to be strictly verified by the Indonesian government for foreign ships entering ALKI. Furthermore, the inspection process is in line with the carbon management of ship fuel, due to the possibility that each ship was provided with two types of MFO fuel, namely low (maximum content of 0.5%) and high-sulfur standard oil (greater than 0.5%). This may violate IMO regulations, but at a procurement price 15% to 20% cheaper than low-sulfur MFO oil. In Indonesia, high-sulfur MFO was commonly used due to economical reason (Wahyudi & Fachruddin, 2020).

The government is mainly concerned about the Prevention of Maritime Environmental Pollution which regulates efforts to avert and overcome pollution to the sea and air such as oil spills, toxic liquid materials, or dangerous cargo in packaging, sewage waste, garbage and exhaust gas (emissions). Based on the regulation, every ship that crosses ALKI will be monitored, ensuring it uses fuel with an energy efficiency level referred to the Energy Efficiency Existing Ship Index (EEXI) and Energy Efficiency Design Index (EEDI) for ships built before and after 2015, respectively (Budiyanto MA et al., 2022). Another carbon management effort adopted was to ensure all ships crossing ALKI used low-sulfur fuel with a maximum content of 0.5% or equipped with a scrabber that functions to normalize sulfur emissions contained in MFO fuel with sulfur content greater than 0.5%. This adaptation effort was embraced by the Indonesian government to ensure the use of foreign ships passing through ALKI used MFO with a low-sulfur content below 0.5% as an international obligation since January 2020. In accordance with the acquired data and records, carbon management could be implemented by a carbon tax based on the validation results of the ALKI supervisory authority and the funds used to compensate ship owners in the form of certificates to finance the conservation maritime environment along ALKI (Aisyah et al., 2020; Lembang et al., 2012).

CONCLUSION

In conclusion, the main risks encountered by the communities along the ALKI included accidents and environmental disturbances caused by carbon emissions. The diverse communities alongside the government and business actors had adapted to the risk of accidents by following the rules of the separation scheme, as well as regulating traffic on ALKI that intersect with inter-island shipping lanes, although limited to areas in straits. Other regions along the ALKI had not been regulated in an integrated and systematic manner, depicting that along the ALKI there was risk of foreign ship accidents with Indonesian-flagged ships. Additionally, air pollution caused by carbon emissions lacked adaptation effort, including the adoption of appropriate actions to control and reduce or avert the emissions produced by thousands of foreign ships. The amount of emissions in ALKI II constituted approximately 0.3% of the total carbon emitted from global ship exhaust, also equivalent to 900 million tons of CO_2. This could be used as Indonesians Nationally Determined Contribution (NDC) in reducing carbon emissions from shipping sector as reported by the United Nations.

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GREEN SPACE EVALUATION OF SHAH ALAM LOW CARBON CITY, SELANGOR, MALAYSIA

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Abstract

This study examines Shah Alam's progress towards achieving its 2030 low-carbon city goal, focusing on the balance between rapid development, population growth, and carbon emissions. It emphasizes the necessity of a holistic approach to sustainable urban development that integrates societal needs with environmental concerns. The study aims to identify (i) the defining characteristics of green spaces in Shah Alam and (ii) the effectiveness of stakeholders' development strategies related to these green spaces. A qualitative methodology was adopted, utilizing six expert interviews conducted both face-to-face and online. Thematic analysis of these interviews revealed detailed insights into the interplay between green spaces and low-carbon urban development. A strong correlation was found between the attributes of green spaces and their carbon absorption capacity, influenced by factors such as area size, plant diversity, and absorption rates. Initiatives like the "Tree for Life" campaign have notably advanced the low-carbon city goals through strategic green space development. These collective efforts underscore the growing trend towards sustainable urban environments and highlight the critical role of comprehensive programs in enhancing green spaces to achieve low-carbon, sustainable cities.

Keywords: Green space, Low Carbon City, carbon reduction, development strategy, sustainable city

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INTRODUCTION

As a rapidly growing city, Shah Alam has experienced significant changes in land use and urban development, leading to a reduction in green space and an increase in carbon emissions. According to the Draft Rancangan Tempatan Majlis Bandaraya Shah Alam 2035, green spaces cover over 29,000 hectares in Shah Alam, constituting 12.9% of the city's total area (MBSA, 2017). However as highlighted in Shah Alam Voluntary Local Review 2021, due to Shah Alam's location in the Klang Valley and promixity to Kuala Lumpur, it faces environmental concerns, making it difficult for municipal management to combat climate change (Urbanice Malaysia, 2021). In response, the MBSA aims to transform Shah Alam into a low-carbon city through Local Carbon City (LCC) initiatives, targeting a 45% reduction in GHG emissions by 2030 (Yusfida Ayu, Khalid, Nor Baizura, Marlyana Azyyati, & Mohammad Yusup, 2023). In 2023, the Shah Alam City Council stood out as a prominent leader in the Malaysian Low-Carbon City Awards, clinching the most awards across five key categories, including greenery (as stated on the official MGTC reporting website for 2024) (Malaysian Green Technology And Climate Change Corporation, 2024).

Therefore, the enhancement of urban public green spaces stands as a pivotal strategy for fostering low-carbon cities, particularly in densely populated regions, because they play a crucial role in attaining carbon neutrality (Zhao, Cai, Xu, Liu, & Yao, 2023).

Shah Alam, a high-density city situated near Kuala Lumpur, faces unique challenges compared to other urban areas. The rapid development and significant population growth in this region contribute to increased carbon emissions, further complicating efforts to maintain sustainable urban environments. To address these challenges, the study aims to (i) identify the defining characteristics of green spaces in Shah Alam and (ii) assess the effectiveness of stakeholders' development strategies related to these green spaces. These findings provide valuable insights for policymakers and urban planners to enhance the sustainability of green spaces within LCC initiatives. Additionally, recommendations for improving carbon sequestration in green areas are proposed based on the evaluation results.

This paper provides a review of the pertinent literature on urban green spaces as carbon sinks in densely populated cities, focusing on the reduction of carbon emissions and the development of low-carbon cities. It then outlines the methodology employed for data collection and analysis, primarily through interviews with stakeholders. The data collection involved consulting experts in climate change, landscape architecture, and town planning to highlight the significance of green spaces in urban areas. The results of the study are then presented and discussed, followed by the conclusion.

Overall, this study aimed to understand the initiatives taken by the authorities, emphasising the importance of green spaces as carbon sinks to support carbon reduction efforts, particularly in densely populated cities such as Shah Alam.

LITERATURE REVIEW

Definition Low Carbon City Concept

A low-carbon city (LCC) can be defined as a city that comprises societies that consume sustainable green technology and green practices and emit relatively low carbon, or GHG, as compared with present-day practices to avoid the adverse impacts of present-day climate change (Haliza, 2020). The aim is to reduce urban carbon dioxide emissions through eco-friendly policies, economies, and governance. LCCs seek to enhance urban liveability, improve residents' quality of life, and boost urban community resilience to climate change (Gao & Zhang, 2020). Over the past 15 years, significant research attention has been focused on LCCs as a crucial effort in combating global warming (Wang, Wang, Chen, Zeng, & Heng, 2023). Research on the successful development of LCCs for carbon reduction should serve as exemplary models for countries facing challenges in reducing their carbon emissions (Wei & Wenmei, 2019).

The LCC concept has been introduced previously in Malaysian urban development and practice through the Low Carbon Cities Framework (LCCF), which delineates local authorities' targets to achieve zero carbon status (Nor Baizura, Yusfida Ayu, D. Ary Adriansyah, Nurul Shakila, & Na'asah, 2023). While the concept of a Low Carbon City (LCC) and its benefits are well-documented, there is limited detailed analysis on how high-density cities like Shah Alam specifically implement these strategies compared to lower-density or less developed urban areas. This study focused on how Shah Alam successfully implemented the LCCF to reduce carbon emissions and achieve a zero-carbon status, providing valuable insights for other countries striving to develop low-carbon cities.

Urban Green Spaces Important Elements in Carbon Sequestration

Urban Green Space (UGS) encompasses urban areas adorned with vegetation, including parks, community gardens, cemeteries, rooftop gardens, meadows, and wooded areas, often referred to as the blue-green zone (Haas, Hassink, & Stuiver, 2021). These spaces are vital in cities for promoting sustainability by enhancing liveability and fostering active community engagement. However, high dense cities like Kuala Lumpur face challenges in preserving green spaces due to land scarcity and competing demands for commercial and residential developments (Mohd Johari, Helmi Zulhaidi, & Junainah, 2019). This necessitates meticulous planning and collaboration among urban planners, policymakers, and community members to ensure sustainable urban landscape for present and future generations

(Owen, Mohd Johari, Sreetheran, Kei, & Junainah, 2022). Prioritising the preservation and creation of urban green spaces allows cities to mitigate the adverse effects of urbanisation, such as air pollution (Venter, Hassani, Stange, Schneider, & Castell, 2024) and heat island effect (Aram , García, Solgi, & Mansournia, 2019). The plant community and vegetation structure in urban green spaces have a high potential for carbon sequestration compared with other areas in the city (Alamah, Sakurah, & Siti Mazwin, 2015)

Therefore, this study aims to address these gaps by defining the characteristics of green spaces in Shah Alam and assessing their contributions to the city's carbon reduction efforts. By exploring the specific attributes of these green spaces and evaluating stakeholder strategies, this research seeks to provide valuable insights and practical recommendations for policymakers and urban planners to enhance the sustainability of green spaces within the LCC framework.

RESEARCH METHODOLOGY

The qualitative research employed interviews as the primary data collection method, chosen for their ability to provide an in-depth exploration of the characteristics of green spaces and low-carbon city initiatives. This approach allows for a comprehensive understanding of participants' experiences and perspectives, as highlighted by Bakhary (2023). The interviews were conducted with diverse individuals, including key stakeholders such as officers from the Shah Alam City Council (MBSA), the Malaysian Green Technology and Climate Change Corporation (MGTC), and experienced landscape architects specialising in green spaces and low-carbon city initiatives. Six individuals were interviewed face-to-face and online to address the study objectives (Table 1).

Table 1: Profile of key informants

No.	Department	Responsibilities	Role	Code
1	Malaysian Green Technology and Climate Change Centre (MGTC)	Review reliable data and identify the improvement.	Analyst	Key Informant 1
2	Planning Department, Shah Alam City Council (MBSA)	Site analysis for land use	Assistant Town Planning Officer	Key Informant 2
3	Landscape Department, Shah Alam City Council (MBSA)	Planning decisions and interpret data on land use	Assistant Town Planning Officer	Key Informant 3
4	Landscape Department, Shah Alam City Council (MBSA)	Planning and identify land use	Assistant Town Planning Officer	Key Informant 4

No.	Department	Responsibilities	Role	Code
5	Associate Professor UiTM Puncak Alam	Conducting significant and impactful research	Landscape Architecture	Key Informant 5
6	Senior Lecturer UiTM Puncak Alam	Conducting independent research in landscape	Landscape Architecture	Key Informant 6

The data analysis for this study employed thematic analysis to identify recurring themes and patterns, providing valuable insights into perspectives on green spaces and low-carbon urban development in Shah Alam. The process began with the transcription of six expert interviews, ensuring accuracy and completeness. In the initial coding phase, an open coding approach was used, highlighting significant statements and assigning initial codes with the help of Microsoft Excel. Following this, focused coding was conducted to review and refine these initial codes, grouping similar or related codes into broader categories. This phase involved constant comparison to refine and develop themes further.

The final stage involved the development of overarching themes based on the research objectives: (i) identifying the defining characteristics of green spaces in Shah Alam and (ii) assessing the effectiveness of stakeholders' development strategies. These themes encapsulated the essence of the data, providing a structured understanding of the study's findings.

ANALYSIS AND DISCUSSION

Overview of Green Space

The interviews conducted with key informants have illuminated the importance of green spaces in Shah Alam as a means to advance towards a low-carbon city, as depicted in Table 2. According to Key Informant 1, green spaces encompass various types of trees that absorb carbon, including city parks, landscape parks, urban forests, and lakes. These areas are crucial for cooling the surrounding environment. Key informants 2 and 3 shared similar views, defining green spaces as areas aiding carbon sequestration and greenhouse gas reduction. These include roadside trees, recreational spaces, parks, and mature trees. They exclude rooftop gardens from the green space category because of the use of flowering trees, which are seen as maximising greenery rather than carbon absorption. Shah Alam's land area allocates 7.33% (equivalent to 30,210.72 hectares) to green spaces, with 40% of this area already developed. Similarly, Key Informants 5 and 6 emphasised the importance of green spaces in landscape architecture. They highlighted specific tree types that efficiently absorb carbon, which is essential for urban planning. Green spaces are described as areas with grass, plants, trees, lakes (such as Taman Tasik Shah Alam), football fields, golf courses, rooftop gardens, and public parks. The presence of mature trees is particularly noted for

their role in creating a robust tree canopy and regulating microclimates by cooling the environment.

Table 2: overview of the interview findings from key informants regarding the characteristics of green spaces of Green Space

No.	Key Informant's Answer	Code
1	*"Green space consists of types of trees that absorb carbon. It includes urban parks, urban forests, landscape parks and even lakes."*	Key Informant 1
2	*"Green space is an area that helps in carbon sequestration including roadside trees, recreational areas, parks and mature trees. However, rooftop garden does not count as green space because it is just a way to maximize greenery, not as a carbon absorber."*	Key Informant 2
3		Key Informant 3
4	*"Any types of trees and land that absorb carbon and help in carbon sequestration. It is also included Shah Alam Lake (Carbon sink), forests (calculate ratio / plot by percent / estimate), farm, grass (count by area)."*	Key Informant 4
5	*"Green areas that help in carbon sink. Lakes and certain types of trees in green areas such as by the side of the road also included as green area."*	Key Informant 5
6	*"Any space that has a green area. It is contributed to the microclimate, reduces the temperature and plays a role in terms of carbon sequestration. This green area consists of either grass, plants, trees, lake (Taman Tasik Shah Alam). The football pitches, golf course, public park is the example of green space."*	Key Informant 6

However, there is a difference in opinions regarding the classification of these green areas. One perspective emphasises carbon sequestration primarily by mature plants, excluding grasses, fields, and flowering plants. This difference stems from the varying backgrounds and viewpoints. Despite this disagreement, there is consensus on the function of lakes as effective carbon absorbers, contributing to Shah Alam's goal of becoming a low-carbon city. Lakes in Shah Alam, such as the prominent Taman Tasik Shah Alam in Section 14, are divided into three zones: northern, central, and southern. These lakes serve multiple purposes, acting as recreational areas, public parks, and significant carbon sinks. In summary, the interviews revealed differing opinions on the classification of green areas, with one viewpoint focusing on mature plants used for carbon sequestration. However, all agree on the crucial role of lakes, such as Taman Tasik Shah Alam, in absorbing carbon and aiding Shah Alam's efforts toward a low-carbon city, and Figure 1 illustrates the conceptual framework on the distinctive attributes of green spaces within the context of Shah Alam low-carbon city.

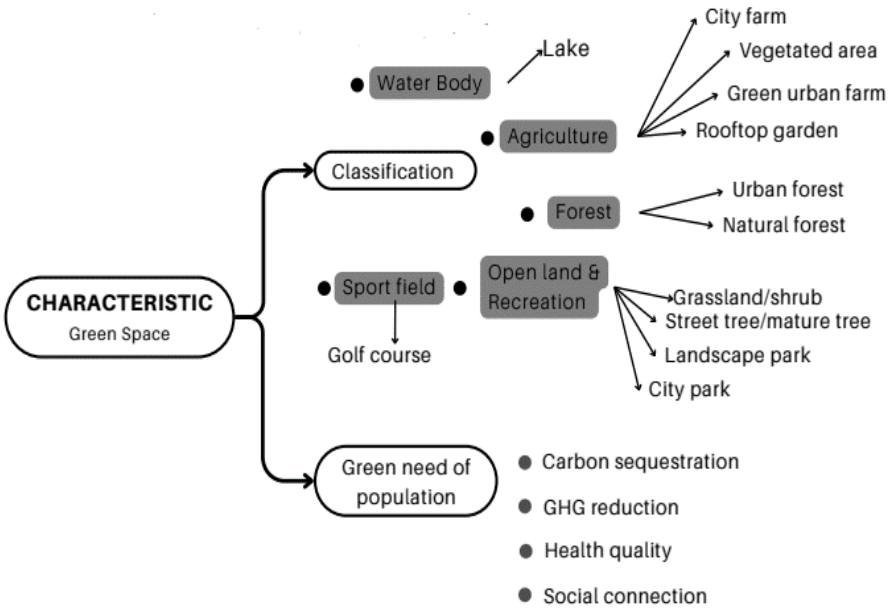

Figure 1: The conceptual framework pertaining to the characteristics of green spaces within Shah Alam Low Carbon City.

In summary, the key informants collectively agree that green areas in Shah Alam play a significant role in carbon absorption and the reduction of local temperatures. These areas contribute to carbon sequestration, microclimate regulation, greenhouse gas reduction, and environmental sustainability. Understanding the elements within urban green spaces is crucial for developing effective carbon reduction strategies in city planning.

Low Carbon City Strategies and Initiatives in Shah Alam

Interviews with key informants revealed numerous programs and initiatives dedicated to green spaces within Shah Alam Low Carbon City, exemplifying a holistic strategy toward environmental sustainability, as depicted in Table 3. Key Informant 1 highlighted the Shah Alam City Council's (MBSA) initiatives aimed at reducing carbon emissions through various programs. These include a car-free day, 3R (reduce, reuse, recycle) activities, community tree planting under "Shah Alam Tree for Life," "Mini ZeeBee," "Green Earth," "Back Alley Greening Initiative," and "Community Garden." Additionally, initiatives, such as green buildings, rainwater collection systems, and rooftop gardens, are encouraged to reduce carbon emissions.

Key Informant 2 and Key Informant 3 emphasised a multifaceted environmental strategy, featuring programs like "Tree for Life," extensive street planting efforts, and city center restoration with a sustainability focus. The city aims to decrease its reliance on vehicles, promote greener alternatives, and designate forested areas for protection. In accordance with the PLAN Malaysia Guidelines, every development project is obligated to dedicate a minimum of 10% of its area to green space. This underscores a firm's commitment to integrating nature into urban planning, reflecting a proactive approach towards fostering sustainable and eco-friendly environments. The implementation of the SPAH system for buildings ensures an eco-friendly approach for water resources.

Key Informant 4 elaborated on initiatives such as the "Green Urban Farm," "Tree for Life," street planting, and the Community Orchard program. These initiatives engage residents, academic institutions, NGOs, and private companies in tree-planting and community engagement activities. Gazetting forests, implementing compulsory litter systems for housing, and conducting tree inventories for mature trees contribute to the Low Carbon City Catalyst Grant (LCC 2030 challenge). Key Informants 5 and 6 provided insights from a landscape architecture perspective. The Low Carbon Building Campaign aims to raise awareness and promote innovative green practices among building owners. It emphasises the preservation of mature trees with specific codes and promotes a sustainable urban ecosystem through the Greening and Placemaking Initiative (GPI).

Table 3: Overview of the interview findings from key informants regarding the strategies and initiatives for establishing a Low Carbon City in Shah Alam.

No.	Key Informant's Answer	Code
1	*"The awareness program with public (3R activity, planting trees), Shah Alam car free day, MBSA building, SPAH, Rooftop Garden (energy, greenery applied in building). The addition of trees after the construction is replaced with new trees. Trees planted high absorption rate tree, so that carbon is balanced. The collaboration with building owner that attract other building to practice the same concept."*	Key Informant 1
2	*"The program of tree planting program (Tree for Life), street planting, restore the city center to make it more sustainable, reduce the use of vehicles, gazette the forest. Every development is required 10% is not reserved for green areas and SPAH system for the building. MBSA have target 80,000 trees planting per year."*	Key Informant 2
3	*"LCC Greenery, tree inventory on how many trees are planted, rooftop garden, green urban farm (encourage planting together). Urban Kid Farm (plant and sell)".*	Key Informant 3
4	*"Include the concept of greenery in urban and development planning: solar energy usage for our street lights, increase these green areas in the initial plan, develop it into a green area, SPAH system for the building"*	Key Informant 4

No.	Key Informant's Answer	Code
5	*"Increase on the landed property, the rooftop garden, street planting (greenery along the street), urban design, GPI (plant trees either in the building or in front of the building), infield development, mature trees are gazetted (there is a code)."*	Key Informant 5
6	*"The importance of greenery in community engagement, including programs for planting and sustainability education."*	Key Informant 6

Thus, the interviews suggest that effective initiatives for green spaces in Shah Alam involve programs such as "Tree for Life," "Community Orchard," and "Mini ZeeBee." These initiatives are well received and foster a sense of belonging among residents to preserve greenery and trees. Collaboration with the government and NGO agencies encourages volunteerism and community involvement in Shah Alam's sustainability efforts.

Partnerships and Collaborations

The key informant interviews highlighted the significant partnerships and collaborations between the city government and various organizations or stakeholders to support green space initiatives in Shah Alam Low Carbon City. As illustrated in Table 4, Key Informant 1 emphasised the involvement of the community, students, and stakeholders in programmes organised by the Shah Alam City Council (MBSA). An example is the ZeeBee program, which utilises backyard spaces for activities such as agricultural competition and vegetable crop cultivation. In Section 7 residential areas, the council collaborated with village committees to design a green programme involving mini gardens and rest areas. The agriculture department also provided briefings on effective planting methods. This inclusive approach, involving households, village committees, and government departments, reflects MBSA's commitment to community and collective responsibility for sustainable urban development.

Key Informant 2 and Key Informant 3 echoed similar sentiments regarding collaboration in Shah Alam. Various entities across governance and community sectors collaborate actively with the city council, highlighting the shared responsibility for sustainability. This includes engagement with SUK Selangor, developers, manufacturers, university students, the Ministry of Agriculture, and PKNS in programs such as Low Carbon Building and Low Carbon Innovation initiatives. These collaborations underscore the concerted effort to reduce carbon emissions and achieve environmental objectives.

Key Informant 4 emphasised the importance of agency collaborations, starting with MBSA's efforts to promote the Low Carbon City agenda in town planning and city management. Initiatives, such as tree-planting programs, involve school and university students. Green Technology Malaysia, a government agency, plays a crucial role as a financial provider and promoter of sustainability initiatives.

Key Informants 5 and 6 highlighted a collective approach in which educational institutions and government agencies work together under MBSA. This collaboration involves local authorities, stakeholders, NGOs, large developers, and building owners to address the environmental, social, and sustainable development issues.

Table 4: Overview of the interview findings from key informants, significant partnerships and collaborations between the city government and various organizations or stakeholders

No.	Key Informant's Answer	Code
1	*"Most programs organized by MBSA involve the community, students and stakeholders. This involvement is not only from the lower level, but also involves the owner of the building together with the organized activities. Example: ZeeBee program uses the backyard of the house, agricultural competition, greening the backyard for vegetable crops. Under flat section 7, create a green program, mini garden, resting place between village committees. The cooperation with the agriculture department to give briefings on planting methods."*	Key Informant 1
2	*"Different level of agency and community have a collaboration with the city council such as SUK Selangor, developer, manufacturer, University students, Ministry of agriculture, PKNS in many types of programs. The involvement to make sure the carbon reduction and ensure goals are achieved."*	Key Informant 2
3	*"Shah Alam community, student from different level of education."*	Key Informant 3
4	*"Local authorities, stakeholders, NGO, UiTM student and community."*	Key Informant 4
5	*"Big developers, owner of the building, community and authorities."*	Key Informant 5
6	*"Community-focused programs, stakeholders' involvement in eco-friendly initiatives."*	Key Informant 6

This discovery reveals the collaborative of diverse stakeholders aimed at realizing the vision of a low-carbon city. These stakeholders exemplify their dedication to environmental sustainability by making significant investments in impactful projects and leading the charge of embracing green technologies. Nevertheless, persistent challenges, such as constrained resource allocation and the need for heightened community awareness have emerged, posing hurdles to achieving a harmonious equilibrium between development and conservation. These challenges compel the nation to initiate and sustain efforts towards low-carbon city initiatives (Siti Afiqah, Zakiah, Aisyah , & Fatiah, 2023). Figure 2 illustrates the development strategies and initiatives aimed at enhancing green spaces within the context of Shah Alam Low Carbon City.

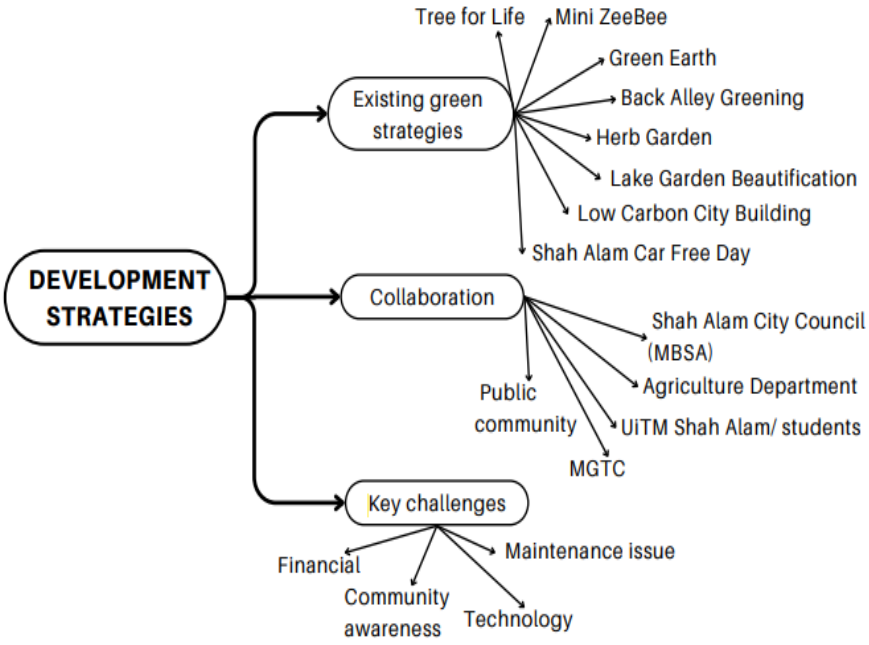

Figure 2: The development strategies and initiatives for green spaces within Shah Alam Low Carbon City.

The study's findings are based on six expert interviews, which, while providing in-depth insights, may not fully capture the diversity of perspectives on green spaces and low-carbon development strategies in Shah Alam. The limited number of interviews may affect the generalizability of the findings.

CONCLUSION AND RECOMMENDATION

This research has shown the significant potential of green spaces in Shah Alam for carbon sequestration through action plans and effective management. These spaces play a crucial role in carbon capture and retention, thereby contributing to environmental sustainability. All stakeholders play an important role in preserving and improving this green space as a valuable asset in reducing climate change and greenhouse gas emissions. It is encouraging that the recommendations can be applied to other locations for the development of low carbon city.

The suggestions addressed in this study emphasise the importance of fostering partnerships among stakeholders, including authorities, community members, and students, to improve communication and integration. Additionally, this study suggests adopting best practices from developed nations and implementing advanced technologies to optimise green space utilisation and

reduce carbon emissions from the industrial and transportation sectors. Future researchers may conduct in-depth research on carbon sequestration in urban planning, particularly by assessing the effectiveness of green spaces and renewable energy integration, and analysing the development strategies across different cities. These insights may support future actions for sustainable urban development and highlight the crucial role of green spaces in carbon capture and environmental sustainability within the broader context of LCC initiatives.

For scaling the findings to other cities, it is essential to consider the unique socio-economic, cultural, and environmental contexts of each urban area. Customizing the action plans and management strategies to fit local conditions can enhance the effectiveness of green space initiatives. Furthermore, collaboration and knowledge-sharing between cities can facilitate the adaptation of successful practices. By doing so, cities can collectively progress towards achieving low-carbon goals and mitigating climate change.

Future researchers may conduct in-depth studies on carbon sequestration in urban planning, particularly by assessing the effectiveness of green spaces and renewable energy integration, and analyzing development strategies across different cities. These insights can support future actions for sustainable urban development and highlight the crucial role of green spaces in carbon capture and environmental sustainability within the broader context of LCC initiatives. By exploring these areas, researchers can provide valuable guidance on how cities worldwide can implement similar strategies and achieve low-carbon urban environments.

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SUSTAINING THE ENVIRONMENT THROUGH E-WASTE RECYCLING

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Abstract

Millions of electrical and electronic devices are thrown away annually due to items breaking or needing to be updated. These discarded electronics are referred to as e-waste. Using an online survey with a quantitative approach, this study examined the interrelationships among knowledge of hazards of e-waste, attitude towards e-waste recycling, pro-environmental intention, and e-waste recycling behaviour among households in Kelantan, Malaysia (n=300). Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to examine the relationships between the variables. The findings of this study reveal a favourable relationship between knowledge of the hazards of e-waste and attitude towards e-waste recycling with pro-environmental intentions. Furthermore, an appropriate relationship was discovered between the intention to e-waste recycling behaviour. The study provides theoretical insights and practical suggestions relevant to regulators and practitioners, focusing on encouraging e-waste recycling to support environmental sustainability.

Keywords: E-waste, Recycling, Environmental, Sustainable

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INTRODUCTION

The global surge in electronic and electrical equipment (EEE) consumption has emerged as a pivotal concern due to the growing popularity of electrical and electronic equipment. This escalating usage has rapidly increased electronic waste (e-waste), posing a common challenge for developing nations worldwide. The proliferation of e-waste is outpacing general waste, with its growth rate being three times faster (Ramzan et al., 2021; Yuan et al., 2019). In 2019, the world witnessed a historic high in electronic waste (e-waste) generation, reaching 53.6 million metric tons (MMT). Forecasts indicate a substantial increase, with an expected surge to 74 MMT by 2030, almost double the amount recorded in 2014. Notably, Asia stands out as the leading contributor, annually generating 18.2 MMT of e-waste (Sabbir et al., 2023). The growing issue of electrical and electronic waste nowadays has sparked concern about the inability of recycling activities to compete with the usage of e-waste generated by regular users.

Electronic waste includes a wide range of devices such as mobile phones, laptops, televisions, dishwashers, freezers, and air conditioners. E-waste is a term that describes electrical and electronic products that are no longer working, have exceeded their useful life, or have become obsolete. It can be broken down into two main sources, either wastes generated from the industrial sector or the residential sector. According to Code SW110, First Schedule, Environmental Quality (Scheduled Wastes) Regulations 2005, electronic waste in Malaysia is categorised as being under the category of Scheduled Waste. Sofian et al. (2023) explained that the organisation in charge of managing electronic trash in the country is the Department of Environment (DOE). Thukral et al. (2023) and Sofian et al. (2023) described that components that fall under Code SW110 for electrical and electronic waste include things like mercury switches, accumulators, cathode ray tube glass, activated glass, polychlorinated biphenyl capacitors, or lead, nickel, chromium, copper, lithium, silver, manganese, or contamination with polychlorinated biphenyls. These types of waste are classified as hazardous waste.

Unutilised and unharmed devices, when appropriately maintained, typically do not have any adverse impact on human health or the environment. However, it is different for devices that are left out in the heat, in the rain, or in a humid atmosphere, as it encourages the synthesis of toxic substances. Similarly, the toxic substances on electronic devices will degrade and seep into the environment through the soil or underground water if they get thrown in a trash can or somewhere else that is not a designated landfill (Mahmod et al., 2021).

Recycling methods are among the most effective ways to manage electronic waste, providing a sustainable approach to handling and repurposing devices and minimising environmental impact. E-waste recycling involves breaking down electronic waste into small fragments through shredding to extract valuable materials. These recovered materials can then be reused in the

manufacturing of new electronic appliances. The recycling program in Malaysia is still in its nascent phase, and there is a conspicuous dearth of involvement among the residents. The recycling rate in the country is significantly lower in comparison to other developed countries (Afroz et al., 2020).

Yahya et al. (2022) stressed that knowledge plays a crucial role in influencing public attitudes and promoting responsible practices to reduce electronic waste generation. By increasing awareness and understanding, we can encourage the public to actively contribute to E-waste reduction efforts. Mahat et al. (2019) stated that improving Malaysians' negative outlook on recycling e-waste is crucial to solving the country's primary e-waste problem. Shifting perspectives and fostering a more positive approach can be key to promoting responsible disposal and recycling habits among the population. Thus, appropriate e-waste disposal and recycling programs are becoming a global concern for academics, practitioners, and governments. An efficient management system for collecting, processing, and recycling e-waste is crucial.

Based on the issue raised above, this study aims to explore the relationships between knowledge of e-waste hazards (K) and attitudes towards e-waste recycling (A) in households, which influence pro-environmental intention (I). Additionally, the study investigated the relationship between pro-environmental intention (I) and e-waste recycling behaviour (B). Finally, the study aims to examine how pro-environmental intention (I) mediates the relationship between knowledge of e-waste hazards (K) and e-waste recycling behaviour (B), as well as between attitudes towards e-waste recycling (A) and e-waste recycling behaviour (B).

DEVELOPMENT OF RESEARCH FRAMEWORK AND HYPOTHESES

Figure 1 illustrates the research framework employed in this study. The following hypothesis is proposed:

H_1: Knowledge of the hazards of e-waste (K) significantly influencing pro-environmental intention (I).
H_2: Attitude towards e-waste recycling (A) significantly influencing pro-environmental intention (I).
H_3: Pro-environmental intention (I) significantly influences e-waste recycling behaviour (B).
H_4: Knowledge of the hazards of e-waste (K) has positive impacts on pro-environmental intention (I) to execute the e-waste recycling behaviour (B).
H_5: Attitude towards e-waste recycling (A) has positive impacts on pro-environmental intention (I) to execute the e-waste recycling behaviour (B).

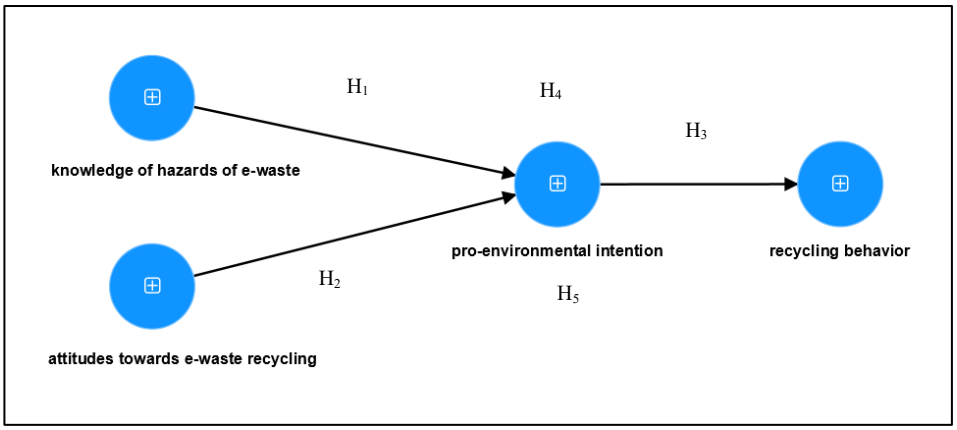

Figure 1: Research Framework

RESEARCH METHODOLOGY

This study has chosen households in Kelantan as the primary target respondents due to the significant amount of e-waste generated by households annually with a sample size of 300 participants (n=300). In this study, a questionnaire was designed to collect primary data from the intended respondents using survey research, a quantitative approach. Google Forms was used to disseminate the questionnaires online. The three measurement items of knowledge of hazards of e-waste, three measurement items of attitude towards e-waste recycling, and four measurement items of e-waste recycling behaviour were adapted from Akhtar et al. (2014). Furthermore, the three pro-environmental intentions were modified and embraced by Thoo et al.'s (2022) research. The survey employed a five-point Likert Scale, encompassing from 1 (Strongly disagree) to 5 (Strongly agree). Following the data collection phase, the obtained data underwent screening, processing, and analysis utilising the Statistical Package for the Social Sciences (SPSS) and SmartPLS software. The decision to use SmartPLS was driven by the research framework of the application, which involved modelling relationships between several components.

ANALYSIS AND DISCUSSION

Respondent's Characteristics

Table 1 presents the demographic characteristics of the 300 respondents. It covers aspects such as gender, age, education level, profession, and income distribution.

Table 1: Respondent's characteristics

Characteristics		**No. of respondents**	**%**
Gender			
	Male	150	50.0
	Female	150	50.0
Age			
	18 to 24	126	42.0
	25 to 34	75	25.0
	35 to 49	52	17.3
	50 to 64	26	8.7
	65 above	21	7.0
Education level			
	Primary school	13	4.3
	Secondary school	65	21.7
	STPM	15	5.0
	Certificate	31	10.3
	Diploma	51	17.0
	Degree	112	37.3
	Master/PhD	6	2.0
	Others	7	2.3
Profession			
	Public sector	49	16.3
	Private sector	77	25.7
	Self-employed	121	40.3
	Others	53	17.7
Income			
	Below RM1000	126	42.0
	RM1001 to RM3000	138	46
	RM3001 to RM5000	26	8.7
	RM5001 above	10	3.3

The sample has an equal gender distribution, with men and women each representing 50% (150) of the total respondents. This balance guarantees that the viewpoints of both genders are equally depicted in the survey findings. Most respondents are young adults, with 42% (126) aged 18 to 24 years and 25% (75) aged 25 to 34 years, indicating a predominantly younger population in the sample. There were 17.3% (52) respondents aged 35 to 49 years old, 8.7% (26) respondents aged 50 to 64, and 7.0% (21) respondents aged 60 and above. Next, the education level of respondents is varied, with the largest group holding a degree of 37.3% (112). A significant portion of respondents, 21.7% (65), have completed secondary school, while only a small percentage, 4.3% (13), have only primary school education. The low percentage of respondents with postgraduate education (Master/PhD) at 2.0% (6) suggests that the sample has a modest level of higher education overall. The largest group of respondents is self-employed, accounting for 40.3% (121) of the sample. This indicates a strong presence of

entrepreneurship or freelance work within the population. The private sector employs 25.7% (77) of respondents, while 16.3% (49) work in the public sector. The other category, which could include students, retirees, or those not formally employed, makes up 17.7% (53) of the respondents. Lastly, income distribution shows that nearly half of the respondents, 46.0% (138), earn between RM1001 to RM3000, which could be considered a middle-income bracket. A significant 42.0% (126) of respondents have an income below RM1000, suggesting a substantial portion of the population is in the lower-income bracket. Only 8.7% (26) of respondents fall within the RM3001 to RM5000 income and a mere 3.3% (10) of respondents earn above RM500.

Assessment of the Measurement Model

The model assessment has two stages. Initial instrument validity and reliability assessments used the measurement model in accordance with Hair et al. (2019). The proposed paths were then examined using a structural model. A number of factors were used to construct the measurement model. These variables included loadings, composite reliability, and average variance extracted (AVE).

Table 2: Reflective Measurement Model Result

Latent Variable	Indicators	Outer Loadings	Composite Reliability	AVE	Cronbach Alpha
Knowledge of hazards of e-waste	C1	0.907	0.903	0.812	0.885
	C2	0.919			
	C3	0.876			
Attitude toward e-waste recycling	E1	0.937	0.907	0.832	0.898
	E2	0.949			
	E3	0.848			
Pro-environmental intention	H1	0.908	0.891	0.818	0.889
	H2	0.924			
	H3	0.881			
Recycling behaviour	J1	0.896	0.901	0.768	0.899
	J2	0.865			
	J3	0.883			
	J4	0.859			

The findings in Table 2 show that the reflective measurement paradigm demonstrates both reliability and validity. All of the loadings surpassed the threshold value of 0.7 (Hair et al., 2014), with item loadings ranging from 0.848 to 0.949. Similarly, the average variance extracted (AVE) values of the constructs surpassed the threshold of 0.50, ranging from 0.768 to 0.832. This result suggests that the items within each construct account for at least 50% of the variance in the latent constructs. The CR values also surpassed the minimum requirement of 0.70, confirming internal consistency in each construct. Convergent validity for

the constructs is confirmed based on these indicators. The indicator loading is presented visually in Figure 2.

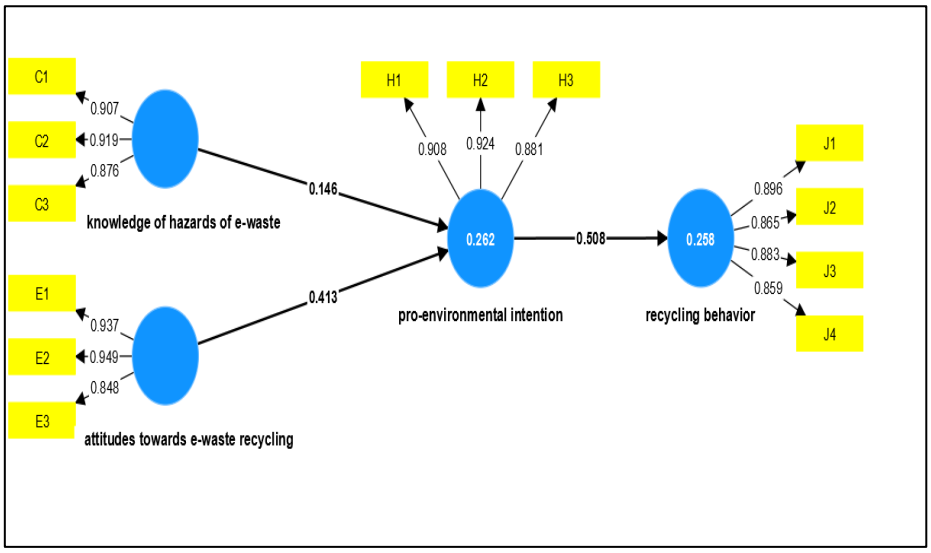

Figure 2: Measurement Model

Table 3: Heterotrait-monotrait ratio (HTMT)

	Knowledge of hazards of e-waste	Attitude toward e-waste recycling	Pro-environmental intention	Recycling behaviour
Attitude towards e-waste recycling				
Knowledge of hazards of e-waste	0.642			
Pro-environmental intention	0.555	0.429		
Recycling behaviour	0.532	0.437	0.566	

Discriminant validity was assessed through the use of the heterotrait monotrait (HTMT) criterion, as recommended by Hair et. al (2019). According to Hair et.al (2019), scores below 0.90 show that each construct is effectively measuring a unique theoretical notion. The results demonstrate that the latent variables' values are significantly lower than the threshold value, suggesting a lack of correlation between the concepts (Table 3). These validity tests indicate that the measurement items possess both validity and reliability. In general, the results of this investigation provided support for each indication in the

measurement model, as depicted in Figure 2. This indicates that the measurement model exhibits appropriate levels of reliability and validity.

Assessment of the Structural Model

After establishing the validity of the measurement model, the next phase involves developing the structural model using a significant number of indicators. The evaluation of the Partial Least Squares Structural Equation Modeling (PLS-SEM) includes evaluating the coefficient of determination (R^2), estimating the path coefficient (β), measuring the effect size (f^2), and determining the prediction relevance (Q^2).

In the structural model, each assumption is represented by a pathway that connects two latent variables as the relationship between them. For the purpose of analysing the relationships between the independent factors and the dependent variables, the SmartPLS software was deployed. In order to determine the level of significance, the relationship between the variables that were defined in the framework was evaluated by analysing the value of the regression coefficient (β). A thorough evaluation of the significance of the regression coefficient β was conducted by examining the t-values that were obtained using the PLS Bootstrapping methodology. The output of the t-statistics was utilised to determine the relevance of each specific relationship. All of the suggested paths are presented in Table 3, together with their respective path coefficients, observed t-statistics, and significance levels. The hypotheses submitted were either approved or rejected based on the results received from the path evaluation, as described in the next section.

Cohen (1988) and Ismail et. al (2023) have proven that f^2 values of 0.02, 0.15, and 0.35 correspond to modest, medium, and large effects, respectively. Table 3 shows that knowledge of the hazards of e-waste toward pro-environmental intention has a small effect size of 1.9%. Meanwhile, attitude towards pro-environmental intention has a medium effect size of 15%. At the same time, pro-environmental intention toward e-waste recycling behaviour has a large effect size of 35%.

Table 3: Path Coefficients of Testing Model

Hyp		ß	f^2	T-Statistics	P-Values	Results
H_1	K -> I	0.148	0.019	2.139	0.032	**Accepted**
H_2	A -> I	0.416	0.154	6.986	0.000	**Accepted**
H_3	I -> B	0.513	0.348	9.088	0.000	**Accepted**

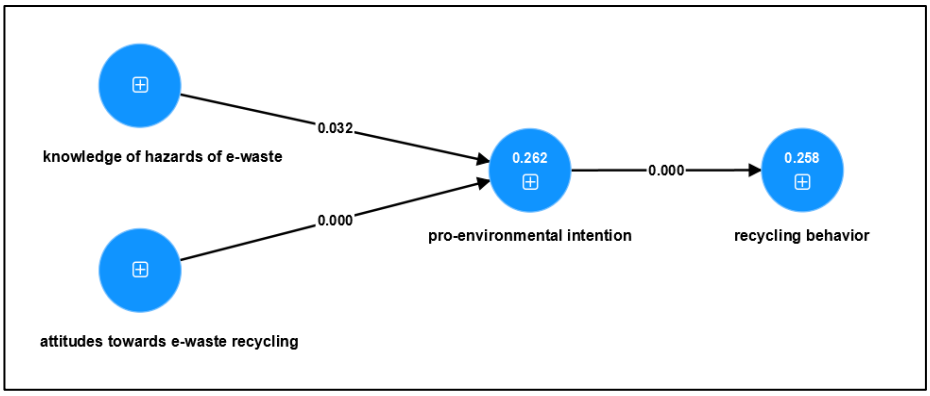

Figure 3: Structural model

A depiction of the path coefficients, observed t-statistics and significance levels of the structural model can be found in Table 3. Figure 3 above shows the structural model with the result of significance levels. If the significance of the path coefficients approaches or is above the 95% confidence level, then the path coefficients are deemed to be acceptable. Based on the findings shown in Table 3, a strong relationship was observed between knowledge related to intention (β=0.148; t=2.139; p-value=0.032). Given that the p-value is less than 0.05, the result is statistically significant, suggesting that the alternative hypothesis (H_1) is accepted. Consequently, understanding the dangers linked to e-waste might enhance consciousness regarding the significance of appropriate disposal and recycling. Increased awareness of the environmental and health hazards associated with e-waste is expected to foster a greater sense of accountability and environmental consciousness among individuals (Roslan et al., 2024; Ismail & Amin, 2020). Also, this knowledge can lead to a stronger intention to engage in pro-environmental behaviours, such as recycling electronics, reducing the purchase of unnecessary gadgets, supporting eco-friendly companies, and advocating for policies that promote sustainable e-waste management.

Secondly, the result specifically demonstrated that attitude toward e-waste recycling has significance towards pro-environmental intention (β=0.416; t=6.986; p-value=0.000). Statistically, the p-value is <0.05. Thus, H_2 was also accepted. A positive attitude towards e-waste recycling can strengthen a person's intention to act in environmentally responsible ways, such as reducing e-waste, reusing electronics, and supporting policies that promote sustainable practices. If individuals hold a positive attitude, they are more likely to be motivated to take specific actions that align with their beliefs, such as participating in recycling programs, choosing products with longer lifespans, or advocating for better e-waste management practices.

Lastly, the results show that pro-environmental intention has a significant relationship with e-waste recycling behaviour (β=0.513; t=9.088; p-value=0.000).

Therefore, H_3 was also accepted, meaning that a strong pro-environmental intention reflects a commitment to engage in behaviours like e-waste recycling. This intention acts as a driving force that motivates individuals to overcome barriers and take action.

The degree to which the independent variable influences the dependent variable is taken into consideration by the coefficient of determination (R^2). In particular, it shows how much the independent variable (or variables) may explain the dependent variable's treatment. How well the independent factors explain this number indicates the variation in the dependent variables. In the structural model of PLS analysis, Hair et al. (2014) say that R^2 values of 0.25, 0.50, and 0.75 mean that the relationship is weak, moderate, or large, in that order. Nevertheless, Hair et al. (2019) observe that the acceptable R^2 value can differ according to the research discipline. According to Cohen (1988), R^2 values of 0.26, 0.13, and 0.02 are considered to represent strong, moderate, and weak effects, respectively, in social science research.

The findings shown in Table 4 demonstrate a significant level of variability (R^2 values ranging from 0.262 to 0.258) in the pro-environmental intention and recycling behaviour construct, which may be accounted for by the suggested predictors. Table 4 indicates that the environmental attitude accounted for 28.8% of the observed variation. Table 4 shows that the understanding of the dangers of e-waste and the attitude towards recycling e-waste were able to account for 26% ($R^2 = 0.262$) of the variation in pro-environmental intention. Furthermore, the components related to pro-environmental intentions were able to account for 26% ($R^2 = 0.258$) of the variability in recycling behaviour. The R^2 score of 0.288 for pro-environmental intention and recycling activity was classified as weak due to its proximity to 0.25, suggesting a nearly weak level. Nevertheless, as said earlier, a value of R^2 more than 0.26 is a strong indicator of intention and behaviour in this particular field of social science research.

Table 4 indicates that the pro-environmental intention has a Q^2 value of 0.208, while the recycling behaviour has a Q^2 value of 0.194. All values were greater than zero, indicating that the model is adequately predictive.

Table 4: Coefficient of Determination (R^2) and Predictive Relevance (Q^2)

	R^2	Q^2
Pro-environmental intention	0.262	0.208
Recycling behaviour	0.258	0.194

A mediation effectiveness study was conducted to fully validate the proposed model. A mediator is a variable that helps explain the relationship between a predictor and an outcome. It acts as an intermediary in the causal route between the independent variable and the dependent variable.

Based on the findings of Table 5, the research affirms that pro-environmental conduct does not act as a mediator in the connection between

knowledge and recycling behaviour. People are able to take independent action based on specialised information regarding electronic waste without being influenced by their overall environmental behaviours or attitudes, as this skill is available to them. Later on, it was shown that the pro-environmental intention had a role in linking attitude and recycling behaviour. Therefore, a higher level of positivity towards recycling directly correlates with a stronger inclination to recycle, which finally leads to the actual act of recycling.

Table 5: Mediation Analysis

Hyp		(ß)	SD	T-Statistics	P-Values	Results
H4	K -> I -> B	0.077	0.038	1.949	0.051	**Rejected**
H5	A -> I -> B	0.214	0.043	4.857	0.000	**Accepted**

CONCLUSION

This study highlights the crucial need to comprehend the hazards linked to e-waste and cultivate a positive attitude towards recycling e-waste. These factors significantly affect the development of environmentally friendly intentions, which in turn shape the actual recycling behaviours of households in Kelantan, Malaysia. The research confirms that both awareness and viewpoints significantly influence the propensity to engage in environmentally sensitive actions, such as recycling electronic waste. These findings offer valuable theoretical insights into the elements that impact recycling behaviour and have practical implications for policymakers and practitioners. The study suggests that by increasing public knowledge and fostering positive attitudes towards e-waste recycling, it is possible to effectively promote sustainable behaviour, thus making a substantial contribution to environmental conservation efforts. Properly disposing of electronic waste through recycling is an essential method for preserving the environment. Recycling e-waste helps protect the environment by reducing the harmful effects of toxic substances, conserving valuable resources, reducing greenhouse gas emissions, and promoting sustainable consumption. Collaboration among individuals, companies, and governments is necessary to effectively manage e-waste and prioritise environmental sustainability in light of technological advancements.

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ENFORCEMENTS INFRASTRUCTURE RESILIENCE INDEX OF THE WATER AND SANITATION SECTORS TO CLIMATE CHANGE IN COASTAL CITIES

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Abstract

Climate change (CC) is a significant global environmental issue that poses severe consequences, particularly on agricultural productivity, lifestyle, infrastructure, and overall population well-being. These impacts are projected to vary among different countries. The primary concern of this research is that infrastructure networks, which both contribute to the causes of climate change and are essential for its resilience, would be more susceptible to its physical impacts, notably in the water and drainage sector. The research aims to develop a model for measuring the climate change resilience index for the water and drainage sector in coastal cities. Through an inductive approach to study climate change and its risks and the resilient infrastructure to climate change and its principles, then analysing structural and administrative adaptation measures, extracting structural, administrative, and emergency plans, then assessing the extent of adopting the principles of planning and confronting climate change, developing a measurement index, then applying it to New York, Melbourne, and Thessaloniki, and finally extracting the conclusions.

Keywords: assess resilience; emergency plans; facing climate change; water; drainage; resilience index; urban resilience.

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INTRODUCTION

Climate change (CC) is an alteration in the typical climatic conditions, including temperatures, wind patterns, and precipitations, that are characteristic of each region on Earth. The long-term effects of extensive climate change will significantly influence natural biological systems. Rising temperatures will result in alterations in weather patterns, including wind directions, precipitation levels, and various extreme climate occurrences. The situation results in extensive and unforeseeable environmental, social, and economic impacts (Environmental Affairs Agency of the Ministry of Environment in Egypt, 2022).

Climate change affects mortality and morbidity by increasing the occurrence of extreme weather phenomena like heat waves, storms, and floods. It also disrupts food systems and leads to a rise in zoonotic diseases, food and waterborne-illnesses, vector-borne diseases, and mental health problems (WHO, 2022). The World Health Organization forecasts that climate change will lead to the deaths of 250,000 individuals from 2030 to 2050 as a result of starvation, malaria, and heat stress. The United Nations FAO has found that climate change leads to severe weather phenomena, droughts, floods, and other calamities that impact the livelihoods of millions of people worldwide. Approximately 78% of the global impoverished population, estimated over 800 million individuals, is significantly impacted by such an issue (FAO, 2019).

LITERATURE REVIEW

Infrastructure

Infrastructure is the set of physical components of interconnected systems that provide necessary goods and services to enable, sustain, or improve community living conditions. Water and sanitation networks include:

- Water purification, treatment, and storage operations.
- Water facilities and structures.
- Water installations: water lines, pumping, electrical and mechanical equipment.
- Wastewater and rainwater collection operations.
- Wastewater treatment operations.
- Reuse of treated wastewater.

The Impact of the Water and Sanitation Sector on Climate Change

Sanitation pollution is an increasingly significant danger to both humans and marine life, and it is the primary cause of coastal contamination on a global scale. Globally, we discharge approximately 80% of wastewater into the environment without any treatment, (UNESCO, 2017), releasing numerous detrimental

contaminants into the ocean, causing direct harm to both individuals and coral reefs. resulting in:

- Physical and biological degradation of coral reefs, seagrasses, and salt marshes;
- a loss of coastal ecological services like erosion control, storm buffering, and fish spawning grounds;
- Detrimental algal blooms that result in the mortality of marine organisms, the closure of coastal areas, and the emergence of diseases in humans; and
- Pathogens, metals, and toxic substances can cause diseases.

Impacts of Climate Change on Water and Sanitation Sector

Climate change has an impact on the water and sanitation sectors. Figure 1 shows how the water and drainage industries are affected by climate change.

Temperature changes	Sea level rise	Changing rainfall patterns	Changing storm patterns
- Increased need for water due to heat. - Increased need for treatment. - Increased evaporation from tanks. - Increased evaporation of irrigation water. - Deterioration of the quality of drinking water due to high temperatures and the spread of pests. - deteriorating water quality.	- Inundation of coastal infrastructure. - Salinization of groundwater sources - Low level of protection provided by coastal defenses - Overburden of sewage systems.	- Increased need for water storage capacity. - Increased risk of dam overflow. - Increased risk of overflowing drains and sewage problems. - Deterioration of water quality, decrease in drinking water and increased treatment costs.	- Structural damage - Low level of protection provided by flood defences.

Figure 1: the impact of climate change on the water and sanitation sector.
Source: OCED, (2018)

The Concept of Climate Change Resilient Infrastructure

It is the infrastructure that is planned, designed, constructed, and operated in a way that anticipates, prepares for, and adapts to changing climatic conditions. It can also withstand, respond to, and recover quickly from disturbances caused by these climatic conditions. Ensuring climate resilience is an ongoing process throughout the life of infrastructure. Efforts to achieve climate resilience can be mutually reinforced through efforts to increase resilience to natural hazards (OCED, 2018). It is known as a network of equipment and components used to confront civilizational climate challenges by relying on nature as much as possible (UNDRR, 2022). the principles of infrastructure resilience are shown Figure (2).

Principles of Climate Change Resilient Infrastructure Planning

Infrastructure can play an essential role in strategies to manage risks and reduce the negative impacts of climate change. The physical effects of climate change, such as rising temperatures, shifting precipitation patterns, increased intensity or frequency of extreme weather phenomena, and rising sea levels, will affect all types of infrastructure. Principles for planning climate-resilient infrastructure include (Cinta Lomba-Fernández, and others, 2019):

- Ensuring infrastructure is resilient to climate change;
- Guaranteeing financial flows;
- Increasing the lifespan of infrastructure;
- Using an approach based on smart infrastructure;
- Using an ecosystem-based approach;
- Taking into account social changes; and
- Taking into account economic changes.

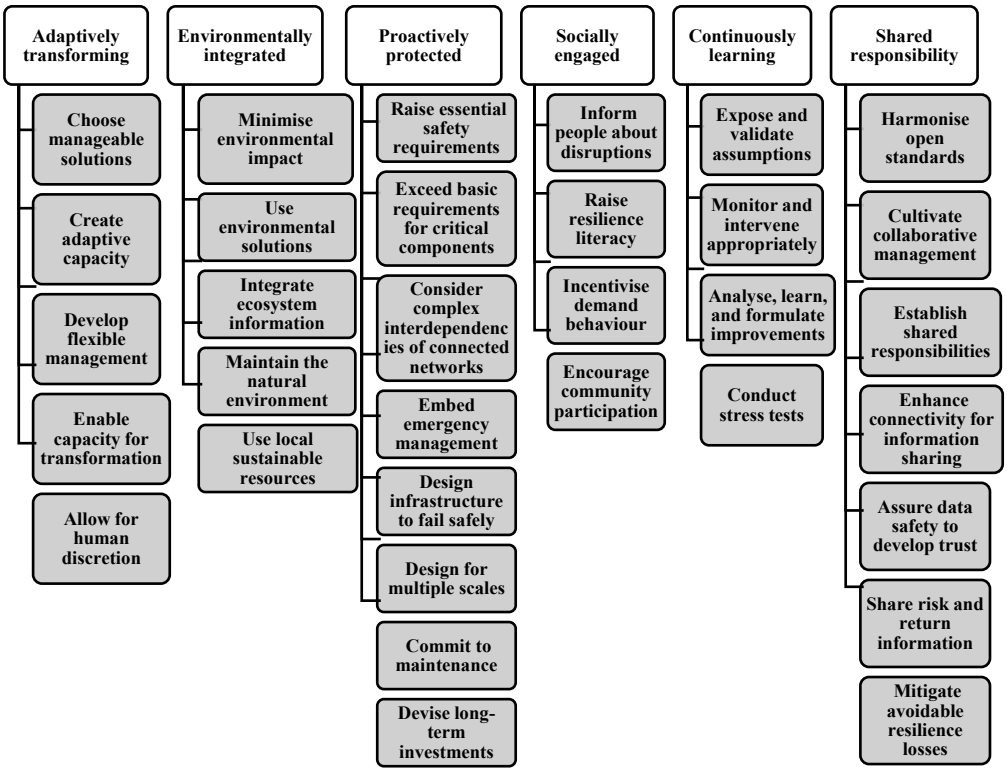

Figure 2: principles of infrastructure resilience.
Source: UNDRR, (2022)

Climate resilient infrastructure plans (water and sanitation sectors)

Plans for resilience to climate change in the water and sanitation sectors can be developed based on achieving the previously mentioned resilience principles. The extent to which these plans achieve the previously described principles will be tested, as shown in Tables (1) and (2).

Table 1: Evaluation of climate change resilient infrastructure water sector plans in terms of achieving the principles

	Climate resilient infrastructure plans		resilient to climate change and facing				smart infrast	ecosy	econo mic	social chang	Increa se	financia l flow
			High tempe rature	Sea level rise	Change rainfall pattern	Chang storm pattern						
Structural plans	1	Equitable access to safe drinking water for all	•								•	high
	2	Provide a good water network								•	•	high
	3	Maintenance of water transmission and distribution networks							•	•	•	low
	4	Ensure that the materials from which water networks are made conform to specifications.	•		•				•	•	•	low
	5	Improve water quality and providing high-quality water.							•	•	•	med ium
	6	Reducing greenhouse gas emissions associated with the operation of water systems	•	•	•	•		•	•	•	•	low
	7	Use various sources to charge environmental water.			•			•	•		•	low
	8	Address increased evaporation in water sources	•		•			•	•		•	med ium
	9	Use various water sources.			•			•	•		•	med ium
	10	Achieve gray water reuse			•			•	•		•	low
	11	Achieve black water reuse.			•			•	•		•	low
	12	Sustainability of irrigation methods			•			•	•		•	low
	13	Use modern technology to conserve water.			•		•		•		•	low
	14	Establish watersheds			•			•	•		•	high
	15	Reduce water pollution and stopping the dumping of waste and hazardous chemicals			•			•	•	•	•	low
	16	Work on natural and human defenses against floods.		•	•	•	•	•	•		•	high
	17	Use of land to provide green spaces and water paths for shading and cooling	•					•	•	•		low
Administrative plans	18	Form a water protection administration	•	•	•	•	•		•	•	•	low
	19	Establish departments and responsibilities for watershed management.	•	•	•	•	•		•	•	•	low
	20	Review water forecasts to ensure they meet community needs.	•		•		•			•	•	low
	21	Protect water resources and associated ecosystems	•					•			•	low

	Climate resilient infrastructure plans		resilient to climate change and facing				smart infrast	ecosy	econo mic	social chang	Increa se	financia l flow
			High tempe rature	Sea level rise	Change rainfall pattern	Chang storm pattern						
	22	Provide research on future water efficiency							•		•	low
	23	Monitor the flow of water streams, groundwater, & climate information	•	•	•	•	•		•	•	•	low
	24	Water prices are appropriate in relation to the income of individuals in those areas.			•				•	•	•	low
	25	Enhance the scope of cooperation and supporting capacity building in water-related programs	•	•	•	•			•	•	•	low
	26	Create an automatic leak notification program.			•		•		•	•	•	medium
	27	Raise population awareness of the need to conserve water.			•				•	•	•	low
	28	Consider the correction of behaviors associated with the actions of community members.			•				•	•	•	low
Emergen-cy plans	29	Water-related risk management	•	•	•	•			•	•	•	Must be available at what ever cost.
	30	Develop emergency designs for water systems.	•	•	•	•			•	•	•	
	31	Periodically review drought preparedness plans.			•				•	•	•	

Source: Author's Calculation

Table 2: Evaluation of climate change resilient infrastructure sanitation sector plans in terms of achieving the principles

	Climate resilient infrastructure plans		resilient to climate change and facing				smart infrastructu	ecosystem	economic changes	social changes	Increase lifespan	Financial FLOW
			High tempe rature	Sea level rise	Change rainfall pattern	Chang storm pattern						
Structural plans	1	Achieve the goal of universal access to sanitation and hygiene services								•		high
	2	Providing a sewage network								•	•	high
	3	Maintenance of sewage transportation and treatment networks.								•	•	low
	4	Separate sewage networks from rainwater networks.		•	•	•			•		•	high
	5	The potential benefits of generating energy from waste are significant.	•	•	•	•		•	•			low
	6	The potential to use waste as organic fertilizer	•	•	•	•		•	•			low
	7	Reduce greenhouse gas emissions associated with the operation of wastewater systems	•	•	•	•		•		•	•	low
	8	prevent individuals from directly dealing with waste.								•	•	high
	9	Drainage treatment			•			•	•	•	•	High/medium
	10	Completely dispose of sewage in a safe manner.		•	•	•		•			•	medium

		Climate resilient infrastructure plans	resilient to climate change and facing				smart infrastructu	ecosystem	economic changes	social changes	Increase lifespan	Financial FLOW
			High tempe rature	Sea level rise	Change rainfall pattern	Chang storm pattern						
	11	Preserve water and natural resources from pollution resulting from sewage						•	•	•	•	**low**
	12	Support natural systems that absorb, delay, and treat rainwater.	•	•	•	•		•	•	•	•	**low**
Administrative plans	13	Raise public awareness to increase the acceptance of wastewater treatment products.			•	•		•	•	•		**low**
	14	Motivate stakeholders to invest in research and technology to improve the use of wastewater treatment outputs.			•	•	•		•		•	**low**
	15	Enhance the scope of cooperation and supporting capacity building in sanitation-related programs	•	•	•	•	•		•		•	**low**
	16	Create an automatic leak notification program					•		•		•	**mediu m**
	17	Availability of public and personal hygiene with various drainage systems								•	•	**low**
	18	Involve the community in developing appropriate drainage programs.								•	•	**low**
Emergency plans	19	Sanitation risk management	•	•	•	•			•	•	•	**Must be available at whatever cost.**
	20	Develop emergency designs for sanitation systems.	•	•	•	•			•	•	•	
	21	Periodically, review storm preparedness plans.			•	•			•	•	•	

Source: Author's Calculation

Develop the Climate Change Resilient Infrastructure Index

Through a survey that 34 experts have conducted, experts assigned the values and weights based on their relative importance. The weights and degrees of the values were verified and the results of the questionnaire as shown in Table 3. The specific weight factor was calculated for each of the principles of resilient infrastructure to climate change using the following equation.1:

$$i = \frac{\sum(x*y)}{340} \qquad (1)$$

Table 3: Matrix of questionnaire results and calculation of the specific weight factor for the principles

Principals		Rating -y- where (10 is the most influential, and 1 is the least influential)										(i)
		1	2	3	4	5	6	7	8	9	10	
Facing high temperatures	number of answers (x)	0	3	2	7	5	1	3	3	5	5	0.70
Facing sea level rise		1	1	2	3	2	5	1	2	8	9	0.82
Facing the risks of drought		4	0	6	4	6	4	5	3	2	0	0.56
Facing storms and floods		1	1	2	5	3	2	7	2	5	6	0.75
Use Smart infrastructure approach		0	2	0	4	4	4	0	7	6	7	0.81

Principals		Rating -y- where (10 is the most influential, and 1 is the least influential)										(i)
		1	2	3	4	5	6	7	8	9	10	
Use Ecosystem-based infrastructure approach		3	1	1	5	4	1	3	2	6	8	0.75
Take into account economic changes		0	2	7	5	5	1	2	5	4	3	0.65
Take into account social changes		5	5	6	4	2	1	1	4	5	1	0.53
Increase the lifespan of the infrastructure system		1	2	2	4	5	3	2	2	6	7	0.75
Guarantee financial flow		4	4	1	4	3	1	2	3	3	9	0.69

Source: Author's Calculation

The specific weight of the evaluation element (wi), where the value of (i) ranges between [1:10]: The element was evaluated based on achieving the principals, as previously done in Table (1), through 10 points represented in.

The value of the element itself (Rj), where the value of (j) ranges between [0:5]: The element was evaluated based on the extent to which the plans for each city were achieved through 5 grades (very good=5, good=4, average=3, bad=2, very bad=1) or not available, so it takes the value zero.

Resilience indicators for the infrastructure sectors under study are calculated through the following equations:

The value of the resiliency of the water sector (RW) calculated using equation (2).

$$RW = \sum(wi * Rj)\ /31 \quad (2)$$

$$IRW = \frac{RW}{50}\ \% \quad (3)$$

Where IRW is the resiliency index for the evaluating element of the water sector, w is the specific weight of the evaluation element, R is the value of the element, 31 is the number of resilience plans for the water sector, and 50 is the maximum resiliency value for the element.

The value of the resiliency of the sanitation sector (RS) calculated using equation (4).

$$RS = \sum(wi * Rj)\ /21 \quad (4)$$

$$IRS = \frac{RD}{50}\ \% \quad (5)$$

Where IRS is the resiliency index for the evaluating element of the sanitation sector, w is the specific weight of the evaluation element, R is the value of the element, 21 is the number of resilience plans for the sanitation sector, and 50 is the maximum resiliency value for the element.

Case Studies Climate Resilient (Water & Sanitation Sector)
The research will study three case studies (New York, Melbourne, and Thessaloniki), Case studies were selected based on the following criteria:

- Spatial criteria: (The cities should be coastal, and the difference in geographical location and the coastline that the city overlooks).
- Socio-economic criteria: diversity in the general culture of the city's population, and diversity is the main activity on which the city depends.
- Administrative standards: diversity in flexibility strategy.

New York City (USA)
New York City (NYC) is one of the major cities in the United States and the most populous city with 8,335,897 residents. (U.S. and World Population Clock, 2023). In October 2012, New York experienced Hurricane Sandy. Which caused severe of damage on different levels. The city lost $19 billion in damages, and many neighbourhoods suffered from flooding. According to new projections, the sea level will rise 0.53 meters by 2050. Since 2012 Sandy, New York has adopted key goals for dealing with climate change risks: preparing for future risks, reducing the time and costs of post-shock recovery, it also suffers from climate change represented by rising sea levels, rising temperatures, and increasing rainfall rates, (NPCC, 2015).

New York City is the largest water supplier in the United States. Approximately 125 miles north of New York City, the Catskill/Delaware watersheds provide over 94% of the city's water supply; the remaining 6% is sourced from the Croton watershed. The reservoir capacity is 550 billion gallons, and the watersheds of the three systems (Figure 3) encompass an area of approximately 2,000 square miles (nyc.gov., 2018). Canals deliver water into New York City; by gravity, 97% of the water reaches residences and businesses; only 3% must be pumped to its final destination. To eliminate bacteria, New York City adds chlorine to its water supply, (nyc.gov., 2023a). The goals of the city of New York are to diminish neighbourhood inundation and deliver water services of superior quality. Water treatment systems are essential to the state's provision of high-quality water services. Despite experiencing a population increase of 1.6 million individuals since 1980, New York has witnessed a reduction in water demand of approximately 35%. The rationalization of municipal potable water usage yields advantageous outcomes for the municipality.

It has contributed to the annual reduction of 68 metric tons of greenhouse gas emissions associated with water and sewer system operation, the limitation of rainfall-induced drainage flow increases into local waterways, and the development of an automated leak notification system that notifies property owners of any abnormal increase in water consumption, (nyc.gov.,2023b). The

city's sewer system is approximately 60% combined and 40% separated, with more than 7,400 miles of sewer mains, 135,000 collection basins, and 95 pumping stations. The Department of Environmental Protection (DEP) works on building and improving sewers in underserved areas, (nyc.gov.,2023b). The city has committed to rebuilding and expanding the stormwater drainage network to mitigate flooding and improve the quality of life for residents. When planning future drainage infrastructure, the (DEP) considers future sea level rising and rainfall intensity with environmental justice in mind.

Figure 3: New York's main water connections through tunnels neighborhood
Source: nyc.gov., 2023a

The city aims to eliminate biosolid waste by 2030. Which means developing a program to reuse it beneficially. Additional processing techniques to qualify for reuse include composting, drying, gasification, and pyrolysis. The city has made citywide investments in stormwater management to improve water quality and prepare for a future climate. It built more natural systems that absorb, delay, and treat rainwater (green infrastructure) in addition to traditional systems for transporting storm water to central treatment (grey infrastructure), (NYC environmental protection, 2023).

Melbourne city (Australia)

The city of Melbourne is a vibrant Centre with 4.3 million residents from different cultures and diverse backgrounds. Melbourne is exposed to many risks from climate change, including high temperatures, droughts, heavy rainfalls, and rising sea levels (Feisal Zeinab and Haron Ahmed Osama, 2020). The city prepares to confront climate change and makes efforts to ensure the resilience, adaptation, and flexibility of its infrastructure, (the water and sanitation sector).

Melbourne's water storage capacity has been 98.2% over the past three years, utilizing rainfall catchment and flows to reservoirs. About 62% of the stored water is available for Melbourne's water supply system. The remainder is water held by other water entitlement holders, such as the Regional Water Corporations, the owner of Victorian Environmental Water (VEWH), irrigation, or water that is not readily accessible under normal operating conditions (due to infrastructure limitations and risks to water quality), (Melbourne Water, 2022a).

Melbourne Water supplies water to the southern countryside and other regional water corporations, including Barwon Water, Gippsland Water, South Gippsland Water, and Westernport Water. While each regional water corporation has its own annual water forecast, Melbourne gets its water from catchments, desalinated water, and rivers and is managed by water corporations, Figure 4.

Residential water uses accounts for 69% of Melbourne's total water use in 2021–2022. Despite above-average rainfall, a summer that has been cooler than average, and changes in water use patterns from continues work from home due to coronavirus, water consumption per capita has increased. Based on updated census data, Melbourne's per capita water use in 2021–2022 was 164 litters per person per day, compared to 2020–2021's per capita rate of 160 litters per person per day, (Melbourne Water, 2022a).

The Melbourne Water Resilience Plan aims to work in partnership with local owner groups to manage the natural resources on which water services depend and build community relationships. The plan fosters a commitment to reconciliation by, (Melbourne Water, 2018):

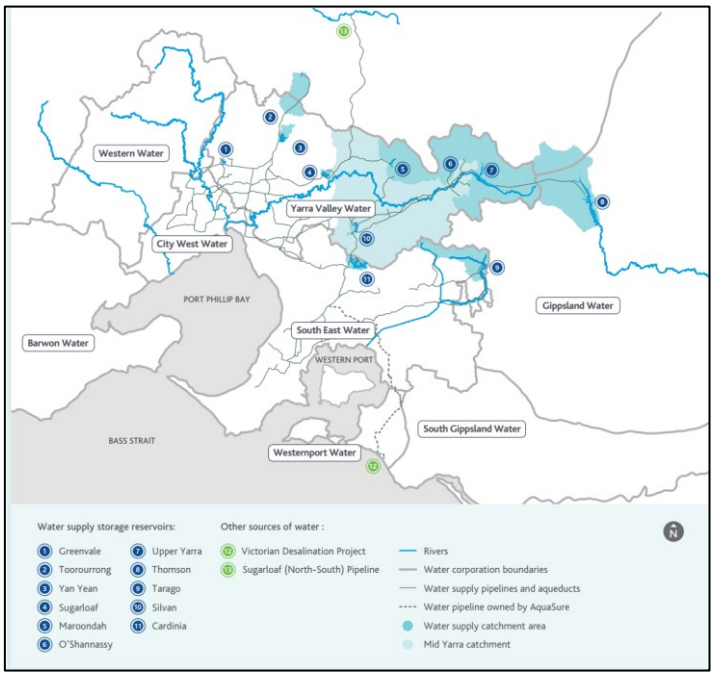

Figure 4: Melbourne Water Supply System
Source: Melbourne water strategy, (2018)

- Understand community needs and expectations, foreseeing their implications, ensuring all core service strategies are linked and improve demand forecasts;
- Fostering sustainable green spaces and water paths for shading and cooling;
- Reducing greenhouse gas emissions from treatment plants;
- confronting the changing climate, investing in climate research, activating the results, and identifying climate risks to the environmental values of waterways;
- Making the most of the water supply system, updating annual operational planning, establishing departments and responsibilities for watersheds management, developing asset management and maintenance;
- Using water efficiently, supporting effective water use across the community, providing research on future water efficiency, periodically reviewing drought preparedness plans, and reviewing water projections;
- Improving the water network, and developing a plan to manage water resource; and
- Using diverse sources of water, investigating the use of it for environmental water charging, and monitoring applications of rainwater and recycled water.

The sanitation system faces major challenges. Melbourne will become a hotter and drier city with the possibility of heavy rain, But severe storms are likely to be more frequent. High wastewater temperatures may lead to increased rates of unpleasant odors and corrosion of pipes. Rainwater may enter the sewage system through cracks in the pipes, which may lead to sewer spills. Climate change affects the services provided to society. Figure (5) presents the sewage system, which includes, (Melbourne Water, 2022b):

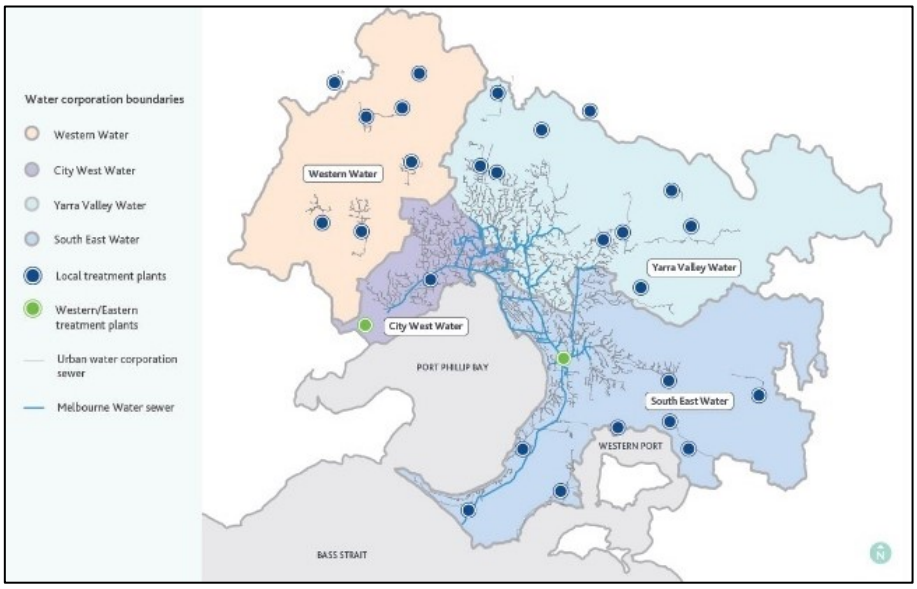

Figure 5: Melbourne sanitation System
Source: Melbourne Sewerage Strategy, (2022)

- network of pipes and pumps exceeding 25 000 km;
- Land on which sanitation assets are located or that act as buffer zones;
- 28 wastewater treatment plants. Provide recycled water or safely release it to the receiving environment, in accordance with EPA licensing requirements;
- Resources recovered from wastewater include recycled water, biogas; and
- Treated water-receiving environments, which include Port Phillip Bay, Bass Strait, and several inland waterways, such as the Yarra River, Jackson Creek.

Melbourne Water transports the majority of its wastewater to two large treatment plants: Eastern (Plantine Bangulmere) and Western (Plantyne Werribee). The plants treat approximately 90% of the total wastewater generated, while the remaining 10% is processed by the remaining 26 smaller local stations.

Thessaloniki city (Greece)

Thessaloniki city is located in northern Greece and is the second largest city in Greece. It is a coastal city located on the coast of Thermaikos Gulf. with a population of 1.9 million. Its port is the second largest in the country. It has a historical, cultural, and economic extension. It has been inhabited since 315 BC. The city is exposed to many climate risks, including surface floods, forest fires, and earthquakes, (Aristotle University of Thessaloniki, 2016).

Greater Thessaloniki's water supply comes from the springs of Aravissos and the Alikmonas River where water is diverted via a 50-kilometer canal down the Axios River, (CWRA,2018), and then to the Thessaloniki Water Treatment Plant. The water supply necessitates the maintenance of numerous pipes. Underground resources (wells) in the Axios-Galikos River Basin provide small amounts of water supply. The Axios River is transboundary, 83% in Macedonia, which has built 11 hydroelectric dams along the river, (Aristomenis P, K., and others, 2006).

Thessaloniki Water Sector Resilience Strategy, (CWRA,2018):

- The existence of a structure for basic services;
- Risk management;
- Strong human resources;
- European Water Framework Directive 2000/60/EC;
- Effective participation of communities;
- Low pollution; and
- Planned upgrade to the sewerage system.

Sewer and storm sewer pipes collect sewage throughout much of the city. Storm water pipes in the central area led to the sea, while sewage pipes feed the central sewer pipeline, which transports wastewater to the Sindos treatment facility. The Gulf of Thermaikos receives its effluent discharge, (Andreas, I, and others, 2014). 35 sewage pumping stations operate to cover all suburbs. The systems operate using programmable controllers. All automated stations are wirelessly connected to the control center, which receives all necessary information for monitoring purposes. The control center contains information technology with appropriate hardware and software to control operations, handle faults, and ensure remote control to enable the stations to operate without interruptions. Treatment is capable of receiving 1,200 m3/day of wastewater from tanker trucks. (S. Yannopoulos, and others, 2017).

Municipal water treatment has adopted a variety of different technologies. Among them, 88% are activated sludge systems, 10% are natural systems, and 2% are connected growth systems. Activated sludge systems consist

of 85% expanded aeration systems, 10% conventional systems, and 5% sequential batch reactors, (Andreas Ilias, and others, 2014). Extended ventilation is the prevailing system, as it offers great advantages for Mediterranean climatic conditions. Treated wastewater was used on farmland and forests. Recently, water recycling, rather than disposal, has been adopted to irrigate crops, forests, and landscapes.

Thessaloniki Sanitation Resilience Strategy, (SUWANU EUROPE, 2022):

- Develop a realistic regional action plan for using reclaimed water;
- Increase administrative capacity and procedures to move forward with the implementation of reclaimed water for irrigation in agriculture;
- Integrate the concepts of water reuse and capture;
- Exploit the opportunities provided by European networks;
- Public awareness to increase acceptance of reused water for crop irrigation;
- Fiscal policy provides incentives to use reclaimed water for irrigation;
- Motivate stakeholders to invest in research and technology to improve and expand the use of reclaimed water in agriculture; and
- Exploit the development of the European and national legal framework that increasingly encourages the use of reclaimed water in agriculture.

Calculating the CC Resilient Infrastructure Index (water and sanitation Sectors)

By Applying the previous equations to determine the value of the resilience index for the water and sanitation sector for case studies. Table (4), (5)

Table 4: Calculating the CC Resilient Infrastructure Index (water Sector).

Climate resilient infrastructure plans			*wi*	New York		Melbourne		Thessaloniki	
				Rj	*R*	*Rj*	*R*	*Rj*	*R*
Structural plans	**1**	Equitable access to safe drinking water for all	1.233	4	4.933	4	4.933	3	3.700
	2	Provide a good water network	1.277	3	3.830	3	3.830	2	2.553
	3	Maintenance of water transmission and distribution networks	2.620	2	5.240	2	5.240	2	5.240
	4	Ensure that the materials from which water networks are made conform to specifications.	3.887	2	7.773	2	7.773	2	7.773
	5	Improving water quality and providing high-quality water:	2.275	5	11.375	4	9.100	2	4.550
	6	Reduce greenhouse gas emissions associated with the operation of water systems	5.680	4	22.720	2	11.360	2	11.360
	7	Use various sources to charge environmental water.	3.403	4	13.613	4	13.613	4	13.613
	8	Addressing increased evaporation in water sources	3.762	3	11.285	3	11.285	0	0.000

Climate resilient infrastructure plans			*wi*	New York		Melbourne		Thessaloniki	
				Rj	*R*	*Rj*	*R*	*Rj*	*R*
	9	Use various water sources.	3.058	5	15.292	5	15.292	2	6.117
	10	Achieve gray water reuse	3.403	4	13.613	5	17.017	3	10.210
	11	Achieve black water reuse.	3.403	4	13.613	5	17.017	3	10.210
	12	Sustainability of irrigation methods	3.403	4	13.613	4	13.613	2	6.807
	13	Use modern technology to conserve water	3.467	5	17.333	5	17.333	1	3.467
	14	Establish watersheds	2.713	5	13.567	5	13.567	1	2.713
	15	Reduce water pollution and stopping the dumping of waste and hazardous chemicals	3.933	4	15.733	3	11.800	1	3.933
	16	Work on natural and human defenses against floods.	5.100	5	25.500	3	15.300	3	15.300
	17	Use of land to provide green spaces and water paths for shading and cooling	4.073	4	16.293	5	20.367	3	12.220
Administrative plans	18	Forming a water protection administration	6.273	5	31.367	4	25.093	4	25.093
	19	Establish departments and responsibilities for watershed management.	6.273	5	31.367	5	31.367	1	6.273
	20	Review water forecasts to ensure they meet community needs.	4.047	5	20.233	5	20.233	2	8.093
	21	Protect water resources and associated ecosystems	2.890	5	14.450	4	11.560	1	2.890
	22	Provide research on future water efficiency	2.090	5	10.450	5	10.450	3	6.270
	23	Monitor the flow of water streams, groundwater, and climate information	6.273	2	12.547	5	31.367	2	12.547
	24	Water prices are appropriate in relation to the income of individuals in those areas.	3.183	4	12.733	4	12.733	4	12.733
	25	Enhance the scope of cooperation and supporting capacity building in water-related programs	5.460	4	21.840	5	27.300	4	21.840
	26	Create an automatic leak notification program	3.652	5	18.258	2	7.303	0	0.000
	27	Raise population awareness of the need to conserve water	3.183	5	15.917	4	12.733	2	6.367
	28	Consider the correction of behaviors associated with the actions of community members	3.183	5	15.917	4	12.733	2	6.367
Emergency plans	29	Water-related risk management	5.460	4	21.840	5	27.300	4	21.840
	30	Develop emergency designs for water systems.	5.460	3	16.380	5	27.300	2	10.920
	31	Periodically review drought preparedness plans.	3.183	5	15.917	5	15.917	3	9.550
Total value of sanitation sector resilience plans				**484.21**		**481.47**		**270.35**	
RW				**15.62**		**15.5**		**8.72**	
IRW				**31.2%**		**31.0%**		**17.44%**	

Source: Author's Calculation

Table 5: Calculating the CC Resilient Infrastructure Index (sanitation Sector).

Climate resilient infrastructure plans			*wi*	New York		Melbourne		Thessaloniki	
				Rj	*R*	*Rj*	*R*	*Rj*	*R*
Structural plans	1	Achieve the goal of universal access to sanitation and hygiene services	0.530	4	2.120	4	2.120	3	1.590
	2	Provide a sewage network	1.277	4	5.107	4	5.107	3	3.830
	3	Maintenance of sewage transportation and treatment networks	1.967	2	3.933	1	1.967	1	1.967
	4	Separate sewage networks from rainwater networks	3.537	3	10.610	2	7.073	1	3.537
	5	The potential benefits of generating energy from waste are significant.	4.933	4	19.733	5	24.667	5	24.667
	6	The potential to use waste as organic fertilizer	4.933	4	19.733	5	24.667	4	19.733
	7	Reduce greenhouse gas emissions associated with the operation of wastewater systems	5.557	2	11.113	3	16.670	3	16.670
	8	prevent individuals from directly dealing with waste.	1.277	5	6.383	5	6.383	2	2.553
	9	Drainage treatment	3.588	5	17.942	5	17.942	5	17.942
	10	Completely dispose of sewage in a safe manner.	3.978	4	15.913	5	19.892	4	15.913
	11	Preserve water and natural resources from pollution resulting from sewage	3.370	4	13.480	4	13.480	2	6.740
	12	Support natural systems that absorb, delay, and treat rainwater.	6.210	5	31.050	2	12.420	2	12.420
	13	Raise public awareness to increase the acceptance of wastewater treatment products.	3.940	4	15.760	5	19.700	5	19.700
Administrative plans	14	Motivate stakeholders to invest in research and technology to improve and the use of wastewater treatment outputs.	4.220	5	21.100	5	21.100	5	21.100
	15	Enhance the scope of cooperation and supporting capacity building in sanitation-related programs	5.743	4	22.973	5	28.717	5	28.717
	16	Create an automatic leak notification program	2.558	5	12.792	0	0.000	0	0.000
	17	Availability of public and personal hygiene with various drainage systems	1.967	4	7.867	4	7.867	3	5.900
	18	Involve the community in developing appropriate drainage programs	1.967	2	3.933	5	9.833	2	3.933
Emergency plans	19	Sanitation risk management	5.460	3	16.380	4	21.840	3	16.380
	20	Develop emergency designs for sanitation systems.	5.460	4	21.840	3	16.380	2	10.920
	21	Periodically, review storm preparedness plans.	3.937	3	11.810	3	11.810	2	7.873
Total value of sanitation sector resilience plans				**291.4**		**289.45**		**241.92**	
RS				**13.87**		**13.78**		**11.52**	
IRS				**27.75%**		**27.567%**		**23%**	

Source: Author's Calculation

DISCUSSION

Coastal cities are exposed to the risks of climate change resulting from global warming, especially the infrastructure of water and sanitation sectors. A method was developed to calculate the resilience index of the water and sanitation sectors' infrastructure to climate change. This was limited to 31 plans for water sector and 21 plans for sanitation sector which include structural, administrative and emergency plans through a study of planning principles and resilient infrastructure for CC in the water and sanitation sectors, and applying and evaluating the indicator based on the case studies, so that the results are:

The city of New York, USA, is the best at achieving infrastructure resiliency in the water and sanitation sectors', according to the resiliency index, as it achieved 31.2% and 27.75% respectively, followed by Melbourne city, Australia at 31.0% and 27.57% respectively. As for the city of Thessaloniki, Greece, it needs to make more efforts, as it ranked last according to the resiliency index, with 17.44% and 23% respectively. Figure (6)

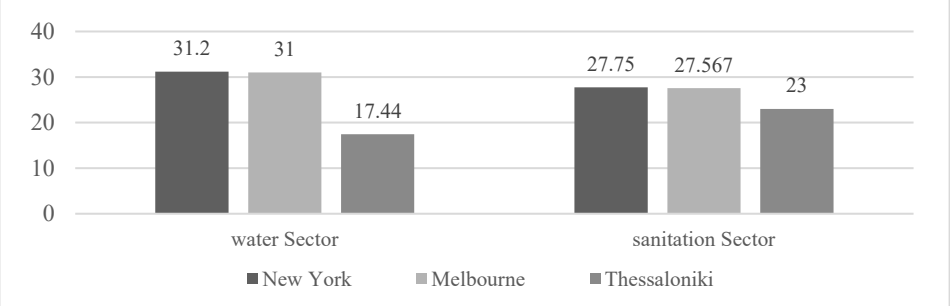

Figure 6: Climate change resilience indicators for the water and sanitation sectors for previous case studies (New York, Melbourne, Thessaloniki)

CONCLUSION AND RECOMMENDATIONS

Based on a study of climate change and infrastructure of the water and sanitation sectors, the study recommends to

- pay attention to resilient infrastructure planning based on resilience against climate changes, preparedness for them, adaptation to them, and rapid recovery after risks;
- Put the plans mentioned in the study, including structural, administrative, and emergency plans, into implementation, and paying attention to financing them and integrating them into development plans;

- Pay attention to coastal cities, especially cities exposed to climate risks and disasters, support research to predict them, identify weak points, and working to strengthen the city's defenses; and
- Generalize this study and measure climate change resilience index to other infrastructure sectors, such as the transportation sector, the electricity sector, and the communications sector

ETHICAL STATEMENT

The datasets used and analyzed during this study are available from the corresponding author upon reasonable request. The authors declare that they have no competing interests, and confirm that the study has not been copyrighted, published, or submitted for publication elsewhere. Additionally, this research did not receive funding from any source. All authors have contributed to the study and have reviewed and approved the final manuscript.

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ASSESSING RAINFALL PATTERNS AND TREND DISTRIBUTION IN THE KELANTAN RIVER BASIN, MALAYSIA AND KLANG RIVER BASIN, MALAYSIA

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Abstract

This study examined rainfall patterns and trends in the Kelantan and Klang River Basin in Malaysia over a ten-year period from 2010 to 2020. The analysis revealed that the Kelantan River Basin experienced an upward trend in rainfall during the Southwest Monsoon season, indicating a gradual increase in precipitation levels over the years. On the other hand, the Klang River Basin showed a relatively stable rainfall pattern without a significant trend observed. The study employed an independent t-test to compare the mean yearly rainfall between the two basins, with the findings showing no significant difference in overall precipitation levels ($t(22) = -0.8$, $p = 0.07$). However, the timing and duration of rainy seasons varied between the two basins. The Kelantan River Basin experienced a rainfall pattern that is aligned with the regular monsoon season. In contrast, the Klang River Basin displayed a notable gap in rainfall during a later month in the monsoon season. Moreover, the analysis considered the spatial variability of precipitation patterns within each basin. Specific stations in the Kelantan River Basin showed a positive trend in rainfall during the monsoon seasons (March, $p = 0.013$), whereas stations along the Klang River exhibited a declining trend (August, $p = 0.119$). These findings emphasize the influence of geographical locations, local climate conditions, and topographical features on rainfall distribution within the same country. In conclusion, this research highlights the need for further investigation into the factors driving these patterns, emphasizing the importance of effective water resource management and climate adaptation strategies in these basins to mitigate the impact of climate change.

Keywords: Rainfall patterns, Kelantan River Basin, Klang River Basin, Trend Distribution, Sen's Slope Estimator, Geospatial Analysis

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INTRODUCTION

Malaysia's climate is generally hot and humid, with varying rainfall patterns influenced by monsoons. Increased rainfall during monsoon seasons has recently caused flash floods in the Kelantan and Klang River Basins (Yahya, 2022). Climate change has significantly disrupted global and regional hydrological cycles, impacting natural rainfall patterns crucial to these systems (Gat, 2010). While past studies have focused on hydroclimatic variables such as rainfall, evaporation, and temperature (Theng Hue et al., 2022; Ata et al., 2021), limited attention has been given to long-term rainfall trends, leaving gaps in understanding climate variability and its impacts.

Monsoon rainstorms in Malaysia provide essential water resources to support agriculture. However, it also poses significant flood risks (Othman et al., 2015). Although they replenish water supplies, their unpredictable intensity can cause severe economic losses and damage infrastructure. Previous analyses have highlighted trends in wet days and total rainfall during monsoons but often focused on short periods using conventional methods (Suhaila et al., 2010). Long-term studies revealed that Malaysia's rainfall patterns involved cycles of wet and dry conditions lasting over 50 years, complicating resource management (Khan et al., 2019).

Mann-Kendall and Sen slope analyses are vital tools in hydrology to identify trends and estimate the magnitudes of rainfall data. These methods inform water availability, flood risks, and ecosystem sustainability, as demonstrated in studies of the Himalayan River Basins (Dawood, 2017) and coastal regions (Mayowa et al., 2015). Integrating Geographic Information System (GIS) technology further enhances rainfall forecasting, helping stakeholders analyze and visualize heavy rainfall patterns (Saha et al., 2022; Rasam et al., 2023). GIS tools allow authorities to prioritize flood mitigation and disaster preparedness, providing actionable insights for decision-making.

This research examined rainfall trends in the Kelantan and Klang River Basins between 2010 and 2020 to identify factors influencing precipitation and visualizing patterns. The study aims to inform flood management strategies and ensure sustainable water resource use by assessing spatial variations and long-term trends. The objectives are to (i) analyze rainfall trends in both basins, (ii) investigate significant differences between them, and (iii) visualize rainfall patterns. The findings are expected to support policymakers, researchers, and stakeholders in developing adaptive measures for managing Malaysia's changing climate.

RESEARCH METHODOLOGY

Study Areas

The study area encompassed two distinct regions: the Kelantan River Basin and the Klang River Basin. In Figure 1, the Kelantan River Basin, located in northeastern Peninsular Malaysia, is characterized by the Kelantan River and its surrounding areas. It covers a large land area and comprises various states separated by the Kelantan River, the South China Sea, and district boundaries. The Kelantan River Basin is a vital ecological and economic resource for the region. It plays a significant role in supporting local agriculture, providing water for irrigation, and sustaining diverse ecosystems. The study area of the Kelantan River Basin extends across approximately 11,900 square kilometers, including both urban and rural landscapes.

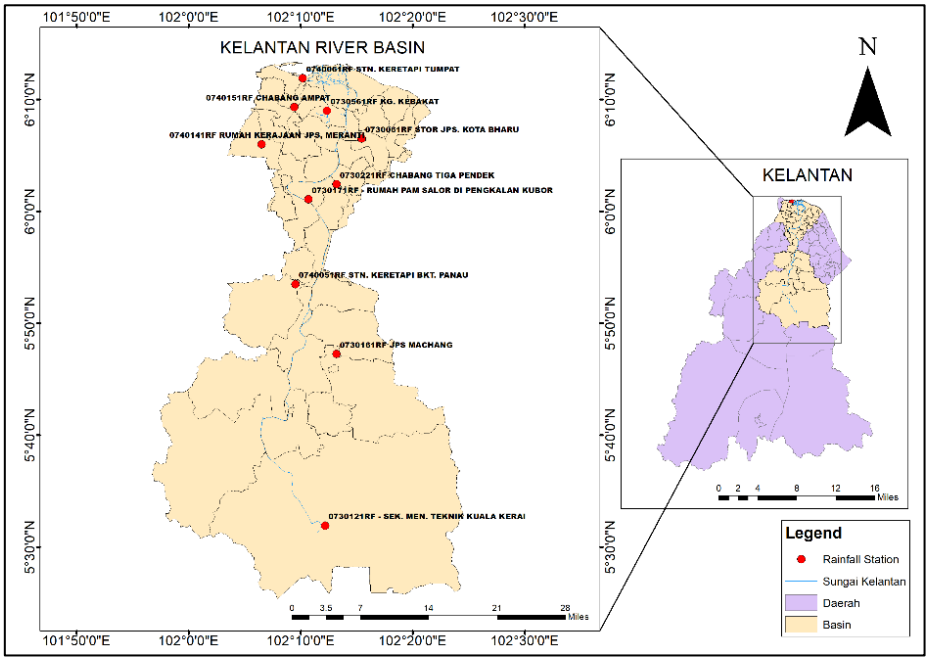


Figure 1: Kelantan River Basin Map

Meanwhile, the Klang Valley, located in the Klang River Basin, as shown in Figure 2, is a highly developed and densely populated region in Malaysia. The Klang Valley is Malaysia's primary economic, business, and commercial center, comprising several major cities and towns. It is a vibrant hub of industrial, commercial, and residential activities, contributing significantly to the country's economic growth. The study area of the Klang River Basin covers approximately 1,288 square kilometers, spanning urban, suburban, and rural

areas. The region showcases a dynamic mix of infrastructure, residential neighborhoods, commercial zones, and natural landscapes.

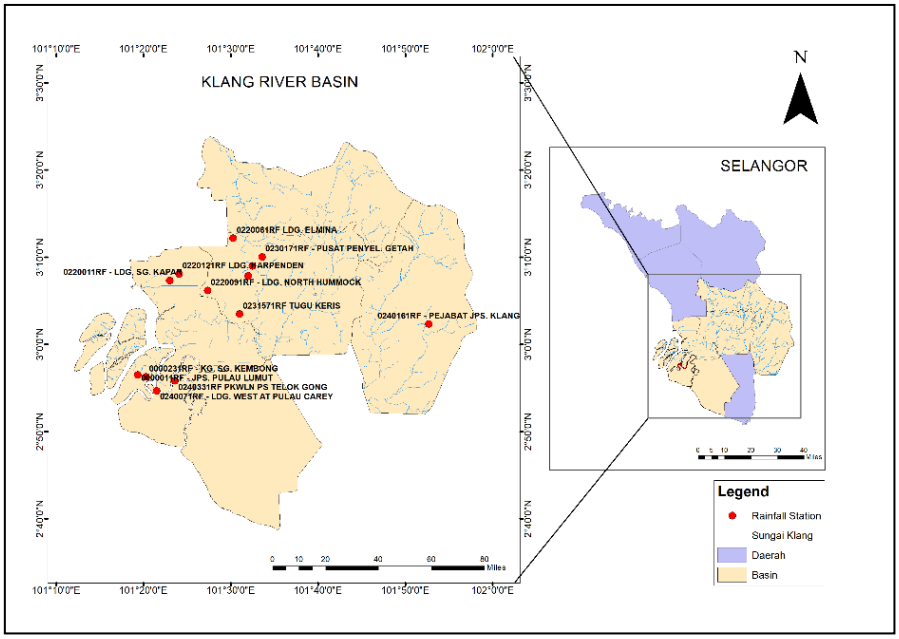


Figure 2: Klang River Basin Map

Secondary Data

The study analyzed rainfall patterns in the Kelantan and Klang River Basins from 2010 to 2020, using ground-based data from the Department of Irrigation and Drainage (DID). Data from the Kota Bharu and Klang Valley stations underwent thorough validation to ensure accuracy. The validation process included verifying data authenticity, assessing consistency, addressing missing values, and cross-referencing with weather stations and satellite data to identify discrepancies. Quality control measures by DID, such as regular maintenance and calibration of rain gauges, were also acknowledged, alongside evaluations of metadata like installation details and gauge locations.

Rainfall data, covering intensity, duration, frequency, and seasonal variations, were collected for hydrological modeling, water resource planning, and flood forecasting. Reliable data are essential for stakeholders, including government agencies, urban planners, and researchers, enabling evidence-based strategies for flood management, water supply planning, and sustainable development. Insights from this study support efforts to enhance the resilience and sustainability of the Kelantan and Klang River Basins, ensuring community well-being and ecosystem preservation.

Data Analysis

Mann–Kendall's Statistic and 'Sen's Slope Statistic Analyses

The Mann-Kendall and 'Sen's slope tests were applied to determine the magnitude and slope trends. Rainfall, temperature, and evapotranspiration time series were subjected to the Mann-Kendall test to detect movement. Additionally, the Mann-Kendall test was used to examine hydroclimatic data's regional variance and temporal trends. This test helps to determine whether a set of time-ordered data has an increasing or decreasing trend at a predetermined significance level.

For the Mann-Kendall test, the data series is defined as xk, where k – 1, 2, …, n – 1, and xj, where j = 1, 2, …, n. Each data point xk serves as a reference point and is compared with the data point xj. The test is calculated using the following equation:

$$S = \sum_{\mathrm{k}-1}^{n-1} \sum_{j-k=1}^{n} sign\,(xj - xk)$$

The values of S and Var(S) were used to compute the standardized test statistics Z, calculated as follows:

$$Z = \begin{cases} \dfrac{S-}{\sqrt{VAR}} & \text{If S} > 0 \\ 0 & \text{If S} = 0 \\ \dfrac{S+}{\sqrt{VAR}} & \text{If S} < 0 \end{cases}$$

Sen's slope test is one of the statistical tests used alongside the Mann-Kendall test to determine the magnitude of changes in each region. The test identifies the rate of increase and decrease by calculating the slope based on the Mann-Kendall values. This simple non-parametric approach can help determine the correct pitch when a linear trend is observed.

Independent T-test Analysis

An independent t-test was conducted to analyze the Kelantan and Klang River Basin rainfall patterns. The test compared the mean between two independent groups, dividing rainfall data into two groups representing each basin. Mean rainfall values were calculated to identify statistically significant differences in average rainfall between the two regions. These findings are useful for managing water resources, preventing flooding, and enhancing environmental sustainability. In this test, the independent variable was the basin, and the

dependent variable was the recorded rainfall patterns. The independent t-test allowed the comparison of mean rainfall values, providing statistical evidence of any significant differences in rainfall patterns between the two areas.

Geospatial Analysis

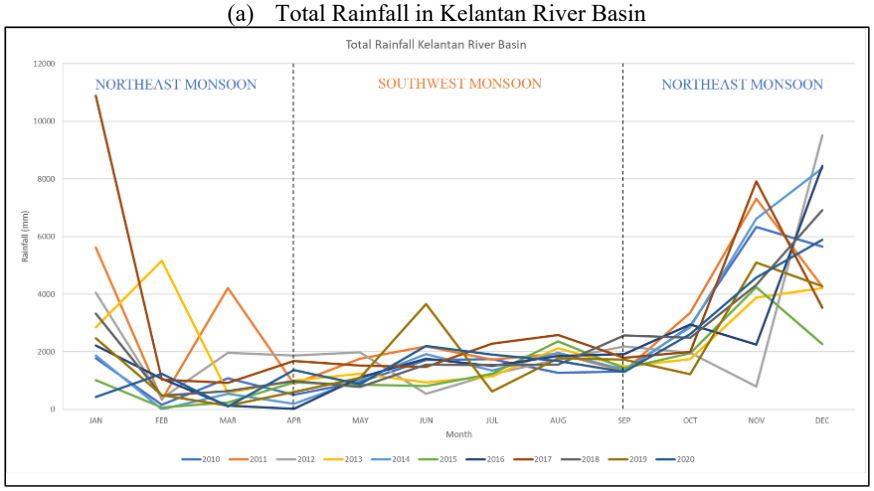
In the geospatial analysis, GIS interpolation was used to interpret statistical tests' results on rainfall data and visually represent them through a trend distribution map. The process started by plotting the location of rainfall stations using GPS coordinates and mapping yearly rainfall data across the study area to assess precipitation variations. GIS tools were used to generate an isohyet map to show the spatial distribution of rainfall over the study period, with an increase trend shown in green and a decrease shown in red. This analysis significantly improved the understanding of rainfall's spatial and temporal variations in the Kelantan and the Klang River Basin, which is essential for water resource management, flood prevention, and environmental sustainability.

RESULTS AND DISCUSSION

Total Rainfall, Average Rainfall, and Mann–Kendall's and Sen's Slope Analyses

Figure 3 shows the annual and monthly rainfall trends in the Kelantan and Klang River basins. Kelantan River Basin consistently recorded a higher annual rainfall than Klang, which was influenced by its hilly terrain and higher elevation. The highest rainfall in Kelantan was in 2014 (8,383.5 mm), followed by 2011 (7,321 mm) and 2018 (6,915.5 mm), with the lowest in 2020 (5,884.5 mm). Conversely, the Klang River Basin experienced its peak in 2012 (5,105 mm) and the lowest in 2020 (2,115.125 mm).

(a) Total Rainfall in Kelantan River Basin



(b) Total Rainfall in Klang River Basin

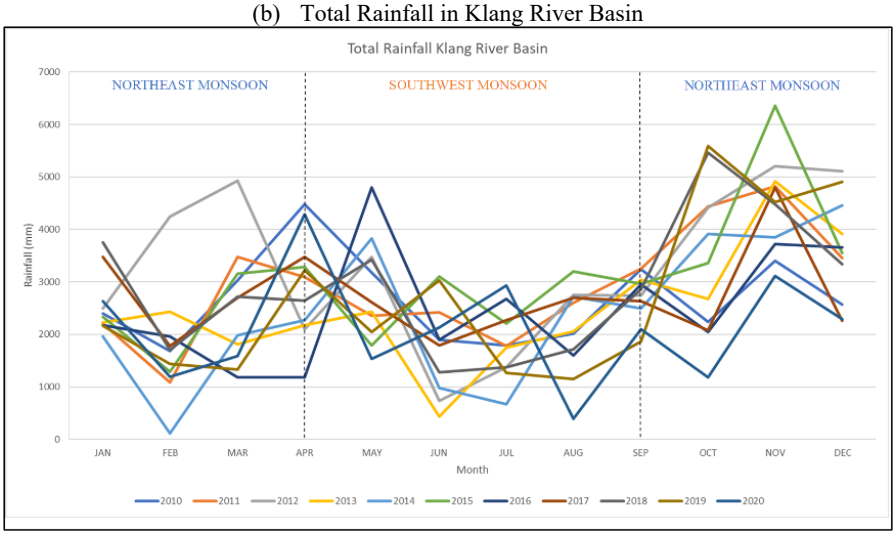


Figure 3: The Monthly Record of the a) Total Rainfall of Kelantan River Basin and b) Total Rainfall of Klang River Basin from 2010 to 2020

November and December consistently recorded the highest rainfall in both basins, exceeding 5,000 mm in specific years. This aligns with the Northeast Monsoon (NEM), which is generally active from October to March and brings intense rainfall due to moist air from the South China Sea. Local factors such as weather patterns, topography, and regional influences also contribute to rainfall distribution. Annual rainfall variations are also impacted by climate oscillations like the El Niño-Southern Oscillation (ENSO), which globally affects rainfall patterns (Wang et al., 2014). Understanding these phenomena is crucial for managing local water resources and implementing effective flood prevention strategies.

In Figure 4, the Kelantan River basin's annual rainfall ranged from 1,453.50 mm in 2015 to 3,138.13 mm in 2017, with 2017 experiencing the highest levels and 2015 the lowest. Meanwhile, the Klang River basin's annual rainfall ranged from 2,115.13 mm in 2020 to 3,297.71 mm in 2012, with the highest levels in 2012 and the lowest in 2020. Both basins showed no clear trend of increasing or decreasing rainfall over the 11-year period, although the interannual variability in the Kelantan River's basin was evident. The basins experienced fluctuations in annual rainfall, suggesting interannual variability without a distinct long-term trend.

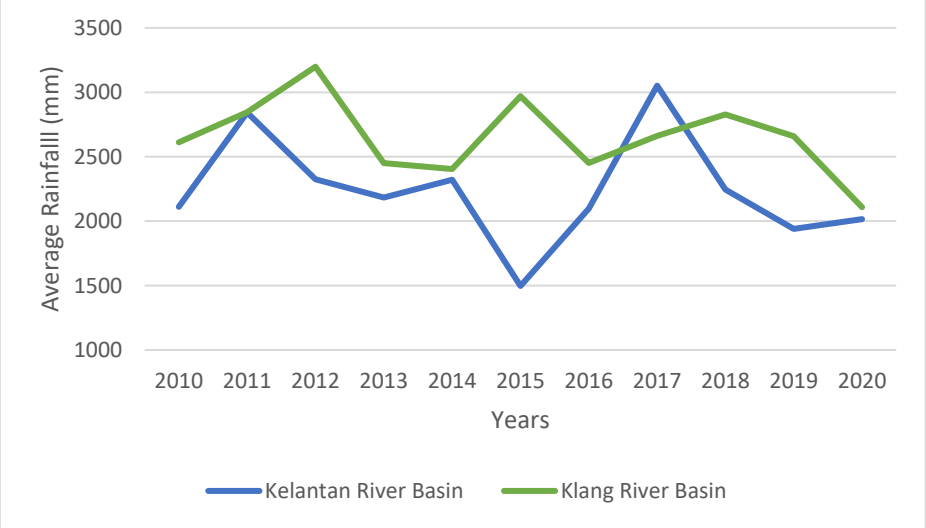


Figure 4: Average Rainfall (mm) in Kelantan and Klang River Basins

The high rainfall levels in the Klang region were influenced by the urban heat island effect, where urbanization increases convection and rainfall (Morris et al., 2017; Wang et al., 2019). In contrast, primarily rural Kelantan displayed less urban impact on rainfall except during the NEM.

In 2014 showed that Kelantan's severe floods occurred despite its lower rainfall distribution compared to the Klang Valley (Figure 4). Since 2013, rainfall trends have shown an increase in Kelantan and a decrease in Klang, which explains the flooding in Kelantan. Meanwhile, similar issues have been avoided in Selangor due to effective water catchment areas and drainage systems.

Limited data from the DID highlights notable rainfall changes in Klang (2012, 2015) and Kelantan (2015, 2017). A substantial data discrepancy becomes apparent when calculating the averages. However, a month-to-month analysis revealed no significant influence on the data (Figures 3a and 3b).

Rainfall trends in the Kelantan and Klang River basins from 2010 to 2020 revealed changing precipitation patterns, underscoring the importance of adaptive water resource management. Strategic planning is essential to mitigate flood risks, ensure water supply during dry periods, and support sustainable agriculture amidst changing climate conditions.

Both basins exhibited notable monthly trends, highlighting potential impacts on water availability and ecosystems. In January, both basins experienced positive rainfall trends, suggesting an increase in precipitation patterns (Table 1). This finding is consistent with the theory that climate change is shifting rainfall regimes (Mitra et al., 2015). These localized increases in rainfall could impact water resource planning and management.

Furthermore, negative trends regarding rainfall patterns were observed in some months. In February, the Kelantan River basin showed an 81.5% increase in rainfall. However, in March, there were decreases of 22.7% and 16.4% in the Kelantan and Klang River basins, respectively (Table 1). These fluctuations raised concerns about water availability and agricultural productivity. Jha et al. (2013) emphasized the vulnerability of river basins to shifting precipitation patterns, underscoring the need for adaptive water management strategies.

In April, both basins exhibited a positive rainfall trend, creating opportunities for improved water resource planning. Nevertheless, this also highlights the need to address challenges such as flood risks and infrastructure demands. In May, there was a negative trend, albeit statistically insignificant, suggesting only minor potential impacts on water availability and ecosystems (Chua et al., 2003).

In June, a positive trend was shown, which was beneficial for water availability and agriculture (Table 1). However, the increase in rainfall raised concerns about risks such as soil erosion and nutrient leaching, which could affect water quality and ecosystem health. Both July and November showed stable rainfall patterns with no significant trends, offering consistency that is beneficial for water management. Despite this, ongoing monitoring and adaptive strategies remain critical.

August and September showed negative rainfall trends in both basins, raising concerns about water scarcity during these months. These findings emphasize the importance of careful water management. As highlighted by Shaaban et al. (2011), it is crucial to address the impacts of shifting precipitation patterns on water resources through sustainable management practices.

The annual analysis revealed a negative rainfall trend for both basins (Table 1). This emphasizes the importance of robust water resource management, including conservation measures, water storage facilities, and diversified water sources, to ensure the resilience of the region's water supply in the face of changing climatic conditions.

Table 1: Mann - Kendall's and Sen's Slope Analysis a) Kelantan River Basin and b) Klang River Basin from 2010 - 2020

a) Kelantan River Basin

Time Series	Min	Max	Mean	Std. dev	Kendall's tau (Z Value)	p-value	Sen's slope (S Value)	Rainfall Trends
JAN	426.5	10886.5	3320.2	2887.5	-0.164	0.533	-153.5	Negative
FEB	12.0	5166.0	951.7	1457.9	0.345	0.161	63.0	Positive
MAR	106.0	4221.0	959.0	1212.2	-0.600	0.013	-159.0	Negative
APR	14.5	1875.5	916.8	575.7	0.091	0.755	13.5	No Trend
MAY	786.0	1978.5	1202.1	390.8	-0.309	0.213	-39.6	Negative
JUN	536.0	3661.0	1708.8	846.2	0.273	0.276	107.8	Positive
JUL	615.0	2290.0	1482.7	444.0	0.055	0.876	15.3	No Trend
AUG	1264.5	2588.5	1893.8	369.0	0.018	1.000	7.143	No Trend
SEP	1305.5	2563.5	1676.8	411.0	0.200	0.436	40.2	Positive
OCT	1225.0	3354.0	2368.4	639.2	-0.200	0.436	-80.6	Negative
NOV	798.5	7911.0	4851.3	2137.5	0.055	0.876	66.5	No Trend
DEC	2269.0	9516.5	5761.8	2314.0	-0.055	0.876	-119.2	Negative
Annually	37592.0	57827.5	47243.8	5463.6	-0.273	0.276	-301.6	Negative
SWM	7517.5	11365.0	8881.2	1178.2	0.200	0.436	152.0	Positive
NEM	9798.0	26292.5	18212.6	4702.0	-0.273	0.276	-466.3	Negative

b) Klang River Basin

Time Series	Min	Max	Mean	Std. dev	Kendall's tau (Z Value)	p-value	Sen's slope (S Value)	Rainfall Trend
JAN	1958.5	3758.5	2530.6	570.6	0.127	0.640	32.7	Positive
FEB	114.0	4244.5	1719.6	1023.4	-0.164	0.533	-82.0	Negative
MAR	1180.5	4930.5	2536.4	1109.3	-0.382	0.119	-145.8	Negative
APR	1184.0	4485.0	2929.0	981.4	0.164	0.533	86.7	Positive
MAY	1539.5	4802.0	2862.4	978.1	-0.200	0.436	-91.1	Negative
JUN	433.0	3102.5	1790.9	875.3	0.164	0.533	91.6	Positive
JUL	670.5	2938.0	1827.6	659.5	0.091	0.755	68.6	No Trend
AUG	391.0	3202.0	2080.9	828.5	-0.382	0.119	-152.0	Negative
SEP	1864.5	3250.5	2739.1	443.1	-0.600	0.013	-86.8	Negative
OCT	1181.0	5592.0	3399.6	1475.5	-0.091	0.755	-33.4	No Trend
NOV	3114.5	6354.5	4472.2	917.9	-0.200	0.436	-62.5	Negative
DEC	2260.0	5105.0	3592.0	973.6	-0.127	0.640	-43.7	Negative
Annually	55681.5	69752.5	62705.8	3901.0	-0.164	0.533	-582.5	Negative
SWM	11875.5	16608.0	14230.0	1659.7	-0.236	0.350	-161.6	Negative
NEM	12000.0	26387.5	18250.7	3864.4	-0.091	0.755	-216.7	No Trend

Independent T-Test Analysis

In Table 2, an independent t-test was conducted to compare the mean rainfall between the Kelantan River and Klang River. This analysis provides insights into potential differences in rainfall patterns between these locations. The results of the t-test indicated that there were no statistically significant differences in mean rainfall between Kelantan River (M = 2257.82197, SD = 1590.393762) and Klang River (M = 2706.73485, SD = 825.353872). These findings suggest that, on average, the two locations experience similar levels of rainfall.

Table 2: a) Group Statistic, b) Independent Samples Test, and c) Independent Samples Effect Sizes comparison of Kelantan River and Klang River from 2010 – 2020

a) Group Statistics

	N	Mean	Std. Deviation
Rainfall			
Sg Kelantan	12	2257.8	1590.3
Sg Klang	12	2706.7	825.3

b) Independent Samples Test Results

	F	Sig	t	df	Mean Difference
Rainfall	3.488	0.07	-0.8	22	-448.9

c) Independent Samples Effect Sizes

	Effect sizes	Standardizer	Point Estimate
Rainfall	Cohen's d	1266.9	-0.4
	Hedges' correction	1312.3	-0.3
	Glass's delta	825.3	-0.5

The lack of a statistically significant difference in mean rainfall between the Kelantan and Klang River basins indicates that they experience similar meteorological conditions, including temperature (25°C–32°C), humidity, and wind patterns, which are characteristic of their shared tropical monsoon climate (Mohtar et al., 2020; Sidek et al., 2021). These findings highlight the influence of regional factors, such as topography and prevailing weather systems, on rainfall patterns.

Although the t-test did not show a significant difference, the calculated effect sizes (Cohen's d = 1.267, supported by Hedges' correction and Glass's delta) indicate a substantial practical difference in rainfall levels between the two basins. This suggests that rainfall variations in intensity and timing could have important implications, particularly for flood management. Local factors, such as land use, drainage infrastructure, and river basin characteristics, further influence flood outcomes (Hasan et al., 2019).

The similar mean rainfall between the two basins does not imply identical timing or duration of rainy seasons. Differences in rainfall onset, duration, and intensity could affect water availability, agriculture, and flood risk, emphasizing the need to consider these temporal variations when assessing hydrological dynamics.

Spatial Maps

Figure 5 provides an insightful analysis of Mann-Kendall's tau, p-values, and Sen's slope for various stations in Kelantan River during the SWM and NEM seasons. The results reveal diverse levels of correlation and significance for the SWM across the stations.

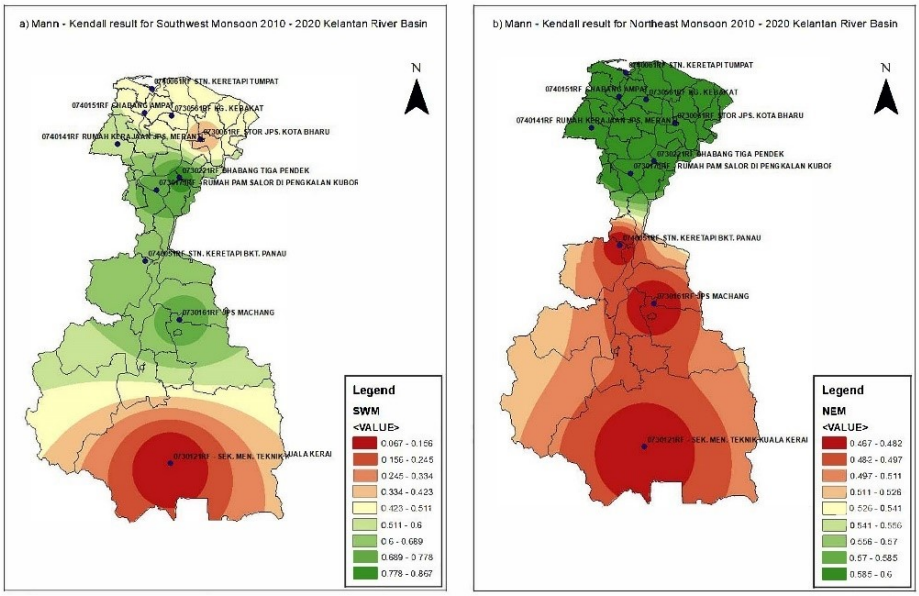


Figure 5: a) Mann–Kendall Results for the Southwest Monsoon Map and b) Mann–Kendall Results for the Northeast Monsoon Map Kelantan River Basin from 2010 - 2020

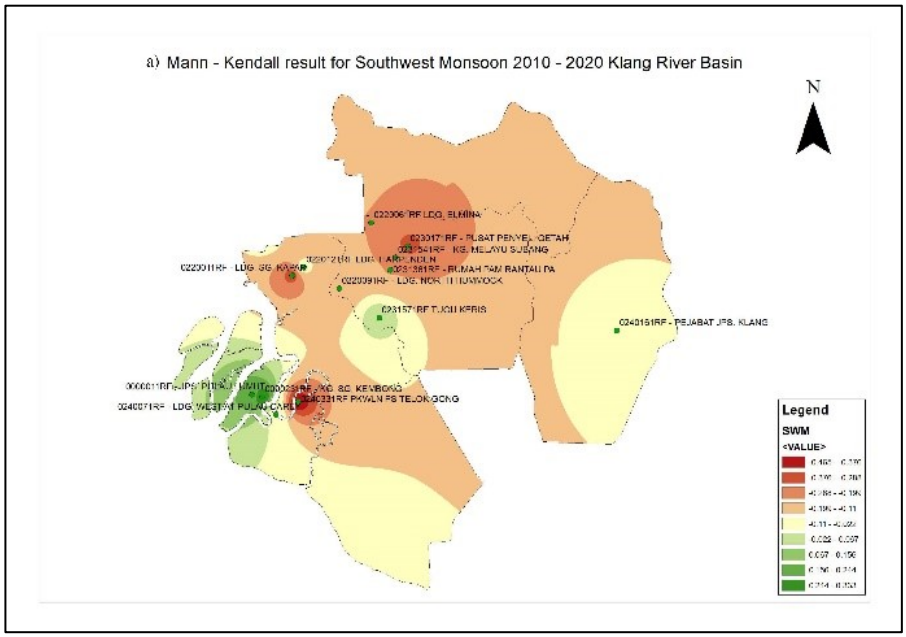
Some stations in Kota Bharu exhibited moderate to strong positive correlations and notable positive rainfall trends during the SWM. For example, the Stor JPS Kota Bharu and Sek. Men. Teknik Kurai showed moderate to weak correlations with slight positive trends. In contrast, stations like JPS Machang, Rumah Pam Salor Di, Chabang Tiga Pendek, Kg. Kebakat, and Stn. Keretapi Bkt. Pa showed strong correlations with significant Sen's slopes, indicating substantial positive trends. On the other hand, Stn. Keretapi Tumpat, Rumah Kerajaan JPS,

M, and Chabang Ampat showed weaker correlations and modest trends.

During the NEM, similar positive trends were observed. Stations such as JPS Machang (0730161RF), Rumah Pam Salor Di (0730171RF), Chabang Tiga Pendek (0730221RF), Kg. Kebakat (0730561RF), Stn. Keretapi Bkt. Pa (0740051RF), Rumah Kerajaan JPS, M (0740141RF), and Chabang Ampat (0740151RF) consistently exhibited positive Kendall's tau values ranging from 0.467 to 0.6, and Sen's slopes ranging from 78.705 to 123.97, with p-values between 0.133 and 0.26.

These trends underscore the influence of station-specific characteristics on rainfall patterns in the Kelantan River basin, reflecting an increasing rainfall during the monsoon seasons. This observation aligns with climate change projections made by Tang (2019) and Pour et al. (2022), which predict greater intensity and variability in monsoon rainfall. The findings enhance the understanding of local precipitation trends and their broader implications in the context of climate change, aiding regional adaptation efforts.

Subsequently, Figure 6 shows rainfall trends in Klang River stations during SWM and NEM. The Kendall's tau values and p-values varied, providing insights into precipitation patterns in the region.



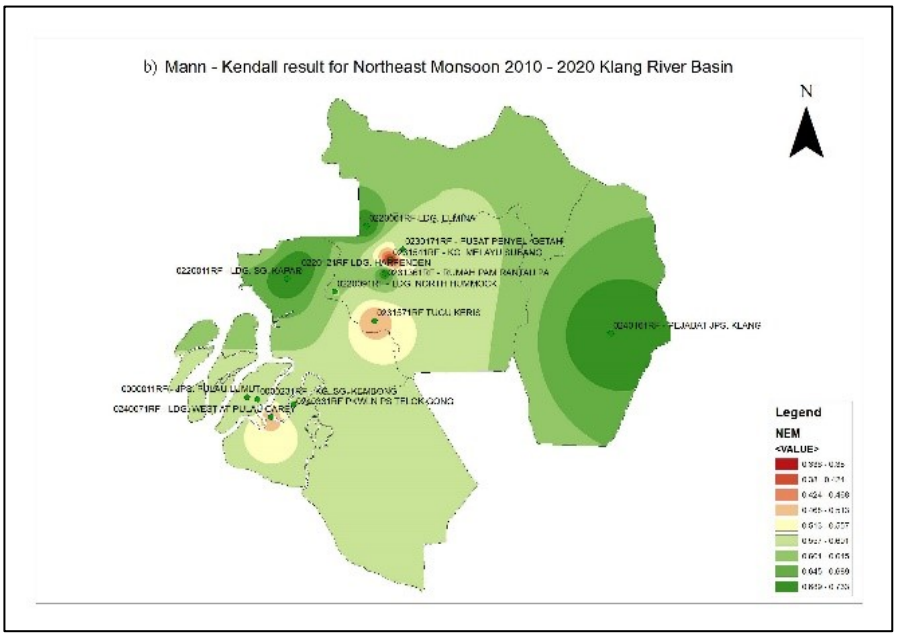


Figure 6: a) Mann – Kendall Results for the Southwest Monsoon Map and b) Mann – Kendall Results for the Northeast Monsoon Map Klang River Basin from 2010 – 2020

During both the SWM and NEM seasons, several stations in Malaysia showed negative correlations with rainfall, indicating a declining trend in precipitation during the monsoon seasons. These stations include LDG. Sg. Kapar, LDG. Elmina, LDG. North Hummock, LDG. Harpenden, Pusat Penyel. Getah and KG. Melayu Subang. However, Tugu Keris station showed a weak positive correlation, suggesting a slightly positive trend in NEM rainfall. Although some p-values were not statistically significant, Sen's slopes confirmed the observed trends. These findings align with previous studies that indicated a decreasing trend in rainfall during the monsoon seasons.

Declining rainfall trends in Klang River during monsoon seasons have implications for water resource management and flood mitigation strategies. As such, the government must develop adaptive measures to address potential challenges related to water availability and extreme weather events. These observations contribute to a better understanding of changing climate dynamics.

CONCLUSION

The analyses of rainfall data from 2010 to 2020 in the Kelantan and Klang River Basin revealed distinct patterns in precipitation trends. The Kelantan River Basin exhibited an upward trend in rainfall during the SWM season, while the Klang River Basin showed a relatively stable rainfall pattern without a significant trend

observed during the same timeframe. The independent t-test revealed no significant difference in mean rainfall between Kelantan and Klang Rivers. The analysis also demonstrated varying levels of correlation and significance across different stations within each basin during both the SWM and NEM seasons.

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THE IMPACT OF THE SURFACE RUNOFF COEFFICIENT (C) ON LAND UTILIZATION

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Abstract

Transformations in land use from undeveloped to built-up land can increase large surface runoff. This research aims to assess runoff coefficient (C) on changes in land utilization over various periods and times. The method used in this research involves analyzing changes in land use to determine the area of each type of land use over a specific period and then analyze the C value due to land changes. The results reveal that land use in the Way Pubian sub-watershed consists of pond, forest, open land, settlements, plantations, and rice fields area. In certain periods, land use changes, so that different C total value results are obtained in 2012, 2017 and 2022 periods. The C value is significantly affected by the type of land use, because the type of particular land use has different surface runoff coefficient values. The C value obtained from the 2012, 2017 and 2022 periods are close to 0, indicating that all rainwater that falls in the sub-watershed area are infiltrating the soil properly and therefore, land use is classified as good. It can be concluded that the value of the surface runoff coefficient (C) affects the magnitude of changes in land use within a certain period of time.

Keywords: Land usage, Runoff coefficient (C), Way Pubian watershed, Central Lampung, GIS

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INTRODUCTION

Land usage is a quite complex study of the appearance (surface) of the earth influenced by numerous determining or changing factors (Ilmi, 2019). Land use is all types of land use by humans, including use for agriculture, sports fields, residential areas, restaurants, hospitals, and cemeteries (Rianasari et al., 2013; Lindgren, 1985; Purwadhi, 2008). Basically, land is a finite natural resource that forms naturally and can be damaged due to human activities (Romdania and Herison, 2023). Therefore, it can be interpreted that the type of land use in an area is seen based on the results of community activities. Transformations in land use will directly and indirectly affect the condition of areas where land changes occur, such as hydrological conditions which include changes in runoff, decreased water quality, changes in river hydrological characteristics, and decreased rainwater infiltration capacity compared to before the changes (Tanuma et al., 2015; Mariati et al., 2022). Transformations in land use from undeveloped to built-up land can increase large surface runoff, where if surface runoff increases it will affect the peak discharge at the watershed outlet (Irmayanti, 2018). This can be interpreted that changes in land use have an impact on the hydrological conditions of a watershed (DAS) and influence the water infiltration capacity. As the infiltration rate decreases, the amount of surface runoff increases, this results in less infiltration into groundwater, and has an impact on decreasing groundwater and surface water supplies (Purwantara, 2013).

The rate at which surface water infiltrates affect land use, namely the surface flow runoff coefficient (C), a number that indicates the comparison between the load of surface flow and the load of rainfall. The C coefficient value ranges from 0–1, with a close to zero (0) C value indicates as good, while a watershed is said to be increasingly damaged if the C value is closer to one (Irmayanti, 2018; Abinowo, 2018; Verrina et al., 2013). The key factors that influence the C coefficient value include soil infiltration rate, land steepness, ground cover plants, and rain intensity. The C value varies over time according to surface flow in the river, especially soil moisture. The runoff coefficient (C) value can be estimated by reviewing land use (Setiawan, 2020). So, a land use map is needed in an area to obtain the coefficient C value. Searching for land use information can also be done directly in the field. However, this activity requires a lot of time, energy, and costs, making periodic monitoring difficult (Sari, 2011; Razak et al., 2015). Thus, remote sensing technology is essential to be able to describe earth objects and monitor changes in land use in an area periodically (Niagara et al, 2020). For this reason, remote sensing research is necessary to obtain information about the shape of the earth's surface and support the search for information on land use in a region.

The use of land use maps of an area provides insights into the conditions of land use. An area that experiences changes affects the infiltration power conditions of a watershed. The problem is that land use mapping for sub-

watershed areas in Lampung Province has not been carried out thoroughly, so research was carried out regarding the C value to see how much land use change has occurred. Although research on the influence of the C value on land use have been carried out in various regions, they were never carried out in the Way Pubian Sub-watershed on a regular basis. Therefore, it is necessary to conduct a land use review to determine the C value on the extent of land use.

This research aims to assess runoff coefficient (C) on changes in land utilization over various periods and times. Through this analysis, we can obtain the surface runoff coefficient (C) value and its effect caused by the size of land use changes.

METHODOLOGY

The Location of the Research

The location of the research is in Way Pubian Sub-watershed, Central Lampung Regency. Geographically it is located at 5°04'24" South Latitude - 104°54'22" East Longitude. Administratively, it covers several sub-districts, including Pubian, Selagai Lingga, Sendang Agung and Padang Ratu sub-districts. See Figure 1.

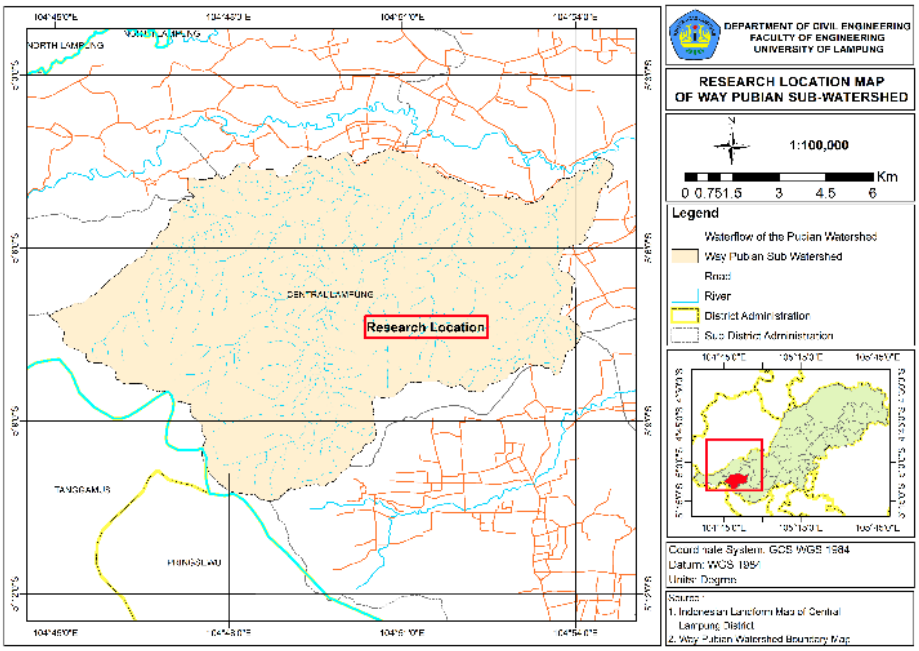

Figure 1: Location Map

Tools and Materials

In this research, the tools used are as follows:

a. Computer
b. ArcGIS 10.2 Software with Concurrent Use License code EFL123456789.
c. Camera

Materials used in this research:

a. Image map on 2012, 2017 dan 2022 period from Google Earth
b. Indonesian Earth Map of Central Lampung regency, scaled on 1: 50.000
c. Border map of Way Pubian sub-watershed, Central Lampung regency
d. Documentation of field observer

Data Collection Method

In this research, the types of data used are as follows:

1. Primary Data

A collection of data directly from the research location and obtained through documentation. Primary data can be obtained from either direct observation or interview. See table 1.

Table 1: Primary Data

No	Data	Source
1	Documentation	Collection by visiting the research location and document the condition of the research location

2. Secondary data

Secondary data is a data regarding the research location that can be obtained indirectly. See table 2.

Data Processing Method

The geographic information system method is employed in spatial data processing. Geographic Information Systems (GIS) is utilizedd in various studies and applications, including transportation network analysis (Ya'acob, 2016). The steps of processing are as follows (Kholisa, 2022):

a. Data Input
   Identification process and data collection necessary for the research.
b. Analysis
   Analysis using guided classification method.
c. Visualisation

Table 2: Secondary Data

No	Data	Source
1	Literature Study	Data can be obtained from sources such as previous research and articles regarding land use
2	Sub Watershed Border	Secondary data collection by proposing data request to Protected Forest Watershed Management Agency (Badan Pengelola Daerah Aliran Sungai Hutan Lindung (BPDASHL)) Way Seputih Way Sekampung
3	Indonesian Earth Map	Data collection by downloading Indonesian Earth Map of Central Lampung regency from Geospatial Information Agency (Badan Informasi Geospasial (BIG)) on Ina-Geoportal website
4	Satelite Image Map	Image data collection from Google Earth by downloading high resolution map on website https://earth.google.com on recorded year 2012, 2017, and 2022

Results presentasion in map form, showing regions that has land use.
There are two methods of processing data, they are:

1. Image Interpretation
   ArcGIS software is used to carry out the interpretation method. The 2012, 2017 and 2022 high quality satellite image data used in this method is digitally processed.

   The steps to interpret image digitally are (Lestari et al., 2021):
   a. Import image data
   b. Correct the geometrics
   c. Image cutting
   d. Image classification

2. Guided Classification
   The supervised analysis is used for guided classification, where the classification criteria are established based on the class signature that is produced by creating a training sample area (Riswanto, 2009; Khairussidqih et al., 2021).

   The process for classification is as follows (Riswanto, 20099):
   1) Training sample stage: construct an “interpretation key” and numerically develop the spectra for each feature.
   2) Classification stage: determine the value of unknown and most similar pixels of the same category

3) Output stage: the areas of various forms of land use in the image are then produced as a matrix table, giving a summary of the matrix in the form of a land use map.
4) Overlay: To view the differences between two maps of the location, the overlapping method was described as one of the features of the ArcGIS software. The land use maps from 2012, 2017 and 2022 were used for the overlay.

Data Analysis

Land Use Change Analysis

Analyzing changes in land use using high-resolution data Google Earth satellite image are as follows (Kelly-Fair et al., 2022):

a. Classification and Post Processing
b. Identify drivers of change based on descriptive methods of process results.

The analysis was performed by comparing land use maps over a duration of five years for 2 periods in 2012, 2017 and 2022. A reasonably lengthy time period was taken in order that significant comparisons can be visible.

Surface Runoff Voefficient Value (C) Analysis

From the analysis results of changes in land use, the effect on runoff coefficient value (C) was analyzed. To calculate the surface runoff coefficient (C) value from the land use map, the C total equation was used, as follow (Kironoto et al., 2000; Herison & Romdania, 2023):

$$C\ total\ = \sum_{i=1}^{n} \frac{Ci\ x\ Ai}{A}$$

Where:
Ai= Area of land cover with land cover type i
A= Area of the whole land coverage
Ci= Coefficient of the surface runoff land cover type
N= Land cover types amount

RESULTS AND DISCUSSION

Land Use Map Processing Result

The results of the processed land use maps for 2012, 2017 and 2022 are obtained based on the results of data processing using image interpretation and guided classification methods. Figure 2, 3 and 4 shows these results.

From the map of land use above, it can be implied that the Way Pubian sub-watershed features 6 types of land use, specifically ponds, forests, open land, settlements, plantations and rice fields. In Figure 2 which depicts the year 2012, it can be seen that the land use area was dominated by forest land with minimum of open land. Meanwhile, for the 2017 map period, there was an increase in land use such as open land and residential areas. The land use map for 2022 reveals a decline in forest land compared to the previous 2 years.

Using ArcGIS program to process land use maps, the area for every type of land use can be calculated with the assist of calculate geometry system. Changes in land use over the three years can be seen in table 3.

Table 3 indicates that there has been changes in land use for the last three years. Notable reduction can be seen in the utilization of forest land. The percentage of land use changes is more detailed in results of the analysis of differences in the region of land use types from the three years, see table 4.

Table 3: Land Use Change

No	Land Use	Land Area Each Year (Ha)		
		2012	2017	2022
1	Pond	3.45	2.66	1.57
2	Forest	8091.36	7342.89	6719.14
3	Open Land	14.41	62.13	122.58
4	Residential Area	681.18	763.92	823.2
5	Plantation	2026.2	2414.05	2783.11
6	Rice Field	802.34	1033.29	1169.34
	Total	11618.94	11618.9	11618.94

From table 4, it is revealed that in 2012 and 2017, several changes that occurred included ponds decreasing by 0.01% from an area of 3.45 to 2.46, forests decreasing by 6.44% from an area of 8091.36 Ha to 7342.89 Ha, open land increased 0.41% from an area of 14.41 Ha to 62.13 Ha, residential areas increased 0.71% from an area of 681.18 to 763.92 Ha, plantations increased 3.34% from an area of 681.18 to 763.92 Ha and rice fields also increased by 1.99% from 802.34 to 1033.29 Ha. From 2017 to 2022, there are changes in land use, including ponds decreasing by 0.01% from an area of 2.66 to 1.57 Ha, forests decreasing by 5.37% from an area of 7342.89 to 6719.14 Ha, open land increasing by 0, 52% from an area of 62.13 to 122.58, residential areas increased by 0.51% from an area of 763.92 to 823.2 Ha, plantations increased by 3.18% from 2414.05 to 2783.11 Ha.

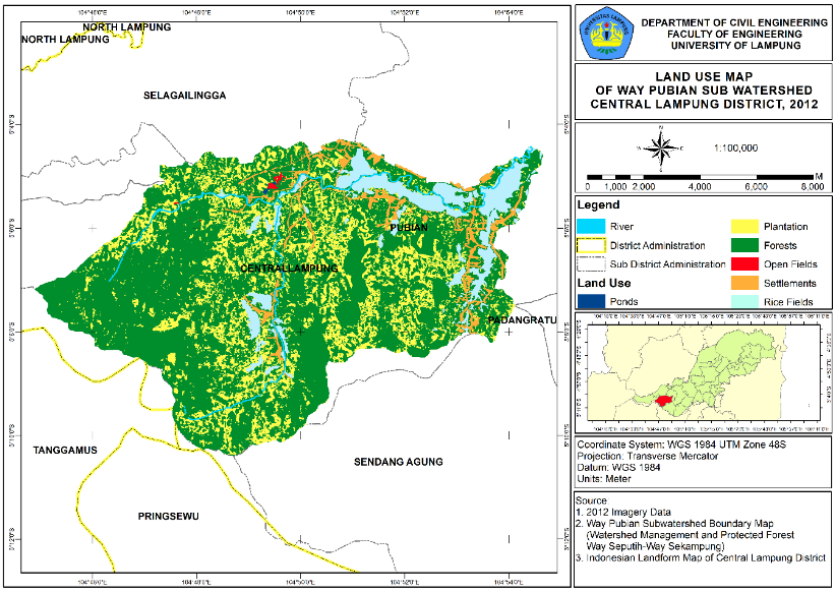

Figure 2: Map of Land Use Year 2012

Changes in land use in this sub-watershed are influenced by several factors, which can be seen in table 5. Changes in land use can be seen from the overlay results of land use maps for 2012, 2017 and 2022, see figure 5.

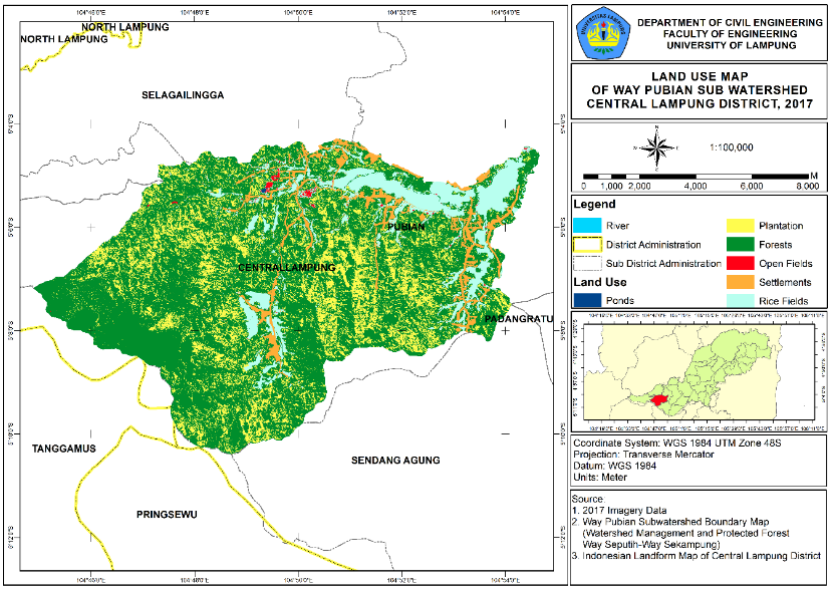

Figure 3: Map of Land Use Year 2017

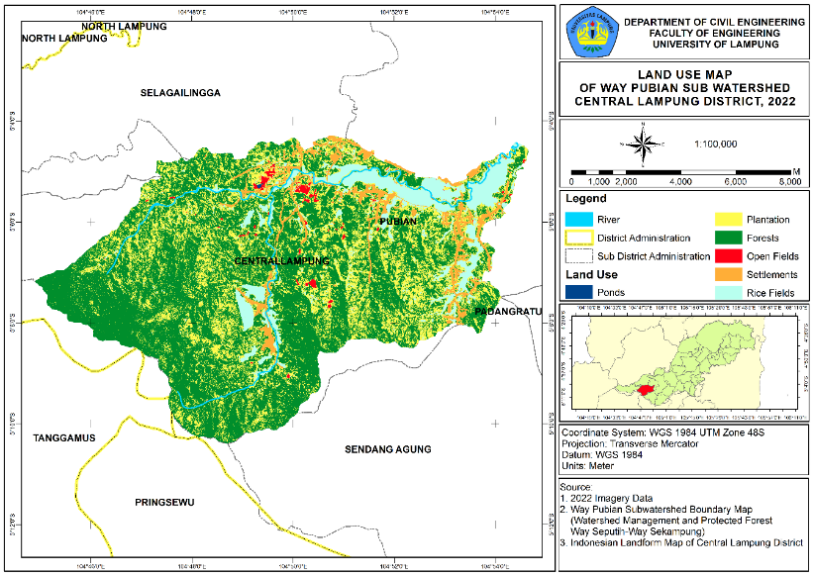

Figure 4: Map of Land Use Year 2022

Table 4: The percentage of land use change in year 2012, 2017, and 2022

No	Land Use	2012		2017		Land Use Change	2017		2022		Land Use Change
		Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)		Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)	
1	Pond	3.45	0.03%	2.66	0.02%	-0.01%	2.66	0.02 %	1.57	0.01 %	-0.01 %
2	Forest	8091.36	69.64 %	7342.89	63.20 %	-6.44%	7342.89	63.20%	6719.14	57.83%	-5.37 %
3	Open Land	14.41	0.12%	62.13	0.53%	+0.41%	62.13	0.53 %	122.58	1.06 %	+0.52%
4	Residential Area	681.18	5.86%	763.92	6.57%	+0.71%	763.92	6.57 %	823.2	7.08 %	+0.51%
5	Plantation	2026.2	17.44 %	2414.05	20.78 %	+3.34%	2414.05	20.78%	2783.11	23.95%	+3.18%
6	Rice Field	802.34	6.91%	1033.29	8.89%	+1.99%	1033.29	8.89 %	1169.34	10.06%	+1.17%
	Total	11618.94	100.00%	11618.94	100.00%		11618.94	100.00%	11618.94	100.00%	

Table 5: Land Use Change Factor

No	Land Use	Changes	Reason
1	Pond	Declining	The degree of absorption of water assets is very high due to the expansion in vegetation from the expansion in plantation so the plant's requirement for water increases. Therefore, the land that function as pond turned dry.
2	Forest	Declining	The cooperation between the government and the community in utilizing protected forest land turned them into plantation lands.
3	Open Land	Increasing	There were lands that was not maintained and cared to by the owner, so that the land is neglected and broken. The planted land became dry and no plantation was placed and therefore it becomes open land.
4	Residential Area	Increasing	Population continues to rise, so that residential land increases due to the increase in housing and other buildings to satisfy community desires.
5	Plantation	Increasing	The cooperation between the government and the community in utilizing protected forest land turned them into plantation lands.
6	Ricefield	Increasing	The government regulation supports in utilizing rice field expansion so that rice fields increase as the means to fullfill the needs of the community.

Figure 5 presents the result of spatial land use analysis adjusted to the results of area observations and interviews with the community within the Pubian District region. Judging from the results, the greatest change is in the decline of land use of forest which were caused by an increase in population.

Population growth is summarized in statistical data on population growth projections in Central Lampung Regency, accessible through the Central Lampung Regency Central Statistics Agency (BPS) website. Statistical data regarding population growth in Pubian District, Central Lampung Regency, one of the sub-districts within Way Pubian Sub-Watershed, shows that in 2012 there were 21,059 people. By 2017, there was an increase in population growth of 21,580 people. Finally, a drastic surge was recorded in 2021 of 54,494 people (Central Lampung Regency Central Statistics Agency, 2023a; 2023b). This data is in accordance with information from local officials about the number of new arrivals moving to the area around the Way Pubian Sub-watershed.

As the population rises, so do their basic needs. With the basic need for rice consumption and their selling price soared, people are prompted to plant and use rice fields as a supply of livelihood. This is reflected with the outcomes of land use analysis, where the area of rice fields has multiplied within the last 10 years. However, land that lacks water tends to be used for palm oil plantations. Unlike rice fields which yield harvests annually, palm oil requires longer timeframe from the start of planting.

The changes in land use that occur can be considered normal. This is due to the fact that some of the forest land is included in protected forest areas.

To support this, refer to the map of the central Lampung Regency Forest area from the Bappeda of Lampung Province (Lampung Province Regional Development Planning Agency, 2021).

This aligns with the use of forest land in the Way Pubian Sub-watershed, which has been excessive due to continuous protection and designation as a conservation area for the government. However, it remains imperative to cautiously pay attention so that changes in land use does not increase, as this could pose unfavourable risks and has the potential to harm the condition of a watershed.

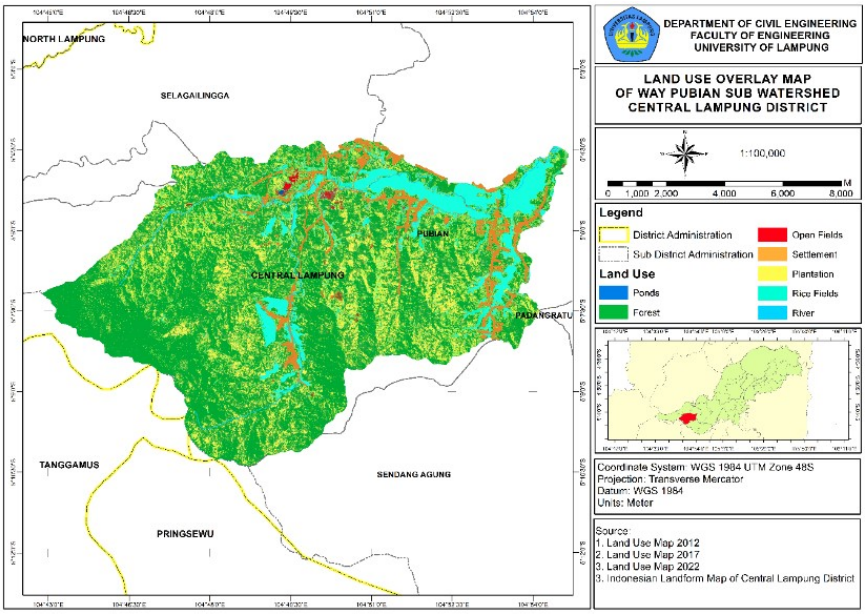

Figure 5: Land Use Overlay Map

Surface Runoff Coefficient Value (C) Analysis

Accoding to Kironoto (2003), the C coefficient value for land use types in the Way Pubian sub-watershed were 0.7 with the type of use obtained were ponds, forest with a C value of 0.001, open land with a C value of 1, residential area with a C value of 0.3, plantations with a C value of 0.1 and rice fields with a C value of 0.01 (Kironoto et al., 2000). Then, the C value is multiplied by the area of land use in the Way Pubian Sub-watershed. The calculation results obtained by the total C value in 2012, 2017 and 2022 are presented in Table 6.

Table 6: Total C Value Year 2012, 2017, and 2022

No	Calculation Year	C total
1	Year 2012	0.0379
2	Year 2017	0.0475
3	Year 2022	0.0574

Calculation of the largest area value with a surface runoff coefficient value of 0.001 significantly impacts the results of the total surface runoff coefficient value, specifically on forest land use. The total C value suggests that changes in land use that took place in 2012, 2017 and 2022 influenced the results of the coefficient value (C) in that area. This is because when the land area was utilized in calculating the C value, the C value results from year to year also change.

The change in the C value from 2012 to 2017 obtained a difference of 0.0096 (11.24%), while from 2017 to 2022 the difference in the C value became 0.0099 (9.44%). If we examine the distinction in changes in the C value, bigger changes occurred from 2017 to 2022. These changes were affected by the magnitude of changes in land use. Based on the calculation results, the value of the runoff coefficient (C) that is closest to 0 is in 2012, while the value of C that is near 1 is the value of C in 2022. All the results in 2012, 2017 and 2022 if seen comprehensively were nonetheless near number 0. This result suggests that all rainwater that falls is properly infiltrating the soil and therefore, land use is classified as good. This result is in line with the percentage level of forest and plantation land use which continues to be excessive.

Similar study was carried out in other areas in Lampung Province. The study is an analysis of land use in the Khilau sub-watershed area, Way Khilau District, Pesawaran Regency in 2022 (Herison & Romdania, 2023). Land use in the Khilau Sub-Watershed is highly occupied by plantation land due to land use changes from forest into plantation. Changes in land function occur due to government cooperation with the community as a form of land use Therefore, these changes affect the value of (C) in the Khilau Sub-Watershed. In the Khilau Sub-Watershed, a total C value of 0.1412 was obtained. In this calculation, the largest area value is 447.4284 ha with a surface runoff coefficient value of 0.1, which greatly impacts the results of the total surface runoff coefficient value, namely for mixed plantation land use (Kironoto et al., 2000). Meanwhile, in 2022 in the Way Pubian Sub-Watershed, the C value obtained was lower, which were 0.0574. These results affect the results of the total C value calculation for forest land use. Therefore, the size of the C value is significantly influenced by the type of land use, because the type of particular land use has different surface runoff coefficient values.

CONCLUSION

It can be concluded that the surface runoff coefficient (C) value influences the changes value in land use within a certain time frame. In the Way Pubian Sub-Watershed in 2012, 2017, and 2022, the total C value was near zero due to all the rainwater in the watershed was properly properly infiltrating the soil and therefore, land use is classified as good.

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CHARACTERISTICS AND STRATEGIC IMPLEMENTATION OF LOW-CARBON INITIATIVES IN SHAH ALAM, SELANGOR, MALAYSIA: INSIGHTS FROM KEY STAKEHOLDERS

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Abstract

This study highlights the critical challenges faced by Shah Alam, such as rapid population growth driven by urbanization and economic development. This surge has intensified traffic congestion, reflecting the city's burgeoning economic prominence through the expansion of its industrial areas. Addressing these issues necessitates sustainable urban planning strategies to mitigate environmental impacts and ensure the well-being of residents amid continued growth. The study aims to (i) determine the characteristics of a Low Carbon City in Shah Alam and (ii) explore the strategic initiatives required to achieve impactful low-carbon urban development. The study utilized a qualitative methodology, focusing on expert interviews to investigate characteristics and initiatives related to low-carbon cities. Six key informants, chosen for their expertise in low-carbon city projects, participated in both face-to-face and online interviews to address the study objectives effectively. Thematic analysis of the interviews provided detailed insights into the characteristics and initiatives of Shah Alam's Low Carbon City. Findings reveal that the characteristics of low-carbon cities are based on five main elements: energy, water, waste, mobility, and greenery. These elements were measured to determine whether an area has achieved carbon and greenhouse gas (GHG) reductions. The Low Carbon City (LCC) initiative in Section 14, Section 1, and Section 5 of Shah Alam has led to a reduction in GHG emissions since the baseline years of 2015 and 2017. Additionally, community cooperation was found to be crucial in advancing low-carbon city efforts. The research concludes that Shah Alam continues to make efforts to reduce carbon emissions, evidenced by the reductions achieved during the implementation of the LCC initiative.

Keywords: Low Carbon City, Low Carbon City Framework, Greenhouse Gases, Sustainable Green City, Carbon Emissions

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INTRODUCTION

Malaysia's rapid development and urbanisation pose challenges due to its high carbon dioxide (CO_2) emissions. As of 2019, the country's carbon footprint per capita surpassed the global average, standing at 10.158 tonnes of CO_2 equivalent per person (Ministry of Natural Resources, Environment and Climate Change, 2022). In the ASEAN region, Malaysia is among the largest emitters of greenhouse gases, contributing 0.52% to global carbon emissions (Association of Southeast Asian Nations, 2021). Due to population growth and economics, the energy sector is likely to be the biggest contributor, and other sectors, such as transportation and agriculture, might also play a role in the country's carbon footprint (Solaymani, 2022). Local authorities have implemented various programmes and initiatives to boost renewable energy enhance energy efficiency, adopt green building techniques, improve transportation infrastructure, and promote sustainable land use. These efforts aim to improve urban resilience to environmental challenges and mitigate the impacts of climate change (Haliza, 2020).

Shah Alam city has achieved notable success in reducing its carbon footprint and tackling greenhouse gas (GHG) emissions, as evidenced by its dominance at the Malaysian Low Carbon City Awards 2023, where the Shah Alam City Council secured the highest number of accolades (Malaysian Green Technology And Climate Change Corporation (MGTC), 2024). The local government in Shah Alam plays a crucial role in implementing Low Carbon City initiatives by developing and enforcing policies for sustainability, coordinating with stakeholders, integrating renewable energy and energy-efficient technologies, promoting green transportation, managing waste effectively, and ensuring sustainable land use practices (Farah Nadia, Zarina, & Nor Azira, 2023). Shah Alam offers a successful illustration of how cities can effectively address greenhouse gas emissions and transition to a more sustainable and low-carbon future.

The choice of Shah Alam as a case study is driven by its status as a rapidly expanding urban center grappling with substantial challenges in carbon emissions and environmental sustainability. This paper aims to (i) define the unique attributes of a low-carbon city in Shah Alam and (ii) investigate the strategic initiatives essential for achieving meaningful progress in low-carbon urban development. The study's findings offer empirically-grounded insights into Shah Alam's evolution toward a low-carbon city, illuminating its characteristics, effects, and management strategies. These insights are crucial for shaping informed policies and guiding decision-making processes effectively.

LITERATURE REVIEW

The Concept of Low Carbon City Framework

Many cities around the world have set the objective of becoming low-carbon cities (Su, et al., 2013). A sustainable city indicator system is essential for guiding low-carbon strategies, urban planning, and policy implementation (Tan, Yang , & Yan, 2015). The Low Carbon City Framework (LCCF) serves as a crucial tool in mitigating the environmental impact of climate change (Siti Kartina, Dasimah, Siti Mazwin, & Mohd Sallehuddin, The Implementation Low Carbon Cities Framework of Local Authority in Development Control towards Green Cities, 2019). The common indicators used in the LCCF for evaluation include Economic, Energy patterns, Social and Living, Carbon and Environment, Urban mobility, Solid waste, and Water (Tan, et al., 2017). The LCCF provides a comprehensive framework for assessing and monitoring the effectiveness of low-carbon initiatives, enabling cities to track their progress towards achieving sustainability goals (Siti Kartina , Dasimah, Siti Mazwin , & Ismail, 2022). This study aims to measure progress by exploring the characteristics of a low-carbon city, with the ultimate goal of reducing carbon emissions and promoting sustainable development. By focusing on key areas, such as energy consumption, waste management, and transportation, cities can identify opportunities for improvement and implement targeted strategies to reduce their carbon footprint.

Low Carbon City Framework (LCCF) of local authority in development control

The planning department within each local authority is typically responsible for overseeing the administration and management of low-carbon city approaches in a local context (Jamaluddin, et al., 2023). Strong urban governance, bolstered by a robust institutional framework and a sustainable development approach, is intricately linked to addressing climate change issues while fostering partnerships with relevant stakeholders such as businesses and civil society organisations can enhance the effectiveness of climate change mitigation efforts (Nor Baizura, Yusfida Ayu, D. Ary Adriansyah, Nurul Shakila, & Na'asah, 2023). Inclusivity and transparency in decision-making processes are imperative to gain support for sustainable initiatives among stakeholders, particularly the local community (Yusfida Ayu, Khalid, Nor Baizura, Marlyana Azyyati, & Mohammad, 2023). Su et al. (2013) suggests that the evaluation of how well an urban area progress towards becoming low-carbon by considering both the specific actions and initiatives taken at the local level (bottom-up), as well as the broader policies and strategies at the city or national level (top-down). Therefore, this study aims to elucidate the measurement and management approaches of Shah Alam low-

carbon city. By comprehending the management approach in urban areas, policymakers can make informed decisions for sustainable development.

RESEARCH METHODOLOGY

This study utilised a qualitative approach by conducting interviews with key informants, such as officers from the Shah Alam City Council (MBSA), the Malaysian Green Technology and Climate Change Corporation (GREENTECH MALAYSIA), and experts from UiTM Puncak Alam in Landscape Architecture. The study objectives were addressed through face-to-face and online interviews with a maximum of six key informants selected based on their expertise in low-carbon city projects, as shown in Table 1, which presents their profiles.

Thematic analysis was employed to analyze the data, concentrating on uncovering and interpreting the underlying meanings within the gathered information. This method involved systematically identifying, organizing, and offering insights into patterns or themes across the data set. By doing so, it facilitated a deeper understanding of the key characteristics and strategic initiatives associated with low-carbon city implementation in Shah Alam. The process included coding the data, searching for themes, reviewing these themes, and defining and naming them to provide a comprehensive analysis. This approach enabled the researchers to derive detailed insights into the elements and initiatives of a low-carbon city. This method allowed for the identification of recurring themes and patterns, providing valuable insights into perspectives on the characteristics and impact of implementing a low-carbon city in Shah Alam. Data triangulation was employed to ensure the validity and dependability of the research findings. This involved cross-referencing data from various sources or methodologies to verify and confirm the findings.

Table 1: Profile of Key Informants

Position	Experiences	Responsibilities	Code
Analyst at Malaysian Green Technology and Climate Change Centre (MGTC)	2 years	Analyze data and trends for improvement.	Informant 1
Assistant Town Planning Officer, Planning Department, Shah Alam City Council (MBSA)	4 years	Optimize land usage through site analysis.	Informant 2
Assistant Town Planning Officer, Landscape Department, Shah Alam City Council (MBSA)	2 years	Data-driven urban planning decisions.	Informant 3
Assistant Town Planning Officer, Landscape Department, Shah Alam City Council (MBSA)	2 years	Community involvement in planning projects	Informant 4
Associate Professor, Coordinator Studies of Landscape Architecture at UiTM Puncak Alam	2 years	Education and influential research in Landscape Architecture	Informant 5
Senior Lecturer of Landscape Architecture at UiTM Puncak Alam	2 years	Education and influential research in Landscape Architecture	Informant 6

ANALYSIS AND DISCUSSION

The Definition of Low Carbon City

The concept of a low-carbon city entails building infrastructure with minimal impact on residents' lives, while emphasising the integration of renewable energy, localised transportation systems, and green buildings (Tan, et al., 2017). However, achieving "Zero Carbon City" status is challenging in areas such as Shah Alam because of industrial presence and lifestyle factors. Informants' express confidence in the concept's potential but highlight difficulties in achieving zero carbon emissions, particularly in industrialized regions. This reflects an ongoing struggle to balance urban expansion with environmental goals

" *A Low Carbon City is a location that can achieve zero carbon emissions*."
Informant 1
""A Low Carbon City is a city capable of providing essential urban development without compromising the needs of its residents"
Informant 2
"Despite the presence of industrial regions here, achieving the 0% carbon target and reducing carbon emissions in Shah Alam remains challenging."
Informant 5
"Because Shah Alam still contains many industrial areas, it is not possible to set a target of 0% carbon emissions."
Informant 6

Informants 1 and 2 expressed confidence in Shah Alam's city ability to become Low-Carbon City and achieve zero carbon emissions, and provide sustainable urban development. However, Informants 5 and 6 highlighted the difficulty of achieving the 0% carbon target for the city due to the presence of many industrial areas. The combination of urban expansion and environmental goals in a city like Shah Alam highlights the ongoing struggle towards full carbon neutrality.

Characteristics of Low-Carbon City

The informants highlighted five key elements of a low-carbon city: energy, water, mobility, greenery, and waste management. Informant 2 underscored the significance of integrating green technology and city services to enhance residents' quality of life while simultaneously reducing greenhouse gas emissions within a low-carbon city.

Informant 3 suggested adopting SMART Lighting or LED lamps in buildings as a practical strategy for optimising energy consumption. Prioritising renewable energy sources and efficient energy reuse is fundamental, along with sustainable water management, to understand their impact on greenhouse gas

emissions. Mobility solutions involve reducing private vehicle use and implementing restrictions on petrol and diesel vehicles in cities.

Informant 6 also stressed the importance of cities' commitment to sustainability, advocating for the incorporation of 10% green space in all developments. Green spaces are crucial for carbon sequestration, whereas efficient waste recycling programmes are essential for reducing emissions. Integrating green technology with city services further enhances urban sustainability and reduces greenhouse gas emissions. Overall, prioritising sustainable energy, water, transportation, green spaces, and waste management is essential for achieving a low-carbon status and improving urban sustainability.

> "*Among the main characteristics of a low-carbon city is the integration of green technology and the latest initiatives with city services to improve the quality of life in order to achieve a reduction in the intensity of greenhouse gas (GHG) emissions."*
>
> -Informant 2
>
> "*A characteristic of a city implementing Low Carbon City (LCC) is that the majority of buildings within the city use SMART Lighting or LED lamps, which can help optimize energy consumption."*
>
> -Informant 3
>
> "*A characteristic of a sustainable city is that every development conducted within the city must incorporate 10% green space to conserve sustainability in the urban environment.*"
>
> -Informant 6

These insights collectively contribute to a holistic vision of a city that prioritises environmental responsibility alongside the well-being and sustainable progress of its inhabitants. Through triangulation methods including interviews and document analysis, the study effectively identified the key characteristics of Shah Alam as a zero-carbon city. Figure 1 illustrates the measurement and management approach of Shah Alam Low Carbon City, offering a comprehensive framework for other cities seeking to reduce their carbon footprint.

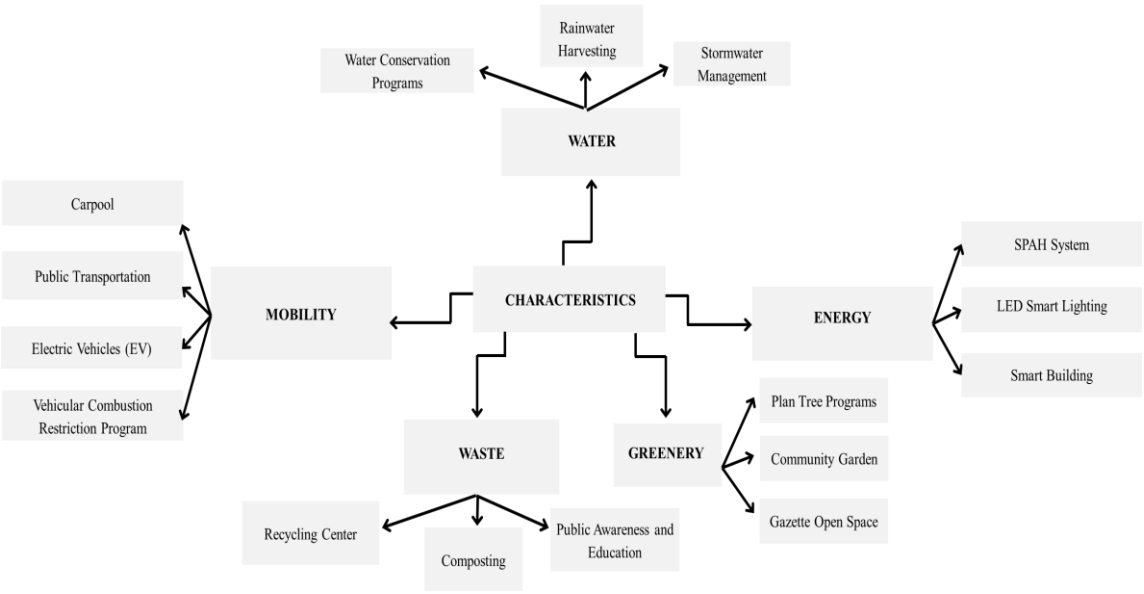

Figure 1: Framework of Characteristics of a Low Carbon City in Shah Alam

Navigating Challenges for Achieving Low-Carbon Cities in Shah Alam

According to Informant 3, financial constraints present a significant barrier to transforming Shah Alam into a low-carbon city as they hinder the implementation of high-impact projects, particularly those measurable within the carbon measurement programme. Converting old or non-green buildings into environment-friendly structures requires substantial capital investment, primarily due to the extensive upgrades involved. Additionally, adopting green technology, developing sustainable infrastructure, and transitioning to renewable energy sources often incur high costs, particularly in the context of urban development, where financial resources may be limited. The difficulty of securing adequate funds and investments further exacerbates this challenge. Despite the long-term benefits, approximately 40 projects may face neglect or delay due to financial constraints, as highlighted by the respondents.

Informant 3 also identified lack of community awareness as a significant obstacle to fostering active community participation in low-carbon urban development initiatives. This lack of awareness stems from a limited understanding of the concept and significance of low-carbon practices in the area. Communities are not exposed to the positive outcomes of areas with low carbon emissions, nor do they grasp the importance of adopting sustainable lifestyles in their daily lives. Their indifference further hampers efforts to educate them on low-carbon city concepts. The interview participants emphasised the need for

comprehensive and impactful education programmes and awareness campaigns that can communicate sustainability information in a manner that is easily understandable and relevant to the community's daily lives.

Informant 4 pointed out that a significant challenge lies in community behaviour, which poses a notable barrier to achieving a low-carbon city. The main daily lifestyle of the population is the use of private vehicles from one destination to another, particularly on weekdays. Every community in Shah Alam uses their own vehicle without using the carpool method, which is sharing a vehicle to work. This practice is very difficult for local residents because of the large area of Shah Alam city and the different destinations they want to go to. Apart from the use of one's own vehicle to go to work, the use of energy in daily life also contributes to high carbon emissions where the excessive use of electricity when it is not turned off after use causes the flow of electricity to continue and contributes to the impact on the environment.

Similarly, Informant 5 highlighted the issue of unsustainable efforts. Transitioning to a sustainable, low-carbon city necessitates continuous and coordinated efforts to accelerate its change. The informant stated that non-constant efforts will be difficult in making a low-carbon city. The challenge faced in the early stages of the application of low-carbon elements in development in Shah Alam is the difficulty in changing the lifestyle of the people of Shah Alam towards a more effective and low-carbon lifestyle. Efforts to change this lifestyle require a careful and continuous approach as well as a deep understanding of the factors that influence society's behaviour.

> ""In Shah Alam, one of the challenges in becoming a low-carbon city is cost. For instance, the expense involved in retrofitting buildings to adopt green technologies, such as transitioning from fluorescent to LED lights, is significant. Moreover, there is resistance to shifting from conventional systems to more sustainable alternatives like the SPAH system. Additionally, community awareness poses another hurdle, as not all residents are willing to participate in low-carbon initiatives due to limited understanding of carbon emissions."
>
> -Informant 3
>
> "A significant challenge faced by Shah Alam as a low-carbon city is the social culture that contributes to carbon emissions. Factors such as increasing reliance on air conditioners and widespread use of private vehicles for commuting exacerbate environmental impacts."
>
> -Informant 4
>
> "Another challenge lies in maintaining sustainable efforts. Achieving a transition to a sustainable, low-carbon city requires continuous and concerted efforts to accelerate change."
>
> -Informant 5

To summarize, the process of turning Shah Alam into a low-carbon metropolis encounters significant obstacles that require holistic resolutions. The implementation of critical initiatives is hindered by financial constraints. Additionally, development is further impeded by a lack of community awareness

and participation, as well as ingrained practices such as reliance on private automobiles and inefficient energy usage. To overcome these barriers, it is necessary to make focused and coordinated efforts to get sufficient funds, improve community knowledge and involvement, and encourage sustainable practices. An uninterrupted, synchronized strategy is crucial, highlighting the necessity for persistent dedication and determination to achieve Shah Alam's goal of a more environmentally friendly and sustainable urban setting.

Criteria Strategies Implemented to Reduce Carbon Emissions

After evaluating the Shah Alam Low Carbon Action Plan 2035, several strategies were identified to reduce carbon emissions. These strategies include promoting energy management, efficiency, and renewable energy; adopting transit-oriented urban development; enhancing waste management practices; integrating development with nature; ensuring effective city governance; and increasing awareness through communication and education efforts. During the interviews, the informants were asked about the progress and updates of the implementation of these strategies.

Transport Policies to Promote Zero Carbon Mobility

The informants emphasised the importance of efficient transportation management in reducing the city's carbon emissions and improving its quality of life. In the Shah Alam Low-Carbon Action Plan 2035, the Council will continue to promote a transit-oriented city by prioritising sustainable development. Four action plans have been outlined to achieve this target: the improvement of transit-oriented cities, the implementation of "City for Walking and Cycling" elements, the promotion of energy-efficient vehicles, and the provision of an inclusive and efficient transportation system. The aim is to achieve the maximum level of carbon reduction, creating a greener and more viable city.

"In Shah Alam, the zero-carbon mobility transport policy aims to enhance transit-oriented development, implement elements of 'City for Walking and Cycling', promote energy-efficient vehicles, and establish an inclusive and efficient transport system."
-Informant 1
" The zero-carbon mobility initiative aims to encourage communities to utilize public transport or implement carpooling measures to reduce carbon emissions."
-Informant 2
" To mitigate carbon emissions, there is a proposal to restrict the entry of petrol or diesel vehicles into the city during specific times."
-Informant 3

Informant 1 emphasises Transit-oriented development, "City for Walking and Cycling," and energy-efficient vehicles for Shah Alam's zero-carbon mobility policy. Informant 2 underscored the promotion of public

transport and carpooling, while Informant 3 suggested restricting petrol/diesel vehicles during specific times to reduce carbon emissions. These insights collectively outline a multifaceted strategy for achieving low carbon mobility in Shah Alam.

Waste Management Practices in Shah Alam

As Malaysia's waste production continues to grow, sustainable waste management has become a pressing issue. The volume of daily garbage reached roughly 25,000 tonnes in 2016 and is predicted to increase to 30,000 tonnes by 2020. The Malaysian government has responded by investing in waste collection, transportation, and disposal, particularly in urban areas, resulting in increased carbon generation.

To address this challenge, the Council has developed three integrated action plans for sustainable solid-waste management to limit the impact of carbon emissions. Green and sustainable waste management, reduction of green waste, and enhanced awareness, education, and participation of all stakeholders are among these initiatives. Malaysia hopes to accomplish more effective waste reduction and reduce its negative impact on the population and environment through this initiative.

> "In Shah Alam, for green waste management and to reduce waste disposal for zero carbon emissions, the Council has established three action plans for sustainable solid waste management. These include implementing green and sustainable waste management practices, reducing green waste, and raising awareness through education and engagement of all stakeholders."
>
> -Informant 2
>
> "In Shah Alam, waste management initiatives aimed at minimizing carbon emissions and promoting sustainability focus on encouraging community waste segregation. Various educational programs are also organized to enhance public knowledge of proper waste management practices."
>
> -Informant 3
>
> "Color-coded waste management is employed in Shah Alam, where initiatives such as recycling textiles and daily household waste are visibly integrated into housing developments. The community in Shah Alam has been provided with blue and green bins for waste disposal."
>
> -Informant 4

Shah Alam employs a three-step sustainable waste management plan, emphasising green practices, waste reduction, and community awareness. The approach also includes carbon reduction through waste management, promoting waste segregation and education. Practical measures, such as color-coded waste bins, enhance recycling visibility, contributing to Shah Alam's goal of reducing carbon emissions and fostering sustainability.

Building and Design Optimized for Energy Efficiency and Neutrality Carbon

The key approach to achieving a 45% reduction in greenhouse gas (GHG) emissions in Shah Alam City by 2035 is to promote Energy Management, Energy Efficiency, and Clean Energy for buildings. This approach aims to promote Energy Management (EM), Energy Efficiency (EE), and Renewable Energy (RE) as efficient, high-quality water management systems. This strategy will strengthen policies and incentive frameworks, establish policies and energy performance indicators, practice energy management and efficiency in buildings, increase the use of clean energy technologies, increase participation through community awareness and education programs, efficiently reduce water use through six action plans, and put in place a high-quality water-management system for buildings. The ultimate goal is to minimise energy use, expenses, the impact of climate change, and reliance on fossil fuels by 2035.

> "In Shah Alam, buildings and urban designs optimized for energy efficiency and carbon neutrality include zero energy buildings. These buildings are designed with features such as extensive use of glass to maximize natural lighting, installation of rooftops on every building, and promotion of smart buildings equipped with solar technology."
>
> -Informant 1
>
> "A building that enhances energy efficiency in Shah Alam incorporates features like mirrors, proper ventilation systems, and surrounding greenery to mitigate carbon emissions."
>
> -Informant 4
>
> "Buildings in Shah Alam that improve energy efficiency utilize the SPAH system, adopt green water systems for sewage, and switch from fluorescent lights to LED lights."
>
> -Informant 6

Shah Alam focuses on energy-efficient buildings with features like glassfilled structures, rooftops, and solar smart technology. Enhancing efficiency involves mirrors, ventilation, trees, SPAH systems, green water sewage, and light-emitting diode (LED) lights. These initiatives align with Shah Alam's commitment to sustainable urban design and carbon reduction.

The progress of Low Carbon City (LCC) in Shah Alam in the last few years reflects positive achievements in the implementation of the initiative. There is increasing acceptance among the local population of the LCC concept. Urban governance plays a crucial role in the administration and management of LCC interventions, and involves various substantive factors and strategies related to the institutional framework and urban governance necessary for LCC development. Among others, the strategies include establishing a database system for LCC; specific guidelines for LCC development; an institutional framework with job descriptions, work plans, and partnerships; and considerations for funding and green finance practices, monitoring, and benchmarking, among other integral elements (Yusfida, et al., 2022).

CONCLUSION

Shah Alam is still working towards achieving a low-carbon city, despite having reduced carbon emissions in the city since the baseline in 2015. The positive response from the collaborative efforts and initiatives among Shah Alam stakeholders demonstrates a discernible decrease in carbon emissions. This positive outcome can be attributed to the effective implementation of Shah Alam's strategy. With continued cooperation from various parties such as communities, NGOs, government agencies, and manufacturers, Shah Alam will undoubtedly become a low-carbon city, thereby ensuring that the quality of life of future generations is preserved. Furthermore, the experts and interviewees agreed that raising community awareness and public participation is crucial. This can be accomplished through regular monitoring by responsible agencies, as well as public support and cooperation.

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We extend our heartfelt gratitude to the town planning authorities, the Shah Alam City Council (MBSA), the Malaysian Green Technology and Climate Change Corporation (MGTC), and the landscape architects for their generous sharing of expertise and tireless efforts in advancing low-carbon city initiatives. Their invaluable contributions have significantly enriched this study, and we are deeply appreciative of their unwavering support and collaborative spirit.

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SIMULATION MODEL OF GREEN OPEN SPACE ON MICROCLIMATE PERFORMANCE IN TROPICAL COASTAL AREA

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Abstract

This research aimed to simulate scenario of green open space to mitigate heating within microclimate performance. It also optimized the composition of the built environment's surface to reduce urban heating. A numerical model was simulated using ENVI-met, and spatial analysis was conducted with ArcGIS software. Three different scenarios were established to propose solutions for heating reduction. Simulation showed that a balanced composition between buildings and vegetation resulted in air temperature decrease of 2.45°C to 3.31°C compared to no-greenery simulation. Meanwhile, when compared to the existing situation, hybrid greenery achieved a 3.50°C air temperature decrease. This research offered valuable insights into the urban environment by prioritizing landscape design, focusing on buildings and the composition of green open space in surrounding areas

Keywords: Green open space, scenario simulation, air temperature, spatial analysis.

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INTRODUCTION

Urban heat island (UHI) is a phenomenon that originates from land cover changes and rapid urbanization, specifically affecting urban ecosystem (Oxoli et al, 2018; Mutani et al, 2019). Due to the consequences of urban landscape and anthropogenic heat release, cities experienced higher surface air temperature that influenced local climate. Therefore, green open space is an effective nature-based solution to improve the quality of the natural environment and mitigate UHI. This approach can reduce heat by modifying the proportion of green vegetation and surface geometrical features, such as building height, density, as well as city design and shape (De Abreu et al, 2015; Ragheb et al, 2016).

Urban ecosystem comprises three different elements, namely impermeable surfaces, vegetated surfaces, and water bodies. These elements are closely related to the actual properties of the urban morphological surface, subsequently influencing both the microclimate of urban area and heat intensity (Chatzidimitriou et al, 2015; Broadbent, 2020; Krayenhoff et al, 2020). Microclimates are governed by the localized outdoor thermal environment, which includes parameters like air temperature, air pressure, wind speed, and direction (Eni et al, 2015; Galagoda et al, 2018). To minimize the high intensity of microclimate, new construction and urban planning using various technologies and strategies can be implemented.

Dense buildings can increase thermal capacity and reduce wind speed in an environment. During the day, building materials and density trap heat, while at night, the heat is released, affecting diurnal air temperature (Krehbiel, 2017). This also applies to other man-made features, such as roads, asphalts, and pavements, which increase anthropogenic heat emission to the atmosphere (Oke et al, 2017; Arifwidodo, 2019). Simulating landscape elements can alter both wind and radiation, as well as atmospheric temperature and humidity at the neighbourhood or community level. Research have shown that a balanced composition of vegetation space among buildings can significantly reduce heat stress but may have a negative impact on wind ventilation (Yahia, 2018; Zhang, 2022). Only a few research focused on local or small-scale modeling of green open spaces, as large amounts of air temperature and land surface temperature are investigated using large-scale remote sensing observations (Peng, 2019). Therefore, to investigate the spatial air temperature variation under microclimate behaviour, scenario simulation of green open space in a specific area was conducted. An urban university campus environment in Semarang, Indonesia, was selected to model simulation. Furthermore, a geographic information system (GIS) was used to generate spatial data and ENVI-met as well as green open space scenario for heat mitigation strategies.

METHODS

Research area

Universitas Islam Sultan Agung in Semarang, northern central Java coastal area, was selected for the research simulation. This area is located at the coordinates 110°27'22.44" – 110°27'36.93" E and 6°57'6.82" – 6°57'23.35" S. The campus environment had high air pollutant and emission levels due to its proximity to an industrial area, settlement, and Java national roads (Figure 1). The campus covered area of 20.7 hectares, comprising building areas (3.88 hectares or 19%), ponds (3.82 hectares or 18%), green open space (4.76 or 23%), and non-vegetation surfaces, such as parking area, pavements, courts (8.19 or 40%). The heights of low-rise buildings were between 4 m - 10 m and medium rise buildings ranged between 10 m - 30 m. Measurements were conducted during the dry season from 19 to 25 September 2022 for 24 hours at 15-minute intervals using a temperature and humidity automatic recorder (Tables 1 and 2). Air temperature data from the meteorological agency were used to validate the ground measurement. Missing data were interpolated and erroneous data for further analysis.

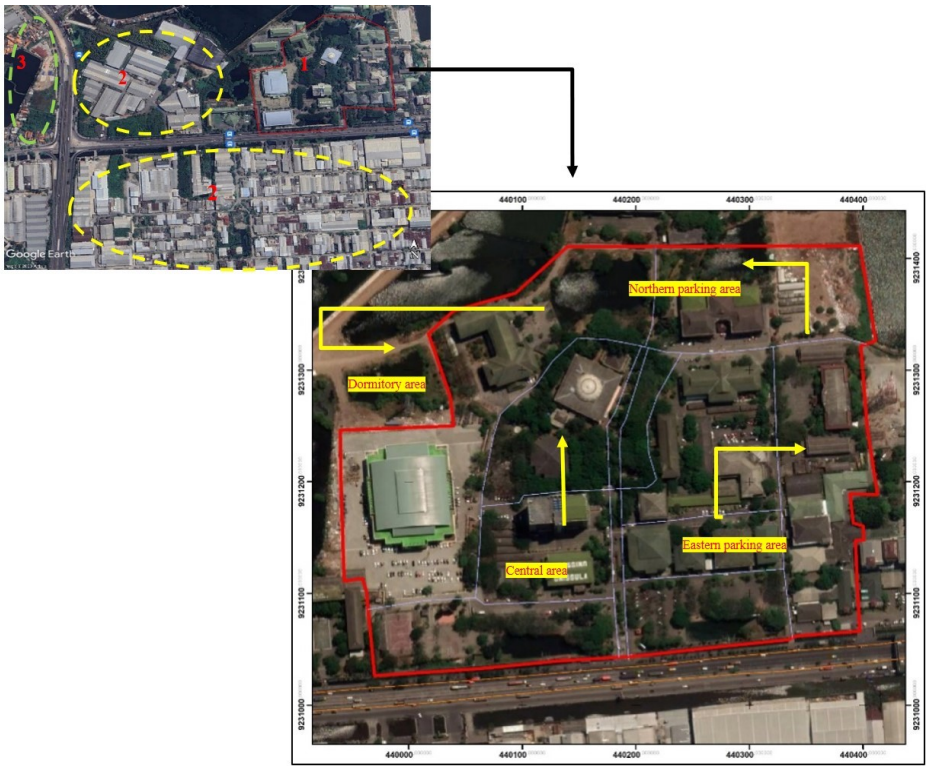

Figure 1: The research location and surrounding area: (1) campus area selected as the research area, (2) industrial area, and (3) settlement.

Table 1: Field measurement from 19 - 22 September 2022

Date	19-Sep-22		20-Sep-22		21-Sep-22		22-Sep-22	
Location	Outdoor air temp [ºC]	RH [%]	Outdoor air temp [ºC]	RH [%]	Outdoor air temp [ºC]	RH [%]	Outdoor air temp [ºC]	RH [%]
Auditorium area (DA)	31	61	31	57	31	55	31	48
Northern parking area (NP)	32	57	32	54	31	52	31	46
Eastern parking area (EP)	33	54	32	54	32	51	32	45
Central area (CA)	33	55	31	58	32	50	32	46

Table 2: Field measurement from 23 - 25 September 2022

Date	23-Sep-22		24-Sep-22		25-Sep-22	
Location	Outdoor air temp [ºC]	RH [%]	Outdoor air temp [ºC]	RH [%]	Outdoor air temp [ºC]	RH [%]
Auditorium area (DA)	30	46	31	49	33	55
Northern parking area (NP)	31	43	31	45	33	53
Eastern parking area (EP)	32	42	32	43	33	52
Central area (CA)	33	44	32	45	33	55

Simulation Setup

The research framework is presented in Figure 2, and model was simulated using ENVI-met software to calculate climatic factor parameters (air temperature) in the research area. ENVI-met is a 3D simulation software designed to analyze surface-plant-air interaction in urban neighborhoods ranging from 0.5 to 10 meters. The software used the principle of thermodynamics and fluid dynamics to calculate urban microclimate such as air temperature, turbulence, and humidity (Zhao et al., 2017).

The following was carried out to set up simulation. Firstly, the map was prepared by digitizing each building and vegetation features, represented in the grid cells of 40 x 40 x 20 m, with a vertical and horizontal grid resolution of 2 m. Secondly, simulation period ran for 24 hours starting at 7 pm, with model output generated every 60 minutes. Thirdly, meteorological settings were configured by inputting wind speed at 10 m height (m/s), wind direction (in degree), roughness length at the measurement site, temperature, and humidity.

Regarding the greening scenario simulation, three scenario models were prepared based on the greenery status to be planted in the selected area, reflecting the current situation (Figure 3). The three scenario simulations, as presented in Figure 4, included base case (zero green open space or no greenery), greenery (a balanced composition between buildings and green open space), and hybrid greenery (80% green open space and 20% buildings). All buildings had a height of approximately 20 m, while the trees reached 10 m. To evaluate the general model accuracy, the base model was compared to observations using R^2. Meanwhile, the root mean squared error (RMSE) was calculated to assess the performance of simulation scenario (Willmott, 2005; Pichierri, 2012).

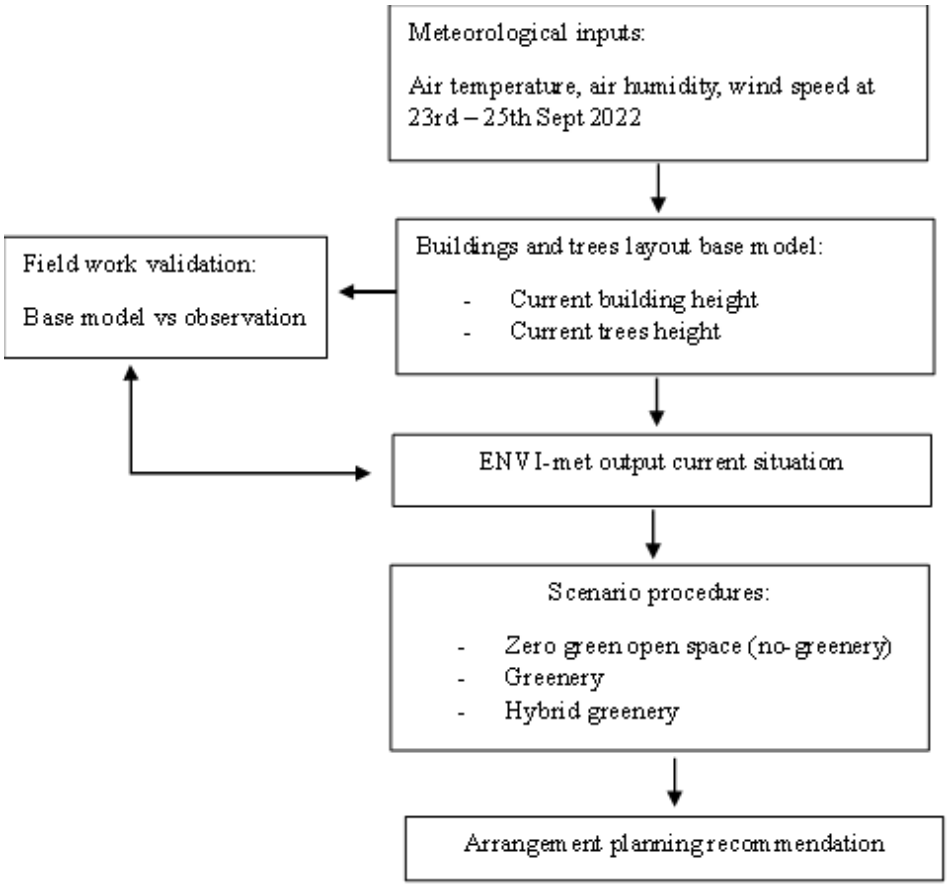

Figure 2: Methodology framework

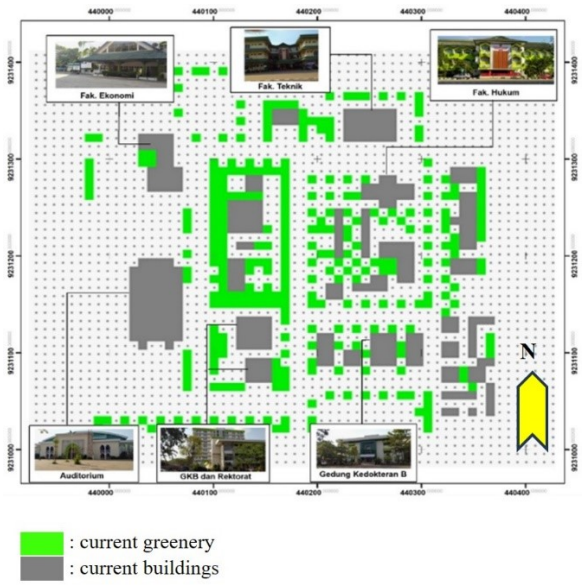

Figure 3: Current site situation as simulation baseline

Figure 4: Proposed scenario of green open space in the focus area: (a) no greenery, (b) greenery, and (c) hybrid greenery.

RESULTS AND DISCUSSION

Model validation

A comparison of air temperature measurements without any scenario and simulation data for the observation period was conducted to validate simulation (Figure 4). Figure 5 shows the scatter plot between air temperature measurements and simulation, with both showing good performance (R^2 = 0.9). The results showed that air temperature performance, on average, increased during the day, starting in the morning, and gradually decreased from the late afternoon to evening. To calibrate the modeled measurements with field location, data from the nearest meteorological agency weather station were used, which showed irregular heating patterns. Considering the entire day, this irregularity might be attributed to the broader coverage area of the nearest weather station instead of fixed-point measurement in the focus area. The fixed-point measurement is a localized measurement that can provide a more detailed representation of air temperature behavior. This measurement showed higher temperature intensities from 10 am to 2 pm, with an average value of 33.1°C, while the control temperature was 27.3°C.

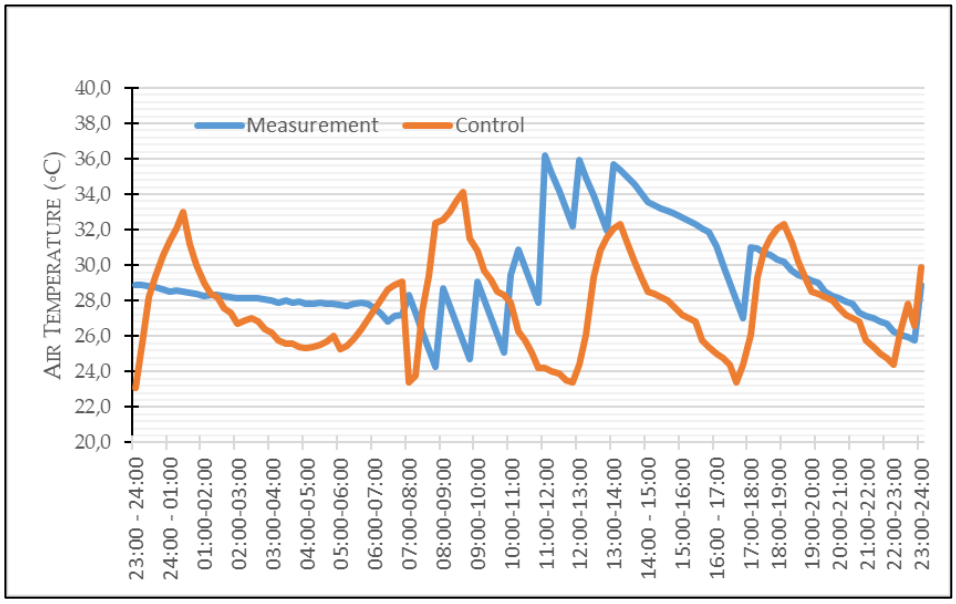

Figure 5: Hourly measured air temperature and control point air temperature.

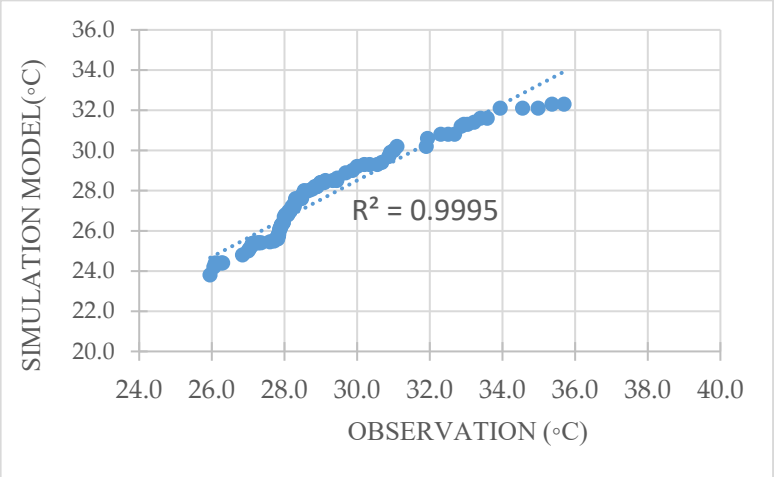

Figure 6: Scatter plot of air temperature measurement and control point.

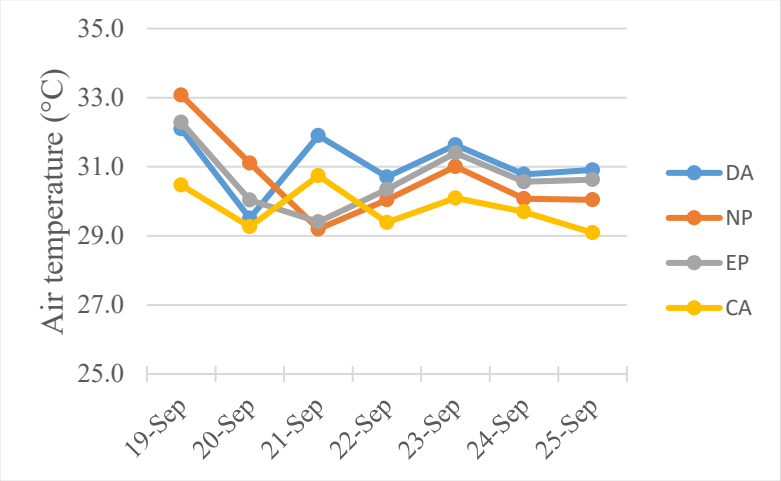

Figure 7: Air temperature measurement points in focus areas.

Figure 6 shows the average daily air temperature in four in situ points from 19 to 25 September 2022. The highest average air temperature was 33.1°C in the northern parking area (NP) on 19 September, and the lowest average was 29.1°C in the CA on 25 September. The variation in air temperature at each in situ measurement point was influenced by the surrounding physical environment, such as shadowing, building density, and local landscape. Generally, the highest air temperature was recorded in open impervious area (Willmott et al., 2005). Interpolation was conducted using GIS based on the in-situ measurement points on two selected days (19 and 23 September) to understand the distribution of daily average air temperature.

The results showed that the daily average air temperature on 19 September 2022 ranged from 32.8°C to 39.4°C (Figure 7a), and ranged from 29.5°C to 32.2°C on 23 September 2022 (Figure 7b). The red gradient mark showed the highest average air temperature, while green gradient mark showed the lowest. According to the map, there was variation in heat distribution corresponding to the different average ranges of air temperature. On the left side (Figure 7a), the cold area was localized in the CA, while on the right side (Figure 7b), the CA was dominated by higher air temperature. Therefore, heat was closely related to extensive sun radiation exposure and atmospheric conditions during the days.

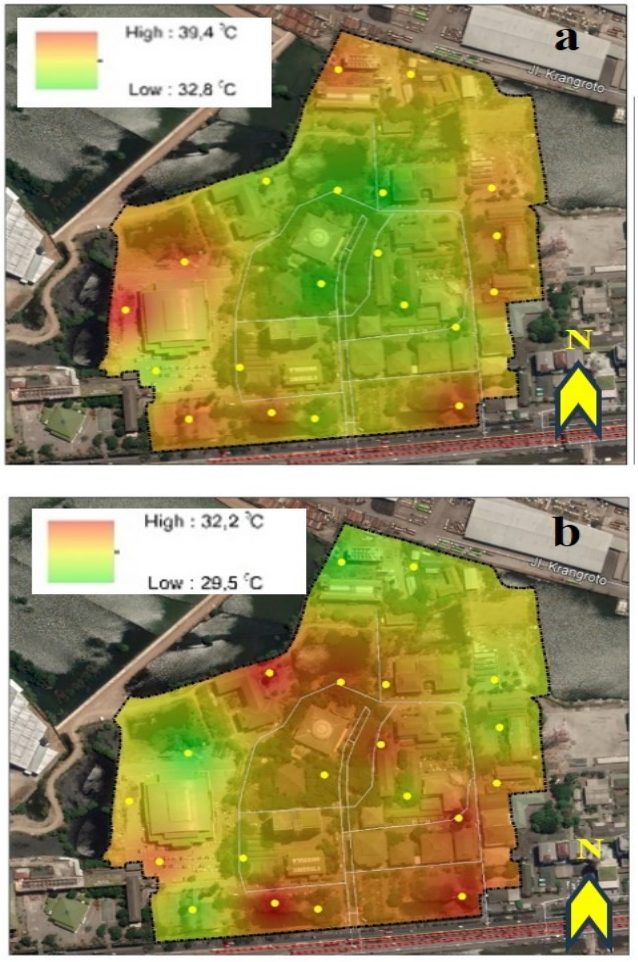

Figure 8: Distribution of air temperature in the selected days, namely (a) 19 and (b) 23 September 2022

Simulation Scenario

Model simulation scenario for green open space under microclimate performance was developed by interpolating the weekly average air temperature using GIS. Figure 8 showed air temperature in three different simulations, namely simulation 1, representing the absence of greenery; simulation 2, a balanced composition between buildings and vegetation; and simulation 3, hybrid greenery (80% vegetation and 20% buildings). The Root Mean Square Error (RMSE), showing the variation of calibration process result, is presented in Table 3. Simulation 2 obtained the lowest RMSE value (2.7). Figures 9 - 11 show the variation in air temperature for green open space scenario under microclimate performance, with air temperature measured at 1.5 m above the ground. The results showed that simulation 1 (Figure 9) had high heat intensity in the absence of greenery, with cooling effects only produced by shadowing. The highest recorded air temperature was 39.5°C, while the lowest was 37.67°C.

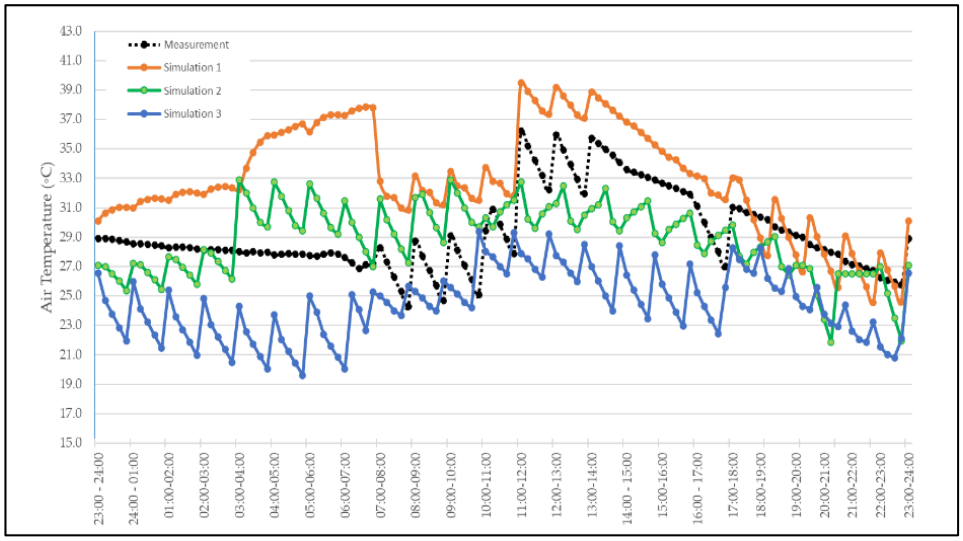

Figure 9: Comparison between air temperature measurement and simulation.

Table 3: Root Mean Square Error (RMSE)

Simulation Scenario	RMSE
1	4.7
2	2.7
3	5.0

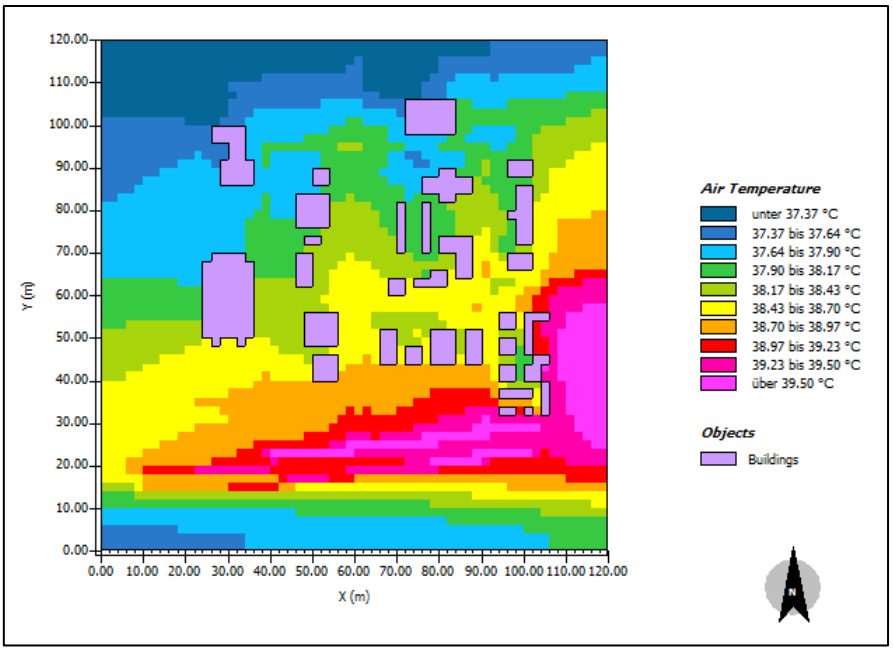

Figure 10: Simulation 1 (no greenery).

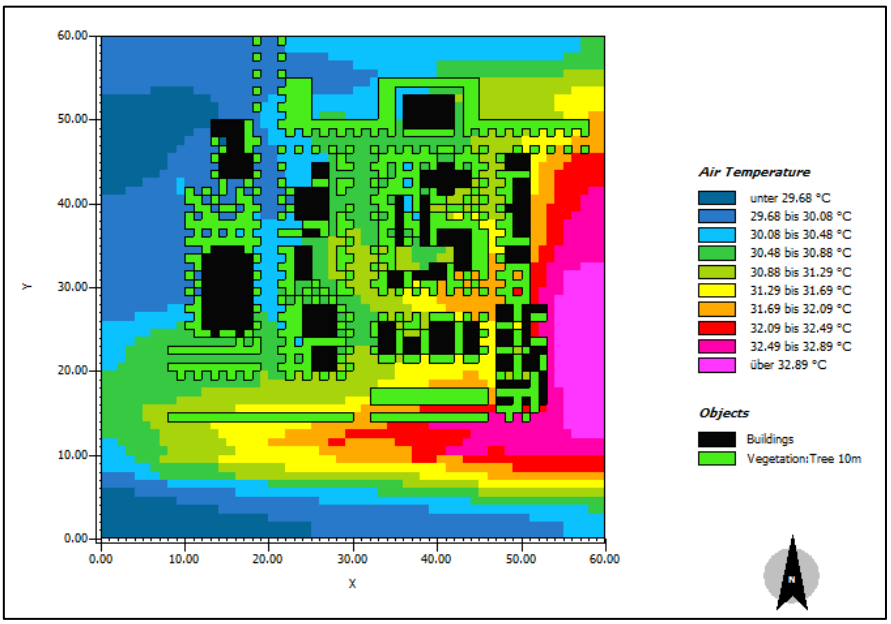

Figure 11: Simulation 2 (a balanced composition between buildings and vegetation).

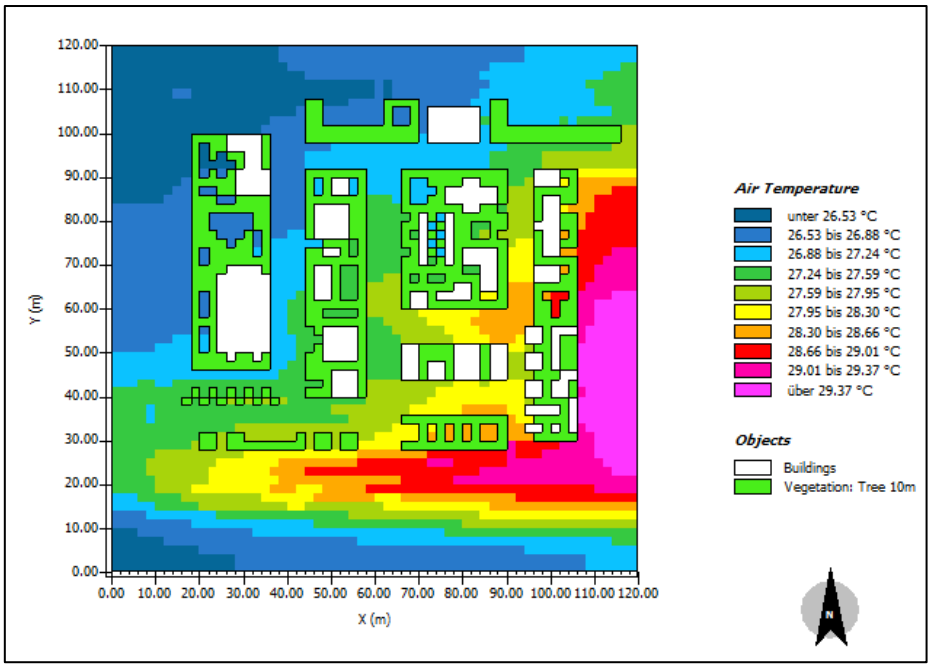

Figure 12: Simulation 3 (hybrid greenery).

Figure 10 shows the spatial variation of air temperature in simulation 2, which was set up with a balanced composition between buildings and vegetation. The results showed this scenario had a better cooling effect on the focus research. The highest air temperature recorded was 32.89°C, and the lowest was 30.06°C. Figure 11 shows the results of air temperature spatial variation in simulation 3, which was set up with hybrid greenery, consisting of 80% vegetation and 20% buildings. Simulation showed that hybrid greenery decreased the heat intensity of air temperature compared to simulations 1 and 2. The highest air temperature was 29.37°C, and the lowest was 26.68°C. The results showed that the distribution of air temperature was significantly influenced by the surrounding landscape environment. The intensity of the cooling effect was consistent with the greenery composition and controlled by different factors, such as artificial surfaces, building shading, solar radiation, and specific periods of solar intensity.

Table 4: Average, minimum, and maximum difference air temperature (°C) between the current situation and simulation scenario

	Simulation 1	Simulation 2	Simulation 3
Average difference	2.47	1.70	-3.50
Minimum difference	1.00	-2.80	-6.90
Maximum difference	3.30	0.01	-0.03

Table 5: Average, minimum, and maximum differences in spatial variation of air temperature (°C) between the current measured situation and simulation scenario

	Scenario 1	Scenario 2	Scenario 3
Average difference	3.67	-0.43	-4.81
Minimum difference	0.24	-2.45	-4.69
Maximum difference	3.30	-3.31	-6.83

Table 5 shows the observed spatial variation in air temperature difference between the current measured situation and simulation. In simulation 1, where there was no greenery, air temperature increased by a range of 0.24°C to 3.30°C. Meanwhile, in simulations 2 and 3, where greenery was introduced, air temperature cooled down from -2.45°C to -0.43°C. Furthermore, trees ranging from 5 m to 15 m in height reduced the heating compared to open pavements or canopies in parking areas.

CONCLUSION

In conclusion, air temperature was selected as the microclimatic parameter, collected at four measurement points, interpolated to investigate spatial variation, and subsequently simulated using ENVI-met scenario output. Three different scenarios were simulated by mitigating heat in the focus area. During sunny days, trees ranging from 5 to 15 m in height reduced air temperature by distributing the wind and providing shade. The best RMSE was observed in simulation 2, which had a balanced composition of buildings and vegetation, while the worst was observed in simulation 3, featuring hybrid greenery. Therefore, a balanced composition of buildings and vegetation in simulation 2 showed a better performance in mitigating heat since high building density, trees, and surrounding built surfaces could influence outdoor air temperature.

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GIS ANALYSIS OF NEIGHBOURHOOD ENVIRONMENT DETERMINANTS THAT INFLUENCE WALKABILITY IN PENANG, MALAYSIA

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Abstract

Understanding the relationship between urban design and physical activities is crucial. Studies have identified three key neighbourhood environment indices that enhance walkability. This research investigates the influences of these indices on residents' walkability to community facilities in two neighbourhoods in Penang Island, Malaysia. Using geographic information system (GIS) technology, we analyse the effect of the built environment on walkability through buffering and thematic map analyses. Pulau Tikus features medium- and low-density housing with enriched community facilities, whilst Tanjung Tokong has a higher residential density, more road intersections and more diverse housing options. Findings indicate that Pulau Tikus offers better amenity accessibility, whilst Tanjung Tokong's high-rise residential buildings and diverse housing types enhance walkability. This study highlights the relationship amongst residential density, road intersections, mixed land use and walkability in two residential neighbourhoods. Higher residential density and more road intersections increase walking activity, whilst mixed land use further influences resident mobility patterns. These insights can aid urban planners in designing more walkable, liveable and sustainable neighbourhoods.

***Keywords**:* GIS, Walkability, Neighbourhood Planning, Sustainable Urban Environments and Community Facilities

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INTRODUCTION

Walking is a common physical activity for many people, and it ranks amongst the most popular forms of exercise worldwide. The built environment has been demonstrated to positively influence physical activities, particularly walking (Baobeid et al., 2021a). However, despite the positive influence of physical activities, engaging in them is still difficult for people. As traffic congestion and car travel concerns grow across communities nationwide, researchers have focused on how land use affects travel behaviour. Evidence that the built environment influences the physical activity behaviour of individuals, particularly walking, is growing (Karwand et al., 2024). Research has shown that various aspects of the built environment, such as residential density, land use mix, street connectivity, walking facilities, aesthetics and safety from crime, can significantly affect walking behaviour (Paydar et al., 2020; Saelens & Handy, 2008).

Walking is recognised as an important activity that can reduce the risk of several health issues, including coronary heart disease, stroke, diabetes, hypertension, various types of cancer and depression (World Health Organization, 2022). According to Ipsos Press (2023), Malaysia recorded the highest level of obesity amongst Southeast Asian countries. The National Health and Morbidity Survey (2019) conducted by the Ministry of Health Malaysia reported that the prevalence of overweight and obesity amongst Malaysian adults was recorded at 50.1%. In addition, the survey found that 25.1% of Malaysian adults are physically inactive, and only 45% of adolescents in the country engage in regular physical activities, particularly walking.

Walkability is defined as the ability to walk to services and amenities safely within a reasonable distance. Research has indicated that a compact and interconnected urban environment, which includes a variety of densities and land uses, reduces distance between key destinations. This proximity encourages people to walk as a mode of transportation (Vichiensan & Nakamura, 2021). Pentella (2009a) highlighted that the walkability of an area is shaped by the design of the built environment and its various features. Crucial community features frequently include how close locations are to one another and how easily people can travel between them. A substantial body of literature indicates that factors, such as street connectivity, residential density and the presence of community facilities (mixed land use), are related to walking activity (Leh et al., 2015). Associations between neighbourhood environmental factors and physical activities, such as walking, have been observed.

Numerous studies have aimed to identify the key factors of walkability that significantly affect the design of the built environment, facilitating increased pedestrian activity within neighbourhoods. Accordingly, the current study aims to identify neighbourhood environmental factors that influence the ability of residents to walk to community facilities in two different neighbourhoods on

Penang Island, Malaysia. Understanding these factors is essential, because walking, whether for practical purposes or recreation, provides significant health benefits, including improvements in cardiovascular and mental well-being (Baobeid et al., 2021b).

LITERATURE REVIEW

Measuring Neighbourhood Environment Indices

Neighbourhood environment indices can be assessed using geographic information system (GIS) technology and self-reported tools, such as questionnaires (Weliange et al., 2021). GIS-derived walkability measures consider various factors, including residential density, land use mix, retail floor area ratio and street connectivity (Adams et al., 2014). Self-reported instruments can evaluate pedestrian environments by capturing elements, such as the presence and condition of sidewalks, aesthetic appeal, safety from crime and traffic conditions (Shigematsu et al., 2009).

Frank et al. (2005) and Leslie et al. (2006) confirmed that residential density, land use mix and street connectivity are significant factors that influence walkability. A 'highly walkable' neighbourhood is characterised by high street connectivity, diverse land use and high residential density. Neighbourhood environment indices can be objectively assessed using GIS software or through observational data collected within the neighbourhood (Leslie et al., 2006).

Influences of Residential Density, Street Connectivity and Land Use Mix on Walkability

Residential density is determined by the number of households per square kilometre (Glazier et al., 2014). In highly dense areas, where congestion and limited parking space frequently hinder automobile travel, people are likelier to walk than drive. Conversely, walking is more prevalent in low-density regions with serene natural surroundings and ever-changing vistas. Increasing neighbourhood density is in line with conventional theory, which predicts a reduction in trip distances, an increase in walking activities and a potential decrease in overall automobile use. In addition, Residents in denser communities, which feature better street connectivity and a diverse mix of land uses, report higher levels of walkability compared with those living in low-density, poorly connected and single-use neighbourhoods (Frank et al., 2006; Saelens et al., 2003).

Street connectivity refers to the density of intersections wherein three or more streets meet within a specific area, typically measured per square kilometre (Wagai, 2016). This connectivity influences the efficiency of travel routes between residential areas, shops, workplaces and other destinations. Neighbourhoods designed with grid-patterned street networks typically exhibit higher levels of connectivity than those with winding, curvilinear layouts (Choi

& Ewing, 2021). Increased street connectivity promotes walking as a mode of transportation by reducing obstacles and minimising major road crossings (Koohsari et al., 2014).

Land use mix access refers to amenities, such as residential, commercial, educational and recreational facilities, within an 800 m radius, as defined by Frank et al. (2005). Research has consistently shown that people are likelier to walk and cycle in neighbourhoods with higher residential density, a mix of land uses and connected streets. Conversely, individuals are less inclined to walk in single-use industrial districts and single-family suburbs, where destinations are far apart and the scenery is uninviting.

According to Saelens et al. (2003), towns with higher residential density, a mix of land uses and grid-like street patterns that feature short block lengths encourage more walking than larger, less connected areas. Leslie et al. (2005) listed five neighbourhood environmental characteristics that are correlated with walkability. These elements are provided in Table 1.

Table 1: Neighbourhood environmental characteristics that influence walkability.

Neighbourhood Environmental Characteristics	Description
Residential density	Dense neighbourhoods encourage mixed-use development, expanding retail/services and shortening walking distances between destinations.
Street connectivity	Higher intersection densities create more walking routes, improving neighbourhood connectivity and shortening distances to destinations for increased accessibility.
Land use mix	Varied retail and services encourage frequent and short walks, creating vibrant neighbourhoods with diverse and captivating environments for pedestrians.
Public transit density	Accessible bus stops shorten distances, promoting walkability and facilitating movement between leisure activities, work and home.
Land use crime density	High crime rates deter walking, boosting reliance on cars and alternative transport due to pedestrian insecurity in neighbourhoods.

Source: Leslie et al. (2005)

Influence of Built Environment Characteristics on Pedestrian Friendliness

Several studies have shown that the microscale characteristics of the built environment, such as elements and features that are directly perceptible to pedestrians on the streets, play a significant role in determining an area's pedestrian friendliness (Nagata et al., 2020). Key features that enhance walkability include well-maintained sidewalks, shaded trees, safety amenities,

adequate street lighting, aesthetic appeal and access to public transportation facilities (Basu et al., 2023).

Khisty (1994) identified seven factors that help reduce barriers to walking: increased attractiveness, improved comfort, greater convenience, higher population density, mixed land use, safety, system coherence (directness) and continuity (completeness). The study conducted by Saelens and Sallis (2002) resulted in the creation of the Neighbourhood Environmental Walkability Scale. This scale assesses residents' perceptions of various design features in their neighbourhoods that are related to physical activities. These features include residential density, mix of land uses, street connectivity, infrastructure for walking and cycling, neighbourhood aesthetics, traffic conditions, safety from crime and overall satisfaction with the neighbourhood. Handy et al. (2002) identified six dimensions of the built environment that influence walking choices: density and intensity, land use mix, street connectivity (including directness and the availability of alternative routes), street scale, aesthetic qualities and regional structure (pertains to the distribution of activities and transportation throughout the region). Moreover, environmental variables that correlate with walking activities include local neighbourhood features, such as convenient facilities, shops, parks and an aesthetically pleasing and safe environment.

Therefore, the current study focuses on neighbourhood environmental indices assessed through GIS, specifically examining residential density, mixed land use and street connectivity.

RESEARCH METHODOLOGY

Study Area

This study aims to identify neighbourhood environmental factors that affect residents' walkability in two different areas of Penang Island, Malaysia. The study was conducted in Penang, Malaysia's island region, focusing on the neighbourhood areas in Pulau Tikus and Tanjung Tokong. These neighbourhoods, with their diverse residential densities that range from low to high, along with their varying land use patterns and road intersection densities, provide an ideal setting for a comprehensive analysis of how different density levels affect walkability. According to Jafari et al. (2023), walkable neighbourhoods are characterised by higher residential densities, proximity to destinations, connected street networks and diverse mixed land uses, which are all key aspects of the built environment that are associated with walking.

The overall land area of Pulau Tikus is 124 ha, whilst Tanjung Tokong covers 150 ha. GIS was used to collect and analyse data. Each study area was divided into three neighbourhood units labelled NA1, NA2 and NA3, as shown in Figures 1(a) and 1(b). The sizes and boundaries of the neighbourhoods adhere to the Green Neighbourhood Guidelines set by the Federal Department of Town and Regional Planning Malaysia. According to Barton et al. (2003), the average

walking distance is 1 km, and very few people walk more than 2 km. The accepted threshold for walking to local facilities is 400 m, whilst the suggested threshold for walking to a town centre is 800 m.

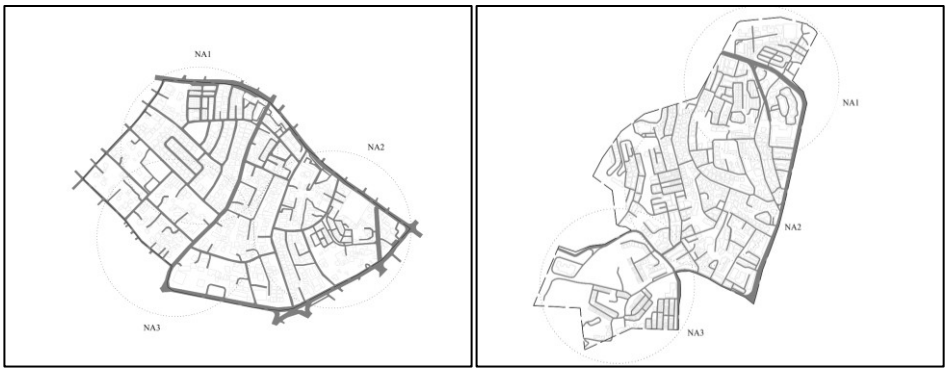

Figure 1: (a) Neighbourhood of Pulau Tikus, Penang (b) Neighbourhood of Tanjung Tokong, Penang
Source: The author

Research Instrument

The research instrument used for data collection is ground truth verification (GTV), which entails the validation of mapped data against actual ground conditions. GTV involves validating mapped data against actual ground conditions. It typically refers to observations or measurements conducted on the Earth's surface to confirm remote sensing data and support GIS analysis. This approach demonstrates considerable precision when delineating geographic attributes under assessment, typically for categorising 'points' into specific land use/cover classifications. The purpose of obtaining GTV is to assist in calibrating and interpreting remotely sensed or GIS data by confirming actualities.

The current research utilized secondary data that comprised Penang land use maps sourced from the Geospatial Information Management Unit, Penang, which conducted GTV surveys to validate the accuracy of land use data attributes. In the present study, survey was performed with the aid of aerial photographs, Google Maps and OpenStreetMap. The survey aimed to update the classifications and attributes of the land use map to reflect current land use in the study area. The findings from this verification were incorporated into the map, ensuring that it included the most recent land use data and attributes before any GIS spatial analysis was conducted.

GIS Spatial Analysis

GIS spatial analysis refers to a collection of techniques wherein outcomes vary depending on the alteration of the location of the object under analysis. It is also characterised as a method that is capable of dealing with an occurrence's spatial

scale and patterns. The current study utilised two types of GIS spatial analysis: buffering and thematic map analyses. Buffering is used to identify areas around specific geographic features by creating a buffer zone around them. Once the buffer zone is established, features can be selected or identified based on their location, i.e. whether they fall within or outside this perimeter. Meanwhile, a thematic map focuses on a particular theme related to a geographic area. This type of map uses spatial data to illustrate the distribution and location of a specific phenomenon, visually representing patterns in the data.

Three neighbourhood environmental characteristics, namely, residential density, street connectivity and land use mix, were selected for analysis. These large-scale aspects of neighbourhood design are frequently studied for their associations with physical activities (Frank et al., 2004; Leslie et al., 2007). Street connectivity, land use mix and residential density are correlated. Analysing these three neighbourhood characteristics allows for the assessment of how 'walking-friendly' a neighbourhood is. The employed GIS spatial analysis methods and the process for conducting these analyses for each examined index are detailed in Table 2.

Table 2: Process of conducting spatial analysis by using GIS in the current study.

Indices	**Explanation**	**Type of GIS spatial analysis**
Residential density, Road intersection, Nonresidential components of mixed land use, and Residential mixed land use	The size of the neighbourhood boundary (400 m), generated from buffering analysis, served as the starting point for conducting the analysis.	Buffering analysis
Residential density	Created using the 'density' attribute as the theme to represent types of residential density layers, and densities within the buffer boundary are analysed.	Thematic map
Road intersection	The total numbers of 3–4-way intersections within the buffer boundary are analysed.	Thematic map
Nonresidential components of mixed land use	Created using 'Gunatanah' attributes as the theme to represent community facilities land use layers, and features within the buffer boundary are identified and calculated.	Thematic map
Residential mixed land use	Utilising the attributes of 'infrastructure and utilities' to represent different types of housing	Thematic map

Indices	Explanation	Type of GIS spatial analysis
	layers, the analysis focuses on houses located within the buffer boundary.	

Source: The author based on Geographic Information Unit and Department of Town and Planning Malaysia (2012)

ANALYSIS AND DISCUSSION

The findings of this study are categorised based on three selected indices: residential density, road intersections and mixed land use. In addition, the analysis of mixed land use is further divided into nonresidential components and residential mixed land use.

Residential Density

In Penang, residential density is assessed by measuring gross density, which considers the number of housing units per acre, including areas designated for streets, parking, open spaces and nonresidential buildings. Residential density is categorised into four levels: (1) low density (1–8 units per acre), (2) medium density (9–24 units per acre), (3) medium–high density (25–50 units per acre) and (4) high density (51–75 units per acre). Figures 2(a) and 2(b) illustrate the residential density in both neighbourhood units, with darker colours representing higher levels of residential density.

The results indicate that residential density affects walkability patterns in Pulau Tikus and Tanjung Tokong. In Pulau Tikus, Neighbourhood Area 1 (NA1) has three types of residential density: low, medium and medium–high. By contrast, NA3 consists solely of low-density housing. The analysis indicates that two out of three neighbourhoods mostly have medium- and low-density housing, whilst only one neighbourhood primarily has high-density housing. The result of Tanjung Tokong exhibited three types of residential density: high, medium–high and low. It also showed that all three neighbourhoods had mostly medium- and high-density houses. A conclusion is drawn that Tanjung Tokong has more high-density houses than Pulau Tikus. Previous research has demonstrated that higher residential density enhances neighbourhood walkability (L. D. Frank et al., 2005; Jafari et al., 2023; B. E. Saelens et al., 2003). Density is considered a cornerstone of walkability in a neighbourhood, because without higher residential densities, having destinations within local access and mixed land uses is not feasible.

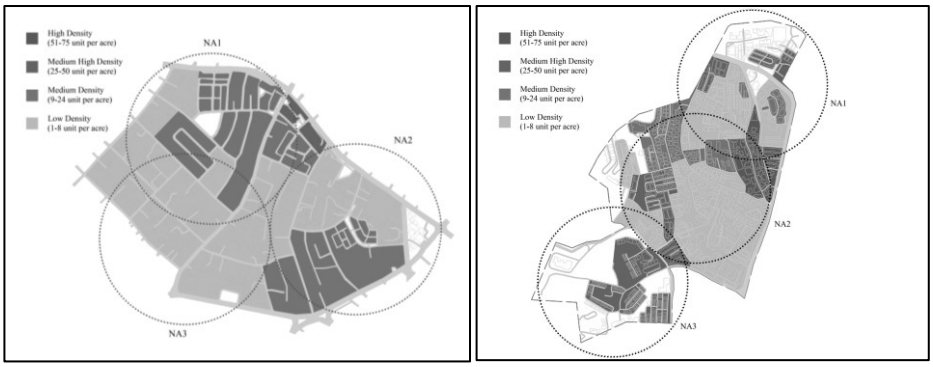

Figure 2: (a) Residential density of Pulau Tikus, Penang (b) Residential density of Tanjung Tokong, Penang
Source: The author

Road Intersection

The analysis of road intersections focuses on determining the number of 3-to-4-way intersections within a neighbourhood unit (Figure 3). In Pulau Tikus, NA1 has the highest number of road intersections, totalling (53), whilst NA3 has the lowest, with only (37). Meanwhile, in Tanjung Tokong, NA2 has more road intersections (94) than the other units, whilst NA3 has the fewest (40). The analysis reveals that Tanjung Tokong has 193 intersections, more than those of Pulau Tikus.

The analysis of road intersections indicates a consistent trend akin to the observed outcomes in walking trips within the neighbourhood, indicating that residents in Tanjung Tokong are engaged in more walking activities than those in Pulau Tikus. In addition, Tanjung Tokong comprises a more significant number of high-rise residences, facilitating numerous shortcuts within housing units, increasing accessibility and providing residents with more routes to reach community facilities by walking. Studies conducted by Frank et al. (2005), Pentella (2009) and Saelens et al. (2003) highlighted that road intersections are associated with street connectivity. A higher number of road intersections provide more potential walking routes and greater accessibility (Federal Highway Administration, 2022; Jabbari et al., 2021). Moreover, improving street connectivity leads to shorter distances towards destinations.

Figure 3: (a) Road intersections of Pulau Tikus, Penang (b) Road intersections of Tanjung Tokong, Penang
Source: The author

Mixed Land Use

This study identifies seven types of community facilities for analysis within the neighbourhood unit: shops, parks/recreational areas, elementary schools, secondary schools, places of worship and bus stops. The results for nonresidential mixed land use in Pulau Tikus show that six community facilities are situated within a 400 m walking distance (NA1, NA2 and NA3), as illustrated in Figure 4(a).

Figures 5(a) and 5(b) illustrate the residential mixed land use, with different colours representing various types of houses. In Pulau Tikus, the results for residential mixed land use reveal four house types in zones NA1 and NA2: bungalows, terrace houses, semi-detached houses and apartments. By contrast, zone NA3 has the fewest house types, featuring only bungalows. Tanjung Tokong comprises two neighbourhood areas (NA1 and NA2), with each area consisting of five houses: bungalows, semi-detached terraces, apartments and flats. Simultaneously, NA3 includes only three house types: bungalows, terraces and apartments.

The study on mixed land use for nonresidential components indicates that Pulau Tikus has a higher number of community facilities within a 400 m walking radius compared with Tanjung Tokong. Furthermore, Pulau Tikus offers more community facilities than Tanjung Tokong. Studies by Leslie et al. (2005), Pentella (2009b) and Saelens et al. (2003) suggested that mixed land use encourages residents to walk in their neighbourhoods. However, in terms of residential mixed land use, Tanjung Tokong has a wider variety of housing types than Pulau Tikus. These thematic map analyses indicate that greater residential mixed land use contributes to improved walkability.

Figure 4: (a) Mixed land use (nonresidential) of Pulau Tikus, Penang (b) Mixed land use (nonresidential) of Tanjung Tokong, Penang
Source: The author

Figure 5: (a) Mixed land use (residential) of Pulau Tikus, Penang (b) Mixed land use (residential) of Tanjung Tokong, Penang
Source: The author

CONCLUSION

This study examined the effects of residential density, street connectivity and mixed land use on walkability in the Pulau Tikus and Tanjung Tokong neighbourhoods of Penang, Malaysia. Using GIS data, the study effectively identified key aspects of the built environment that were relevant to pedestrian activities through buffering and thematic map analyses.

The findings emphasize the significant influences of residential density, road intersection density and mixed land use on walkability patterns in the studied neighbourhoods. This observation is aligned with previous research, highlighting the importance of diverse amenities, ample road intersections and high residential density in fostering walkability (Baobeid et al., 2021a; Yang, 2023). Tanjung Tokong exhibits higher residential densities and a more significant number of road intersections, theoretically enhancing walkability by offering increased

accessibility and route options. Despite these advantages, however, Pulau Tikus demonstrates a higher level of walkability, which is likely attributed to diverse community facilities and a well-integrated mixed land use environment within walking distance. This finding suggests that although factors, such as density and street connectivity, are pivotal for walkability, the availability of nearby amenities and varied housing options also play a crucial role in promoting pedestrian activities.

The current study adds to the growing literature on built environment factors and their effect on physical activities. Through the proficient utilisation of GIS data, spatial analysis has been proven effective in delineating and identifying components of the built environment that are crucial to walkability. This finding reaffirms the significance of integrating GIS methodologies into physical activity research. In addition, this study enhances urban walkability by promoting higher residential densities, increasing street connectivity and developing mixed-use areas with strategically located community facilities.

Although this study delves into the influence of various neighbourhood environmental factors on walkability, its scope remains limited by a narrow focus on a few determinants of walking behaviour. Broadening its examination to encompass critical elements, such as footpath conditions, accessibility, proximity to facilities, transportation options, topographical features, barriers and urban design attributes, including building orientation, lighting and green spaces, is imperative for future research (Giles-Corti & Donovan, 2003; Handy et al., 2002; Rodríguez & Joo, 2004). In addition, exploring a wider range of GIS variables associated with physical activities can provide a more comprehensive understanding of walkability. Doing so will more effectively help capture the long-term effect of urban planning interventions on pedestrian-friendly environments.

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DISCLOSURE STATEMENT

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

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LANDSLIDE SUSCEPTIBILITY ANALYSIS USING REMOTE SENSING AND GIS: A CASE STUDY IN HULU LANGAT, SELANGOR, MALAYSIA

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Abstract

Landslides pose significant hazards globally, especially in expanding populations in unstable areas. This study uses geospatial analysis for landslide susceptibility in Hulu Langat, Selangor, Malaysia. The primary objectives are to understand landslide factors, analyse susceptibility, and recommend mitigation strategies. The methodology involves the Analytic Hierarchy Process (AHP) evaluating nine parameters: elevation, slope terrain, slope aspect, lithology, soil types, distance from rivers, land cover, precipitation, and distance from faults. Key findings show lower elevations, specific soils, acid intrusive lithology, and proximity to rivers and faults are particularly susceptible to landslides. Findings show that Landslide Concern Zone (LCZ) are mainly dispersed along the vicinity of Sungai Langat and Sungai Semenyih. The study emphasizes tailored mitigation, proactive land-use planning, and integration of disaster management with urban planning to enhance resilience and inform policy.

Keywords: landslide, susceptibility, remote sensing

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LANDSLIDE HAZARD AND GEOSPATIAL ANALYSIS

Landslides are a significant natural hazard that occurs worldwide, affecting various terrains and climates. These events result in substantial economic losses, fatalities, injuries, and long-term disruptions to communities. A landslide is a movement of soil, rock, and biological materials downslope under the force of gravity (Highland & Bobrowsky, 2008). It also refers to the landform that results from such movement. Landslides can involve various types of materials and movements, such as rockfalls, debris flows, and slope failures, occurring on surfaces of rupture with little internal deformation. Different types of landslides can be recognized by the kind of movement and material involved (Schulte, 2024). Landslides may also exhibit a combination of movements, such as rockslide—debris flow, forming complex failures encompassing more than one type of movement (Highland & Bobrowsky, 2008; Wubalem, 2022).

Landslide susceptibility is a crucial aspect in understanding and mitigating the risks associated with landslide occurrences. Defined as the likelihood of landslides occurring in an area based on terrain conditions, landslide susceptibility mapping involves identifying and evaluating the factors that contribute to slope failures (Wubalem, 2022). Land use/cover characteristics, hydrological, climatological, lithological, geomorphological, geological structure, and seismic elements are frequently among these components.

Heavy precipitation, seismic activity, volcanic eruptions, forest fires, and human activities, can cause landslides (Highland & Bobrowsky, 2008). Landslides can occur on land or underwater and impact a variety of environments, including natural forests and farmed areas. In addition, Highland & Bobrowsky (2008) emphasize that landslides are not limited to a particular climate, as they can affect areas with varying humidity levels.

Landslide analysis much simpler by technological improvements, especially in the areas of computer systems, remote sensing, and geographic information systems. More thorough and precise data gathering, processing, and visualization are possible to be conducted. According to Wubalem (2021), these developments make it easier to create comprehensive maps of landslide susceptibility, which are essential for locating high-risk locations and developing mitigation plans. The process of creating these maps not only highlights the most influential factors in landslide occurrences but also helps in estimating the relative contribution of each factor, thereby enabling the prediction and management of future landslide hazards (Gaidzik & Ramírez-Herrera, 2021; Wubalem, 2021).

In addition to being crucial for comprehending the spatial distribution of probable landslide events, landslide susceptibility mapping is also important for land management and urban planning. Such mapping is particularly important in hilly places with tropical climates that are frequently affected by hurricanes,

where landslides can be fatal (Gaidzik & Ramírez-Herrera, 2021). Authorities can improve community safety and resilience by making well-informed decisions about infrastructure development, land use, and disaster preparedness by incorporating susceptibility maps into planning procedures. By integrating susceptibility maps into planning processes, authorities can make informed decisions about land use, infrastructure development, and disaster preparedness, thereby enhancing community resilience and safety. Incorporating a comprehensive Disaster Risk Reduction (DRR) strategy can improve Malaysia's planning delivery system (Ibrahim, 2024).

Remote sensing can be used to map hazards and determine susceptibility without any problems. In their respective works, Chelariu et al. (2023) and Aksha et al. (2020) studied GIS-based multi-criteria decision making (MCDM) techniques, to choose development-friendly locations while considering the danger of natural disasters into account. The study emphasised how crucial it is to incorporate geohazard concerns into spatial design to reduce risks and improve disaster resilience. Using GIS methods, Ntelis et al. (2019) evaluated the Evritania Prefecture's susceptibility to landslides. The study determined that tectonic elements, land cover, precipitation, slope angle, lithology, and distance from streams are important factors that affect the occurrence of landslides. Precipitation was also utilized by Althuwaynee et al. (2015) to examine the occurrence of landslides. These methods offered a framework for comprehending and forecasting the risks of landslides in connection with rainfall events. In order hand, to facilitate the development of effective risk management and mitigation strategies, El Jazouli et al. (2019) and Ibrahim et al. (2022) focused on GIS-multicriteria evaluation and AHP for landslide susceptibility mapping in their respective sites.

Study Area

Hulu Langat (Figure 1) is one of the nine districts of Selangor, located in the southeast of the state of Selangor Darul Ehsan. It covers an area of 829.44 km³ (207,475.57 acres) and is home to nearly 1.4 million people (Department of Statistics Malaysia, 2022). Selangor's easternmost district is called Hulu Langat. It borders Negeri Sembilan to the east and south, Pahang to the north, Gombak district to the northeast, and Sepang district to the southwest. It borders Kuala Lumpur to the east. There are seven Mukims, or subdistricts, within the district of Hulu Langat. They are Kajang, Semenyih, Hulu Langat, Hulu Beranang, Cheras, and Ampang. Primarily, the district of Hulu Langat is under the jurisdiction of Majlis Perbandaran Kajang (MPKj), except for Mukim Ampang, which is under jurisdiction of Majlis Perbandaran Ampang Jaya (MPAJ).

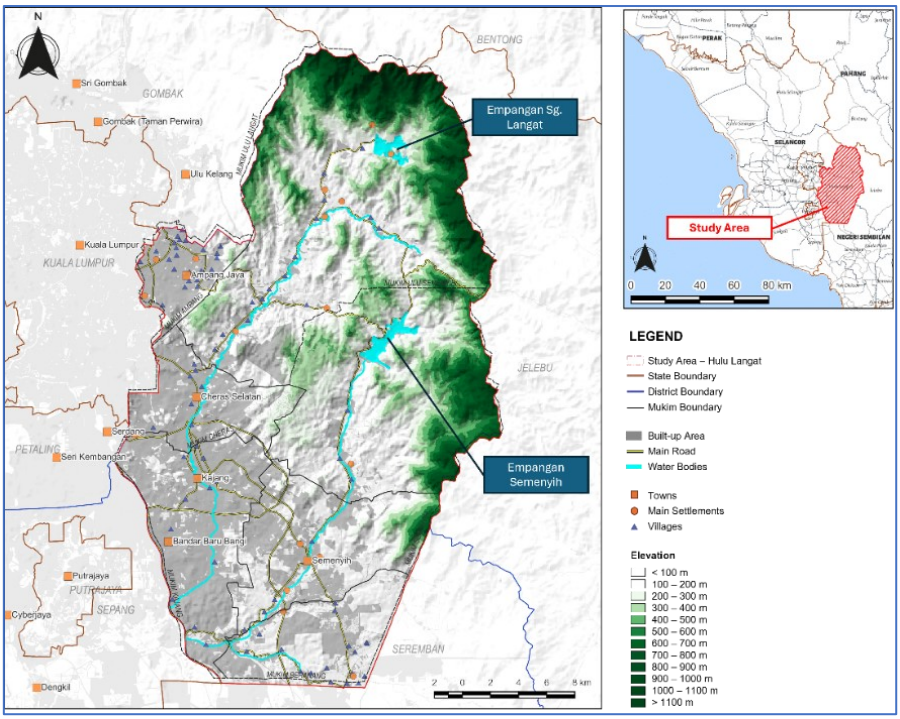

Figure 1: Study area of the Hulu Langat District

The Hulu Langat district in Selangor, Malaysia, is, apart from the extensive urban settlement, also renowned for its rich environmental diversity, encompassing forest reserves, river basins, rivers, dams, and significant elevations. These features not only contribute to the district's ecological health but also play a vital role in supporting the local communities and sustaining biodiversity.

RESEARCH METHODOLOGY

Establishing a systematic framework of conduct can ensure smoothness and seamless work processes, which may eventually lead to a comprehensive output. The methodology for this research can be divided into five parts: preliminary study, literature review, data collection, GIS evaluation, zoning, and reporting. These methodologies have been applied through determined phase accordingly. This research design will also illustrate the methodological process adopted for this research, which will be based on majorly secondary data. Figure 2 shows the overall structure of how process of identifying landslide susceptibility, by using GIS and remote sensing.

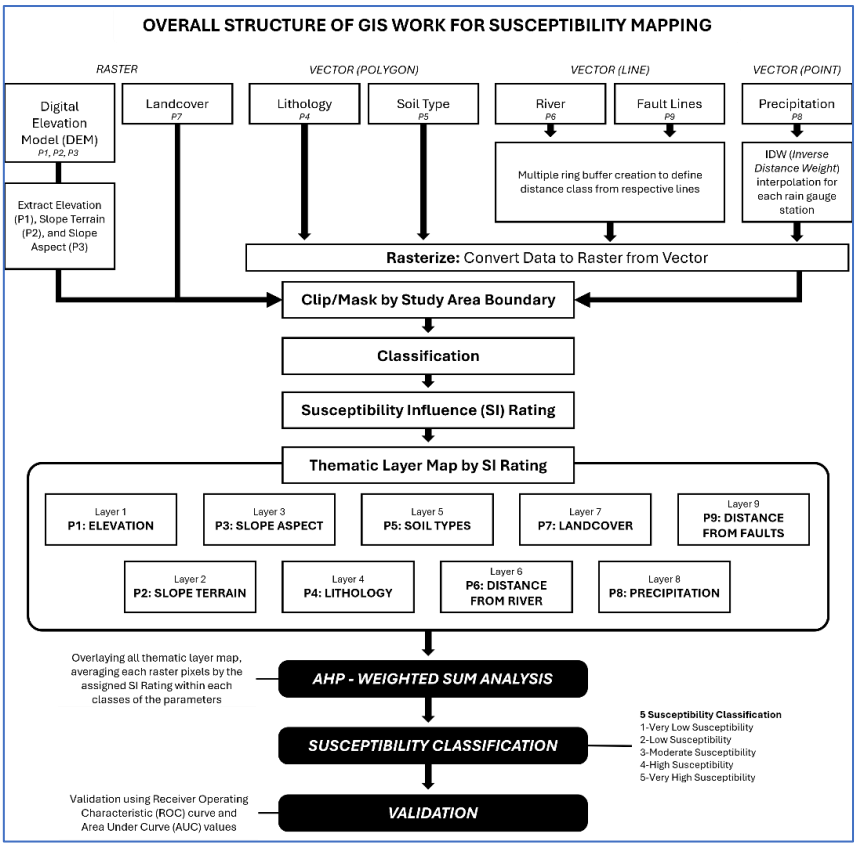

Figure 2: Methodology of the study

The preparation for thematic layers for landslide susceptibility in Hulu Langat will be comprised of nine (9) major parameters. The parameters involved for the analysis are elevation, slope terrain, slope aspect, lithology, soil types, distance from river, landcover, precipitation, and distance from faults. The susceptibility influence (SI) rating assignment is given to each class of parameters.

Table 1: Parameter and detailed used in this study

Parameters	Source	Variable type	Spatial resolution (m) and data type	Classification method
Elevation	DEM (Digital Elevation Model) SRTM (Shuttle Radar Topography Mission) 3-Arc Seconds (90m). https://earthexplorer.usgs.gov/	Continuous (DEM based)	30 (grid data)	Equal interval
Slope terrain	SRTM	Continuous (DEM based)	30 (grid data)	Manual classification
Slope aspect	STR	Continuous (DEM based)	30 (grid data)	Azimuth classification
Lithology	Department of Mineral and Geoscience (JMG – *Jabatan Mineral dan Geosains*)	Discrete (polygon)	30 (vector data)	Lithology classification
Soil types	Department of Agriculture (DOA)	Discrete (polygon)	30 (vector data)	Soil classification
Distance from river	Department of Irrigation and Drainage (JPS)	Discrete (ring buffer from line)	30 (grid data)	Equal interval
Landcover	LANDSAT 8 (OLI_TIRS) https://earthexplorer.usgs.gov/	Discrete (Satellite image based)	30 (grid data)	Supervised classification
Precipitation	Malaysian Meteorological Department (MET Malaysia)	Continuous (IDW interpolation from point)	30 (grid data)	Equal interval
Distance from faults	Malaysian Meteorological Department (MET Malaysia)	Discrete (ring buffer from line)	30 (grid data)	Equal interval

Figure 3 shows the SI maps for all parameters. For elevation (P1), the classification for elevation is initially divided into 200-meter intervals. Within the study area, the elevation ranges from 0 meters (sea level) to 1450 meters. There are four main elevation classes: low land (<150 meters), hilly land (150-300 meters), highland (300-1000 meters), and mountain (>1000 meters) (Bahagian Penyelidikan dan Pembangunan, 2011). These classes are all present within the study area. Literature on landslides in similar regions, such as Selangor and Kuala Lumpur, indicates that landslides are more frequent in areas below 400 meters in elevation (Saadatkhah et al., 2015; Zulkafli et al., 2023). Consequently, a higher SI rating is assigned to the lower elevation classes, reflecting the increased risk of landslides, while the higher elevation classes receive progressively lower SI ratings.

For slope terrain (P2), the interpretation of slope terrain is measured in angular degrees (°), with the steepest slope in the study area being 54.8°. Slopes are categorised into four classes: Class I (<15°), Class II (15°-25°), Class III (25°-35°), and Class IV (>35°) (Bahagian Penyelidikan dan Pembangunan, 2011). In the study area, over half of the land falls within Class I, followed by 24% in Class II, 10% in Class III, and 1% in Class IV. Generally, steeper slopes are more prone to landslides. However, slope alone is not the primary trigger for landslides. In the context of Selangor and Kuala Lumpur, many landslides have been reported on slopes less than 25°, reflecting a complex interplay of factors beyond just slope

steepness (Alnaimat, 2013; Lee & Pradhan, 2007; Saadatkhah et al., 2015; Zulkafli et al., 2023). Considering the diverse urban and rural characteristics of Hulu Langat, a higher SI rating will be assigned to steeper slopes, reflecting their greer potential risk for landslides.

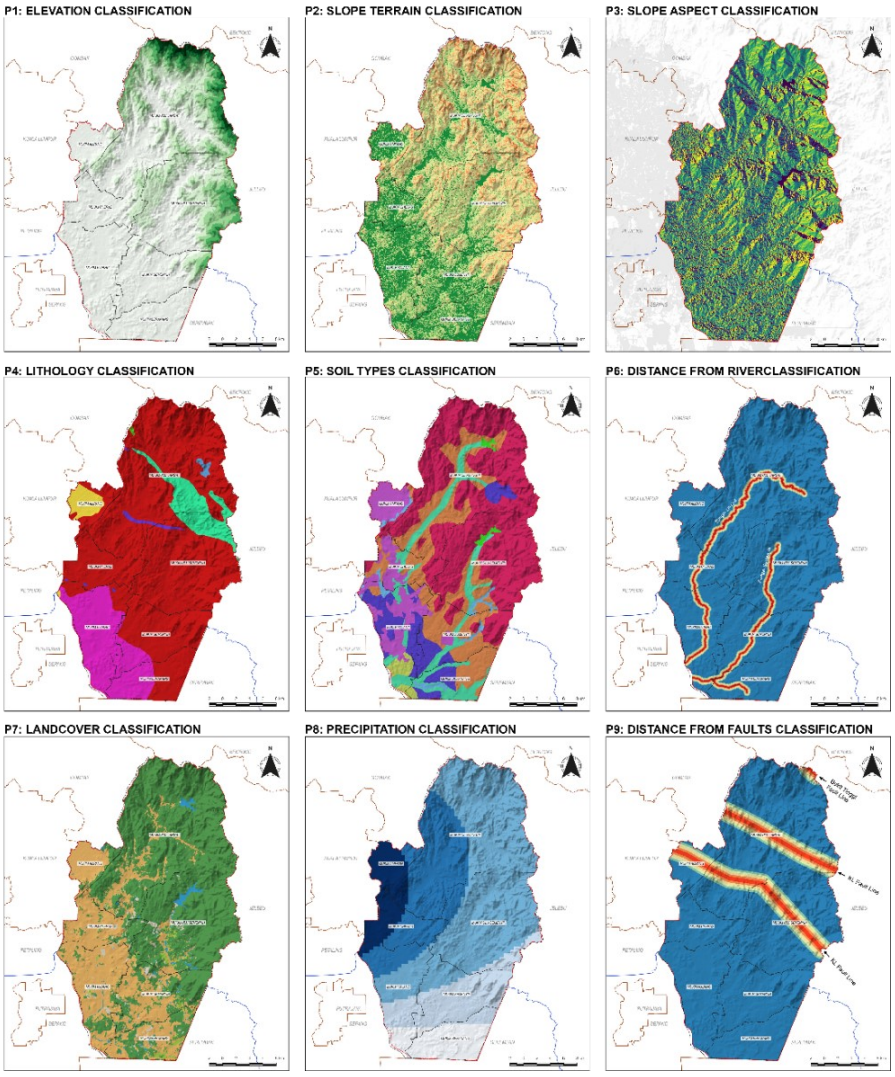

Figure 3: Thematic layer parameters map.

The slope aspect (P3) is a significant factor influencing landslide occurrence. Studies conducted in Malaysia indicate that most landslides occur on slopes facing the monsoon directions, specifically northeast and southwest (Lee & Pradhan, 2007; Saadatkhah et al., 2015). Therefore, higher SI ratings are

assigned to slopes with aspects facing northeast and southwest, and the lowest SI ratings are given to slopes facing opposite directions, reflecting their lower risk of landslides.

Within Hulu Langat, seven lithology (P4) classes have been identified. According to landslide studies in Malaysia, most landslides occur in areas with geological compositions predominantly of sandstone, acid intrusive, mudstone, siltstone, granite, conglomerate, and volcanic rocks (Lee & Pradhan, 2007; Sofiyan Sulaiman et al., 2019; Zulkafli et al., 2023). Schist and limestone lithology types have a lower influence on landslide activity (Sofiyan Sulaiman et al., 2019). Acid Intrusive (AI) formations are one of the prominent geological structures within the study area. Other geological compositions include acid to intermediate volcanics, schist, limestone, vein quartz, and others. Based on the literature, the highest SI rating is assigned to acid intrusive formations. The second highest SI rating is given to areas containing acid to intermediate volcanic (AIV) and phyllite-schist-slate (PSS) compositions, due to their volcanic and sandstone compounds. Consequently, lithologies containing schist, limestone, and quartz are assigned lower SI ratings, reflecting their reduced influence on landslide activity.

Eight (8) categories of soil types (P5) have been identified within Hulu Langat. The most prominent soil type is Tanah Churam (TC), covering 46% of the area, followed by Rengam-Jerangau (R-J) at 22%, and Tanah Bandar (TB) at 10%. According to landslide studies in Malaysia, soil types with the highest influence on landslide activity are Tanah Bandar (TB), followed by Tanah Churam (TC), and Serdang-Bungor-Munchong (S-B-M) (Lee & Pradhan, 2007; Sofiyan Sulaiman et al., 2019). Therefore, the SI ratings for the soil type parameter are assigned based on these findings from local literature, ensuring that the most landslide-prone soil types receive the highest ratings.

Saadatkhah et al. (2015) explained that most of the past landslides in the Hulu Kelang area occurred within 0-75 meters of distance from rivers (P6). In contrast, reported landslide events in Kuala Lumpur were within 500 meters from rivers (Zulkafli et al., 2023). Additionally, studies by Lee & Pradhan (2007) indicated that landslides in Selangor predominantly occurred within 357 meters from rivers. Therefore, the highest SI rating for this parameter will be assigned to areas within 200 meters of rivers. Conversely, the lowest SI rating will be given to areas more than 500 meters away from rivers, reflecting the decreased influence on landslide activity with increased distance from rivers.

Landcover (P7) one of the factors of landslide. Hulu Langat has significant forest coverage, accounting for 62% of the area, or approximately 130,000 acres. Built-up areas make up 32%, equating to around 67,000 acres. Other land cover types in Hulu Langat include water bodies, vegetation, and cleared land. According to landslide literature, built-up areas are highly prone to landslides, while areas with green coverage, such as forests, vegetation, and

plantations, have a lower likelihood of landslides (Alnaimat, 2013; Kalimuthu et al., 2015; Saadatkhah et al., 2015; Zulkafli et al., 2023). Thus, the SI rating for land cover in Hulu Langat is assigned based on these findings, with the highest rating given to built-up areas and the lowest rating to non-built-up areas (Table 2).

The data of annual cumulative rainfall in 2022 from the rain gauge stations at KLIA (Kuala Lumpur International Airport) and Petaling Jaya is used for parameter P8 – Precipitation. According to this data, Hulu Langat received an annual average rainfall of 3241 millimetres, with a monthly average of 270 millimetres and a daily average of 7 to 9 millimetres. Based on landslide literature and the correlation with rainfall, areas that receive higher rainfall have a significantly higher likelihood of landslides (Alnaimat, 2013; Kalimuthu et al., 2015; S. Lee & Pradhan, 2007).

Within the Hulu Langat study area, there exist two principal fault lines (P9): the Kuala Lumpur fault lineament situated in the northern half of the territory, and a minor segment of the Bukit Tinggi fault lineament, located in the northernmost part of the area as well (Shuib et al., 2017). Landslide incidents are usually reported 400–1200 meters away from fault lines, according to landslide literature relevant to fault lines (Alnaimat, 2013; Dou et al., 2015; Lee & Pradhan, 2007).

Table 2: Weight and SI assignment to parameters.

Parameter	Class	SI Rating	Parameter weight
P1 – Elevation	< 400 m	5 – Very High Susceptibility	**0.12** Rank = 2
	400 m – 600 m	4 – High Susceptibility	
	600 m – 800 m	3 – Moderate Susceptibility	
	800 m – 1000 m	2 – Low Susceptibility	
	> 1000 m	1 – Very Low Susceptibility	
P2 – Slope Terrain	< 15°	1 – Very Low Susceptibility	**0.13** Rank = 1
	15° - 25°	2 – Low Susceptibility	
	25° - 35°	3 – Moderate Susceptibility	
	35° - 45°	4 – High Susceptibility	
	> 45°	5 – Very High Susceptibility	
P3 – Slope Aspect	NE, SW	5 – Very High Susceptibility	**0.12** Rank = 2
	N, E, S	4 – High Susceptibility	
	W	3 – Moderate Susceptibility	
	NW	2 – Low Susceptibility	
	SE	1 – Very Low Susceptibility	
P4 – Lithology	AI	5 – Very High Susceptibility	**0.10** Rank = 3
	AIV & PSS	4 – High Susceptibility	
	S	3 – Moderate Susceptibility	
	L/M	2 – Low Susceptibility	
	SPSL & VQ	1 – Very Low Susceptibility	
P5 – Soil Types	TB	5 – Very High Susceptibility	**0.09**

Parameter	Class	SI Rating	Parameter weight
	TC & S-B-M	4 – High Susceptibility	Rank = 4
	R-J	3 – Moderate Susceptibility	
	R-BT, BM-M & TL	2 – Low Susceptibility	
	T-A-TLT	1 – Very Low Susceptibility	
P6 – Distance from River	< 200 m	5 – Very High Susceptibility	**0.12** Rank = 2
	200 m – 300 m	4 – High Susceptibility	
	300 m – 400 m	3 – Moderate Susceptibility	
	400 m – 500 m	2 – Low Susceptibility	
	> 500 m	1 – Very Low Susceptibility	
P7 - Landcover	Built-up Area	5 – Very High Susceptibility	**0.12** Rank = 2
	Cleared Land	4 – High Susceptibility	
	Vegetations	3 – Moderate Susceptibility	
	Forests	2 – Low Susceptibility	
	Water Bodies	1 – Very Low Susceptibility	
P8 – Precipitation	2801 mm – 2977 mm	1 – Very Low Susceptibility	**0.10** Rank = 3
	2977 mm – 3153 mm	2 – Low Susceptibility	
	3153 mm – 3330 mm	3 – Moderate Susceptibility	
	3330 mm – 3506 mm	4 – High Susceptibility	
	3506mm – 3682 mm	5 – Very High Susceptibility	
P9 – Distance from Faults	< 600 m	5 – Very High Susceptibility	**0.10** Rank = 3
	600 m – 900 m	4 – High Susceptibility	
	900 m – 1200 m	3 – Moderate Susceptibility	
	1200 m – 1500 m	2 – Low Susceptibility	
	> 1500 m	1 – Very Low Susceptibility	

RESULT

Using the equal interval classifier, the study area's landslide susceptibility (LSS) score, which ranged from 1.78 to 4.20, was classed into five landslide susceptibility classes: very low, low, moderate, high, and very high (Figure 4). Very low, low, and moderate susceptible occurrences make up 2.10%, 32.23%, and 50.16% of the entire study region, respectively, according to the analysis results displayed in Table 3. The entire study area is represented by the high (14.74%) and extremely high (0.77%) susceptibility of areas.

Table 3: Landslide susceptibility (LSS) in the study area

CLASS	LSI	Description	AREA (%)	AREA (acres)
5	3.72 – 4.20	Very High Susceptibility	**0.77**	**1,590.39**
4	3.23 – 3.72	High Susceptibility	**14.74**	**30,587.55**
3	2.75 – 3.23	Moderate Susceptibility	**50.16**	**104,072.60**
2	2.26 – 2.75	Low Susceptibility	**32.23**	**66,871.62**
1	1.78 – 2.26	Very Low Susceptibility	**2.10**	**4,353.41**
Interval	***0.484***		**100.00**	**207,475.57**

In order to assess the effectiveness of binary classification models, this study used the receiver operating characteristic (ROC) curve, which plots the true positive rate (sensitivity) against the false positive rate (1-specificity) across a range of thresholds (Sur et al., 2020; Vakhshoori & Zare, 2018). The model's performance is summarized by the area under the ROC curve (AUC): a value of 1.0 indicates a perfect model, while 0.5 indicates no discriminative power. Using 182 historical landslide points, the result of ROC and AUC demonstrate a good degree of satisfaction (AUC = 0.755, 75.5%).

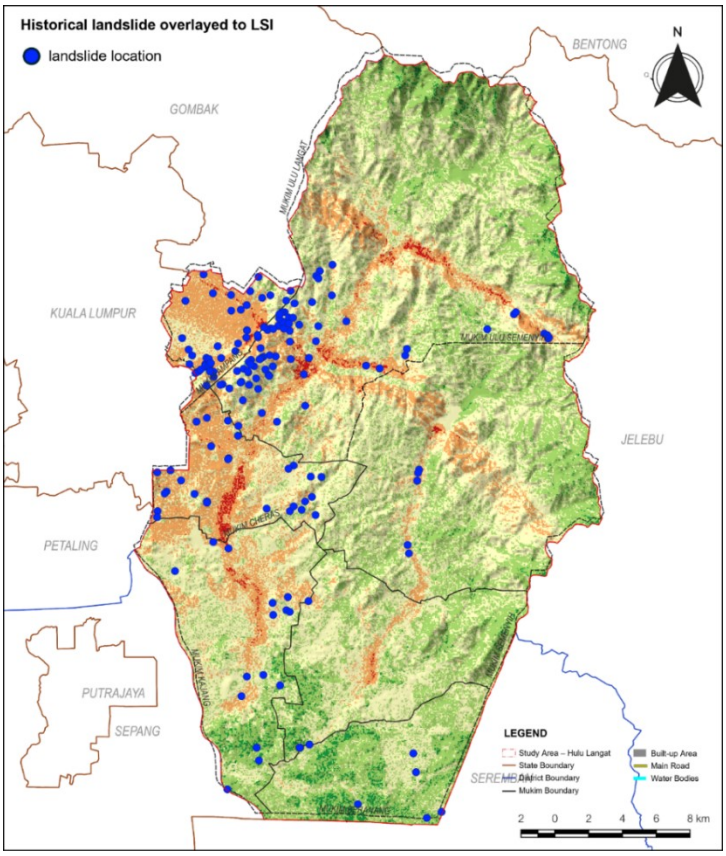

Figure 4: Historical landslide locations overlayed to LSS map

Analysis and Finding

Following the results of LSI (see Table 4-1 and Figure 4-1), there is a total of 32,177.94 acres of land area (15.51%) in Hulu that is subjected to high potential risk of landslides, with most of it being in the area of Bangi, Kajang, Cheras and Ampang. This study has categorized nineteen (19) landslide concern zones (LCZ) identified within the study area, classified into three levels of concern: critical,

significant and notable. Figure 5 shows the LCZ for each class. The LCZ Class 1 – critical concerns include seven zones: Ampang Jaya South, Balakong - Cheras, Batu 13 - Batu 14, Empangan Semenyih, Kajang - Sungai Chua, Kampung Sungai Balak - Kampung Batu 10, and Pekan Semenyih.

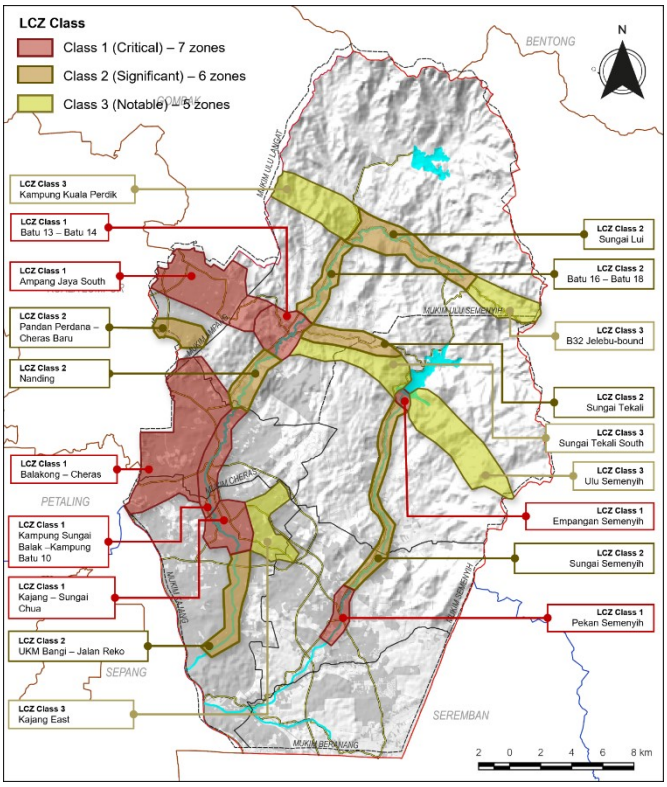

Figure 5: Landslide Concern Zones

These areas are deemed to have the highest risk and require immediate attention and mitigation measures to prevent landslides and ensure the safety of the population and infrastructure. The LCZ Class 2 – significant concerns consist of seven zones: Batu 16 - Batu 18, Nanding, Pandan Perdana - Cheras Baru, Sungai Lui, Sungai Semenyih, Sungai Tekali, and University Kebangsaan Malaysia (UKM) Bangi – Jalan Reko. These zones have a substantial risk of landslides, necessitating significant monitoring and preventative actions to mitigate potential impacts. The presence of critical infrastructure and populated areas in these zones underscores the importance of addressing the risks effectively. Lastly, the LCZ Class 3 – notable concerns include five zones: B32 Jelebu-bound, Kajang East, Kampung Kuala Perdik, Sungai Tekali South, and Ulu Semenyih. While these areas are not as critically endangered as those in Class

1 and 2, they still present a notable risk of landslides. Proactive measures and continuous monitoring are essential to manage and reduce the susceptibility to landslides in these zones.

By delineating these concerning zones into three classes, responsible authorities, interested agencies and stakeholders can observe and prioritize their efforts and resources, focusing first on the most critical areas while also addressing significant and notable concern zones in a systematic manner. This can also be one way to a structured approach for categorizing and addressing landslide risk allows for targeted interventions and resource allocation, focusing on the areas with the highest need for mitigation efforts.

Mitigation efforts including monitoring and engineering solutions for high-risk zones (LCZ 1) as with the highest likelihood of landslides, require immediate and ongoing attention. Frequent observations and monitoring of these zones are essential to detect early signs of landslides and implement timely interventions. Raising awareness among local populations about the risks and preventive measures is also crucial. Engineering solutions such as slope stabilization, constructing retaining walls, and improving drainage systems should be prioritized in these high-risk areas. These measures can significantly reduce the risk of landslides and protect lives and property. To enhance the effectiveness of monitoring and early warning systems, advanced technologies such as Light Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (InSAR) can be employed.

Significant and notable concern areas (LCZ Class 2 and LCZ Class 3) also require regular inspections and monitoring, albeit less intensively than the critical zones. Ensuring safety in these areas involves implementing stricter building regulations and revising the design of structures to prevent exacerbating the landslide risk. Adopting construction practices that enhance the structural integrity and resilience of buildings can significantly reduce the vulnerability of these areas to landslides. This includes designing foundations and supports that can withstand ground movements and incorporating materials and techniques that improve overall stability.

Emergency preparedness programs play a vital role in equipping local populations to respond effectively to landslide events. Regular community drills can help residents understand evacuation routes and safety procedures, ensuring a coordinated response during emergencies. Infrastructure upgrades, such as reinforcing roads, bridges, and public buildings, can enhance the community's resilience and reduce the impact of landslides. Public awareness campaigns are equally important in educating residents about the risks and encouraging proactive measures to mitigate them. These campaigns can provide information on recognizing early warning signs of landslides, safe construction practices, and steps to take during and after a landslide event.

CONCLUSION

The parameters used in this analysis; elevation, slope terrain, slope aspect, lithology, soil types, distance from river, landcover, precipitation, and distance from faults are important to be used in landslide analysis. However, the established methodology serves as a valuable guide for future susceptibility mapping efforts. While additional disaster studies specific to Malaysia will enhance our understanding of hazard and susceptibility, more powerful tools can significantly impact the integration of socio-economic and physical urban planning with disaster management. These tools include strong legislation, statutory documents, comprehensive planning guidelines, building regulations, and political will. By leveraging these instruments, we can drive effective change and ensure a more resilient urban landscape in the face of disasters.

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ASSESSMENT OF THE IMPACTS OF COASTAL DEVELOPMENT AND CLIMATE CHANGE ON FISHING COMMUNITIES IN KUALA TERENGGANU, MALAYSIA

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Abstract

Fishing communities face numerous challenges affected by rapid coastal development and climate change. These issues have threatened the sustainability and livelihoods of their community. The objective of this study was to investigate the impacts of coastal development and climate change on fishing communities in Kuala Terengganu. This research was carried out with 125 members of fishing communities in Kuala Terengganu's coastal areas. The data were collected through questionnaires and analysed using XLSTAT software. The findings from this study showed that the type of climate change did not affect the impacts of climate change towards the fishing community. Moreover, the level of social functionality of the fishing community in Kuala Terengganu remains unaffected by the ongoing development. In conclusion, fishing communities in Kuala Terengganu have successfully managed to preserve their social functionality and resilience despite the challenges posed by coastal development and climate change. Thus, to ensure the long-term resilience and prosperity of these communities in the midst of continuous environmental changes, it is essential to implement sustainable planning and adaptation measures.

Keywords: Climate Change, Coastal, Community Development, Fishing

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INTRODUCTION

Climate change and coastal developments have a major impact on the socioeconomic status of coastal fishermen in various regions around the world (Hashim et al., 2019). Whilst coastal development can lead to habitat damage, pollution, and restricted access to traditional fishing grounds, climate change contributes to rising sea levels, shifts in fish populations, and an increase in extreme weather events (Domit et al., 2022). The majority of residents living in coastal areas are employed in maritime or sea product-related industries (Fadzli, et al., 2023). Coastal fishermen are highly dependent on natural resources, especially the sea, as their primary source of livelihood.

Peninsular Malaysia consists of coastal areas, with the coastline extending approximately 4800 kilometres (Azali, 2022). Terengganu, a state located in the most coastal areas of Malaysia has a high population of fishermen (Bagheri et al.,2021). Nowadays, development around coastal areas has grown rapidly. In Kuala Terengganu, coastal development includes the development of infrastructures for tourism, urban growth, and the establishment of commercial entities (Ismail et al., 2023).

Many studies have highlighted that the increasing rate of coastal development is potentially influencing the community's social, economic, environmental, and infrastructure accessibility conditions (Zakaria et. al., 2022). Moreover, climate change also affects the coastal ecosystem, leading to changes in the habitat of various fish species and other marine organisms (Baharudin, Ali & Idros, 2023). Comprehensive policies are required to prevent negative consequences while promoting sustainable development in coastal regions to mitigate the impacts.

The objective of this paper was to examine the impacts of coastal development and climate change on fishing communities. This research aimed to discover the impacts of climate change and coastal developments in relation to the Sustainable Development Goals (SDGs), specifically Goal 13 on climate action and Goal 11 on sustainable cities and communities. The findings provide insightful information on how these global issues impact local communities, as well as offer suggestions on promoting sustainable development in coastal areas.

LITERATURE REVIEW

Fishing Communities in Kuala Terengganu

Fishermen are individuals or groups whose profession involves catching fish, shellfish, squid, shrimp, and various other types of aquatic animals in bodies of water such as seas, rivers and lakes. Coastal fishermen are traditional fishers who use small boats to fish within a range of up to five nautical miles from shore (Sembok et al., 2020). According to research by Abdullah et al. (2022), urban

residents living in coastal areas have also started engaging in fishing, alongside the villagers who have traditionally dominated this activity in Terengganu.

In 2019, Malaysia's fishing community contributed to a 12% increment in the nation's agricultural industry towards the sustainability of Malaysia's Gross National Product via their fisheries-based products (Department of National Statistics, 2020). According to the Malaysian Department of Fisheries, in 2022, there were 8526 registered fishermen in Terengganu state, with only 878 in the Kuala Terengganu district (The Department of Fisheries Malaysia, 2023). The Department of Fisheries Malaysia, under the Fisheries Development Authority of Malaysia (LKIM), is responsible for assisting and monitoring the welfare and affairs of the fishermen.

Nevertheless, despite changing demographics and environmental challenges, Kuala Terengganu's fishing communities continue to play a vital role in Malaysia's economy and cultural landscape. Sustainable management and continuous assistance are necessary to maintain the prosperity and resilience of fishermen in the face of evolving environmental and economic conditions.

Climate Change

Climate change refers to long-term changes in the Earth's average weather, including air temperature, rainfall patterns, wind and several other climate factors. Weather variations could negatively affect our daily activities and the functioning of the Earth's natural system. The Intergovernmental Panel on Climate Change (IPCC) estimates, based on the observed scenarios, that there is more than a 50% chance that the global temperature will rise by 1.5 degrees Celsius or more between 2021 and 2040 (Boehm & Schumer, 2023). As for the high-emission trajectory, the world may surpass the threshold between 2018 and 2037, or perhaps sooner (Ismail et al., 2024).

Fishing communities were among the groups that would be affected by climate change as they highly depend on marine resources. As mentioned by Islam et al. (2020), fishermen rely on the surrounding conditions such as sea temperature and rainfall patterns to determine the availability of fish resources. As a result, the fishing community's catch-related issues have worsened due to unpredictable climate change, which has severely damaged and depleted marine resources. Fishermen also face the issue of having to sell their catches to the general public at extremely low prices, often more than 50% below the average price due to the impacts of climate change (Putri, Rosyadi, & Rahmawati, 2022). This highlights the urgent need for international cooperation and adaptive methods to mitigate these effects and protect marine ecosystems, safeguarding the fishing communities' livelihoods and resilience.

Coastal Development and Social Functionality

Coastal development refers to the construction of infrastructure, the expansion of urban areas, and the establishment of commercial entities along coastlines to accommodate growing population demands and foster economic growth (Tien et al., 2020). The development of coastal areas is closely linked to fishing communities and has a range of effects, both beneficial and adverse. Some of the benefits include significant economic activity in coastal regions, which serve as hubs for tourism, recreation, farming, fishing, and residential real estate which often features some of the highest property values in the nation (Hamid et al., 2023). On the other hand, the adverse impacts include the degradation of the nearby marine and coastal environments, as well as the socio-cultural aspects, infrastructure accessibility, and the fishing sector (Zakaria et al., 2022).

The term "social functionality" refers to a social group's or community's ability to interact effectively and maintain social cohesion (Yadav, 2024). It involves several aspects such as interpersonal relationships, teamwork, and the ability to adapt to the demands and expectations within the community (Rosni, 2017). Understanding social functionality is essential for evaluating the roles and purposes that behaviours, actions and institutions serve, besides acknowledging their importance in establishing and maintaining social order and unity (Wandi et al., 2021). Coastal development can have a substantial impact on social functionality by altering the dynamics of the community, access to resources, and cultural practices. Changes in infrastructure, economic activity, and population density can affect the local population's traditional lifestyles, social cohesiveness, and community resilience (Dehghani et al., 2022). To address these challenges, proper management of coastal development is essential to strike a balance between the well-being of the local communities, environmental preservation, and economic progress (Huy, 2022).

RESEARCH METHODOLOGY

This study was conducted specifically in the coastal area of Kuala Terengganu, Terengganu. Data were collected using convenience sampling and quantitative methods, incorporating direct interviews and survey questionnaires. The questionnaires were distributed randomly among 125 individuals from the fishing communities residing in the Kuala Terengganu coastal areas. Figure 1 illustrates the location of Kuala Terengganu, the designated study area.

The questionnaires consist of three sections. The demographic section included items on the respondents' gender, race, religion, age, marital status, education level, working experience, income, and number of dependents. All questions were presented in Malay. Responses were measured on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

For statistical analysis, the collected data were entered into an Excel file and analysed using XLSTAT software. Descriptive analysis was utilised to analyse and present the respondents' demographic data. The arithmetic mean was used to determine the average response level based on the five-point Likert scale was determined. Regression analysis was also performed to evaluate the degree of association and relationships in accordance with the study's objectives.

Figure 1 Location of the study area, Kuala Terengganu (mark with yellow colour).
Source: Map of Terengganu

ANALYSIS AND DISCUSSION

Table 1 shows the demographic background of 125 respondents from Kuala Terengganu. The ages of the respondents ranged from 15 to 70 years old. Since the respondents varied widely in terms of their backgrounds and characteristics,

the random sampling conducted was representative of the population of fishing communities in Kuala Terengganu.

Table 1: Socio-demographic profile of respondents

Socio-demographic		Percentage (%)
Gender	Woman	**0**
	Man	**100**
Race	Malay	**100**
	Chinese	0
	Indian	0
Religion	Islam	**100**
	Others	0
Age	Below 18	2.4
	18 - 25	16.7
	26 – 35	23.0
	36 – 45	18.3
	46 – 55	**27.0**
	55 and above	12.6
Marital Status	Single	30.2
	Married	**67.5**
	Widow	2.3
Education Level	No formal education	4.0
	Primary school	19.8
	Secondary school	**70.6**
	Diploma/STPM	5.6
	Degree	0
Working Experience	<10 years	**42.9**
	10 – 19 years	34.9
	20 – 29 years	15.2
	> 30 years	7.1
Income	< RM500	4.8
	RM500 – RM1000	**69.8**
	RM1000 – RM2000	22.2
	> RM2000	3.2
Number of Dependents	None	37.3
	1 – 3 people	**37.3**
	4 – 6 people	19.0
	> 7 people	6.4

From the table above, the predominant gender, race and religion among the fishing communities in Kuala Terengganu are male, Malay and Islam, respectively. Most of the respondents were aged between 46 to 55 years old (27.0%), followed by respondents aged between 26 to 35 years old (23.0%) and the least respondents were those below 18 years old (2.4%). Around 67.5% of the respondents were married, 30.2% were single and 2.3% were widows.

In terms of education level, 70.6% of the respondents studied until secondary school, 19.8% up to primary school, 5.6% were diploma/STPM holders and the remaining 4.0% had no formal education. Moreover, the majority of the respondents have working experience below 10 years (42.9%), 34.9% with 10 - 19 years followed by 15.2% with 20 - 29 years and the minority of the respondents have working experience more than 30 years (7.1%). Among the 125 respondents, 69.8% of respondents' incomes were RM 500 – RM 1000, 22.2% with incomes of RM 1000 – RM 2000, 4.8% had incomes below RM 500 and 3.2% had incomes of RM 2000 and above. The number of dependents for none and 1-3 people were at 37.3%, meanwhile for 4 - 6 people were at 19.0% and more than 7 people were 6.4%.

The Relationship of Types of Climate Change and Its Effects on the Fishing Community in Kuala Terengganu.

Table 2 describes the regression analysis statistics for the types of climate change and their effects on the fishing communities in Kuala Terengganu. The independent variables for this research were the types of climate change and the dependent variables were the effects on fishing communities in Kuala Terengganu. The table below displays the mean value of 2.768 for independent variables and 2.751 for dependent variables.

Table 2: Regression Analysis Statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Independent Variable	125	0	125	1.000	4.000	2.768	0.496
Dependent Variable	125	0	125	2.133	3.400	2.751	0.283

In addition, the regression of variables is shown in Table 3. The dependency between the independent and dependent variables is influenced by the R^2 value. In the table below, the R^2 value is 0.023, representing 2%. This indicates that the effects of climate change in Kuala Terengganu were only influenced by this 2% types of climate change. Hence, it could be considered that types of climate change (independent variables) did not influence the impacts of climate change (dependent variable) on the fishing community in Kuala Terengganu.

Table 3: Regression of Variable

Observations	125
Sum of weights	125
DF	123
R^2	**0.023**
Adjusted R^2	0.007
MSE	0.203
RMSE	0.450
MAPE	11.837
DW	1.655

Moreover, Table 4 demonstrates the analysis of variance. In this study, the difference between one variable is determined using an analysis of variance. The table below shows the P-value was 0.241, hence, there is no relation between the types of climate change (independent variables) and impacts of climate change (dependent variables) on Kuala Terengganu's fishing community.

Table 4: Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	Pr > F	p-values signification codes
Model	2.000	0.584	0.292	1.438	**0.241**	°
Error	123.000	24.958	0.203			
Corrected Total	125.000	25.541				

Computed against model Y=Mean(Y)

Signification codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1

The Relationship Between the Levels of Social Functionality of the Fishing Community Against Coastal Development in Kuala Terengganu.

Table 5 determines the regression analysis statistics for levels of social functionality of the fishing communities against coastal development in Kuala Terengganu. The independent variable for this study is the level of social functionality of the fishing communities, while the dependent variable is the impact of coastal development. From the table below, the mean for both variables were 2.534 and 2.660 with standard deviations of 0.342 and 0.341, respectively

Table 5: Regression Analysis Statistics

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Independent Variables	125	0	125	1.867	3.600	2.534	0.342
Dependent Variables	125	0	125	1.733	3.667	2.660	0.314

Moreover, Table 6 presents the value of R^2 that was calculated using XLSTAT software. The R^2 value indicates to which extent the independent variable influences the dependent variable. The R^2 value in the table below was 0.238, equivalent to 24% of the level of social functionality affecting the impact of coastal development around Kuala Terengganu. Since the value of R^2 was less than 50%, thus, it reflects that coastal development did not have significant impacts on the level of social functionality of fishing communities around Kuala Terengganu.

Table 6: Regression of Variable

Observations	125
Sum of weights	125
DF	123
R^2	**0.238**
Adjusted R^2	0.231
MSE	0.090
RMSE	0.300
MAPE	8.951
DW	1.654

Besides, an analysis of variances was employed to determine the differences between each research variable. Table 7 displays a P-value of <0.0001, indicating that the results are statistically significant.

Table :7 Analysis of Variance

Source	DF	Sum of squares	Mean squares	F	Pr > F	p-values signification codes
Model	1.000	3.456	3.456	38.339	**<0.0001**	***
Error	123.000	11.086	0.090			
Corrected Total	124.000	14.542				

Computed against model Y=Mean(Y)
Signification codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1

CONCLUSION

In conclusion, the results of the analysis describe that the observed effects on the fishing communities in Kuala Terengganu were not significantly impacted by climate change. Moreover, it was found that the fishing communities in Kuala Terengganu have an excellent level of social functionality. This research encourages ecologically friendly fishing and farming methods, developing climate-resilient infrastructure, and promoting sustainable spatial planning. Education and raising public awareness are also crucial for enhancing flexibility and lessening the effects of climate change. Sustainable coastal management must prioritise community well-being and environmental stewardship to ensure the resilience of fishing communities. By promoting sustainable practices and adaptive resilience, the livelihoods and cultural heritage of Kuala Terengganu's fishing communities can be preserved.

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COMMUNITY, CULTURE AND CONSERVATION: MAPPING THE BIOCULTURAL LANDSCAPE RESOURCES OF SUNGAI TEMBUS, SEBERANG PERAI FOR TOURISM

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Abstract

Integrating biocultural resources into tourism development is vital to promote sustainable practices that benefit the local community and the environment. Biocultural landscape resources include biodiversity and cultural heritage, where natural and cultural attributes are interconnected and can affect the sustainability of one another. Hence, examining biocultural resources as a connected network between nature and culture is integral. This paper investigates the biocultural landscape resources of Sungai Tembus, Seberang Perai, as unique opportunities to leverage the ecological features of the area and the local cultural practices. Through a mixed-method approach, the study gathered on-ground data through semi-structured interviews with local community members to gather their insights and experiences, which were complemented by mapping the resources using Geographic Information System (GIS) and photographic documentation. The result of the study shows that the local community's livelihood and tourism activities depend on biocultural resources. The findings reveal that the cultural heritage is shaped by the ecological features, highlighting the importance of community engagement in conservation efforts and tourism planning.

Keywords: Bio-cultural, community, landscape, tourism

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INTRODUCTION

Biocultural diversity entails the interconnectedness of biological and cultural diversity (Maffi & Woodley, 2012). Biocultural resources are essential for sustainable development to preserve a place's natural and cultural ecosystem. According to Elyasi & Yamacli (2023), a society's tangible and intangible aspects shape cultural heritage, where preserving cultural heritage values is crucial to define a society's social and cultural fabric. In tourism, safeguarding these values is necessary to maintain community identity and environmental resilience because they shape the destination's attractiveness.

Several studies have drawn the correlations and causal connections between natural and cultural resources. The diversities of these resources create a dynamic that underpins biocultural diversity. O'Neill et al. (2017) emphasises that biodiversity studies are important in recognising cultural diversity and traditional knowledge in biodiversity conservation. Amo-Rodríguez et al. (2010) asserts the need for landscape planning that integrates biological and cultural aspects, where cultural resources' conservation, restoration and management are pertinent to the local population that drive conservation in rural areas.

Sungai Tembus is a rural mangrove area in Seberang Perai, Pulau Pinang. It is part of a Key Biodiversity Area of the Teluk Air Tawar – Kuala Muda corridor, where this area has been acknowledged to be one of the landing sites for migratory shorebirds. This paper aims to document and analyse the biocultural resources of Sungai Tembus. The objectives are (i) to identify and map Sungai Tembus' physical, natural and cultural resources, (ii) to gain insights from the local community as custodians of the area, and (iii) to examine the role of the biocultural landscape resources of Sungai Tembus. The significance of this study extends both locally and globally, as it provides an understanding of Sungai Tembus' unique biocultural landscape that is part of the migratory bird flyway.

LITERATURE REVIEW

Biocultural Resource

Biocultural resources comprise the biological and cultural diversity of communities. Recognising the local community and indigenous people's role as stewards of biocultural resources has gained significant attention globally and is supported by emerging research (Amo-Rodríguez et al., 2010; Nemogá, 2016; Newing et al., 2023). Local practices are a deep-rooted knowledge system that is pivotal in sustaining natural and cultural resources in an area. As such, biocultural conservation can serve as a tool for mitigating the decline of biodiversity and cultural diversity (Gavin et al., 2015). This approach recognises that biological and cultural diversities are interconnected, where they influence and sustain each other. Nature and culture are not separate entities. By integrating cultural practices and traditional knowledge with biodiversity conservation efforts,

biocultural approaches can enhance the resilience of ecosystems and communities to preserve natural and cultural heritage.

Local communities and indigenous people are important contributors to supporting biocultural resources. Newing et al. (2023) draws attention to these communities' role as biodiversity custodians. Management practices of biocultural sites should incorporate both traditional and scientific knowledge to foster a more comprehensive sustainable conservation effort. The Kunming-Montreal Global Biodiversity Framework (GBF) calls for active involvement of the local communities and indigenous people in decision-making and equitable sharing of benefits from biodiversity-based activities (David Cooper & Noonan-Mooney, 2013). The GBF contends sustainable tourism practices that minimise environmental impact, respect local cultures, and contribute to biodiversity conservation and local livelihoods.

The biocultural approach investigates the dynamic relationship between ecological and cultural processes, linking nature and culture at various scales (Maffi & Woodley, 2012; Nemogá, 2016). This approach highlights the need to respect the rights and worldviews of the local communities while acknowledging their role as stewards of the area. Amo-Rodríguez et al. (2010) introduces the Biocultural Resource Management Model, a conceptual framework that integrates biological and cultural resources for sustainable management. The model recognises the interdependence between nature and culture through a community-centric approach and interdisciplinary collaboration. The sustainability of the biocultural resources must balance ecological, economic and socio-cultural dimensions. For instance, sustainable tourism can become a potential means to promote biocultural conservation while generating economic opportunities for the local communities.

Biocultural Tourism

Biocultural tourism is the intersection of biodiversity, culture and tourism. The concept of biocultural tourism illuminates the role of local communities in sustainable development, as it can support the conservation of local ecosystems and local practices (Kaulen-Luks et al., 2022). It includes a range of tourism branches, such as ecotourism, nature-based tourism and rural tourism, and is closely linked to the local and indigenous communities and their traditional knowledge (Luković et al., 2022). The concept of biocultural diversity is central to understanding the dynamics between nature-based tourism and the role of the local community (Gavin et al., 2015). The safeguarding of traditional ecological knowledge (TEK) is crucial in reducing the loss of biocultural diversity, as local communities are the custodians of the area and hold valuable knowledge (La Rosa et al., 2021). Their involvement in tourism planning is essential for sustainability and respect for culture and nature.

The intersection of biodiversity, culture and tourism are pertinent to environmental conservation, community well-being and sustaining local cultural practices. Biodiversity is a fundamental component of many cultural practices (Gavin et al., 2015), since much of the traditional local food, building materials, traditional medicine, agriculture and fishery, and crafts derive from natural materials. Using natural materials and softscapes, particularly in natural areas, can contribute to a better quality of the surrounding environment (Sani et al., 2020). The interdependence of biodiversity and culture is undeniable and essential for protecting the place's cultural heritage and economic development. The biodiversity of an area also serves as a key attraction for nature-based tourism, ecotourism and biocultural tourism, with potential income generation for the local economy. There needs to be an integrated approach that consider the ecological, cultural and socioeconomic dimensions of tourism development. Through biocultural landscape resource planning, holistic conservation and development strategies can address ecological and cultural aspects, achieving broader sustainability goals.

Community, Culture and Conservation

Local communities are pivotal in balancing ecological conservation and the preservation of cultural practices, as these two aspects are often interconnected. Ecological conservation focuses on protecting ecosystems and biodiversity, while local cultural practices encompass traditional knowledge and customs related to the environment. This connection is increasingly recognised as essential for sustainable development, with communities' deep understanding of their natural surroundings offering valuable insights into maintaining ecological health (Reyes-Garcia et al., 2013; Sudiasmo & Muspita, 2020). However, several challenges hinder the effective integration of these elements. The loss of traditional ecological knowledge (TEK) due to urbanisation and generational shifts poses a significant threat to environmental sustainability and cultural identity (Muhumuza & Balkwill, 2013). External pressures, including economic development, climate change and tourism, further exacerbate these issues, complicating the balance between ecological preservation and cultural needs (Ruiz-Mallén & Corbera, 2013). To overcome these challenges and leverage local knowledge for ecological and cultural conservation, several strategies have been proposed. One key approach is community-based conservation (CBC), where the local community actively participate in managing their natural resources. Successful examples of Community Conserved Areas (CCAs) in countries like India and Kenya demonstrate how local customs and knowledge can inform conservation decisions, allowing for the coexistence of ecological protection and cultural practices (Brooks et al., 2012). These programs preserve the environment and foster a sense of ownership and pride within communities, contributing to

social cohesion and cultural resilience (Salerno et al., 2021; Teressa, 2022). Participatory planning and policy development are also crucial for the success of community-driven conservation efforts as involving local communities in decision-making ensures that ecological and cultural considerations are incorporated into conservation policies (Ghayoumi et al., 2023; Robinson & Makupa, 2015).

RESEARCH METHODOLOGY

This study's methodology employed a mixed-method approach, integrating resource mapping using a Geographic Information System (GIS), photographic documentation, and semi-structured interviews. This approach aimed to capture the spatial distribution of biocultural landscape resources in Sungai Tembus and the insights of local respondents regarding their cultural practices, local knowledge, and perspectives.

The GIS map effectively visualises and analyses the distribution of natural, cultural and physical attributes found in Sungai Tembus. GIS-integrated spatial data was collected through fieldwork mapping to identify significant site resources. The collected data were processes and analysed using QGIS software. Mapping was done using the Lat Lon Tool QGIS Phyton based on the photos taken on-site. The points were categorised into three main resource types: physical, natural, and cultural resources. After the points were created by using Lat Lon Tools XY Coordinate Feature, a point displacement legend was used to show the concentration of several overlapped resources, making it easier to identify areas with high resource density. This approach ensures a clear and comprehensive understanding of the site's diverse characteristics and facilitates informed decision-making for preservation and development purposes.

The selection of respondents for the semi-structured interview was purposive, and they comprised a community leader, a local fisherman, and a boatman, who are all actively engaged in management and activities at Sungai Tembus. The interviews followed a flexible format, allowing the respondents to elaborate on their experiences and perspectives. The interview responses were then analysed according to common themes and patterns, allowing insights of the cultural dimensions of biocultural resources in the study area.

ANALYSIS AND DISCUSSION

Case Study Area: Sungai Tembus, Seberang Perai

Sungai Tembus is a mangrove-rich riverine area located in Penaga, within the North Seberang Perai District of Pulau Pinang, Malaysia. It is surrounded by paddy fields and rural settlements, where most of the locals are paddy farmers and fishermen. The river, Sungai Tembus, flows out to the Straits of Malacca, shaping an estuary of mudflats. Sungai Tembus is part of the Teluk Air Tawar –

Kuala Muda flyway site for migratory birds that migrate through the East Asian-Australasian Flyway ("300 Mangrove Saplings Planted along Sg Tembus," 2024). It was reported that an estimation of more than 15,000 migratory birds from northeast Asia stop at this area, while at least 3,000 local shorebirds inhabit Sungai Tembus. The mangrove forests along Sungai Tembus have been gazetted as permanent reserved forests to protect the rich biodiversity of the area and promote sustainable ecotourism (*Penang Gazettes Eight Mangrove Forests as Permanent Reserved Forests*, 2023). Among the sighted birds are Asian openbills (*Anastomus oscitans*), storks and herons. The birds would nest in the mangroves and search for food in the mudflats and waters.

Biocultural Landscape Resource Mapping

Figure 1 shows the distribution of three attributes: natural resources, cultural resources, and physical infrastructure. The natural resources (marked with 'N') are mainly distributed along the river, estuary, and sea, primarily because Sungai Tembus' significant land cover is mangrove forest. The cultural resources (marked with 'C') are mainly concentrated near the rural settlements in the Nypa palm area. The physical infrastructure (marked with 'P') is concentrated in the jetty area of Sungai Tembus since this is where the operation hub is located.

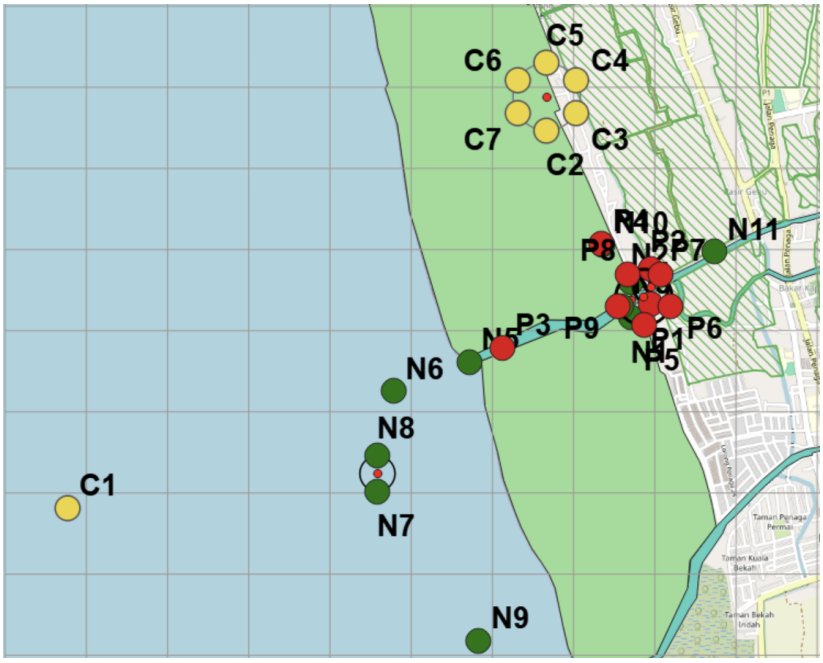


Figure 1: Distribution of biocultural resources (refer to Table 1-3 for photos)

Natural Resources

The natural resources of Sungai Tembus are connected to the mangrove and river ecosystems (refer to Table 1). From the jetty area, even without going far down the river, visitors can see birds that fly through the area and rest on top of the mangrove trees. The abundance of the birds was visible, and it was evident that the mangrove forest was their habitat. Smaller shore birds were observed feeding on the mud flats. Then, towards the sea, birds gathered at mangrove structures.

Table 1: Natural Resources at Sungai Tembus

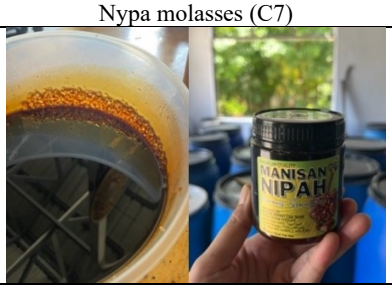
Mangrove forest (N10)	River – Sungai Tembus (N2)
	
Local birds and migratory birds (N3)	Mudflat area (N5)
	
Bird habitat at the mangrove (N9)	View towards Gunung Jerai (N6)
	
Sea snails harvesting area (N7)	Paddy field and watering channel (N11)
	

Cultural Resources

Fishery activities are the main cultural resources of Sungai Tembus. The Sungai Tembus Jetty is one of the jetties for fishermen in this area, other than the one in Kuala Muda. Aside from the mangrove forest, Sungai Tembus is abundant in

Nypa palms (*Nypa fruticans*) (refer to Table 2). The locals could harvest Nira from the Nypa palms, a sweet sap made into a drink, jelly, vinegar and molasses. One of the locals named Pak Man developed the Nypa products as an attraction for visitors to visit the area.

Table 2: Cultural Resources at Sungai Tembus

Fishing activities (C1)	Kebun Nipah Pak Man (C2)
	
Nypa palm farm (*Nypa fruticans)* (C3)	Nira harvesting from the Nypa palms (C4)
	
Nira drink and nira jelly (C5)	Nypa vinegar (C6)
	
Nypa molasses (C7)	Local community selling Nypa products
	

Physical Infrastructure

Sungai Tembus has the basic facilities for a fishermen's area, such as a jetty for them and visitors, a centre for their association with a meeting hall, a prayer room, a toilet, and a space that they see the potential to transform into a gallery in the

future (refer to Table 3). This area is also equipped with interpretive signage that explains the area's status as a biodiversity Area and provides information on migratory birds.

Table 3: Physical Infrastructure at Sungai Tembus

Fishermen jetty	Sungai Tembus Unit Fishermen Association
	
Proposed gallery area	**Interpretive signage**
	

Biocultural Landscape Resource Network

The resource mapping and photographic documentation revealed that the natural resources and cultural resources are interconnected, supported by the physical infrastructure. Figure 2 visualises the biocultural landscape resource network, which illustrates the relationships and outcomes of the interactions of the various resources. Natural resources, such as rivers, mangroves, and the sea, have become avenues for local people to support their livelihoods. The biodiversity of the area is crucial to maintaining the ecosystem. Even without tourism activities, these natural resources are essential to their daily life. With the potential of tourism activities, such as boating, bird watching, experiencing local food and the rural area, and buying local products, the locals could generate another income stream to support their off-season fishery and paddy farming activities. Additionally, tourism can become the means to develop Sungai Tembus sustainably, as the biocultural resources are assets to the local community.

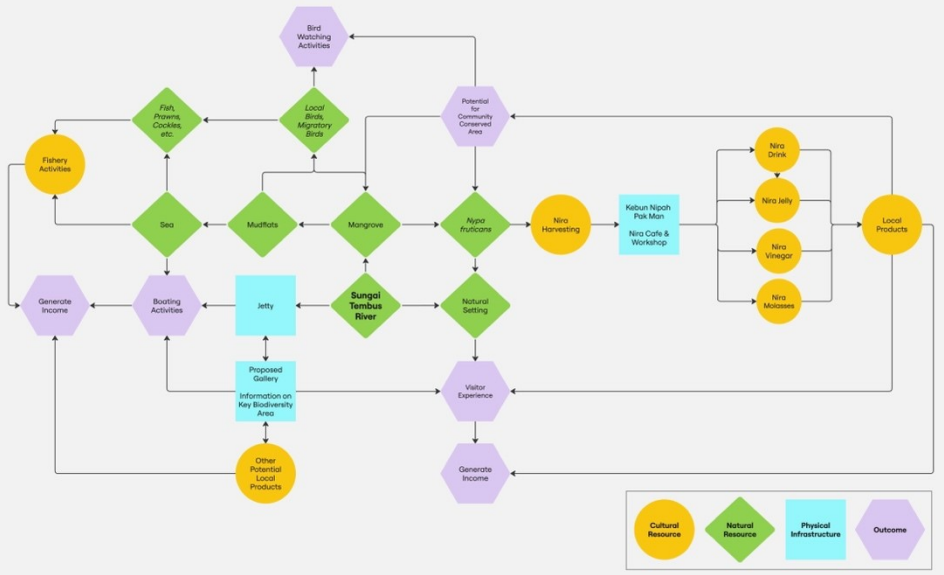


Figure 2: Biocultural Landscape Resource Network of Sungai Tembus

Community Insights

Each of the respondents from the local community were asked about the past and current conditions of Sungai Tembus, activities that have been conducted in the area, their respective views on the challenges and potentials of Sungai Tembus, and their aspirations for the community. Respondent 1 is the Chairman of the Sungai Tembus Unit Fishermen Association, Respondent 2 is a part-time fisherman and boatman, and Respondent 3 is a full-time fisherman. The findings from the interviews are analysed thematically in Table 4.

Table 4: Community insights on the resources of Sungai Tembus

Themes	Sub-Themes
Mangrove conservation and threats	**(i) Mangrove replantation efforts** - Importance of mangrove conservation, community-led initiatives and NGO involvement in mangrove planting and nurseries. - Respondent 1: programs from local people to replant the mangrove trees in Sungai Tembus **(ii) Environmental Challenges** - Aquaculture and sedimentation were major threats. - Respondent 1: concerns about waste from aquaculture - Respondent 2: river sedimentation hindered boat navigation; river widening program and desiltation that is done every 2 to 5 years **(iii) Biodiversity** - Mangrove serve as habitats for birds and marine life.

Themes	Sub-Themes
	- Respondent 1: the area is rich with local birds and migratory birds; about 200 Spoonbills seen in the area. - Respondent 2: concerns over the illegal hunting of baby birds
Biocultural resources	**(i) Local products and crafts** - Respondent 1: community relies on traditional resources such as Nypa products and dried fish; hoped for a grant to build a workshop to process dried fish as local products; challenges is to sustain the business to the younger generation. - Respondent 3: fish curry and coconut pancake is also a specialty for the area; challenge to find the youth to work **(ii) Traditional knowledge** - Community understands the local ecology - Respondent 1: calling for collaboration between researchers and locals for better project outcomes. - Respondent 2: routine of the fishermen's community, where the ones who catch fish go out at 4:30 in the morning, while the ones who catch prawn go out at 7:00 in the morning.
Ecotourism potential	**(i) Tourism activities** - Respondent 2: current tourism activities include bird watching, cockle harvesting and boat tours. - Respondent 3: visitors can go to explore Penang and Rimau Islands. **(ii) Infrastructure and development needs** - Respondent 1: proposed creating a gallery and workshop for visitors - Respondent 3: suggested a 'visitor adoption program'; there are around 50 families in Sungai Tembus. **(iii) Opportunities for modernisation** - Respondent 3: hopes for changes and improvements in the community's livelihood, including becoming 'modern fishermen' and leveraging tourism for economic growth. From September until November, it is usually high tide, and they do not go to the sea.
Socioeconomic challenges	**(i) Youth engagement** - Respondent 3: lack of interest among youth in traditional fishing **(ii) Economic barriers** - Respondent 3: high cost of fishing boats and the need for external support (e.g., grants) to improve facilities.

The perspectives from the respondents collectively highlight the challenges and aspirations of the Sungai Tembus community in balancing fisheries, conservation and tourism development. Fisheries is one of the primary livelihoods, with fishermen navigating changing environmental conditions. They all acknowledge the community's role in conservation, mainly through mangrove replantation programs, protecting local biodiversity and keeping the area in good condition. Tourism development is seen as an opportunity for economic

diversification, which could promote Sungai Tembus as a sustainable community-driven tourism.

The Way Forward

Community-Led Conservation

Community participation is crucial in ensuring the continuity of conservation efforts. The interviews' findings highlight the local residents' critical role in maintaining the mangrove ecosystems, protecting biodiversity and sustaining local products. Community-led conservation initiatives, supported by various agencies' collaboration, show the locals' commitment and environmental stewardship. However, as Sungai Tembus develops further as an ecotourism site, there needs to be stronger community governance supported by local policies and partnerships with conservation and sustainable tourism organisations. Establishing Community Conserved Areas (CCAs) could encourage more participatory decision-making platforms among the community to further support the resilience of Sungai Tembus' biocultural landscape.

Enhancing Biocultural Landscape Resources

The biocultural landscape resources of Sungai Tembus show the interdependency between the mangrove ecosystem and traditional livelihood activities, such as fishing and Nypa palm harvesting. Though these activities may not seem big in scale, they underscore the need to be sustained through targeted conservation and value-added initiatives. Local products, such as Nypa-based food and crafts, can be further developed through capacity-building programs and financial support and linked with the larger tourism products of Seberang Perai. The sustainable commercialisation of biocultural resources into biocultural products can position Sungai Tembus as a unique attraction in Seberang Perai. More efforts are needed to document and promote these resources to ensure that traditional ecological knowledge can be transmitted to the younger generations. Knowledge-sharing programs such as workshops and events can become the starting point for fostering collaborations between local communities, researchers, and policymakers.

Biocultural Tourism Development

Biocultural tourism has significant potentials to pave a sustainable economic development for Sungai Tembus. There are already well-known tourism activities, such as birdwatching, boat tours and customised rural experiences. To further develop the resources in Sungai Tembus, the community's and local government's approach should be done strategically and focus on low-impact and community-driven tourism initiatives. Training is crucial and this could be supported hand-in-hand with relevant NGOs, commercial entities and academic

institutions. Integrating edutourism into biodiversity and cultural heritage can generate supporting tourism products for the area and create awareness of the importance of biocultural resources for the younger generations. The infrastructure needs to be continuously improved while minimising environmental degradation to facilitate and enhance the quality of the visitor experience. However, it is vital that tourism development is not over-commercialised and over-developed and that equitable local benefits are ensured.

Investment in Training and Infrastructure

For Sungai Tembus to develop sustainably, tourism, conservation and economic progress must be community-centred. Investments should focus on ecotourism infrastructure, skills training for youth, and financial support for fishermen and Nypa producers. Grants for visitor centres, workshops for nature-based products and cultural tourism programs could help integrate biocultural resources into conservation strategies, ensuring economic resilience and environmental sustainability are achieved.

CONCLUSION

This study has explored the intricate relationship between community, conservation, and culture through the biocultural landscape resources of Sungai Tembus. The findings delineated integrating natural and cultural resources that serve essential roles in the local community and the need to sustain and enhance these resources. Local communities are the custodians of biodiversity and cultural heritage, making their participation in conservation and tourism essential. The mapping of the biocultural landscape resources of Sungai Tembus illustrated the area's interconnected ecological and cultural assets. The natural resources such as mangrove forests, migratory bird habitats and aquatic life are already an ecotourism attraction of the site, which could be further supported by traditional rural cultural heritage. However, collective efforts are needed to overcome the challenges of declining interest among the younger generations in traditional activities and economic barriers and to sustain the area's environmental quality. Integrating local knowledge, conservation efforts, and responsible tourism initiatives is imperative.

To preserve the ecological and cultural integrity of Sungai Tembus, a balanced approach is needed to promote biocultural tourism. Community-driven conservation programs and tourism business training can support the local community and foster economic growth. Any long-term sustainable development needs policy support, financial assistance and multi-stakeholder collaborations. Policies must empower local communities, ensuring conservation and tourism development efforts align with their traditional knowledge and aspirations. In conclusion, this study contributes to the broader discourse on biocultural resource

conservation and tourism by illuminating the roles and aspirations of the local community. Future studies could explore deeper community governance, resource management and tourism product development in rural areas. Integrating biodiversity, cultural heritage, and economic growth in Sungai Tembus can exemplify how biocultural landscape resources are intertwined and how they seek to balance preservation and progress.

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EXTRINSIC AND INTRINSIC MOTIVATION OF URBAN TOURISTS TO TRAVEL WITH PUBLIC TRANSPORT FOR LEISURE: ANALYSIS OF TRIPADVISOR REVIEWS

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Abstract

Analysis of online reviews on tourism studies has been widely used among researchers. Transportation plays an important role and acts as a medium to connect tourists towards tourist destinations. There is still a lack of studies concerning their reasons for using public transport. Hence, this study addresses to investigates the extrinsic and intrinsic motivation of tourists to use public transport in Kuala Lumpur through TripAdvisor. This research analyses 3,345 reviews of Go KL City Bus, Light Rail Transit (LRT) Kelana Jaya Line, Mass Rapid Transit (MRT), Monorail and RapidKL Bus in Kuala Lumpur, manually using NVivo 12.0 to determine their reasons for using the bus service through content analysis. The findings indicate that the majority of the tourists' motivation to ride public transport is for sightseeing and exploring the city for free. Understanding tourists' motivation to use public transport could assist tourism agencies in providing proper facilities for them to reach tourism destinations easily.

Keywords: TripAdvisor Reviews, Public Transport, Urban Tourists, Motivation

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INTRODUCTION

The internet become one of the needs that everyone relies on. These days, internet searching has become one of the main sources for tourists to obtain information on tourism destinations and activities. Tourists rely on sources including the internet to do some information searching regarding their trip and destination (Heitmann, 2010). This means applications, like TikTok and Instagram, are considered reliable sources for people to obtain information especially if it is related to their interests. TikTok has played an increasing role in influencing destination image, altering tourist behaviour, and mediating tourist experiences (Du et al., 2022). This sharing behaviour led others to rely on their experiences. For instance, TikTok users from China mentioned that watching such videos can motivate them to consider potential travel places in the future (Lu X. and Lu Z., 2019). This shows that online platforms are one of the important methods that people refer to. However, the online reviews from tourists on public transport services failed to be captured.

Little research has been done on determining the motivation to use public transport among urban tourists. The success of measures designed to minimise private car use through behavioural change is highly dependent on the psychological elements that impact individuals' transport mode decisions (Donald et al., 2014). Motivation has been identified as a key predictor of behaviour in a variety of contexts, including mode of transportation use (Fu and Juan, 2017). Taking account of the argument, the motivation to use public transport among tourists should be discovered.

This research aims to identify the motivation of tourists the use public transport to travel for leisure in Kuala Lumpur through TripAdvisor. TripAdvisor provides reviews from travellers for travel and hospitality businesses in the form of comments and ratings (Barreda and Bilgihan, 2013). The specific objective of this study is to explore the extrinsic and intrinsic motivation attributes that tourists consider in travelling by public transport through TripAdvisor site reviews. In this work, the research interest is particularly on the motivations of tourists who utilize public transport in Kuala Lumpur.

LITERATURE REVIEW

Self-Determination Theory (SDT)

This research adopted the intrinsic and extrinsic motivation from the perspective of Self-Determination Theory (SDT) by Ryan and Deci (1985). This research looks specifically at the extrinsic and intrinsic motivation with the SDT. According to SDT, the provision of support for needs improves intrinsic motivation and internalisation, leading to greater achievement. Conversely, the direct use of extrinsic rewards and evaluations to control achievement outcomes tends to have the opposite effect, resulting in lower-quality motivation and performance (Ryan and Deci, 2020). Even so, this research speculates that both

extrinsic and intrinsic motivation could positively drive tourists to use public transport. Motivation is closely related to the process of decision-making, and this variable has been widely discussed in tourism studies (e.g. Slabbert and Laurens, 2012; Vuuren and Slabbert, 2012). Motivation is regarded as one of the fundamental factors in the decision-making process of tourist consumers (Amorim, Jiménez-Caballero & Almeida, 2020).

Extrinsic Motivation

Extrinsic motivation refers to behaviours that are performed for reasons other than their intrinsic pleasures (Ryan and Deci, 2020). The benefits developed the interest of people to perform the behaviour. In tourism studies, the destination's attractions are perceived to dwell in the place of interest, for instance, culture, history, geography, and sites (Le-Klähn et al., 2015). The service offered attracts tourists to visit the destination. In this research, public transport is the external sources of motivation that encourage tourists to utilise the service. The selection of transportation mode is influenced by factors; time limitations, financial limitations, ease of access, and availability (Hall, Le-Klähn and Ram, 2017). The punctuality of public transport plays a crucial role in influencing a user's decision which leads to a substantial level of users' satisfaction (Lumsdon and Page, 2004). Regular commuters responded favourably to these services by expressing their positive impressions of punctuality (Sheikh Muhamad Hizam et al., 2021). The good services give users satisfaction; thus, they continuously use public transport. This shows that the service quality of public transport is the extrinsic motivation for tourists to travel by public transport.

Intrinsic Motivation

Intrinsic motivation pertains to participating in an activity due to its inherent appeal or enjoyment (Ryan and Deci, 2000). To be precise, intrinsic motivation represents the feelings that people gain after they experience extrinsic motivation. This research would like to adapt the motivational aspects to the use of public transport for leisure among urban tourists. For instance, tourists who visited the Camel Xiangzi Museum (CXM) in Qingdao, China were "Literary Motivated" due to their emotional connection with the legacy, author, intellectual aspects, and residence associated with the authors of the Camel Xiangzi novel (Bu et al., 2021). The tourists' sentiments towards the authors exemplify the inherent incentive that compels them to visit the museum. The study conducted by Sie et al. (2021) showed that self-determined motives and tour preferences have a significant impact on the creation of memorable experiences and emotions during holiday trips. Consequently, the tourists' feelings were unearthed after their journey. 'Exploring' (Oh, Uysal and Weaver, 1995; Katsikari et al., 2020) and 'mingle' (Oh, Uysal and Weaver, 1995; Paris and Teye, 2014; Richards, 2015) are some of the themes of tourists' motivation while travelling in their

destination, which this research assumes to share the same motivations to travel with public transport.

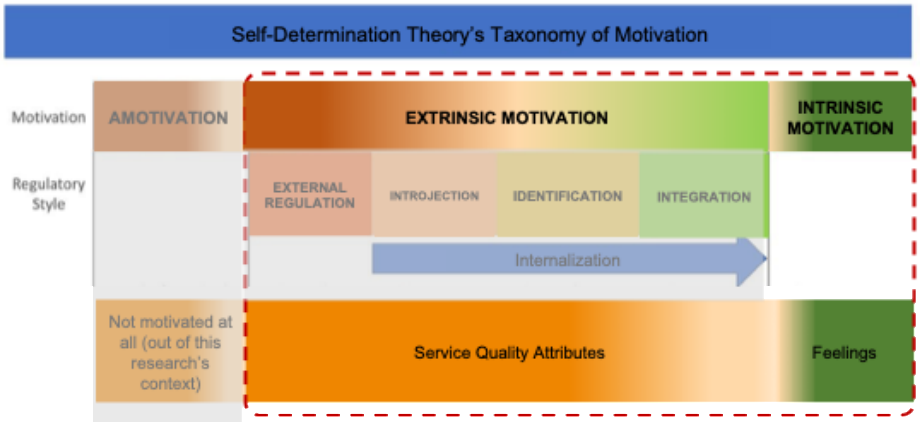

Figure 1: Theoretical Framework

RESEARCH METHODOLOGY

To answer all the research questions, this research obtained the reviews of users from the TripAdvisor platform. This method is known as Netnography. Archival data, elicit data and field note data are three types of netnography and this research uses archival data through the TripAdvisor website. This research was not involved in any creation of data and solely captured the reviews from the site.

TripAdvisor, Inc., runs user-generated content mobile apps, comparison shopping websites, and online travel agencies (TripAdvisor Inc. 2022 Form 10-K Annual Report, 2023). TripAdvisor is a platform for sharing travel experiences and a reflection of the growing use of modern technology by travellers to share their opinions of the sites and attractions they visit (Baleiro, 2023). This is also known as electronic word-of-mouth (eWOM). The discovery that the eWOM platform on which a review is posted can be a potential factor in influencing consumers' product evaluations contributes to our understanding of consumers' processing of eWOM (Lee and Youn, 2015). Participants who are less motivated to process information are more likely to make suboptimal decisions based on e-WOM-recommendations (Gupta and Harris, 2010). This indicated how powerful eWOM influences readers' decision-making by reading online reviews.

TripAdvisor is often regarded as a website that has fundamentally altered the way consumers make travel decisions, from information search to post-purchase (Amatulli et al., 2019). This indicates that one of the methods travellers use to learn about their destination is TripAdvisor. Since TripAdvisor requires each reviewer to register their personal information with them and

forbids the use of commercial email addresses, it appears that the site's policies are primarily concerned with verifying the credibility of the reviews provided (Jeacle and Carter, 2011). Additionally, TripAdvisor makes an effort to lessen the issue by prominently posting notices warning that fake reviews won't be tolerated and that hotels that try to game the system will suffer penalties in their rankings and have a notice posted on their listing disclosing that they have attempted to post fake reviews (O'Connor, 2010).

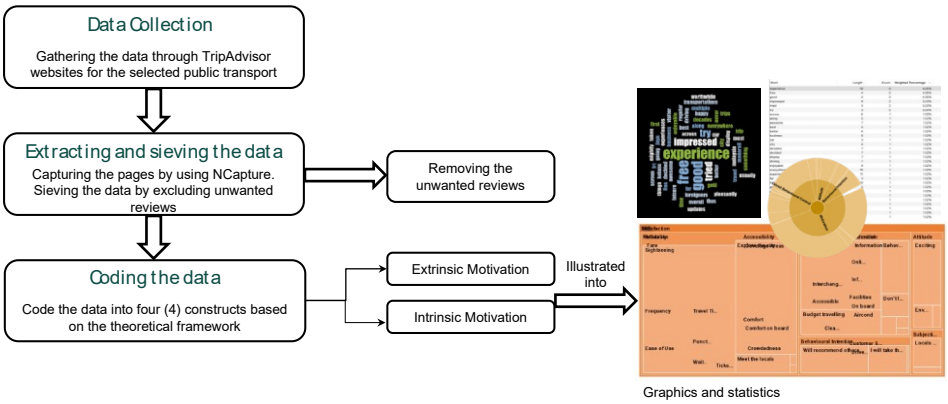

Figure 2: Steps of conducting this research

Data Collection on TripAdvisor

This research managed to gather 3,345 TripAdvisor reviews of five (5) modes of public transport in Kuala Lumpur. Public transport services are mainly located in urban areas to fulfil the needs of the people to commute. Kuala Lumpur, the capital city of Malaysia, has various alternatives to public transport to travel. Compared to other states, Kuala Lumpur is a high-density city, which explains the provision of public transport as well. There are many public transport users in Kuala Lumpur every day, including tourists. Therefore, this study selected Kuala Lumpur as a case study to conduct this research. This research only selected two categories of public transport: rail and bus.

Despite the public transport in Kuala Lumpur was established in 1996 (Yahya et al., 2020), it was found that the first review was written based on the experience of the users in 2014. Therefore, this research obtained reviews from 2014 until 2022, with a total of eight years. This research elicits their thoughts, experiences, satisfaction and tips on travelling by using the PT services based on their written reviews in TripAdvisors. The first step in obtaining the data is to select the type of Kuala Lumpur's public transport available in the TripAdvisor reviews.

Extracting and Sieving the Data

In this step, this research went through the selected public transport modes used by tourists to capture reviews on the page by using NCapture. Followed by going through the reviews at a glance and exploring the number of reviews and ratings given by each of the transport modes. This research investigated the users' profiles to identify the users' country of origin. It was discovered that there were many reviews from locals on the page as well. In this case, the reviews from those reviewers that declared Kuala Lumpur as their city from their profile were excluded because this study only focused on tourists' feedback.

Coding the Data

The last stage involved coding the reviews into two (2) constructs: extrinsic and intrinsic motivation. Extrinsic motivation, which is perceived as public transport services has seven (7) attributes, while intrinsic motivation as enjoyment has five (5) attributes. All the extracted reviews of public transport were analysed by using NVivo. Theoretical ideas taken from previously published literature serve as the codes in deductive coding (Linneberg and Korsgaard, 2019). This research coded all the reviews to determine their motivation by using a deductive approach. This method has been widely used by several previous studies including in tourism research and more (Garay, 2019 Chang et al., 2019). Each of the words and sentences was read line by line and coded according to the themes. Our analysis discarded any reviews that related to satisfaction because they focused on the motivation for using public transport services.

This research started with GoKL City Bus reviews on the page and captured each page from 1 to 5 stars. This research repeated these steps exactly for the other five (5) public transport services. This approach is being used to ensure all types of public transport services are being considered and to avoid bias. Figure 3 illustrates an example of how the excerpt has been reviewed and coded for this research. The reviewer found that the public transport system in Kuala Lumpur has been improved through accessibility when he revisits the city this year. The first sentence verified that this reviewer is a repeat visitor and used the same mode of transport with his recent visits.

The second sentence described how public transport has been improved and integrated into other parts of the city. This typically shows that both the first and second sentence is correlated with each other, and the reviewer repeated his behaviour during his recent visits. In this case, the action performed by the reviewer was influenced by his previous experience with the monorail. Therefore, this research classified both excerpts as extrinsic motivation: accessibility because the tourists mentioned the accessibility of the monorail.

In the last sentence, the reviewer declared that the monorail offers the city view since it is elevated. This sentence does not clearly picture the satisfaction on the sightseeing of the reviewer, but the reviewer only stated it as

'superb sightseeing'. Since TripAdvisor is one of the trustworthy websites of its popularity (Jeacle and Carter, 2011), the use of words in each sentence may influence the decision of any readers whether it is positive or negative feedback, thus, in such a situation, this research coded the last sentence as 'Sightseeing' in Motivation because this sentence may influence readers to ride monorail for sightseeing purpose.

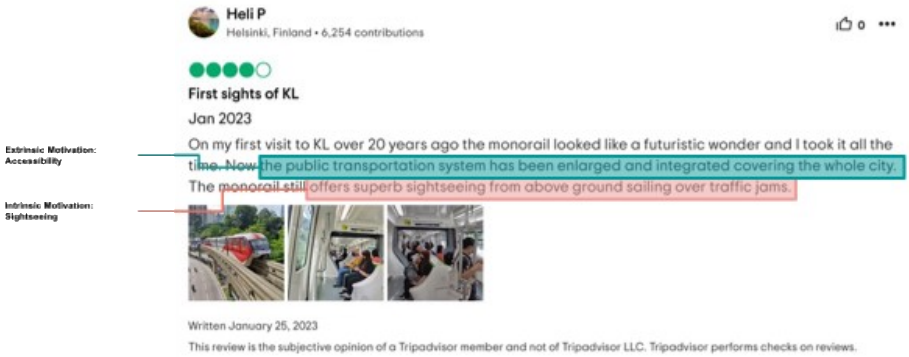

Figure 3: Illustration of TripAdvisor review

Figure 4: Map of public transport around the tourists' attractions in Kuala Lumpur

By referring to **Figure 4**, there are many public transport options offered to reach tourism destinations. Majority of tourist attractions focused on urban tourism destinations, for instance, Petronas Twin Tower, Menara Kuala

Lumpur and Pasar Seni. However, rails seem to be the most reliable transport because they connect directly towards the destination. Although RapidKL Bus provide a much wider destination, they offer too many stops and do not necessarily focus on tourist destinations.

ANALYSIS AND DISCUSSION

The demographic analysis showed that most of the reviewers came from Australia with 220 (6.56%), followed by the United Kingdom with 187 (5.06%). Meanwhile, TripAdvisor also received a single review from ten countries of origin (0.30%), which are Cambodia, Hong Kong, Iraq, and Kazakhstan. Kyrgyzstan, Maldives, Nepal, Hungary, Malta and Russia. This study also includes reviews from locals (2.4%) who do not stay or work in Kuala Lumpur because they are considered tourists as well.

Extrinsic Motivation

Figure 3 shows a Treemap result of the extrinsic motivation in NVivo 12.0. The reliability aspect was mentioned the most among the other attributes of public transport. Analysis of the 3,345 reviews on TripAdvisor revealed that the most prominent aspect of service quality was the reliability of public transport. Subsequently, comfort, accessibility, information, customer service, amenities, and safety followed. Even so, when it comes to evaluating the comments, these attributes are intertwined with each other. For instance, the fare is the most mentioned among all the sub-attributes, but it must be supported with good accessibility of public transport.

Frequency, travel time, punctuality, crowdedness

Increased frequency of public transport decreases the amount of time spent travelling. There are both positive and negative responses to the frequency. Based on feedback, the Go KL City Bus operates with a frequency of 5 minutes. Nevertheless, there have been instances where the bus failed to adhere to the scheduled arrival time. As one of the tourists mentioned,

It could be better for tourists if the bus is run on a more regular or timely basis. It happened that we didn't see a bus for over 30 minutes, and sometimes a few buses arrived at the same time.

This suggests that the tourists anticipated a high frequency of service. In the second phase, the visitors disclosed that they experienced a prolonged wait for the bus. Other tourists raised the same concern and advocated an alternative method of transportation, which is to use taxis. This suggests that tourists prioritise a faster means of travel when they are travelling. The dissatisfaction expressed by tourists regarding those buses is comparable to the disappointment

with the bus service in Lagos (Nwachukwu, Gladys and Chikezie, 2019). Nevertheless, this is in contrast with the reviews on rail transport. Many reviews advised taking the MRT to avoid traffic congestion. In addition, the frequent use of rail transit enhances tourists' satisfaction, which was found similar to the case in Munich (Le-Klähn, Hall and Gerike, 2014). However, KTM Komuter was the only rail transport that received more negative reviews. The dissatisfaction has arisen for almost 10 years of past studies (e.g. Khalid et al., 2014). This shows that the commuter has no improvement in its service. The infrequent occurrence of public transport resulted in a longer period of travel. The difficulty of travelling may prompt tourists to seek an alternative that facilitates their journey to their desired destination. Providing an additional mode of transportation is a tremendous method to avoid a lengthy journey.

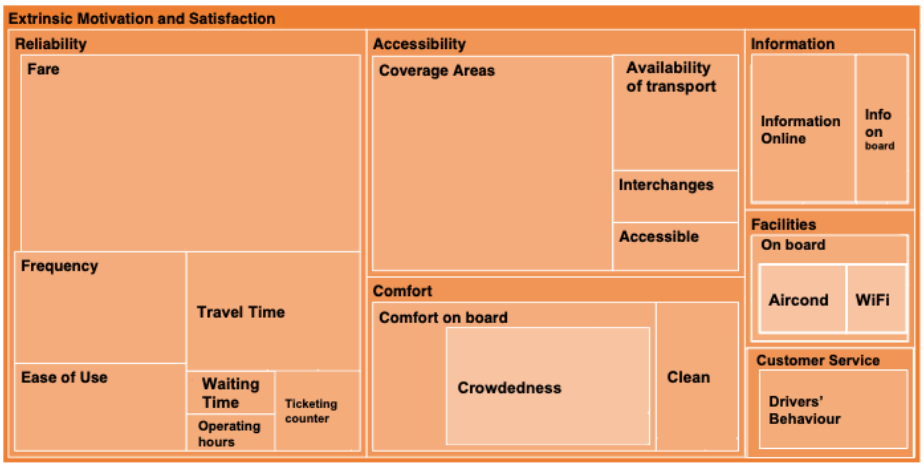

Figure 5: Result of the extrinsic motivation mentioned in TripAdvisor

Table 1: Distribution of reviews for each construct

Attributes	Sub-attributes	Frequency (%)	Sample Reviews
Reliability	Fare	562	"Free buses on four routes going around Kuala Lumpur"
	Frequency	161	"…the duration of each of the next bus is quite often"
	Ease of Use	127	"…easy to use…"
Accessibility	Coverage Areas	459	"It has a great network around the city so you can easily see all the important things that lie within its routes"
	Availability of public transport	130	"Regular bus service…"
	Interchange	58	"All these lines intersect at different stops which makes it possible to change lines and go many places in city center"

Attributes	Sub-attributes	Frequency (%)	Sample Reviews
Comfort	Crowdedness	220	"Gets packed during rush hour though"
	Cleanliness	106	"The bus was clean, comfortable"
	Comfort on board	98	"The ride was quite comfortable"
Information	Information on board	72	"Only the sound system what tells you the stops is poor"
	Online information	35	"KL transport system is good but then info is not easily available online"
	Information at the station	31	"Couldn't get a printed map from the tourist information offices and instead used a picture taken of the map at a bust stop"
Facilities	Air conditioner	109	"The buses are quite new and the air conditioning was good"
	WiFi	56	"… it also provides free Wifi"
Customer Service	Drivers' behaviour	77	"A more polite drivers, who always make sure the safety of the passengers"
	Driving skills	18	"Drivers very careful and helpful"
	Staff's behaviour	8	"very helpful and friendly staff"

Intrinsic Motivation

The findings suggested that there are three main items of motivation were determined to be significant, (a) sightseeing (34.6%), (b) exploring the city (22.3%) and (c) meeting the locals (3.13%). It was discovered that tourists commonly cited "sightseeing", followed by "to explore the city" as their motivations for utilising the public transport bus service in Kuala Lumpur. Several previous studies also found that "sightseeing" was one of the motivations of tourists to travel (Fodness, 1994; Oh, Uysal and Weaver, 1995; Katsikari, 2020). This relatively shows that sightseeing is one of the activities that tourists do when riding public transport. At the same time, they also be able to experience exploring the city and meet people who share the same interests.

In the case of Go KL City Bus, it has achieved one of its goals by providing a bus service for tourists to tour around Kuala Lumpur, as evidenced by several tourists' feedback on TripAdvisor, such as "a wonderful way to do sightseeing and getting to see the beautiful city of Kuala Lumpur" and "Go KL City Bus is a good way to travel around the city taking in the sights of KL for free". As described earlier, Monorail Kuala Lumpur received similar reviews from tourists. "A great way to see the city from on high and escape the throngs down below. Well worth making use of" is one of the reviews for the monorail. Many tourists find it interesting to ride a monorail because it is elevated and offers them a view of the city's skyscrapers. This indicates that tourists consider sightseeing as a part of their enjoyment while riding public transport. Some tourists find travelling by public transport as something fun to do, although they have to face massive traffic jams and crowdedness in the public transport itself.

The word 'overjoyed' as conveyed by the tourist indicated their exciting experience in riding public transport. This type of review convinces readers that riding public transport is something fun to do. This proves that motivation is related to attitude in performing a behaviour.

They also regard sightseeing in public transport as something worth doing. Interestingly, none of the reviews shares a bad side of sightseeing in the city although Kuala Lumpur faces traffic congestion every day. The city view that tourists were looking at were skyscrapers and buildings, such as Petronas Twin Towers, Menara Kuala Lumpur and Masjid Jamek. It is assumed that the view of the city is something that tourists find pleasing, no matter how the city looks like. The perspective of tourists on the city's view is different with locals. Tourists seek experiences, while locals prioritise service quality of public transport (e.g. Khalid et al., 2014; Allen et al., 2019; Sukhov et al., 2021). Locals do not regard sightseeing as a part of their travel motivation to use public transport.

There are many ways to explore the city, such as by walking and riding public transport. A written review, "This is a good way to get around the city, there are currently three colour coded bus routes each going to different areas of Kl taking in tourist attractions around the city" demonstrated the tourist's experiences in exploring the city with Go KL City Bus. This explains the benefits tourists get to enjoy on the attractiveness and services offered by the bus operator. This is partially resembling Richard (2015); Oh, Uysal and Weaver (1995), however, this research is in the context of travelling with public transport. This means that exploration of a city necessitates a picture of the travelled routes and destinations where tourists are drawn to services that facilitate good access to their destination of choice.

'Interacting with locals' is seen to be the least attribute in motivation. This activity requires a high interaction between tourists and locals. Kelly (2016) found that interaction with others is crucial for backpackers, therefore, by judging the reviewer's characteristics, it is assumed that the reviewer was among the backpackers. This is an interesting finding, as they share the same attitude in travelling by public transport with their reasons to visit the tourist destination. One review stated 'The buses are heavily used by commuters for work so it's a great way to mingle with locals' indicating the tourists' excitement to interact with locals although it was crowded. This finding is in contrast with the Hierarchy of Walking Needs by Alfonzo (2005), whereby comfort is one of the priorities in the hierarchy. In other words, tourists regard the circumstances on a positive side as they get the advantage of interacting with locals.

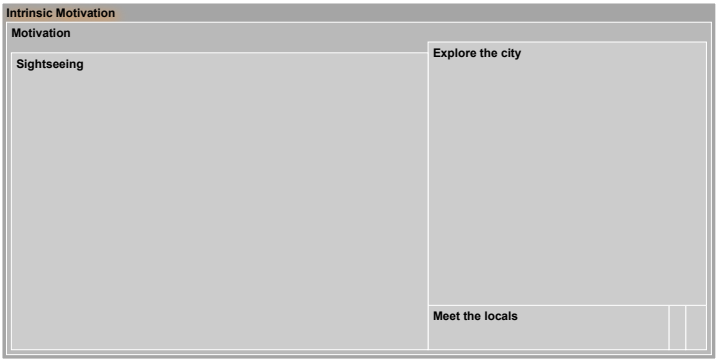

Figure 6: Result of the intrinsic motivation mentioned in TripAdvisor

Table 2: shows the distribution of each construct by public transport services.

Attributes	Frequency (%)	Sample Reviews
Would like to explore the city	93 (22.3)	"The GO KL City Bus has several routes that intersect so it really is a great way of getting around KL"
Engage with the locals	13 (3.13)	"If you have time to spare, and want to see some parts of KL that you wouldn't go or have missed out, as well as to mingle with the locals and tourists"
Sightseeing	144 (34.6)	"a wonderful way to do sightseeing and getting to see the beautiful city of Kuala Lumpur"

CONCLUSION

In conclusion, motivation to travel with public transport is primarily based on the seeking of experiences. It is also supported by the satisfaction of the public transit services, the beliefs of tourists, and the people around them. There is no correlation between an individual's motivation to travel and circumstances that force them to use public transportation. This also revealed that motivation is the willingness to accomplish the behaviour. Our findings show that people may demotivated to use the GoKL City Bus because of the heavy traffic that leads to longer travel time.

The present research has some limitations for future research. Firstly, this research solely adopts the TripAdvisor website to retrieve the reviews. Future research may consider any other online websites or social media, such as Google Reviews, YouTube, Twitter and more. These days, people rely heavily on internet sources which are referred to as e-wom. There are many of information that people can get from the internet. In this case, social media, such as Facebook, Twitter, Instagram and TikTok act as personal sources because people tend to share their itinerary through those applications. The evolution of the internet has made people to refer everything on social media. Moreover, our study focuses on Kuala Lumpur, one of the urban cities in Southeast Asia. Therefore, future studies

may discover more countries and analyse the differences in motivations between tourists in Malaysia and other countries. The possibility of different motivations could happen as a result of the situation of the city itself.

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AN INVESTIGATION OF TOURIST SATISFACTION IN MALAYSIA CULTURAL MUSEUM: INDOOR SPACE EXPERIENCE

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Abstract

Cultural tourism is an expanding sector of the global travel industry, with tourists seeking genuine and immersive experiences that connect them to the cultural heritage of the region. Malaysia's cultural museums enable visitors to learn about the country's diverse ethnic groups, religious practices, historical events, and artistic accomplishments. This proposed study aims to fill the existing research gap by conducting a comprehensive evaluation of tourist behavior in Malaysia's cultural museums. The research employs a quantitative method by collecting data through surveys from 381 respondents. The statements in the survey embody various elements, including education, escape, aesthetics, and entertainment. The results indicate that the aesthetic element is the most valued by the respondents during their visit, while the escape element is the least valued. The majority of the respondents belong to a younger age group, which tends to appreciate aesthetics the most. Almost one-third of the respondents visited the museum for work-related reasons, which explains why the escape element was the least appreciated. Historically, museums have evolved over time, with the earliest known as "Cabinets of Curiosities" in the 1500s. Existing museums can begin to incorporate other attractions or offer more activities to make the visit more engaging and enjoyable for visitors.

***Keywords*:** Cultural museum, tourist behavior, tourist satisfaction, experience economy

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INTRODUCTION

Cultural tourism is an expanding sector of the global travel industry, with tourists seeking genuine and immersive experiences that connect them to the cultural heritage of the region. Malaysia's cultural museums enable visitors to learn about the country's diverse ethnic groups, religious practices, historical events, and artistic accomplishments. The interplay between the museum environment, the presentation of cultural artifacts, and the perceptions and behaviors of tourists creates a complex web of interactions that necessitates systematic exploration.

Studies on tourist behavior in cultural museums have become increasingly popular in recent years. Researchers have examined visitor motivations, learning outcomes, levels of engagement, preferences for interpretive techniques, and the impact of socio-cultural factors on the museum experience. While extensive research has been conducted on museums worldwide, there is a lack of in-depth studies on Malaysia's cultural museums. This research is crucial for tailoring experiences to the interests and expectations of both local and international visitors.

This proposed study aims to fill the existing research gap by conducting a comprehensive evaluation of tourist behavior in Malaysia's cultural museums. The research will employ a mixed-methods approach, integrating quantitative methods such as data collection through surveys, and qualitative methods such as interviews. The objective of this study is to examine tourist behavior in Malaysia's cultural museums, focusing on aspects like visitor motivations, levels of satisfaction, patterns of interaction, and cultural engagement.

LITERATURE REVIEW

Tourism

The UNWTO technically defines tourism as the activities of individuals who travel to and stay in locations outside their regular environment for no more than one consecutive year for leisure, business, and other purposes unrelated to the performance of a paid activity from within the visited place. Lin and Simmons (2017) describe tourism as an activity that typically involves traveling into, out of, or within a country for recreational purposes. The author Susan and John (2007) identified 11 types of tourism according to the growth of tourism and the development of tourist behaviour which are Visiting friends and relatives, Business tourism, Religious tourism, Health tourism, Social tourism, Educational tourism, Cultural tourism, Scenic tourism, Hedonistic tourism, Activity tourism, Special interest tourism.

Tourist Behavior

Tourist behavior can be characterized as the activities tourists participate in, the goods they buy, and any extra services they utilize during their holiday (Juvan et al., 2017). This indicates that the term 'behavior' encompasses a broad range of

variables. This notion is backed up by Engel, et al. (1995), who also define tourist behavior as the activities directly related to acquiring, using, and disposing of products and services, including the decision-making processes that precede and follow these actions. Understanding tourists' behavior is essential for assessing the effectiveness of tourism planners and service providers (Amir, et al., 2017), as well as for planning and implementing future tourism services (Rana & Singh, 2004). Studying tourist behavior can be a critical element in the successful development of tourism services (Amir, et al., 2014).

Concept of Experience Economy

Experiences, which were once viewed as a component of services in economic terms, are now recognized as a distinct economic category, separate from both goods and services (Chin et al., 2005). This fourth economic category has become identifiable today due to the undeniable demand from consumers for experiences, and the growing number of businesses that are intentionally designing and promoting them. Pine & Gilmore (1998) proposed four domains of experiential value, known as the 4Es: Educational, Esthetic, Escapist, and Entertainment experiences. The nature of these experiences varies depending on whether the customer's participation is active or passive and the extent to which they are absorbed or immersed in the experience. As per the diagram below, the 4Es are differentiated by the kind of customer engagement. The Entertainment and Esthetic dimensions are characterized by passive participation in a business-provided experience, while active participation is common in Educational and Escapist experiences (Chin et al., 2005).

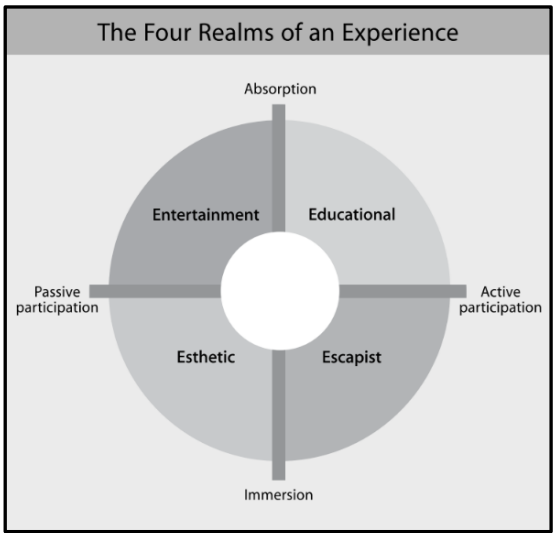

Figure 1: Pine & Gilmore's four realm of an experience
Source: Pine & Gilmore (1998)

RESEARCH METHODOLOGY

In this study, a questionnaire survey was utilized to collect quantitative data. A survey is a technique for assessing the views or experiences of a group of people by asking them a series of questions. Here, a questionnaire is defined as a collection of written or printed questions with a variety of possible answers. It is specifically designed to facilitate statistical analysis. For the data analysis, several methods including descriptive analysis by using frequency are presented in this paper.

The sampling size for this study is 380 respondents. There exist two categories of sampling methods: probability sampling and non-probability sampling. Probability sampling provides the most dependable representation of the entire population, whereas non-probability sampling depends on the researcher's discretion or chance, and typically cannot be employed to generalize about the whole population (Walliman, 2011). There are four types of probability sampling: simple random sampling, stratified sampling, cluster sampling, and multistage sampling. In this study, simple random sampling was the chosen technique, with questionnaires distributed via face-to-face interactions at various locations and through an online form.

Relative Importance Index is a technique in the analysis of relative importance. It was designed to determine the impact of a specific variable on the forecast of a criterion variable. The objects are organized to allow comparison of any two objects, one of which "rated higher," "rated lower," or "rated about the same" the other. A Likert scale is applied for relevant queries, before converting to Relative Importance Indices.

$$\text{Relative Important Index} = \frac{4n_4+3n_3+2n_2+1n_1}{A\times N}$$

n^4 = Number of respondents for Very Satisfy;
n^3 = Number of respondents for Satisfy;
n^2 = Number of respondents for Unsatisfy;
n^1 = Number of respondents for Very Unsatisfy;
A = Highest weight;
N = Total number of respondents.

ANALYSIS AND DISCUSSION

Most of the survey participants fall within the 19 to 24 age group, representing 34.6% of the total respondents. This is followed by the 25 to 34 age group, which accounts for 26.5%. The under 18 age group makes up 17.3% of the respondents, while the 35 to 44 age group comprises 15.2%. The age groups with the least representation are those over 65 and those between 44 to 64, with 0.5% and 1.0%

respectively. Detailed age group distribution of the respondents is presented in Table 3 below.

Table 1: Age group percentage of the respondents

Age group	Frequency (N)	Prcentage (%)
>18	66	17.3
19-24	132	34.6
25-34	101	26.5
35-44	58	15.2
45-54	18	4.7
55-64	4	1.0
>65	2	0.5
Total	381	100

Based on the survey, 29.4% of the respondents visit the museum to socialize with friends or family, while 23.6% do so to expand their knowledge. Formal visits account for 16.0% of the museum visits, and 7.9% of respondents visit for research purposes. Corporate events, meetings, package tours, and accompanying a friend are the reasons for 4.5% of the visits. The least common reasons for visiting the museum are to engage in sports activities (1.3%) and to attend exhibitions (3.9%).

Table 2: Purpose of visit by the respondents.

Age group	Frequency (N)	Percentage (%)
Formal visit	61	16.0
Increase knowledge	90	23.6
Research	30	7.9
Corporate event	17	4.5
Sport activity	5	1.3
Meeting	17	4.5
List of places in package	17	4.5
Hang out with friend or family	112	29.4
Accompany friend	17	4.5
Exhibition	15	3.9
Total	381	100.0

Table 3 shows in the lobby area, the survey participant primarily valued the assertion that the main lobby's ambiance is thrilling, signifying the elements of escape. This is followed by the aesthetic elements, as indicated by the

statement that the environment of the main lobby is distinctive and captivating. The least valued aspect is the entertainment element, as suggested by the statement that the lobby is engaging. This is followed by the educational elements, which are represented by the statement that the main lobby features an informative bulletin board.

Table 3: Rank of the most appreciated statement by the respondents in the lobby area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The main lobby/concourse has an informative information board.	352	747	62	13	1174	1524	6094	0.19265	3
The atmosphere in the main lobby/concourse is exciting.	388	735	38	20	1181	1524	6094	0.19380	1
The main lobby/concourse environment is unique and interesting.	388	717	54	18	1177	1524	6094	0.19314	2
The main lobby/ concourse is interactive.	276	804	60	14	1154	1524	6094	0.18937	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

Table shows the survey participants most valued the statement that the environment of the ticket hall entrance is distinctive and engaging, which suggests the aesthetic element. This is followed by the statement that the ticket hall entrance has an informative bulletin board, indicating the educational element. The entertainment element is ranked third, as suggested by the statement that the ticket booth entrance is interactive. Lastly, the statement that the atmosphere upon entering the ticket hall is thrilling, which signifies the escape element, is appreciated.

Table 4: Rank of the most appreciated statement by the respondents in the entrance of the ticketing area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The entrance to the ticket hall has an informative information board.	288	780	80	8	1156	1524	6094	0.18969	2
The atmosphere when entering the ticket hall is exciting.	276	702	138	9	1125	1524	6094	0.18460	4
The entryway environment in the ticket hall is unique and attractive.	352	741	80	6	1179	1524	6094	0.19347	1
The entrance to the ticket booth is interactive.	332	699	118	6	1155	1524	6094	0.18953	3

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

In the ticketing area, respondents most valued the educational element, as indicated by the statement that the ticket counter has an informative bulletin board. The aesthetic element, represented by the statement that the ticket counter environment is distinctive and captivating, was ranked second. The entertainment element, suggested by the statement that the ticket counter space is engaging, came in third. The escape element, represented by the statement that the atmosphere at the ticket counter is thrilling, was ranked last.

Table 5: Rank of the most appreciated statement by the respondents in the ticketing area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The ticket counter has an informative information board.	308	759	84	9	1160	1524	6094	0.19035	1
The atmosphere at the ticket counter is exciting.	304	678	108	23	1113	1524	6094	0.18264	4
The environment of the ticket counter is unique and interesting.	340	657	138	11	1146	1524	6094	0.18805	2
The space at the ticket counter is interactive.	264	705	138	11	1118	1524	6094	0.18346	3

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

Not all museums have exhibits in their ticketing areas, which is why only 355 responses were collected for the exhibit material there. The aesthetic aspect was the most admired, as evidenced by the statement "the exhibits at the ticket counter are unique and intriguing." The educational component, characterized by the statement "the exhibits at the ticket counter come with informative boards," was the second most appreciated. The escape element, represented by the statement "I enjoyed the exhibits at the ticket counter," was ranked third, while the entertainment element, indicated by the statement "the exhibits at the ticket counter are interactive," came in fourth.

Table 6: Rank of the most appreciated statement by the respondents toward the exhibit material in the ticketing area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
Exhibition materials in the ticket counter are equipped with informative information boards.	280	708	48	27	1063	1420	5680	0.18715	2
I appreciated the exhibits in the ticket counter	280	651	90	23	1044	1420	5680	0.18380	3
The exhibition materials in the ticket counter are unique and interesting.	324	663	70	18	1075	1420	5680	0.18926	1
The exhibit materials in the ticket counter are interactive.	232	699	84	22	1037	1420	5680	0.18257	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

At the entrance of the indoor exhibition area, the statement "the museum's exhibition space entrance has an informative board" was the most appreciated by respondents, signifying the educational element. This was followed by the statement "the museum's exhibition space entryway is unique and interesting," representing the aesthetic element. The least appreciated element was entertainment, as indicated by the statement "the museum's exhibition space entrance is interactive." The statement "the atmosphere is thrilling when entering the museum's exhibition hall" was next, indicating the escape element.

Table 7: Rank of the most appreciated statement by the respondents toward the entrance of indoor exhibition area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The entrance to the exhibition space in the museum has an informative information board	500	672	60	2	1234	1524	6094	0.20249	1
The atmosphere when entering the exhibition hall in the museum is exciting	516	636	46	17	1215	1524	6094	0.19938	3
The environment of the entry way in the exhibition space in the museum is unique and interesting.	484	702	38	7	1231	1524	6094	0.20200	2
The entrance to the exhibition space in the museum is interactive.	468	675	58	10	1211	1524	6094	0.19872	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

At the entrance of the indoor exhibition area, the statement "the museum's exhibition space entrance has an informative board" was the most appreciated by respondents, signifying the educational element. This was followed by the statement "the museum's exhibition space entryway is unique and interesting," representing the aesthetic element. The least appreciated element was entertainment, as indicated by the statement "the museum's exhibition space entrance is interactive." The statement "the atmosphere is thrilling when entering the museum's exhibition hall" was next, indicating the escape element.

Table 8: Rank of the most appreciated statement by the respondents in the indoor exhibition area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The exhibition rooms in the museum have informative information boards.	536	666	42	4	1248	1524	6094	0.20479	2
The atmosphere in the exhibition space in the museum is exciting.	564	642	30	11	1247	1524	6094	0.20463	3
The environment of the exhibition space in the museum is unique and interesting.	628	600	32	8	1268	1524	6094	0.20807	1
The exhibition space in the museum is interactive.	508	627	72	9	1216	1524	6094	0.19954	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

The educational aspect of the exhibit material in the indoor exhibition area was most valued by respondents, as evidenced by the statement "the exhibits in the museum's exhibition rooms come with informative information boards." This was followed by the escape element, represented by the statement "I concentrated on inspecting the exhibits in the museum's exhibition hall." The aesthetic element, indicated by the statement "the exhibits in the museum's exhibition space are unique and interesting," came next. The entertainment element, as shown by the statement "the exhibits in the museum's exhibition space are interactive," was the least appreciated.

Table 9: Rank of the most appreciated statement by the respondents toward the exhibit material in the indoor exhibition area

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The exhibits in the exhibition rooms in the museum are equipped with informative information boards.	564	666	20	8	1258	1524	6094	0.20643	1
I focused on examining the exhibits in the exhibition hall in the museum	556	636	38	11	1241	1524	6094	0.20364	2
The exhibits in the exhibition space in the museum are unique and interesting	508	696	22	11	1237	1524	6094	0.20298	3
The exhibits in the exhibition space in the museum are interactive.	496	666	36	17	1215	1524	6094	0.19937	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number.

The educational element is the most appreciated in the toilet area, as evidenced by the statement "the toilet has an informative information board". This is followed by the escape element, which is described by the statement "the atmosphere when in the toilet is exciting". The entertainment element comes next, represented by the statement "the toilet atmosphere is interactive". Lastly, the aesthetic element is ranked fourth, as per the statement "the toilet is unique and interesting".

Table 10: Rank of the most appreciated statement by the respondents in toilet

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
Toilet have informative information boards.	200	723	140	20	1083	1524	6094	0.17772	1
The atmosphere when in the toilet is exciting.	244	633	138	40	1055	1524	6094	0.17312	2
The toilet is unique and interesting.	200	648	158	36	1042	1524	6094	0.17099	4
The toilet atmosphere is interactive.	220	624	166	35	1045	1524	6094	0.17148	3

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

In the area of the souvenir or craft shop, the escape element is most valued by respondents, as indicated by the statement "the atmosphere of the souvenir and craft shop is exciting". The education element is the second most appreciated, as per the statement "the gift and craft shop has informative information boards". This is followed by the aesthetic element, represented by

the statement "the atmosphere of the souvenir and craft shop is unique and interesting". The entertainment element, described by the statement "the atmosphere of the souvenir and craft shop is interactive", is the least appreciated.

Table 11: Rank of the most appreciated statement by the respondents in souvenir and craft shop

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The gift and craft shop has informative information boards.	452	660	64	16	1192	1524	6094	0.19560	2
The atmosphere of the souvenir and craft shop is exciting.	480	633	74	13	1200	1524	6094	0.19691	1
The atmosphere of the souvenir and craft shop is unique and interesting.	460	630	68	22	1180	1524	6094	0.19363	3
The atmosphere of the souvenir and craft shop is interactive.	456	597	88	24	1165	1524	6094	0.19117	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

In eateries such as restaurants or cafes, the statement "the restaurant's ambiance is engaging" suggests that the entertainment aspect is highly valued. The escape factor, represented by the statement "the restaurant's atmosphere is enjoyable," comes in second. The aesthetic element, expressed through the statement "the restaurant's ambiance is distinctive and captivating," follows next. The statement "the restaurant possesses an informative bulletin board" signifies the educational component, which is the least favoured by the respondents.

Table 15: Rank of the most appreciated statement by the respondents in restaurant or cafe

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The restaurant has an informative information board.	328	615	98	18	1059	1416	5664	0.18697	4
The atmosphere in the restaurant is fun.	372	588	98	16	1074	1416	5664	0.18962	2
The atmosphere of the restaurant is unique and interesting.	352	603	98	16	1069	1416	5664	0.18874	3
The atmosphere of the restaurant is interactive.	400	618	78	9	1105	1416	5664	0.19509	1

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

In a resource center, the aesthetic aspect, as expressed by the statement "the resource center's atmosphere is distinctive and captivating," is the most

valued by visitors. This is followed by the educational component, represented by the statement "the resource center has an informative bulletin board." The entertainment factor, indicated by the statement "the resource center's environment is engaging," is the least appreciated. Meanwhile, the escape element, conveyed by the statement "the atmosphere at the resource center is thrilling," ranks third.

Table 13: Rank of the most appreciated statement by the respondents in resource center

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The resource center has an informative information board.	328	645	62	9	1044	1348	5392	0.19362	2
The atmosphere at the resource center is exciting.	384	618	32	9	1043	1348	5392	0.19343	3
The atmosphere of the resource center is unique and interesting.	364	612	66	9	1051	1348	5392	0.19492	1
The resource center has an informative information board.	328	645	62	9	1044	1348	5392	0.19362	2

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

In a research or seminar room, the aesthetic aspect, represented by the statement "the seminar/research room's atmosphere is unique and interesting," is the most favoured by the respondents. This is followed by the entertainment component, expressed by the statement "the seminar/research room's atmosphere is engaging." The education element, indicated by the statement "the seminar/research room has an informative bulletin board," is ranked fourth. Meanwhile, the escape factor, conveyed by the statement "the atmosphere in the seminar/research room is unique and interesting," is third in preference.

Table 14: Rank of the most appreciated statement by the respondents in research or seminar room

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The seminar/research room has an informative information board.	280	669	62	12	1023	1344	5376	0.19029	4
The atmosphere in the seminar/researcher room is exciting.	336	600	76	14	1026	1344	5376	0.19085	3
The atmosphere of the seminar/researcher room is unique and interesting.	392	603	54	10	1059	1344	5376	0.19699	1
The atmosphere of the seminar/research room is interactive.	372	615	48	14	1049	1344	5376	0.19513	2

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

In a mini theater, the aesthetic aspect, represented by the statement "the mini theater's atmosphere is unique and interesting," is the most favoured by the respondents. This is followed by the escape component, expressed by the statement "the atmosphere in the mini theater is thrilling," which is ranked second. The education element, indicated by the statement "the mini theater has an informative bulletin board," is ranked third. Meanwhile, the entertainment factor, conveyed by the statement "the atmosphere of the mini theater is engaging," is the least appreciated.

Table 15: Rank of the most appreciated statement by the respondents in mini theatre.

Statement	VS	S	U	VU	T	TN	A x N	RII	Rank
The mini theater has an informative information board.	320	654	54	8	1036	1332	5328	0.19444	3
The atmosphere in the mini theater is exciting.	404	591	54	8	1057	1332	5328	0.19839	2
The atmosphere of the mini theater is unique and interesting.	468	546	50	9	1073	1332	5328	0.20139	1
The atmosphere of the mini theater is interactive.	336	612	72	9	1029	1332	5328	0.19313	4

Note: VS=Very Satisfy; S=Satisfy; U=Unsatisfied; VU=Very Unsatisfied; T=Total; TN=Total Number

Table 16: Overall rank result of indoor area in cultural museum.

Components	**Education element**	**Escape element**	**Aesthetic element**	**Entertainment element**
Lobby area	3	1	2	4
Entrance of ticketing area	2	4	1	3
Ticketing area	1	4	2	3
Exhibit material in ticketing area	2	3	1	4
Entrance of indoor exhibition area	1	3	2	4
Indoor exhibition area	2	3	1	4
Exhibit material in the indoor exhibition area	1	2	3	4
Toilet	1	2	3	4
Souvenir and craft shop	2	1	3	4
Restaurant or café	4	2	3	1
Resource center	2	3	1	4
Research or seminar room	4	3	1	2
Mini theater	3	2	1	4
Frequency ranked first	**4**	**2**	**6**	**0**
Frequency ranked fourth	**1**	**2**	**0**	**9**

Based on the overall rank result, the most appreciated element is aesthetic element which ranked first at 6 components by the respondents which include entrance of ticketing area, exhibit material in ticketing area, indoor exhibition area, resource centre, research or seminar room and mini theatre. The survey reveals that 51.9% of the participants are 25 years old or younger. This demographic could significantly influence the study's findings. According to Annechini et al. (2020), younger individuals are more likely to appreciate and be drawn to aesthetics than their older counterparts. They believe that museums offer an environment conducive to effortless learning through high levels of fascination, which they consider the optimal experience. Cattaneo (2020) suggests that aesthetic appreciation is a result of the interplay between three primary neural systems: sensory-motor, emotion-valuation, and meaning-knowledge. Consequently, the interior of Malaysia's existing cultural museums seems to stimulate these neural systems in visitors.

The least appreciated element is entertainment element. It can be perceived at 9 different components which are lobby area, exhibit material in ticketing area, entrance of indoor exhibition area, indoor exhibition area, exhibit material in indoor exhibition area, toilet, souvenir and craft shop, resource center and mini theatre. Simpson (2009) suggests that a key reason people engage in tourism and leisure activities is to seek relief from personal and societal pressures. The fact that 16% of respondents visited the museum for formal reasons, 7.9% for research, and 4.5% for meetings held at the museum could explain why the element of escape is least valued. The dual role of museums as workplaces has been a longstanding issue. Forgan (2005) emphasized that museums serve as a crossroads between scientific research and public display, attracting significant interest from researchers. This dual role often leads to a conflict between viewing the museum as a place of leisure or work, which could be why the element of entertainment is least appreciated in the museum's indoor area.

CONCLUSION

In summary, this research has explored the visitor experience in the indoor section of a cultural museum in Malaysia. The study focused on several components of the museum, including the loby area. Entrance of ticketing area, ticketing area, exhibit material in ticketing area, entrance of indoor exhibition area, indoor exhibition area, exhibit material in the indoor exhibition area, toilet, souvenir and craft shop, restaurant or café, resource center, research or seminar room and mini theatre. The findings indicate that the aesthetic element was the most appreciated by the respondents, with 51.9% of them being of a younger age group. The escape element was the least appreciated, as 28.4% of the respondents visited the museum for work-related purposes.

As per Annechini et al. (2020), museums have evolved from the "Cabinets of Curiosities" that emerged in the 1500s, indicating that museums are

institutions that evolve over time. Thus, existing cultural museums can be transformed into tourist attractions that prioritize visitor experience. To enhance the escape element in the existing cultural museum, the overall environment can be made more activity oriented. For instance, the Formosan Aboriginal Village, a cultural museum in Taiwan, was transformed from a cultural village into an indigenous theme park divided into three sections: Aboriginal Village Park, Amusement Isle, and European Park. This village emphasizes the outdoor environment of Taiwan's nine major tribes.

Similarly, Malaysia's existing cultural villages could introduce workshops to enhance the escape element. This approach has been implemented in the Mah Meri Cultural Village, where visitors can learn crafting and carving skills from the Mah Meri tribes. Some of these skills require several classes or hours of learning to master, which can help visitors focus on their visit and forget about their work environment. For future research, it would be beneficial to select a specific cultural museum in Malaysia as a case study to obtain more precise data about visitor experiences using the same data collection method and analysis. Future studies could also consider measuring visitors' expectations before their visit to the cultural museum. This data could help identify the gap between visitors' pre-visit expectations and post-visit experiences, providing a more detailed analysis of whether the existing cultural museum meets tourists' expectations (Ab Rahman et al., 2023)

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HEDONIC PRICING MODEL (HPM) ON SOUTH TANGERANG RESIDENTIAL PROPERTY VALUE

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Abstract

This study investigates the effects of location, structural, and environmental attributes on residential property values in South Tangerang City, Indonesia. The research employs the Hedonic Pricing Model (HPM), formulated mathematically using the multiple linear regression approach to determine the relative contribution given by these attributes. To achieve the objective, data were collected from information on residential properties in South Tangerang City which is accessible on various property buying and selling websites. The data collection was limited from July 2023 to January 2024. The results showed that some variables affected the value of residential properties, such as distances to KRL stations, public parks, top high schools, and the Central Business District (CBD), as well as building areas, land areas, and the number of rooms (bathrooms and bedrooms). However, other variables, such as distances to malls, hospitals, universities, and population density, had no partial effect on residential property values. If we look at the types of variables, the standardized coefficient beta test revealed that building areas were the most dominant variable affecting the property values in the region. This finding is different from other results, showing that property values are local. The influence of property attributes can vary across regions, so the impacts and relationships are different, too.

Keywords: Hedonic Pricing Model (HPM), property value, residential property

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INTRODUCTION

Many studies have explored factors affecting the property values of land and buildings. Simply put, the studies agree that the building's location, environment, and character attributes are variables that shape the value of a property (Riyanto *et al*., 2021). These variables are then incorporated into the Hedonic Pricing Model (HPM). According to previous studies, HPM is commonly used in property valuation research to determine the factors that affect the price of a property (Güler et al., 2019; Sa'at et al., 2021). This model expresses that the price of a property is the sum of its individual attribute values (Lisi, 2019). The attributes or characteristics attached to the property include location, size, age, and quality (Price, 2017).

Appraisers must be able to analyze the relationship between property attributes and the value of the property. International Valuation Standards or IVS (2022) states that identifying and analyzing the characteristics of the appraised property enables appraisers to obtain an accurate estimate of the property value. Moreover, as property transactions increase, the need for accurate value estimation from appraisers will be increasingly needed.

Bartke and Schwarze (2021) state that appraisers have a role as "information intermediaries" in a real property transaction. The appraiser analyzes the characteristics of the property and the existing market risk to estimate the property value and then conveys this estimate to the buyer or seller. This information serves as the basis for buyers and sellers in negotiating and making decisions related to property transactions. By providing this information, appraisers help reduce information gaps and uncertainty in the real property market. Otherwise, buyers and sellers must rely on their own knowledge and expertise to estimate the value of a property, which can be time-consuming and complex.

This motivated the authors to conduct research on attributes or factors that affect residential property values in South Tangerang City. South Tangerang City was chosen due to its location in the Jabodebek-Banten area. It is one of the areas with increasing residential property buying and selling transactions in Indonesia. In addition, the development of the construction sector in this city has triggered demand for residential properties in the area. The results of this study will provide an overview for appraisers of how certain factors affect the value of residential properties in South Tangerang City so that the valuation results can be more accurate.

LITERATURE REVIEW

Hedonic Pricing Model (HPM)

The hedonic model was first introduced by Court (1939) in his research to analyze automobile prices in the United States. He stated that the hedonic model can be used to measure the value of an item with complex attributes, such as a car.

Court's results were further developed by other researchers, such as Lancaster (1966) and Rosen (1974).

Although the hedonic model was introduced by Court (1939), the theoretical basis for this model was first put forward by Lancaster (1966) through hedonic utility theory. He argued that the utility of a good is not derived from the good itself. Rather, it is the individual "characteristics" of a good that create its utility. In other words, the utility of an item is simply the combination of the individual utility of each of its characteristics.

Hedonic utility theory was used by Rosen (1974) as a basis for developing HPM. He argued that the value of a good is an aggregate of characteristics that produce utility. In other words, the total price of a good should be the sum of the individual prices of its characteristics. This implies that HPM can be used to "dissect" the price of an item into smaller parts of that item using certain analytical tools (e.g. regression). In this way, the contributions of each part to the overall value of the item can be identified (Sopranzetti, 2010).

Of many items, residential property is one type that uses HPM as a frame of reference (Sopranzetti, 2010). The price of a residential property depends heavily on its intrinsic and extrinsic attributes, each of which can be evaluated independently (Lisi, 2019). He noted that the monetary value of residential property attributes is implicit and cannot be observed directly. However, these attributes can be assessed through the selling price of the property and their relative contributions. Typically, these contributions can be measured using regression models

Linear regression is the most often used model to express the mathematical formulations of HPM on residential properties (Crespo & Gret-Regamey, 2013; Lisi, 2021). As previously explained, the monetary value of property attributes is implicit, but through regression models, the monetary contribution of each property attribute to property prices can be identified by estimating the coefficient of these attributes (Lisi, 2021; Rosen, 1974). The value of a residential property is analyzed based on its independent variables, which are usually a collection of structural characteristics, accessibility, and environment.

Factors Affecting Residential Property Value

Research suggests that location, structural, and environmental functions are the main attributes widely used in HPM for real property (Riyanto et al., 2021). These attributes can be further divided into several variables or factors, each of which can have a positive or negative impact on property values (Kauko, 2003). The contribution made by each variable also varies.

The first attribute is the location of the property. The immobility nature of residential property makes the location one factor that determines property value because buyers not only buy physical land and buildings but also the

location (Kiel & Zabel, 2008). Not surprisingly, there is a common saying that the three things that determine a house's price are location, location, and location.

Location is closely related to the monocentric model. The monocentric model states that residential property prices depend on the distance between the property location and the Central Business District (CBD) (Riyanto et al., 2021). Surianto et al. (2019) stated that CBD is the center of comfort needed by humans. Hence, properties near the CBD tend to have higher economic capabilities. However, the concept of location is not limited to knowing the relationship between property values and their distance to the CBD only. Some studies try to find out the relationship between property values and their distance to other objects, such as subway stations (Crespo & Gret-Regamey, 2013; Dai et al., 2020; Hong & Ryu, 2021; Mathur, 2020), shopping malls (Berawi et al., 2020; Farber & Yeates, 2006; Mathur, 2020; Surianto et al., 2019; Yilmazer & Kocaman, 2020), or public parks (Berawi et al., 2020; Hong & Ryu, 2021; Olanrele et al., 2023; Park et al., 2017; Sander & Haight, 2012). Thus, the value of residential properties is influenced not only by their distance to the CBD but also by their closeness to other important places.

The second attribute affecting the property value is the characteristics of the building. These characteristics can be the age of the building, design quality, area of space, number of spaces, quality of building materials, and room layout. Likewise, the physical and structural factors of the building can have a positive or negative effect on property prices (Moses & Yusoff, 2018).

The environment is the third property attribute. Price (2017) explained that although landscapes are not a common type of private item, their presence on a property can increase the marketability of the property. This opinion is in line with the results of a study by Cetintahra and Cubukcu (2014), mentioning that the aesthetics of the property environment can arouse a sense of joy, cohesiveness, and pleasure. Hence, it will affect the value of the property. In addition to landscape, other factors related to the environment also affect the value of a property, such as exposure to pollution and health (Price, 2017) or security and safety (Dai et al., 2020)

The three attributes described earlier indicate that the value of the residential property is local. Local factors such as location, environment (neighborhood), and available amenities have a greater influence on property value than global factors. In addition, residential property attributes can impact different areas in different ways due to cultural, economic, and social differences in each region.

RESEARCH METHODOLOGY

Model Building

This section outlines the methodology used in this study to analyze the factors influencing residential property prices. To do so, this study used the basic model

developed by Berawi et al. (2020), as illustrated in Figure 1. The model was developed to identify variables that affect residential property prices for landed houses and apartments near the first phase of the Jakarta MRT station construction project. The model has considered the influence of location attributes, property characteristics, and environment on residential property prices.

However, the author made adjustments to some variables. First, the authors adjusted the distance variable to the MRT station. In order for the variables to be more relevant to the local conditions, the condition variable was changed from the MRT station to the Commuter Line Train (KRL) station. The adjustment was made because KRL is the only type of train used as public transportation in South Tangerang City. In addition, the variables of apartment area, apartment communal land area, and apartment communal space area were also not used because the type of residential property analyzed in this study was limited to landed houses.

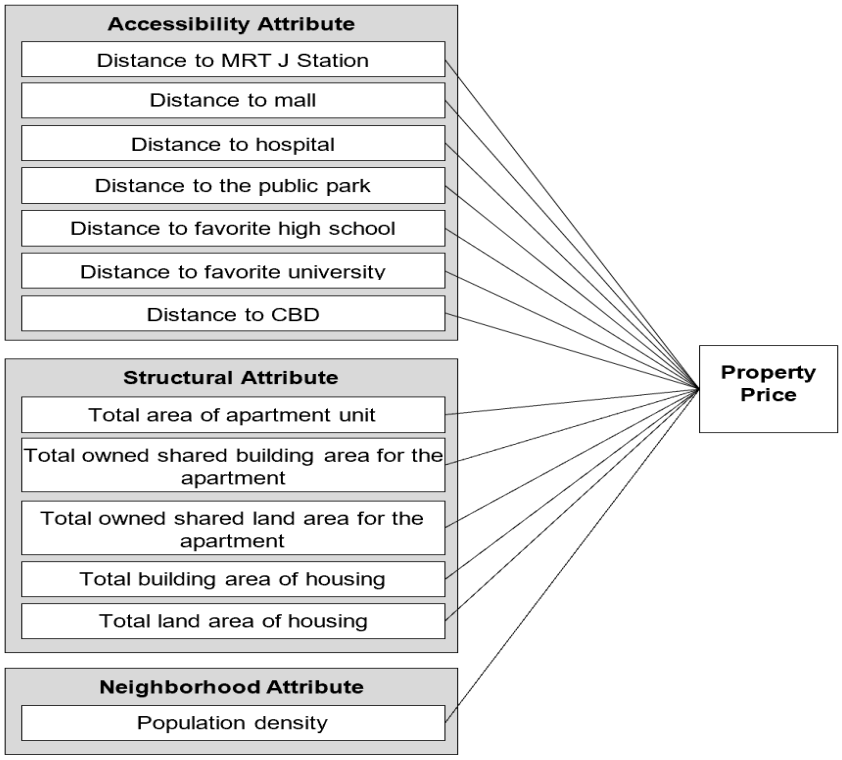

Figure 1: Base Model
Source: Berawi et al. (2020)

In addition to the model developed by Berawi et al. (2020), this study added several new variables that were relatively relevant to the study's objectives. New variables were added, including the number of bathrooms and bedrooms. Several studies have found a significant positive relationship between the number of bathrooms and residential property value (Bujanda, 2014; Hong & Ryu, 2021; Mathur, 2014; Mathur, 2019; Metz, 2015). Nevertheless, it is important to note that research also found a significant negative relationship between the two variables (Mathur, 2014; Mathur, 2019). The final model, which serves as the research framework, is shown in Figure 2.

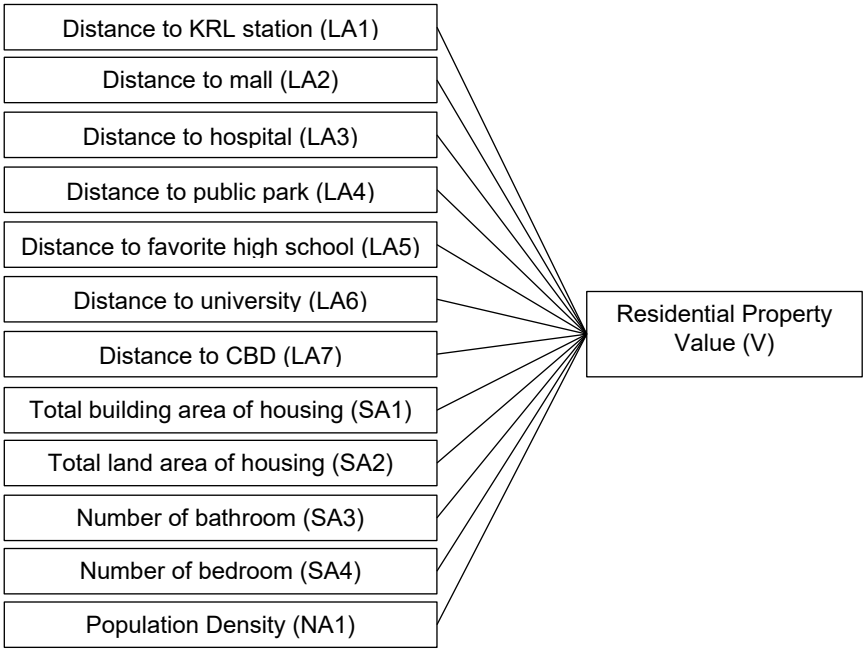

Figure 2: Final Model

Data Description

This research was conducted in South Tangerang and employed primary and secondary data. The primary data involved variable data related to property location, collected from Google Maps and measured based on actual distance. Meanwhile, the secondary data were information on residential property obtained from property buying and selling websites on the internet. The search was listed from July 2023 to January 2024. Secondary data in this study also included information about the population obtained from Statistics Indonesia.

The dependent variable in this study is the estimated property value in South Tangerang City. Before using this variable, the data needed adjustments

because the price was still in the form of the property offer price. To convert the offer price to the estimated transaction value, the offer price was reduced by a certain percentage, reflecting the difference between the offer and the transaction price. The study used a 6% adjustment to convert the offer price into an estimated residential property value. This percentage was obtained from research conducted by Riyanto et al. (2023). The study found that the offer price of residential properties in Jakarta is, on average, 6% higher than the transaction price. The variables used in this study are further described in Table 1.

Table 1: Description of Variables

Code	Description	Unit
Dependent Variables		
V	Estimated property value obtained from property buying and selling websites on the internet	Rupiah
Independent Variables		
Location Attributes (LA)		
LA1	Distance from residential property to the nearest KRL station	Meter
LA2	Distance from residential property to the nearest mall	Meter
LA3	Distance from residential property to the nearest hospital	Meter
LA4	Distance from residential property to the nearest public park	Meter
LA5	Distance from residential property to the nearest favorite high school	Meter
LA6	Distance from residential property to the nearest university	Meter
LA7	Distance from residential property to CBD	Meter
Structural Attributes (SA)		
SA1	Total building area of residential property	m2
SA2	Total land area of residential property	m2
SA3	Number of bathrooms owned by a residential property	Fruit
SA4	Number of bedrooms owned by a residential property	Fruit
Neighborhood Attributes (NA)		
NA1	Population density in the neighborhood around residential properties	Person/m^2

After collecting the data, multiple linear regression analysis was used to analyze and predict the value of the dependent variable from one or more independent variables (Saunders et al., 2019). A statistical application, Stata 14.2, was used to perform the multiple linear regression models.

Following that, classical assumption testing was applied to ensure the models' accuracy, consistency, and unbiased nature (Mardiatmoko, 2020). These tests included normality tests, multicollinearity tests, and heteroscedasticity tests. In addition, the authors also conducted simultaneous parameter tests (F-test) and measurement of the coefficient of determination (RSquare). The standardized coefficient beta test was also carried out to determine which independent variable has the most dominant influence on the dependent variable.

ANALYSIS AND DISCUSSION

Table 2 shows the results of the multiple linear regression of the dependent variable. It shows an estimated value of residential property and twelve independent variables that have been previously selected.

Table 2: Results of multiple linear regression analysis

V	Coef.	p-value	Beta	Sig
LA1	-82.134	0.013	-0.1197	*
LA2	-128.140	0.102	-0.1454	
LA3	21.481	0.769	0.0181	
LA4	-73.049	0.175	-0.0651	
LA5	92.644	0.063	0.0825	
LA6	209.091	0.001	0.2262	*
LA7	-177.479	0.002	-0.1593	*
SA1	8.707.070	0.000	0.5674	*
SA2	3.905.898	0.000	0.2310	*
SA3	3,185e+08	0.000	0.2977	*
SA4	-2.543e+08	0.000	-0.2709	*
NA1	33.375	0.257	0.0497	
Constant	4.364e+08	0.298		
Number of obs				136
Prob > F				0.0000
R-squared				0.8112
Adj. R-squared				0.7928

**p<0.05*

Source: Author's Calculation

In addition, to provide an alternative interpretation of the influence of the independent variable on the dependent variable, the author also transformed the linear model into a natural logarithm model (Ln), as shown in Table 3. The Ln model helps avoid heteroscedasticity, identifies coefficients that indicate elasticity, and bring the data scale closer. In a study on property valuation, Ishijima and Maeda (2015) stated that the application of linear models to property data does not always yield reliable results. Thus, the Ln model can improve the explanatory ability of the model, making it a widely used model among researchers for provides more accurate results.

Table 3: Results of multiple linear regression analysis (Natural Logarithm Model)

LnV	Coef.	p-value	Beta	Sig
LnLA1	-0.1263	0.035	-0.0986	*
LnLA2	0.0981	0.288	0.0836	
LnLA3	-0.0739	0.174	-0.0659	
LnLA4	-0.1449	0.010	-0.1224	*
LnLA5	0.1228	0.004	0.1194	*
LnLA6	0.0670	0.183	0.0796	
LnLA7	-0.1886	0.005	-0.1478	*
LnSA1	0.4995	0.000	0.4609	*

LnV	Coef.	p-value	Beta	Sig
LnSA2	0.3179	0.000	0.2320	*
LnSA3	0.4417	0.000	0.3544	*
LnSA4	-0.2842	0.018	-0.1763	*
LnNA1	0.1822	0.082	0.0725	
Constant	17.499	0.000		*
Number of obs				136
Prob > F				0.0000
R-squared				0.8255
Adj. R-squared				0.8085

**p<0.05*

Source: Author's Calculation

Table 4 summarizes the classical assumption tests for both regression models. Of the three tests, the linear model only satisfied the multicollinearity test. It failed to meet the normality and heteroscedasticity tests. Conversely, the Ln model met the normality, multicollinearity, and heteroscedasticity tests. Based on the results of these tests, the author decided to use the Ln model as the basis for analyzing the influence of location, structural, and environmental attributes on residential property values.

Table 4: Classical assumption testing

Classical Assumption Test	Testing	Model Linear	Model Ln
Normality	*Skewness and Kurtosis Tests*	0.0016	0.4014
Multicollinearity	*Variance Inflation Factor*	2.51	2.65
Heteroscedasticity	*Breusch-Pagan/Cook-Weisberg Test*	0.0000	0.5582

Source: Author's Calculation

Based on Table 3, the F-test results from the multiple linear regression analysis show that the twelve selected independent variables simultaneously affect the dependent variable. The results showed that 80.85% of the estimated value of residential properties in South Tangerang City could be explained by variables, such as distances to KRL stations, malls, hospitals, public parks, top high schools, universities, CBD, building area, land area, number of the bathrooms, number of the bedrooms, and population density. The remaining 19.15% was explained by other variables outside the twelve independent variables. Additionally, the standardized coefficient beta revealed that the building area variable (LnSA1) had the most dominant independent variables affecting the estimated residential property value (LnV).

Of the seven independent variables related to location attributes, four independent variables had a significant effect on the dependent variable. The four independent variables included distance to the nearest KRL station (LnLA1), distance to the nearest public park (LnLA4), distance to the nearest top high school (LnLA5), and distance to the CBD (LnLA7). Three other independent

variables – distance to the nearest mall (LnLA2), distance to the nearest hospital (LnLA3), and distance to the nearest university (LnLA6) – were found to have no significant influence on the dependent variable.

Among the significant variables, there was a significant relationship between the distance of residential property to the nearest KRL station (LnLA1) and the estimated value of residential property (LnV). Under conditions of other variables, the fixed value, a 1% increase in the distance to the nearest KRL station, reduced the estimated value of residential property by 0.1263%. This negative coefficient of LnLA1 confirms previous studies conducted at different locations (Crespo & Gret-Regamey, 2013; Dai et al., 2020; Hong & Ryu, 2021; Mathur, 2020). Mathur (2020) emphasizes that train stations are facilities that serve the entire surrounding community. Thus, their presence is a key factor affecting residential property values.

In addition to the proximity to KRL stations, Table 3 also shows the importance of public parks in determining property values. It shows that the distance of residential properties to the nearest public park statistically has a statistically significant and negative effect on the estimated value of residential properties at a 95% confidence level. The analysis indicates that a 1% increase in the distance to the nearest public park would reduce the estimated value of residential properties by 0.1449%. This result aligns with previous studies, such as Park et al. (2017) and Sander and Haight (2012). Public parks are perceived by the community as a place to provide education, entertainment, physical activities, and social interaction.

Similarly, the distance to the nearest top high school was another variable that significantly affected the estimated property value in South Tangerang City. The regression coefficient of the variable LnLA5 showed that a 1% increase in the distance between a residential property and the nearest top high school would increase the estimated value of the residential property by 0.1228%, assuming the value of the other variable is fixed. This finding differs from other studies that found a negative relationship between the distance to the nearest high school and the value or price of the property (Berawi et al., 2020; Hong & Ryu, 2021; Metz, 2015). However, Metz (2015) also found that residential properties that are too close to schools often have lower values due to the effects of disruption or congestion around the school.

Another critical attribute that might affect the property values was the distance to the Central Business District (CBD). This study revealed that this variable had a significant and negative influence on the estimated value of residential property. Each increase in the distance to the CBD by 1%, *ceteris paribus*, would reduce the estimated value of residential properties by 0.1886%. This finding confirms that the distance to the CBD is a consistently significant variable. Other studies conducted in different locations have shown that property values decrease farther from the CBD or city centre. (Batog et al., 2019; Berawi

et al., 2020; Dai et al., 2020; Farber & Yeates, 2006; Forys, 2022; Hong & Ryu, 2021; Mathur, 2014; Mathur, 2019; Metz, 2015; Surianto et al., 2019). This shows that closeness to the CBD is important for determining property values.

In addition to location attributes, Table 3 shows the roles of structural attributes in determining property values. It was reported that variables such as building area (LnSA1), land area (LnSA2), number of bathrooms (LnSA3), and number of bedrooms (LnSA4) had significance values smaller than the confidence level of 95% ($\alpha = 5\%$). Thus, it can be concluded that partially all independent variables related to structural attributes have a significant influence on the estimated value of residential properties in South Tangerang City (LnV).

This study shows that building area significantly influences the estimated value of residential properties in South Tangerang City. Each 1% increase in building area resulted in a 0.4995 increase in the estimated value of the residential property, assuming other variables remain fixed. Numerous studies have also found that building area positively affects residential property values (Batog et al., 2019; Berawi et al., 2020; Bujanda, 2014; Crespo & Gret-Regamey, 2013; Farber & Yeates, 2006; Mathur, 2014; Mathur, 2019; Mathur, 2020; Metz, 2015). The building area is closely related to space availability for daily activities. The larger the building area, the more space there is for resting, cooking, working, and other activities.

The land area variable is another independent variable that significantly affects the estimated value of residential property in South Tangerang City. Similarly, a 1% increase in land area would increase the estimated value of residential property by 0.3179%. This finding is in line with other studies conducted in different locations, which suggest that more land or parcel in a residential property generally leads to higher property value (Batog et al., 2019; Bujanda, 2014; Farber & Yeates, 2006; Forys, 2022; Mathur, 2014; Mathur, 2019; Mathur, 2020; Metz, 2015). It can be concluded that the influence of land area seems to be consistent across different locations

Further, the results of the study in South Tangerang City show a significant and positive relationship between the number of bathrooms and the estimated value of residential properties. The regression coefficient in the LnSA3 variable indicated that every 1% increase in the number of bathrooms increased the estimated value of residential properties in South Tangerang City by 0.4417%. This is congruent with earlier studies, stating that the number of bathrooms has a positive relationship with property value (Bujanda, 2014; Hong & Ryu, 2021; Mathur, 2014; Mathur, 2019; Metz, 2015). This finding is also in line with that expressed by Sirmans et al. (2005), who claim that the number of bathroom variables in HPM studies mostly produces a positive relationship. This is understandable because the bathroom is an important facility that supports activities for bathing, washing, and lavatory.

Another interesting variable that is taken into account is the number of bedrooms. In contrast, this variable statistically had a significant and negative effect on the estimated value of residential property at a 95% confidence level. This study's finding indicates that each 1% increase in the number of bedrooms reduced the estimated value of residential property by 0.2842% under fixed, variable conditions. Some studies have also found a significant negative relationship between the number of bedrooms and property value (Mathur, 2014; Mathur, 2019). In particular, Mathur (2014) argued that this negative relationship occurs because increasing the number of bedrooms can reduce the overall living space in a property, as the total area is divided among more rooms.

Regarding environmental (neighborhood) attributes, the population density variable (LnNA1) did not have a significant influence on the estimated residential property value in South Tangerang City (LnV). These findings are consistent with studies by Dai et al. (2020) and Olanrele et al. (2023), who also found no significant effect between population density and property values. However, other studies have also found that higher population density can lead to a decrease in the property value in surrounding neighborhood (Berawi et al., 2020; Bujanda, 2014; Crespo & Gret-Regamey, 2013).

CONCLUSION

This study has shown that the Hedonic Price Model (HPM) can be used to identify which attributes affect the value of a residential property and analyze the relative contribution of these attributes. The results revealed that the value of residential properties in South Tangerang City was significantly influenced by variables such as distances to KRL stations, public parks, top high schools, CBD, building area, and land area, as well as the number of bathrooms and bedrooms. On the other hand, distances to malls, hospitals, universities, and population density were known to have no effect on property values in this region.

These findings highlight that property values are local, and the influence of property attributes may have different impacts and relationships in different regions. This variation happens due to cultural, economic, and social differences in each region.

In appraisal practice, especially when using the market data comparison approach, HPM offers an alternative method for property appraisers to consider the effect of certain attributes on property values. Despite the promising results, this study still has a limitation, as the adjustment process tends to be subjective based on the experience and knowledge of each assessor. HPM can overcome this subjectivity issue because adjustments to HPM methods are more data-driven.

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LATENT DEFECTS: NAVIGATING THE DEFECTS LIABILITY PERIOD AND LEGAL ACTION DEADLINES FOR HOMEBUYERS IN MALAYSIA

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Abstract

This article provides a comprehensive understanding of latent defects in real property construction and a guide for homebuyers to navigate the defects liability period and legal action deadlines in Malaysia. Latent defects, hidden flaws that may emerge over time, pose significant risks to homebuyers. By uncovering the nature and implications of these defects, this article highlights the importance of recognising and addressing them within the defect liability period. It also explores the legal action deadlines set by the limitation legislation, emphasising the need to understand and adhere to these time limits for seeking remedies. This article serves as a valuable guide for homebuyers purchasing real properties from housing developers, ensuring they are equipped to identify and address latent defects, make effective use of the defect liability period, and initiate legal actions within the prescribed timelines.

Keywords: Defect Liability Period, Latent Defects Claims, Housing Developers, Limitation Act

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INTRODUCTION

In the realm of purchasing newly constructed properties, homebuyers anticipate a dwelling that is free from defects and safe for habitation. However, beneath the surface of the property, there are hidden risks known as latent defects, which may not be immediately noticeable but have the potential to appear and cause significant problems over a certain period of time. Understanding the concept of latent defects is of paramount importance for homebuyers, as it empowers them to effectively navigate the defects liability period and comply with legal action deadlines. This article aims to explain the topic of latent defects in constructed properties, providing insights into their characteristics, consequences, and the crucial need for prompt detection and resolution. In addition, it analyses the defects liability period prescribed under the Housing Development (Control and Licensing) Act 1966 (Act 118), the allocated timeframe during which developers hold responsibility for addressing defects after delivery of vacant possession to the homebuyers. It also explores the legal action deadlines prescribed by the Limitation Act 1953 (Act 254), which establishes time limits, particularly for initiating legal actions pertaining to latent defects. By providing a comprehensive understanding of latent defects, the defects liability period, and legal action deadlines, this article equips developers, homebuyers, legal practitioners, and policymakers with valuable guidance to navigate and refine the process of resolving latent defects claims.

LITERATURE REVIEW

Latent defects in real property construction have been a subject of concern and research in various contexts. Previous studies have highlighted the impact of latent defects on the structural integrity, safety, and aesthetic appeal of real properties (Chong & Low, 2006; Ali & Wen, 2011). It is essential to understand the causes, consequences, and potential mitigation measures to effectively address latent defects (Hassan et al., 2022) where a comprehensive legislation plays crucial roles in regulating real property construction and addressing defects (Wah, 2018). Previous literature also highlights issues in relation to poor workmanship, substandard materials, and construction processes which led to defects in real property (Abdullah et al., 2017a; Wena et al., 2017).

In Malaysia, Act 118 is a significant piece of legislation that aims to protect homebuyers and ensure construction quality (Sufian & Rahman, 2008). The Act provides provisions related to warranties, defect rectification, and developer's responsibilities. Additionally, Act 254 establishes time limits for legal actions, including claims for construction defects. Previous research has extensively explored the subject of latent defects in the context of constructed properties, including studies conducted in Malaysia, shedding light on various

aspects related to their identification, impact, and the legal frameworks surrounding them (Fatt, 2021).

In a Malaysian study conducted by Sibly et al. (2011) examined the occurrence and characteristics of latent defects in residential buildings within the local context. The research emphasised the need for homebuyers in Malaysia to be aware of these latent defects during the defect liability period and the importance of timely reporting to ensure effective resolution. Abdullah et al. (2017b) investigated the conduct of vendors and purchasers indirectly by analysing judicial rulings from Malaysia, Australia, and the United States. The cases reviewed demonstrate that buyers often neglect their obligation to perform pre-purchase inspections, while some vendors have been found to hide property defects and deceitfully misrepresent property conditions actively. The paper proposes consumer education initiatives targeting both vendors and purchasers, along with advocating for expanding the jurisdiction of entities such as the Tribunal for Homebuyers Claims to encompass disputes related to property conditions.

The above-mentioned studies conducted in Malaysia collectively highlight the importance of recognising and addressing latent defects in the local construction industry. They emphasise the significance of navigating the defects liability period and complying with the relevant legal action deadlines stipulated by Malaysian laws and regulations. By drawing on these studies, this article aims to provide valuable insights and guidance for homebuyers in Malaysia, enabling them to effectively address latent defects, comply with legal requirements, and protect their interests in the context of constructed properties.

RESEARCH METHODOLOGY

The methodology employed in this study focuses on a qualitative research approach that primarily examines relevant laws and decided cases. An extensive review of legal statutes, regulations, and precedent-setting cases in the Malaysian context was conducted to gain insights into latent defects, the defects liability period, and legal action deadlines. This study also conducts document analysis of data recorded by the Ministry of Housing and Local Government *(Kementerian Perumahan dan Kerajaan Tempatan, KPKT)* between the years 2018 and 2022 with regard to claims in the Tribunal for Homebuyer Claims (THC). This data analysis is essential in providing a comprehensive understanding of the legal frameworks and judicial interpretations surrounding these aspects of constructed properties for Malaysian homebuyers and the practical realities of the surrounding issues. A comparative analysis of the statutory provisions and case reports from the UK is also conducted to provide insights into the legal framework of latent defect and Defect Liability Period laws in the said jurisdiction.

ANALYSIS AND DISCUSSION

Defect Liability Period under Act 118

The Defect Liability Period (DLP) refers to the duration during which a contractor retains liability for rectifying any detected defects. The assessment of the adequacy of this period revolves around its capacity to accommodate the emergence of both patent and latent defects. Predominantly, deficiencies arise from inadequate workmanship and the utilisation of substandard materials throughout the construction process (Oluwole et al., 2012). The DLP under Act 118 establishes a specific timeframe, i.e. at 24 months from the date of delivery of vacant possession under Schedules G, I, H and J of Act 118, during which developers bear the responsibility for addressing defects in constructed properties. After the delivery of vacant possessions, homebuyers are required to inspect the property for any defects, damage, or poor workmanship. If any defects are found, homebuyers need to submit a written complaint to the developer or management office, requesting the necessary repairs at the developer's cost. To safeguard the homebuyer's interests, 5% of the purchase price is retained by the stakeholder solicitors, as specified in the statutory Sale and Purchase Agreement (SPA) between the developer and the homeowner prescribed under Act 118. This 5% retention sum (less the cost for repair works done, if any) will eventually be fully released to the developer after the expiry of the DLP.

Defects covered under the DLP may include any faults arising from defective workmanship or materials, as well as deviations from the approved plans and descriptions. As stated in Clause 27(1) or 30(1) of the SPA, respectively, the developer is obligated to repair and rectify such defects within 30 days of receiving a written notice from the homeowner. If the developer fails to rectify the defects within the given timeframe, homebuyers have the right to engage their own contractor to carry out the repairs. The cost of repairs must be communicated to the developer before commencing the works, giving them an additional opportunity to fulfill their obligations to repair. From the context of the homebuyers' right to take legal action against the developer for failure to make good of defects, the time frame is limited to 24 months from the date of delivery of vacant possession. However, at times there are cases where defects to the property may only appear after the expiry of the DLP which is known as 'latent defects. In such situations, it becomes vital for homebuyers to understand their rights to hold the developer accountable for the defects.

Section 16B of Act 118 establishes the Tribunal for Homebuyer Claims to enable disgruntled homebuyers to file a claim against housing developers without going to the courts (Latif, 2002). By virtue of section 16M, subject to sections 16N and 16O, the Tribunal shall have jurisdiction to determine a claim lodged under section 16L where the total amount in respect of which an award of

the Tribunal is sought does not exceed RM50,000. The limitations placed under section 16N include:

(i) It cannot handle claims regarding land recovery or disputes over wills, settlements, goodwill, choses in action, or intellectual property rights.
(ii) Its jurisdiction is specifically for claims arising from sale and purchase agreements between a homebuyer and a licensed housing developer.
(iii) Homebuyers must file claims within 12 months from the issuance of the certificate of completion and compliance, the expiry of the defects liability period, or the termination of the sale and purchase agreement.
(iv) If there is a prior dealing between the homebuyer and the developer regarding the housing, the absence of a sale and purchase agreement at the time of the claim doesn't affect it.
(v) The Tribunal cannot address claims related to personal injury or death.

Under section 16O, despite claims or issues exceeding RM50,000, the Tribunal can still hear and decide on them if there is a written agreement between the parties granting the Tribunal jurisdiction. Such an agreement can be made either before lodging a claim or even after a claim has been lodged but before the Tribunal has recorded an agreed settlement or made a determination. According to the statistics published by the Ministry of Housing and Local Government (*KPKT*) in 2023, the number of cases registered and solved by the Tribunal from 2018 to 2022 are as follows:

Table 1: Cases Registered and Settled by the Tribunal for Homebuyer Claims (2018 – 2022)

Year	Case registered	Case settled
2018	1,523	1,828
2019	2,356	2,232
2020	1,330	885
2021	1,352	1,540
2022	1,348	1,265

Source: KPKT (2023) KPKT Statistics.

While the statistics do not expressly provide data regarding cases involving latent defects, the data classifies the cases into technical and non-technical claims. Technical claims typically cover issues relating to defective workmanship, defects in construction materials, and non-compliance with the

building plans and specifications in the sale and purchase agreement as documented in *Remeggious Krishnan v SKS Southern Sdn Bhd [2023] 1 LNS 352*.

The statistics in 2022 regarding non-technical claims which cover defects are as follows (KPKT, 2023):

Table 2: Technical Claims Registered and Settled by the Tribunal for Homebuyer Claims (Jan – Dec 2022)

Month	Case registered	Case settled
January	19	63
February	20	75
March	10	26
April	20	21
May	7	16
June	15	19
July	13	25
August	12	21
September	24	28
October	13	33
November	12	22
December	27	20
TOTAL	**192**	**369**

Source: KPKT (2023) KPKT Statistics.

The number of cases according to States is shown as follows (KPKT, 2023):

Table 3: Technical Claims Registered and Settled by the Tribunal for Homebuyer Claims by States (Jan – Dec 2022)

State	Case registered	Case settled
Johor	44	47
Kedah	7	7
Kelantan	0	2
Melaka	4	2
Negeri Sembilan	1	3
Pahang	21	17
Perak	16	19
Perlis	1	1
Penang	10	20
Sabah	0	0
Sarawak	0	0
Selangor	61	113
Terengganu	2	4
Federal Territories	25	134
TOTAL	**192**	**369**

Source: KPKT (2023) KPKT Statistics.

Latent Defects under Act 254

"Defect" simply means the lack or absence of something essential to completeness per Bruce J in *Tate v Latham & Son [1987] 1 QB 506.* In this case, the court made a distinction between "patent defect" and "latent defect". A patent defect is one that is readily noticeable which can be imposed upon the buyer and typically stems from what is visibly evident or implied by it. Therefore, it would not be equitable to expect the purchaser to uncover all potential issues through extensive investigation beyond what is visibly apparent. Thus, the buyer should only be responsible for defects that are obvious upon inspection, including those that are a direct result of what is visibly discernible. Conversely, latent defects are hidden flaws or faults in constructed properties that are not easily discovered and may not be immediately apparent or observable during the initial inspection or handover or within the DLP. They often surface years after a building's completion or occupation which exceeds the DLP (Zolkafli et al., 2014).

In *Sanderson v National Coal Board [1961] 2 All ER 796* at 799, Holroyd Pearce LJ developed basic principles regarding defects:

(i) Defect is defined as failure of the product to meet an objective standard of safety that the court must evaluate.
(ii) The test for determining if a product is defective depends on whether its safety falls below the standards that public are entitled to expect. The test is objective in nature. Safety standard is measured based on the legitimate expectation of the public.
(iii) The assessment of legitimate public expectation requires consideration of all pertinent factual and legal circumstances. This evaluation must occur at the point when the product was supplied.
(iv) When determining whether a product meets the expected safety level, the court may consider all relevant information available at the time of evaluation, regardless of whether the information was available at the time of the sale or has been discovered later.
(v) The onus is on the buyer to establish defect and a causal link to the injury he suffers due to the defect.

In Malaysia, Section 6 of Limitation Act 1953 (Act 254) deals with the general limitation period for civil actions founded on tort or breach of contract. It establishes a general limitation period of six years for most civil claims, including claims related to latent defects, from the date the cause of action accrued. This means legal action must be initiated within this timeframe to preserve the right to seek remedies. Section 6 applies to actions founded on contract or tort, which includes claims for damages arising from civil wrongs negligence, nuisance, or trespass. It also covers actions related to the recovery of possession of land,

enforcement of charges, and actions to recover sums under written laws (excluding penalties or forfeitures). The limitation period is enacted primarily to dissuade litigants from neglecting their legal rights over time and to mitigate the uncertainties and potential anxieties associated with intentional delays in legal action (Balan, 2013).

Section 6 of Act 254 and DLP prescribed under the statutory SPA, means that while the DLP provides a specific time frame for reporting and rectifying defects, it does not override the stipulated limitation period. The DLP serves as a contractual agreement between the developer and the homebuyer, establishing the developer's responsibilities and obligations regarding defects during that period. However, if latent defects are discovered after the expiration of the DLP but within the six-year limitation period under Section 6, homebuyers will still have the right to pursue legal remedies for those defects against the developer. The rule of statutory construction necessitates the harmonisation of the legislation to maintain legal order, certainty, and consistency with legal norms in various forms of legislation (Sitorus et al., 2018).

Judicial Interpretation of Latent Defects and Defect Liability Period in Malaysia

Before 2019, there were several decided cases that emphasised the rights of homebuyers over latent defects against the developers. The court in Paramount *Gardens Sdn Bhd v Triple Well Sdn Bhd [2004] 3 MLJ 478*, addressed the issue of latent defects and the duty of the developer to rectify them. It ruled that the defect liability period provided under the housing development agreement was a crucial time frame for homebuyers to report and seek redress for latent defects. The Court of Appeal in *AmBank (M) Bhd v Abdul Aziz Hassan & Ors [2010] 3 MLJ 784* (Abdul Aziz's case) ruled that section 6(1)(a) of the Limitation Act serves as an absolute bar, and the courts do not possess the authority to extend the limitation period; such prerogative is reserved for Parliament. It was further decided *in Chip Aik Construction Sdn Bhd v Tan Saw Keow [2012] 7 MLJ 323*, that in solving the dispute of latent defects in a property, the court upheld that homebuyers must initiate legal action within the prescribed timeframe to preserve their rights.

The decisions made in the abovementioned cases were criticised for not adequately addressing the potential injustice caused by latent defects. This omission raised concerns about the fairness of outcomes for parties affected by such defects. The case of *AmBank (M) Bhd v Kamariyah bt Hamdan & Anor [2013] 5 MLJ 448* (Kamariyah) marked a notable departure from the strict interpretation which recognised the potential unfairness of adhering strictly to the limitation period if the damage was not reasonably discoverable within that timeframe. The court acknowledged that latent defects may only become

apparent after a significant period of time and that it is crucial to consider the discoverability of the damage. The Court of Appeal in Kamariyah introduced the concept of the "discoverability rule" to mitigate the potential unfairness resulting from a strict interpretation of section 6(1)(a) of the Limitation Act in the earlier case of Abdul Aziz. The discoverability rule suggests that the limitation period should commence from the date when the damage was discovered or when it ought to have been discovered.

Another case that highlights the application of the "discoverability rule" in the context of latent defects is *The Ara Joint Management Body v Mammoth Land & Development Sdn Bhd [2017] MLJU 631.* The case is about the discovery of latent defects in the buildings of The Ara Bangsar Development which came to light in 2014, seven years after the completion of construction in 2007. The joint management body of the development, acting on behalf of the residents, filed a lawsuit against the developer for latent defects in October 2016, a total of nine years after the completion of construction. While the developer relied on Abdul Aziz's case to seek the dismissal of the claim on the grounds that it was time-barred, the court, however highlighted and applied the "discoverability rule" in the context of latent defects. It was decided by the court that the limitation period for filing a claim related to latent defects starts running from the time when the defects are reasonably discoverable, rather than from the time of the property's completion or delivery. This decision recognised the importance of considering the actual knowledge or reasonable discovery of the defects by the affected party, providing flexibility in determining the starting point for the limitation period in cases involving latent defects. The case of *Dua Residency Management Corporation v Edisi Utama Sdn Bhd & Anor [2021] LNS 174* further affirmed the findings in Kamariyah that the cause of action will not accrue unless the defects have first been discovered.

While the Malaysian courts applied the initial strict enforcement of the six-year limitation period for claims regardless of whether the damage was known or discoverable, the case of Kamariyah brought about a shift in the courts' approach by introducing the "discoverability rule." This rule emphasised the importance of considering the actual discovery or when the damage should have reasonably been discovered. This development signifies the courts' recognition of the need to consider the practical aspects of latent defect claims and ensures a fairer assessment of when the limitation period should begin.

Judicial Interpretation in the UK

In reference to the UK's development on latent defects claims, a notable case that demonstrates this predicament is *Pirelli General Cable Works Ltd v Oscar Faber & Partners (1983) 2 AC 1* where a factory suffered damage due to the incorrect usage of construction material in the chimney. Although the chimney was

constructed in 1969, the faulty condition was only discovered in 1977, and legal action was initiated in 1978. The central issue revolved around whether the six-year limitation period should commence from the date of construction or when the fault could have been or was discovered. The House of Lords held that the cause of action in tort for damage resulting from negligent design or construction of a building arises at the point when the damage occurs, not when it is discovered or should have been discovered through reasonable diligence. Since the cracks in the chimney had formed no later than April 1970, which was more than six years prior to the claim, the action was barred by statutory limitation.

In *Ketteman and Others v Hansel Properties Ltd [1985] 1 All ER 352,* the court held that the plaintiffs' claims against the architects and the local authority were not time-barred, as the cause of action arose when the physical damage to their houses manifested, namely, when cracks appeared in the walls in August and September 1976. This occurrence fell within the six-year limitation period starting 27 May 1974. It was considered rare for a building to be deemed 'doomed from the start'. Additionally, the defendants could not invoke a limitation defence based on economic loss resulting from faulty foundations, as such loss could not give rise to a cause of action until physical damage occurred, unless the houses were deemed doomed from the outset.

In *London Borough of Bromley v Rush & Tompkins Ltd and Another 4 (1985) ConLR 44,* the issue was on the date of the accrual of a cause of action in tort for damage caused by the negligent design or construction of a building. Bromley brought forth claims against Rush & Tompkins for negligence and breach of statutory duty in constructing Sherman House, as well as against consulting engineers Shepherd for negligence in design or failure to ensure compliance with specifications. Sherman House, a large office block made of reinforced concrete, was completed around 1967, with Bromley occupying it in 1968. By 1975, cracks were observed in the exterior, and a detailed inspection in early 1976 revealed severe cracks indicating potential concrete spalling, posing a risk to pedestrians. Consequently, extensive remedial work was undertaken in 1977, with Bromley seeking damages for the expenses incurred. The court determined that the damage occurred when hairline cracks in the concrete, caused by corrosion of the steel reinforcement, appeared, which based on evidence, transpired before 5 March 1974. Thus, the cause of action arose more than six years before the writ was issued on 5 March 1980, rendering Bromley's claim statute barred.

To address the perceived harshness resulting from the decision in Pirelli’s case, the UK Latent Damage Act 1986 was enacted. This legislation aimed to amend the laws in the UK to provide a fairer approach to latent defect claims by introducing the concept of discoverability and allowing the limitation period to be calculated from the date when the damage could have reasonably

been discovered. These amendments were intended to strike a balance between the interests of claimants and defendants in latent defect cases, recognising the challenges posed by defects that may not become apparent until years after construction or occupancy (Mullany, 1991). The Latent Damage Act 1986 introduced sections 14A and 14B into the Limitation Act 1980. Section 14A permits a claim to be initiated within six years from the accrual of the cause of action or within three years from the discovery of a defect, with a maximum period of 15 years from the date of negligence under section 14B. This legislation, effective from 18 September 1986, does not extend to personal injury cases but applies to situations where damage resulting from negligence is discovered after the expiration of the standard limitation period. Its purpose was to address perceived injustices arising when hidden damage remains concealed long after the typical limitation period has elapsed (Butterworths, 2023).

The application of the Latent Damage Act 1986 can be seen from the case of *Horbury v Craig Hall & Rutley [1991] CILL 692 where* the defendant's surveyor conducted a survey negligently for the claimant. Minor errors were initially identified and rectified by the claimant without resorting to legal action. However, more significant errors emerged over three years after the survey, prompting the claimant to initiate legal proceedings. It was held that the three-year limitation period stipulated by the Latent Damage Act 1986 commenced upon the defendant's knowledge or deemed knowledge of the negligent survey, rendering the claim time-barred. The claimant's argument for a separate limitation period for the later discovered, more serious defects was unsuccessful; thus, was not permitted to abandon the earlier claims in favour of the later ones.

Latent Defects and DLP After 2019 in Malaysia

The decision in Pirelli's case carries persuasive value for Malaysian courts since Section 2 of the UK Limitation Act 1939 is similar to Section 6(1) of Act 254. The law on latent damage in West Malaysia is re-defined with the coming into force of the amendment to the Limitation Act 1953 on 1 September 2019, brought about by the Limitation (Amendment) Act 2018 (Amendment Act). Section 5 of the Amendment Act provides that Section 6A of the Act shall only apply to all action or proceedings for latent damage effective from 1st September 2019 and subject to the following criteria:

(i) the claim is for negligence not involving personal injuries;
(ii) the person having the cause of action have the knowledge required for bringing an action for damages in respect of the relevant damage, and a right to bring such action;
(iii) the action is brought within three (3) years from the date the damage was discovered; and

(iv) the fifteen (15) years limitation period under Section 6A(3) has not passed.

Thus, in the context of DLP, this provision allows a homebuyer to bring action against a developer for defects in the property within three years from the earliest date they have of such knowledge. This means that even if six years have passed since the defect occurred, the homebuyers still could file a claim within three years of discovering the defect. However, Section 6A(3) imposes a 15-year time limit for initiating legal action. This means that a homebuyer cannot commence proceedings 15 years after the cause of action arises. The cause of action can be based on a breach of contract (when the breach occurred) or tort (when the damage occurred). It is crucial to note that the homebuyer still has a responsibility to exercise reasonable diligence in discovering any damage as Section 6A(4)(b)(iii) indicates that the owner should have acquired knowledge about the damage from his observation or ascertainable facts or through appropriate expert advice that it was reasonable for them to seek.

The application of Section 6A of the Limitation Act in the context of the application of a defect liability period in construction cases are illustrated as follows:

Illustration 1 - AA purchased a house from BB, a developer in 2000. In 2005, AA discovered a crack that had caused significant damage to the walls. Upon investigation by an expert, it was revealed that the cracks had occurred in 2002, which was two years after AA had moved into the house. According to Section 6A (2), AA has a three-year limitation period from the time of discovery of the damage in 2005 to file an action in court against BB for damages. This means that AA must initiate legal proceedings within three years from the time they became aware of the crack. If AA fails to file the action within this timeframe, their right to seek compensation may be barred by the limitation period.

Illustration 2 - YY purchased a house from ZZ in 2000. It was only in 2017 that YY discovered a crack that had caused significant damage to the walls. After conducting a building report, it was revealed that the cracks had actually occurred in 2001, one year after C had moved into the house. In this case, YY cannot commence legal action against ZZ because they have already exceeded the 15-year limitation period outlined in Section 6A (3). According to this section, the right to file a legal action for damages resulting from a latent defect expires 15 years from the date the cause of action accrued. Since the cracks occurred one year after YY moved into the house in 2000, the 15-year limitation period would have expired in 2016, before YY even discovered the damage. Consequently, YY

is unable to initiate legal proceedings against ZZ due to the expiration of the limitation period.

In *Cekap Mesra Development Sdn Bhd v Che Seman bin Abdullah [2021] MLJU 2292,* the plaintiff found many defects in the property bought from the defendant based on a sale and purchase agreement (SPA) dated 6 March 2000. The said property was completed in 2002 and vacant possession was delivered to the plaintiff on 7 June 2002. Despite the rectification by the defendant, the plaintiff claimed that the defects continued to reoccur. In 2009, the plaintiff engaged an engineer to investigate the causes of the recurrence of the defects and was informed on 15 April 2009 that the defects were caused by the failure of structural support for the dead and live loads of the said property. The plaintiff then made complaints to the Ministry of Housing and several local authorities about those findings concerning the ill-constructed structural support of the said property, which was built by the defendant, but to no avail. He spent almost 10 years seeking resolution to his grievances after he discovered the defects in 2009 while continued paying the housing loan. In allowing the defendant's appeal, the High Court made the following observations:

(i) The plaintiff failed to clearly plead in the statement of claim of his cause of action against the defendant. Although the plaintiff's counsel's submission seemed to suggest that the claim was premised on the breach of SPA, there was no clear statement to the same effect in the statement of claim.
(ii) The statement of claim also failed to disclose any cause of action of a tort action. The statement of claim failed to particularise the defendant's duties and the breach of duties, if any.
(iii) The defect liability period had ended on 7 December 2003. Assuming that the defendant failed to rectify the defects within the period, the cause of action could have arisen against the defendant under clause 23 of the SPA. The limitation period for a case arising from the contract would end on 7 December 2009. The plaintiff filed his action in January 2021.
(iv) Assuming that the action was based on the tort of negligence, it was still barred by the six-year limitation.
(v) Even if the Court were to apply the specific provision of section 6A, the action is still time-barred. The section may, in the circumstances set out in the section, defer the limitation period to such time the plaintiff could have acquired the knowledge for bringing the action and the right to bring such action.

However, the determination of the date on which the cause of action accrued is still important for purposes of section 6A. In the present case, the absolute latest date that the plaintiff could have discovered and acquired the knowledge for bringing the action and the right to bring such action was at the time he was informed of the cause of the recurrence of the defects on 15 April 2009. Applying Section 6A (2) read together with Sections 6A(4)(a) and 6A(4)(b) of the Limitation Act, the plaintiff was allowed to take out an action within three years from 15 April 2009. The limitation period under Section 6A would have set in by 15 April 2012. Hence, even if the deferred limitation period is applicable, the plaintiff's action is still time-barred.

CONCLUSION

In conclusion, the application of Section 6A of Act 254 within the framework of a defect liability period in real property construction cases offers an extended timeframe for homebuyers to initiate legal action pertaining to latent defects. While the defect liability period establishes a specific duration during which developers are accountable for rectifying defects, Section 6A introduces a broader limitation period. It serves to mitigate potential injustices by granting homebuyers the opportunity to pursue legal remedies for latent defects against the developer even after the defect liability period has expired. It provides an extended timeframe to identify and address hidden defects that may not have become apparent within the initial defect liability period. Under the new provision, the homebuyers can bring actions against developers for latent defects within three years from the time they discovered the damage regardless of the time that has passed since the defect occurred. However, the homebuyers could not initiate legal proceedings more than 15 years after the date of cause of action occurred. The interaction between the defect liability period and the limitation period introduced in Section 6A establishes a balanced approach, allowing for the responsibilities of developers and the rights of homebuyers to be upheld.

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THEMATIC EXPLORATION OF THE GASTRONOMY OF ORANG ASLI PAHANG

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Abstract

The Orang Asli Pahang commemorate their cultural heritage with vibrant cultural gastronomies. These gastronomies, embodying the spirit of community, culture, and nature, are integral to preserving ancestral customs and fostering social cohesion. This study thematize the intricacies of the gastronomy to better understand the inspiration, interrelationships with other domains of cultural heritages and other specifics involved the gastronomy. Purpose: The primary objectives are (i) to document the cultural gastronomy of Orang Asli Pahang, and (ii) to assign themes to the cultural gastronomy widely applicable to all tribes of the Orang Asli in Pahang. Method: Qualitative research method is employed to explore, document and thematize the cultural gastronomies of Orang Asli Pahang. Such methods include content analysis, semi-structured interviews, and thematic analysis. Findings: There exists a rich tapestry of cultural gastronomy that interrelate with other domains of cultural heritage. Cultural gastronomy of the Orang Asli is often inspired by the immediate environment and its natural resources. Indigenous communities often base their cuisine on local plants, animals, and landscapes. This close connection to the environment affects ingredient selection and generations-old hunting, gathering, and preparation methods. Concerning all tribes of Orang Asli Pahang, the cultural gastronomy is thematized under foraging approaches, raw cooking ingredients and name of dish and dish preparation.

Keywords: Intangible Cultural Heritage, Cultural Gastronomy, Orang Asli Pahang

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INTRODUCTION

This paper aims to establish the themes that are widely applicable to the documentation of cultural gastronomy across all tribes of the Orang Asli in Pahang. This study significantly contributes to the ongoing investigation into the field of Intangible Cultural Heritage [ICH], with a specific focus on the indigenous culture of the Orang Asli in Pahang.

In pursuit of documenting and assigning the metadata for the repository of cultural gastronomy among the Orang Asli in Pahang, the primary objectives of this paper are outlined below:

i. To document the cultural gastronomy of Orang Asli Pahang,
ii. To assign themes to the cultural gastronomy widely applicable to all tribes of the Orang Asli in Pahang

CULTURAL GASTRONOMY METADATA AND THEMES

Cultural gastronomies are primarily classified under the fifth domain of UNESCO's Convention for the Protection of the Intangible Cultural Heritage. The fifth domain is about traditional craftsmanship. However, the manifestation of any specific ICH is not limited to one domain. Often, the completion of a single cultural manifestation requires multiple ICH domains (Abu Bakar, et al., 2014).

Museums and heritage institutions frequently use various types of repositories to document and manage cultural heritage materials and items. Metadata is essential for the operation of a cultural repository because it allows for the organisation and discovery of cultural materials, ensures consistent standardisation, provides contextual information, and enables preservation and management. This process improves accessibility and interoperability across cultural manifestation archives. Metadata is information that explains and contextualises specific data (Monova-Zheleva et al., 2020). For example, metadata for a cultural manifestation may include the title, location, participants, and materials used.

The critical metadata for cultural gastronomies includes (i) the incorporation of ICH domains and (ii) the identification of themes, which refer to the underlying inspiration and motivations for the gastronomy's manifestation. The incorporation of ICH domains refers to categorising cultural gastronomy based on the domains outlined by UNESCO's Convention for the Safeguarding of the ICH, ensuring that they are classified within the existing framework. The identification of themes focuses on the underlying causes that define each cultural gastronomy. This may include marital celebrations and seasonal changes.

With this intention, this study seeks to thematize the complexities of cultural gastronomies to better understand the underlying motivations, interrelationships with other domains of cultural heritage, and other specifics involved in cultural gastronomy of the Orang Asli.

UNDERSTANDING CULTURAL GASTRONOMY

Gastronomy examines food appreciation, preparation, and enjoyment across cultures. Food's historical, traditional, ritualistic, and customary aspects are examined to determine its role in identity, social cohesion, and values and beliefs. The term ‘gastronomy’ comes from ‘gastro,’ meaning cooking, and ‘nomi,’ meaning rules or laws. The social, cultural, and religious meanings people attach to food-related objects and behaviours make it more than just food preparation and consumption. Food is central to gastronomy research and appreciation. Exploring food involves choosing high-quality ingredients, mastering culinary techniques, understanding diverse flavour profiles, assessing nutritional factors, and acknowledging the profound cultural, historical, and social significance of food production and consumption. Food is also studied in semiotics, which studies food meanings. Besides its physical function, food has cultural and intellectual meanings. It is one of the 'grey zones' of cultural and heritage tourism, along with religion, events, festivals, and architecture (Amir et al., 2017; Abdillah et al., 2020; Rojas-Rivas et al., 2020; Arana & Zúñiga, 2022).

The Orang Asli culture has a rich gastronomic heritage that is deeply rooted in traditional practices, which are inextricably linked to their cultural identity and relationship with nature. Their culinary traditions are a rich tapestry of flavours, cooking techniques, and food-related rituals that reveal profound insights into their way of life and beliefs. The Orang Asli, unlike other ethnic groups, maintain their distinct culinary identity by continuing to rely on traditional cooking methods, such as using bamboo over wood stoves, which impart unique flavours to their dishes and set them apart from other communities (Manaf, Omar, & Mohamad, 2022).

Despite their rich culinary heritage, Orang Asli traditional foods have received little attention on the global stage, with few records documenting their recipes and preparation techniques. Their culinary practices are deeply connected to the environment, with ingredients sourced directly from the surrounding forests and natural landscapes. Like indigenous tribes around the world, the Orang Asli rely on plant resources for survival and nourishment, emphasising the importance of subsistence agriculture in their traditional economy. They grow a variety of crops, including upland rice, millet, corn, yams, bananas, and a wide range of vegetables such as pumpkins, long beans, cucumbers, and okra. These ingredients not only nourish their diet, but also demonstrate their deep connection to and reliance on their natural surroundings. Globally, indigenous communities' reliance on plant-based resources emphasises the importance of sustainable agricultural practices in preserving cultural heritage and ecological balance (Anuar et al., 2023). Gastronomy provides a holistic view of the complex relationships between people, environments, and cuisine. Beyond food, it reflects history, geography, and social dynamics.

METHODOLOGY

This study conducted qualitative research, in particular a thematic literature review driven by the objective formulated, followed by content and thematic analyses to establish existing findings. Multiple resources were utilized, such as books, journals, reports, academic publications, community documentation and scholarly articles on Orang Asli Pahang. The initial findings helped to shape the creation of interview questions and an organization that enabled smooth discourse during the interview sessions with different Orang Asli tribes.

Guided by key themes and sub-themes identified in the initial findings, the semi-structured interview aimed to explore and document the gastronomy of Orang Asli Pahang. The semi-structured interviews were conducted primarily with community leaders, known as *Tok Batin*, or, if they were unavailable, with key representatives of the targeted communities (refer to Table 1). The interviews were audio-recorded and later transcribed for further analysis. The analysis was principally focused on identifying the names of the gastronomies, the involvement of ICH domains, and assigning suitable themes to the cultural gastronomy (refer to Figure 1).

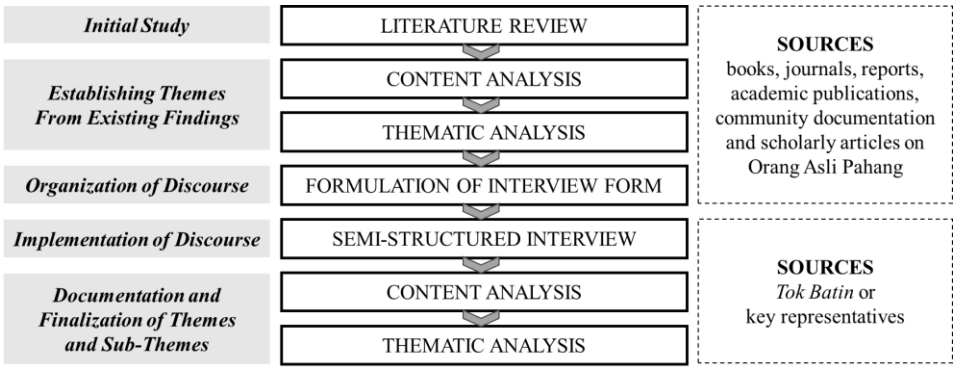

Figure 1: Flowchart of Fieldwork Approach

Table 1: Targeted Community for Semi-Structured Interviews

Targeted Community	Daerah	Tribes
Kampung Kuala Atok	Jerantut	Bateq
Kampung Sungai Pian	Temerloh	Jah Hut
Kampung Kuala Enggang	Temerloh	Che Wong
Kampung Sungai Rening	Cameron Highlands	Semai
Kampung Kuala Boh	Cameron Highlands	Semai
Kampung Sungai Tiang	Jerantut	Semoq Beri
Kampung Pelawan	Bera	Semelai
Kampung Sungai Bot	Bentong	Temuan
Kampung Gumum	Pekan	Jakun

FINDINGS

The gastronomies of Orang Asli Pahang essentially are culturally rooted, using local ingredients and traditional cooking methods.

Transcribed Interview Data

The following sections indicate the summary of cultural gastronomy-related findings from the semi-structured interviews of each Orang Asli Pahang tribe.

Orang Asli Batek

The tribe consume the prey they hunted, including monkeys, squirrels, frogs, wild fowl, moths, freshwater fish, and forest plants like wild yams, tubers, fruits, agarwood, bamboo, rattan, resin, honey, and others. River and forest hunting are the main food sources. The men are responsible to find products with economic value. These animals are killed with bamboo blowpipes. The blowpipe sharp tip or Mata Damak is filled with poison as bullets to kill the prey. Learning to blowpipes begins in childhood where the children will be taught to use blowpipes by tying their stomachs with canes to test their strength in blowing out the evil eye. If the tied cane breaks, the child is qualified to hunt with the adults. In case of poisoning, blowpipe antidote is brought along during hunting.

Orang Asli Jah Hut

The tribe considers rice their staple food. They also consume the prey they hunted daily as side dishes, such as fowl, frogs, and small animals. They also feed on cassava tubers cooked in bamboo by burning. *Kerabu Bunga Betik* using *Perah* Fruit. The elders can make the energy drink by mixing seven types of herbs to related to *Tongkat Ali*, namely *Payung Ali, Misai Ali, Janggut Ali, Urat Ali, Wali Ali, Ubi Jaga* and *Kacip Siti Fatimah.*

Orang Asli Che Wong

The tribe consume the prey they hunted in the forest and rivers. They also consume sago worms as a protein source as well as cassava tubers as starch.

Orang Asli Semai

The tribes consume their crops, such as Huma rice, millet, corn, cassava tubers, banana, caladium and various types of vegetables such as pumpkin, long beans, cucumbers, okra beans. The protein they consume are mainly from the prey they hunted, such as monkeys, fowl, wild boars, birds, lizards, squirrels, and freshwater fish. The tribe practice a traditional economy based on subsistence agriculture. Getting food is typically accomplished by hunting and fishing, which are mostly done by men. Hunting equipment such as blowpipes, snares, *Belatik* and traps are crafted using forest resources.

Orang Asli Semoq Beri

The primary food source for the tribe is the prey they hunt in the forests and fish in the rivers such as wild fowl and freshwater fish. They also consume tuber.

Orang Asli Semelai

Tapioca is the staple crop for the tribe. Other popular foods include Stamp fish, *Tudung Periuk* fish, and oil-free stir-fried yams. *Pulut Kukus Periuk Kera* is a traditional dish consumed by the tribe. This dish is highly unique in that it necessitates the steaming of glutinous rice prior to consumption. In the past, the indigenous community utilised Huma rice, a type of glutinous rice, to steam glutinous rice in a cooking vessel. The intimate relationship between the indigenous community and the natural environment is illustrated by the use of a pot that is derived from a wild plant. During the wedding feast, chicken-based side dishes must be served, while yellow glutinous rice and sweet glutinous rice must be prepared during the circumcision feast (one plate of yellow glutinous rice and sweet glutinous rice per boy). The tapioca and other ready-to-cook foods are served in bowls. Food will be served in bowls and arranged lengthwise. The side dish is placed in the middle while the rice placed on the side of the dish. Food should be served in the order started by serving water to wash hands, then rice and after that side dishes (for example, stew) are served. It is encouraged to arrange the plates kneeling so that it looks more polite. Arranged plates should not be stacked and served in a chipped state. If that is the case occurs then a penalty of RM 80 will be charged.

Orang Asli Temuan

The common staples are boiled or roasted cassava tubers, while *Daun Semomok* is used as replacement for onion. The tribe's culinary preparations typically involve boiling or roasting food over an open flame, and the use of garlic and onions is infrequent. The common staples are boiled or roasted tapioca or *Ubi Kiki*r - fermented, dried out in the sun, then roasted until it becomes granulated. Others include *Sambal Bunga Kantan*, *Pucuk Rebung*, the tender shoots of bamboo plants, are commonly prepared by frying them with chilli for enhanced flavour. For protein, the tribe favours jungle fowl, which is marinated with thinly sliced *Daun Semomok*, salt, chilli, and turmeric, stuffed into bamboo, and roasted over fire. Ikan Pais, another popular protein dish, is marinated in *Tempoyak* (fermented Durian), fresh turmeric, and Kulim leaves, which adds flavour and aroma and later wrapped in banana leaf and roasted over fire.

Orang Asli Jakun

For protein, the tribe consume the prey they hunted, including lizards, squirrels, frogs, and wild fowl. *Ubi Sireh* is a traditional food of the Jakun tribe, consisting of a tuber wrapped in *Palas* leaves. *Ubi Kacau,* or stir-fried yam is another traditional food of the tribe made from cassava tubers. The cassava tubers will be

soaked for several days, dried in the sun, and crushed until it crumbles. The crushed cassava tubers will be stirred in a pan on low heat. Stir-fried yam can be eaten with other side dishes, such as bamboo shoots.

Themes of Orang Asli Cultural Gastronomy

Based on the transcribed interview data, three (3) themes for metadata for cultural repository were generated to encapsulate the interview findings:

1. Foraging Approaches: Equipment and Craftsmanship or Skills
   This refers to the method of gathering food and resources from nature, which include hunting, fishing, and gathering wild plants.
2. Ingredients: Carbs. /Starch/Grains, Protein, and/or Vegetables/Fruits.
   These are the unprocessed ingredients used in cooking, such as fruits, vegetables, meats, grains, herbs, spices, oils, and other natural ingredients are used to make dishes.
3. Name of Dish and Dish Preparation
   This refers to the dish's name and its preparation technique, including cooking, seasoning, and presentation.

The themes are applied as metadata to organize the interview data on the cultural gastronomy of Orang Asli Pahang.

Table 3: Foraging Approaches

Tribes	Equipment	Craftmanship/Skills
OA Bateq	Bamboo Blowpipes	Hunting small animals
		Bamboo blowpipes with *Mata Damak* (sharp-tipped darts) filled with poison to kill their prey.
	Bamboo Canes	Children are trained from a young age to use blowpipes. They tie their stomachs with canes to test their strength in blowing the darts. If the cane breaks, the child is deemed strong enough to hunt with the adults.
	Poison Antidote	Hunters carry an antidote for blowpipe poison to use in case of accidental poisoning.
OA Semai	Blowpipes, Snares, Traps *Belatik*	Hunting small animals, such as fowl, wild boars foraging plants and farming (traditional subsistence agriculture)
OA Jah Hut	unspecified	Hunting small animals and foraging herbs
OA Che Wong	unspecified	Gathering wild plants, hunting wild fowl and other small animals, and fishing freshwater fish, and farming (traditional subsistence agriculture)
OA Semoq Beri		
OA Semelai		
OA Temuan		
OA Jakun		

Table 3: Raw Cooking Ingredients

Tribes	Carbs/Starch/Grains	Protein	Vegetable/Fruits
OA Bateq	honey	monkeys, squirrels, tragulus, frogs, wild fowl, rodents, freshwater fish	Cassava tubers, fruits, agarwood, bamboo, resin
OA Jah Hut	rice (staple), cassava tubers	fowl, frogs, small animals	-
OA Che Wong	cassava tubers	sago worms	-
OA Semai	*Huma* rice, millet, corn, tapioca, tuber, banana, caladium	monkeys, fowl, wild boars, birds, lizards, squirrels, freshwater fish	pumpkin, long beans, cucumbers, okra beans
OA Semoq Beri	cassava tubers	wild fowl, freshwater fish	-
OA Semelai	cassava tubers (staple), stamp fish, tudung periuk fish, oil-free stir-fried yams	*Tudung Periuk* fish, Stamp fish	-
OA Temuan	boiled or roasted cassava tubers (staple)	jungle fowl, *Ikan Pais* (type of fish)	*Daun Semomok*, bamboo shoots
OA Jakun		lizards, squirrels, frogs, wild fowl	cassava tubers *Palas* leaves,

Table 4: Name of Dish and Dish Preparation

Tribes	Name of Dish	Dish Preparation (Craftmanship)
OA Jah Hut	*Ubi Kayu*	Cassava tubers is placed in bamboo and cooked by burning the bamboo.
	Kerabu Bunga Betik	Cooked with Perah fruit
	Energy drink	Elders mix seven types of herbs related to *Tongkat Ali* (*Payung Ali, Misai Ali, Janggut Ali, Urat Ali, Wali Ali, Ubi Jaga,* and *Kacip Siti Fatimah*).
OA Semelai	*Pulut Kukus Periuk Kera*	Glutinous rice is steamed in a cooking vessel derived from a wild plant.
	Chicken-based dishes	Chicken dishes must be served during wedding feasts.
	Yellow/ Sweet Glutinous Rice	These dishes are prepared for circumcision feasts, with one plate of each per boy.

Tribes	Name of Dish	Dish Preparation (Craftmanship)
OA Temuan	*Ubi Kayu*	Cassava tubers is fermented, dried out in the sun, and then roasted until it becomes granulated.
	Sambal Bunga Kantan	-
	Pucuk Rebung	Tender bamboo shoots are fried with chili for enhanced flavor.
	Marinated jungle fowl	Jungle fowl is marinated with thinly sliced Daun *Semomok*, salt, chili, and turmeric, then stuffed into bamboo and roasted over fire.
	Ikan Pais Bakar	Fish is marinated in *Tempoyak*, fresh turmeric, lemongrass and *Kulim* leaves, then wrapped in banana leaf and roasted over fire.
OA Jakun	*Ubi Sireh*	Tuber is wrapped in Palas leaves
	Ubi Kacau	Cassava tubers is soaked for several days, dried in the sun, and crushed until it crumbles. The crushed cassava tubers is then stirred in a pan on low heat. This dish can be eaten with other side dishes, such as bamboo shoots.

These findings suggest that Orang Asli Pahang mainly consumes root vegetables like cassava tubers, and *ubi takop*, supplemented by hunting wild chicken and freshwater fish. They also grow tuber plants around their homes and purchase food from stalls in their villages. Further research indicates that some hawkers regularly visit the villages to sell food supplies to the indigenous communities.

Orang Asli demonstrates a diverse range of sophisticated foraging techniques through hunting, fishing, and gathering in their natural environment. They employ snares, traps, and bamboo blowpipes with poison-tipped darts to hunt small animals such as monkeys, squirrels, frogs, sago worms, wild fowl, and freshwater fish. Alongside gathering forest plants such as tubers and bamboo shoots using basic foraging methods, they also practice subsistence farming focusing on cultivating and harvesting starch food, fruits, and vegetables.

These tribes also use many local raw cooking ingredients. Their dishes feature wild plants, forest produce, and traditional fishing and hunting methods, reflecting their close relationship with nature. Cassava tubers, wild fowl, freshwater fish, bananas, pumpkin, long beans, cucumbers, and fruits are common ingredients among tribes. Every tribe has its own cooking style shaped by nature and culture. Energy drinks from Jah Hut contain seven Tongkat Ali herbs. Traditional Semelai food includes *Pulut Kukus Periuk Kera* and steamed

glutinous rice. Temuan cuisine includes boiled or roasted tubers, *Ubi Kikir*, *Sambal Bunga Kantan*, *Pucuk Rebung*, marinated jungle fowl, and *Ikan Pais*.

Orang Asli's innovative use of natural cooking materials shows their connection to the environment. Bamboo and Periuk Kera exemplify this resourcefulness. Bamboo is strong and versatile, making it a great cooking vessel. Its segmented structure allows rice or glutinous rice to be mixed with water and coconut milk, sealed, and cooked over an open flame or hot coals for a distinct aroma and flavour. *Periuk Kera*, made from gourd fruits, is lightweight but durable. Hollow out the gourds, removing the seeds and flesh, to make a vessel for cooking rice or glutinous rice over a fire, infusing it with flavour. Bamboo and *Periuk Kera* show how natural resources can enhance traditional dishes with unique flavours and aromas.

Data Input Efficiency through Metadata Management

The gathered data is expected to be entered into the cultural repository database based on the metadata as follows.

Table 6: Example of Data Input

Metadata	**Input**	
Name of Dish	*Ubi Kayu*	
Foraging Approach	Foraging/Farming Cassava Tubers (Subsistence Agriculture). The cassava tubers must be pulled out by the roots. If broken, the remaining roots must be pulled out of the soil.	
Foraging Equipment	Knife/Machete	
Ingredients	Protein	: -
	Vegetable/Fruits	: -k
	Carbs/Starch/Grains	: Cassava Tubers
	Others	: Sugar/Chilli (optional)
Cooking Tools	Pierced Bamboo, Fire	
Dish Preparation	Peel the skin off the cassava tubers and place them in pierced bamboo. Cook the tubers over a fire. After they are cooked, remove the tubers from the bamboo. Serve with sugar and/or chilli paste and/or spicy anchovies.	
Dish Presentation	Serves in Banana Leaves	
Tribe	Orang Asli Jah Hut	
Location	Kampung Sungai Pian	
ICH Manifestation	Cultural Gastronomy	
ICH Domain	Traditional Craftmanship	
Supporting ICH Domains	☑ Oral Traditions and Expressions (as vehicle) ☐ Performing Arts ☑ Social Practices, Rituals, and Festive Events ☑ Knowledge & Practices (Nature & Universe)	

Metadata	Input
Source	Community Representatives
Keywords	*Ubi Kayu*, Cassava Tubers, Bamboo, Banana Leaves

Transmission of Orang Asli Cultural Gastronomy

Cultural gastronomy falls under the fifth ICH domain, Traditional Craftsmanship. To effectively transmit these traditions, it is necessary to consider multiple ICH domains that encompass various aspects of the cultural heritage. The first ICH domain, Oral Tradition, and Expression, is crucial as effective vehicles to transmit the culinary knowledge. The recognition of ingredients and dish names is the most apparent use of oral tradition, apart from transmitting the culinary method and practices. Passing on culinary knowledge also necessitates the incorporation of the fourth domain: Knowledge and Practices Involving Nature and The Universe. Social Practices, Rituals, and Festive Events, which fall under the third domain, also play a crucial role in preparing some dishes for specific rituals and gastronomies. Therefore, cultural gastronomy should not be treated solely under traditional craftsmanship; it also encompasses other ICH domains to ensure comprehensive cultural embodiment and transmission.

CONCLUSION

The two objectives of this study are to document the cultural gastronomies of the Orang Asli in Pahang and to assign themes to these gastronomies that are broadly applicable to all tribes of the Orang Asli Pahang. The establishment of existing findings was the first step in the process of documenting the cultural gastronomies. This facilitated the formulation and organization of interview questions, executed at the various locations of the targeted respondents.

Based on the transcribed and coded interview data, three themes were generated and assigned, namely (i) Foraging Approaches focussing on equipment and craftsmanship or skills, (ii) Raw Cooking Ingredients, concerning starch, protein, and vegetables, and finally (iii) Name of Dish and Dish Preparation. Passing on Orang Asli gastronomy traditions reveals a rich tapestry of ICH domains that extend far beyond Domain 5 of ICH, namely Traditional Craftsmanship. Recipe names, and cooking techniques are just a few examples of the many culinary arts that rely on Oral Traditions for transmission. As a reflection their holistic relationship with their environment, Social Practices, Rituals, and Festive Events (Domain 3) and Knowledge and Practices (Domain 4) also play important roles. Thus, in order to guarantee the inclusive transmission and preservation of their heritage, cultural gastronomy among the Orang Asli interweaves various ICH domains.

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INVESTIGATING THE CORRELATION BETWEEN PROPERTY OVERHANG AND HOUSING SATISFACTION AMONG HOME BUYERS IN MALAYSIA

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Abstract

The Malaysian real estate sector has flourished due to the rapid advancement of the global economy in recent years. Nevertheless, property overhang continues to threaten the nation's economy. This study seeks to enhance developers' comprehension of purchasers' preferences by assessing the correlation between characteristics contributing to residential overhang along with variables affecting satisfaction levels with residential buildings. Questionnaire surveys were distributed to 157 developers and property agents, of which 110 were completed and returned. Similarly, 148 surveys were distributed to homebuyers, with 110 responses received. The data was evaluated using the Statistical Package for the Social Sciences (SPSS) version 24.0, where Bivariate Correlation Analysis was performed. The study's results indicated a positive correlation between the majority of the parameters, while a few exhibited a negative correlation with one another. Future research may examine the effects of property overhang on the nation and provide strategies to mitigate these effects, therefore raising awareness among developers, the real estate sector, and the construction sector.

Keywords: residential, property overhang, housing satisfaction, homebuyers, affordability

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INTRODUCTION

Alongside the rapid expansion of the global economy in recent years, the real estate industry in Malaysia has also experienced significant growth. The real estate business is a crucial contributor to Malaysia's economic development and provides social security to its citizens. Nevertheless, the recent worldwide breakout of the catastrophic COVID-19 pandemic has significantly impacted the global community, leaving individuals to confront the unforeseeable situations it has engendered. The lethal COVID-19 pandemic not only impacts public health but also significantly affects the global economy. Segal and Gerstel (2020) reported that the Organisation for Economic Co-operation and Development (OECD) projected a reduction in global Gross Domestic Product (GDP) growth by half a percentage point, from 2.9% to 2.4% for 2020, while Bloomberg Economics suggested that in a worst-case pandemic scenario, full-year GDP growth could decline to zero. Inevitably, with all the economic uncertainty around the world, it is inevitable that various industries in Malaysia will suffer due to this global pandemic that has brought the world to its knees.

However, despite all this turmoil and uncertainties, the real estate industry still caters to various investment opportunities in the property market, for there is no unfavourable timing for acquiring property, whether for personal or investment purposes. When purchasing a residential property, there is always a heated debate when deciding whether to purchase a landed or high-rise property as both types of properties bring various benefits. As such, finding the type of property that suits the buyer's needs can be challenging as both landed and high-rise residential properties vary substantially in many ways. With that in mind, the type of residential properties in Malaysia creates an opportunity for homebuyers to choose from based on their preferences and needs. Therefore, it is important to understand what residential properties are available in Malaysia and which type of housing can satisfy the homebuyer's preference.

PROBLEM STATEMENT

The evolution of Malaysia's real estate industry has undergone significant growth alongside the rapid expansion of the global economy in recent years. Nonetheless, property overhang continues to pose a challenge to the nation's economy. Property overhang can be defined as dwelling units that have received a certificate of fitness for occupancy yet have remained unsold for over nine months (Rahim et al., 2019).

In 2022, 389,107 transactions valued at RM179.07 billion occurred, reflecting a 29.5% increase in volume and a 23.6% rise in value compared to 2021. The residential sub-sector dominated the entire property market, accounting for 62.5% of the volume, with 243,190 transactions valued at

RM94.28 billion. According to the 2022 data, the total volume of overhang residential and serviced apartments amounted to 51,724 units, valued at RM38.6 billion. The three states with the highest overhang of residential and serviced apartment properties are Johor (19,390 units), Federal Territory Kuala Lumpur (9,441 units), and Selangor (6,624 units). Condominiums, apartments, and serviced flats are the predominant categories of overhang properties, priced between RM500,001 and RM1,000,000. This phenomenon will adversely affect overall economic activities and related real estate development, as the unproductive capital immobilised in unsold units fails to generate any economic momentum, thereby impacting approximately 150 industries associated with the real estate sector (Ng, 2020).

Table 1: Previous studies related to homebuyer's preference and satisfaction

No	Authors	Scope of study
1	Jaafar et al. (2005)	To study the factors that influence housing satisfaction amongst homebuyers.
2	Tan (2009)	To identify whether homeownership improves the home environment and how it affects the child's cognitive ability, improves local amenities of their communities, improves homeowners' connection to their neighbours, promotes neighbourhood stability through longer stay and better maintenance and improvement in the neighbourhood and whether it is an effective instrument to accumulate wealth.
3	Tan (2012a)	To determine homeowner preferences amongst first-time homebuyers in Malaysia.
4	Tan (2012b)	To identify factors affecting housing satisfaction of medium and high-cost housing
5	Lim and Chang (2018)	To study the residential building typology and characteristics and identify the factors influencing preferences for the types of housing available in Malaysia.
6	Thanaraju et al. (2019)	To evaluate the relationship between the three main factors identified, which are financial, location, and neighbourhood, towards the housing preferences of homebuyers in Kuala Lumpur.

Source: Author (2024)

Table 1 tabulates the findings of previous studies on homebuyers' preferences and satisfaction with housing when purchasing a residential property. The previous studies mainly focused on preferences, demands, and satisfaction and identified what motivates home-buying among homebuyers. Nevertheless, they did not focus on examining the correlation between the elements affecting homebuyer satisfaction, which directly impacts the property overhang in Malaysia. Although sufficient knowledge and understanding can be gained from previous studies on homebuyers' preferences, further studies should be conducted

to evaluate further the relationship between factors causing property overhang and factors that influence the satisfaction level of homebuyers. Nevertheless, they did not focus on examining the correlation between the elements affecting homebuyer satisfaction, which directly impacts the property overhang in Malaysia.

FACTORS CAUSING RESIDENTIAL OVERHANG IN MALAYSIA

The property overhang refers to properties that have received a Certificate of Fitness for Occupation from local authorities and have remained unsold for over nine months following their market debut. Rahim et al. (2019) characterised it as the existing housing inventory in the market that fails to meet buyer desires. Extensive construction by house developers has exacerbated the current property overhang crisis since they have failed to satisfy purchasers' demands. To address this issue, the government has implemented many public housing initiatives, like Perumahan Rakyat 1Malaysia (PRIMA), to promote homeownership and mitigate the surplus of unsold properties. Nevertheless, despite all measures, the problem endures in the present real estate market. Consequently, it is essential to ascertain the variables contributing to residential overhang in the country to mitigate and decrease the current housing inventory in the market. Table 2 illustrates the numerous elements contributing to residential overhang.

Table 2: Factors Causing Residential Overhang

No	Factors Causing Residential Overhang	Authors
1	Affordability Issue (Pricing)	Plecher, 2020; Soon and Tan, 2019; Rahim *et al.*, 2019
2	Weakening Purchasing Power	Lee, 2019; Bardan, 2019;
3	Interest Rates	Faure, 2014; David-Pur *et al.,* 2020
4	Country's Economic Performance	Zelazowski, 2017; Department of Statistic Malaysia, 2024
5	Loan Financing Challenges	Soon and Tan, 2019; Bank Negara Malaysia, 2024
6	Mismatch between House Prices and Household Income	Ramlan and Zahari, 2016
7	Mismatch between Demand and Supply	Soon and Tan, 2019; Cheah and Almeida, 2016
8	Lack of Feasibility Studies	Bause *et al.,* 2014; Karim *et al.,* 2017
9	No Coordination Planning among Local Authorities	Maidin and Ali, 2009; Rahim *et al.,* 2019; Karim *et al.,* 2017
10	Mismatch in Location and Product Type	Karim *et al.,* 2017; Poh, 2019

Source: Author (2024)

FACTORS INFLUENCING THE LEVEL OF SATISFACTION OF RESIDENTIAL PROPERTIES.

According to Jaafar et al. (2005), housing satisfaction is the perceived disparity between a respondent's requirements and goals and the actual context of the current residential scenario (Jaafar et al., 2005). It is important that the housing satisfaction of the occupants is met during the development of housing as the determinants of a successful housing project depend on the ability of housing developers to satisfy buyers' satisfaction and expectations towards housing (Aigbavboa, 2016). A study by Ha (cited in Aigbavboa, 2016) also explained that a housing development's lack of success is possibly due to insufficient knowledge and understanding of the determining factor of occupant housing satisfaction towards housing. Therefore, understanding the buyer's point of view on housing satisfaction will assist housing developers in developing houses that not only meet the needs of buyers but also satisfy their expectations towards housing. Hence, an in-depth understanding and study of factors influencing the housing satisfaction of homebuyers is essential to meet homebuyers' demands and motivate them to purchase housing to curb the issue of property overhang. Factors that influence the level of satisfaction with residential properties are shown in Table 3.

Table 3: Determinants Affecting the Degree of Satisfaction in Residential Properties

No	Factors Influencing the Level of Satisfaction of Residential Properties	Authors
1.	Common Facilities	Sia et al., 2018; Abdul Ghani and Lee, 2015
2.	Built-up Area	Chin, 2016; Olanrewaju and Tan, 2017
3.	Security	Al Shawabkeh et al., 2020; Tan and Cheah, 2012; Tan, 2011
4.	Parking Convenience	Guo, 2013
5.	Maintenance	Au-Yong et al., 2018; Sia et al., 2018
6.	Household Income	Rameli et al., 2016; Jaafar et al., 2005
7.	Location and Accessibility	Olanrewaju and Tan, 2017; Leh et al., 2016
8.	Lifestyle Living	Abdul Ghani and Lee, 2015; Reid, 2015
9.	Demography	Majid et al., 2012; Choong and Cham, 2015; Chin, 2016
10.	Sense of Community	Reid, 2015; Al Shawabkeh et al., 2020

Source: Author (2024)

METHODOLOGY

A quantitative data approach was selected for this study, and the source of quantitative data originated from Likert scale questionnaire surveys. Based on the number of developers registered as members of the Real Estate and Housing Developers' Association (REHDA), a number of 544 developers from both Kuala

Lumpur and Selangor were chosen as the population sample for this research study. Based on the list of members from the Malaysian Institute of Estate Agents (MIEA), a total number of 1,244 property agents from Kuala Lumpur and Selangor served as the population sample for this study. Therefore, both developers and property agents combined amounted to a cumulative population size of 1,788. The sample size obtained is 95 based on the Yamane sample size calculation (Israel, 2003). The employed population of Wilayah Persekutuan Kuala Lumpur and Selangor, with a total number of 4,313,900 employed personnel, was taken as the population sample. The sample size obtained is 100 based on the Yamane sample size calculation (Israel, 2003). Bivariate Correlation Analysis was adopted when there was a need to identify the relationship between two variables of a research study (Perinetti, 2019). Additionally, it was used to relate the effect of two or more phenomena that occurred simultaneously and whether they were linked. The correlation represented the strength of the association between the variables, quantified as a single number ranging from -1 to +1. A positive relationship between the variables is generally signified by a positive value, a negative relationship is denoted by a negative value, while a Correlation Coefficient value of zero signifies the absence of a relationship between the variables (Statistics Solutions, 2020).

RESULTS

Bivariate Correlation Analysis was performed to ascertain the link between elements contributing to residential overhang and those affecting residential property satisfaction levels. The Correlation Coefficient will be interpreted in accordance with Schober et al., 2018, whereby the range between 0.00-0.10 is interpreted as a "Negligible correlation", the value between 0.10-0.39 is considered to be having a "Weak correlation" while the range between 0.40-0.69 is treated as having a "Moderate correlation". Furthermore, variables with a Correlation Coefficient value ranging from 0.70 to 0.89 are regarded as exhibiting a "Strong correlation," while a Correlation Coefficient value between 0.90 and 1.00 indicates a "Very strong correlation" between the variables. Consequently, variables exhibiting a "Moderate Correlation" are delineated in Table 4.

Table 4: Summary of the Moderate Correlation between the factors

Factors causing residential overhang in Malaysia	**Factors influencing the level of satisfaction of residential properties**	**Value**
Affordability Issue (Pricing)	Built-up Area	0.521
	Household Income	0.557
	Location and Accessibility	0.517
Weakening Purchasing Power	Household Income	0.477

Factors causing residential overhang in Malaysia	Factors influencing the level of satisfaction of residential properties	Value
Loan Financing Challenges	Household Income	0.421
Mismatch between House Prices and Household Income	Built-up Area	0.424
	Household Income	0.404
Mismatch between Demand and Supply	Common Facilities	0.408
	Location and Accessibility	0.418
Mismatch in Location and Product Type	Location and Accessibility	0.460

Source: Author (2024)

As shown in Table 4 above, the Affordability Issue (Pricing) has a Moderate Correlation with Built-up Area, Household Income, as well as Location and Accessibility. Affordability Issue (Pricing) impacts buyers' ability to purchase a property. Rahim et al. (2019) stressed that housing is considered affordable when households are not paying more than 30% of their income for loan financing, including utility bills. Housing affordability also affects the built-up area of the residence, as larger homes incur more costs. Furthermore, location and accessibility are other factors influencing affordability, as the accessibility and availability of public transportation services play an important role in determining housing prices (Olanrewaju & Tan, 2017).

Weakening Purchasing Power has a Moderate Correlation with Household Income. Bardan (2019) reported that the nominal starting salaries of fresh graduates prevail at a moderate level. As such, it is justifiable that a moderate correlation exists between these factors. When the Weakening Purchasing Power of homebuyers amongst fresh graduates occurs, it affects their ability to purchase a property, especially when the housing price is unaffordable.

The Loan Financing Challenges factor has a Moderate Correlation with the factor in relation to Household Income. Bank Negara Malaysia (2024) reported that banks will conduct affordability assessments to fully understand the financial conditions of their loan applicants before approving their housing loans. The loan applicant's Household Income will be evaluated to determine their capacity to meet financial commitments. Hence, when the Household Income of the loan applicant is insufficient to cover the monthly instalments, financial institutions will not approve their loan applications, leading to Loan Financing Challenges for loan applicants. As such, a moderate correlation exists between these two factors. Therefore, housing loan applicants must ensure they are not paying more than 30% of their income to furnish the loan financing.

Table 4 tabulates the Moderate Correlation of the Mismatch between House Prices and Household Incomes with Built-up Area as well as Household

Income. A study by Syafiee Shuid (cited in Ramlan and Zahari, 2016) indicated that a disparity between House Prices and Household Income arises when buyers are unable to afford the available housing categories—be it low-cost, medium-cost, or high-cost—due to the variance in Built-up Areas, which consequently affects pricing. Therefore, the relationship between House Price, Household Income and Built-Up area should be considered to ensure that various types of housing based on pricing can be made available to all household income groups.

The disparity between Demand and Supply has a Moderate Correlation with factors pertaining to Common Facilities, Location, and Accessibility. Soon and Tan (2019) commented that home buyers will not consider purchasing a property that does not meet their demands and expectations. Therefore, it is essential to comprehend the variables and features that influence the purchase decisions of homebuyers to satisfy their needs. As such, the Common Facilities provided in a housing development enhances the living experience of the homebuyers. However, it is important to take note that not all homebuyers are in favour of having Common Facilities provided in their housing. Thus, a proper understanding of the demands of homebuyers is essential, and the availability of Common Facilities plays a role in the demands of homebuyers, forming a moderate correlation between these two factors. A study by Leh et al. (2016) concluded that housing in urban areas is preferable amongst young people compared to suburban areas. This is because the distance to their working area and other facilities and amenities are easily available and accessible within the vicinity. Hence, it is undeniable that the location factor of a residential property plays a role in ensuring the satisfaction of homebuyers towards their home and influences the Demand and Supply factor.

There is a Moderate Correlation between the Mismatch in Location and Product Type and the factor with regard to Location and Accessibility. A mismatch in Location and Product Type occurs when homebuyers lose interest in housing that is in an unattractive location and does not meet the homebuyers' preference (Karim et al., 2017). This mismatch is moderately correlated with the Location and Accessibility factor because the Location and Accessibility factor is also considered in the Mismatch in Location and Product type.

CONCLUSION

This paper is valuable for developers, property agents, and employed homebuyers, as it enables developers to identify the determinants of homebuyer satisfaction with residential properties and to tailor their construction projects accordingly, thereby mitigating the risk of property overhang in the country. On the other hand, property agents will gain a certain degree of understanding of the factors that satisfy homebuyers and can recommend housing that suits the homebuyer's preference. Through this study, homebuyers can also identify the

factors that increase satisfaction towards residential property and refer to it as a benchmark when purchasing a property. Future research may examine the effects of property overhang on the nation and provide strategies to mitigate these effects, therefore raising awareness among developers, the real estate sector, and the building industry.

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THE IMPACT OF SHARING ECONOMY (AIRBNB) ON HIGH-RISE NEIGHBOURHOODS BASED ON STRA GUIDELINES: URBAN PLANNERS' PERSPECTIVE

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Abstract

This study examines the impact of Airbnb as part of the sharing economy, which has introduced various challenges in high-rise neighbourhoods. It explores how the implementation of Short-Term Residential Accommodation (STRA) guidelines can help regulate short-term rental activities and address emerging issues in high-rise residential areas. Specifically, the research aims to explore the impact of Airbnb from the perspective of urban planners, focussing on how this service affects neighbourhoods and cities. Using a qualitative approach, semi-structured interviews were conducted with key stakeholders, and the findings were analysed through thematic analysis. The results reveal both positive and negative implications of Airbnb. On the positive side, Airbnb stimulates the state's economy, particularly through the tourism sector, and provides an alternative source of income for residents. On the downside, the presence of short-term rentals can lead to increased property prices and raise concerns about neighbourhood safety. This research suggests that the STRA guidelines could play a key role in creating a balanced solution for the future of short-term rentals in Malaysia, ensuring that both residents and businesses can benefit from this evolving industry.

***Keywords*:** Sharing Economy, Short-Term Residential Accommodation Guidelines, High-Rise Neighbourhood, Airbnb, Planners' Perspective

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INTRODUCTION

A home-sharing network like Airbnb has gained much attention and is experiencing exponential growth, resulting in regulatory and political battles. However, realising its full potential would necessitate the democratisation of platform ownership and governance. Despite Airbnb's rising popularity, many short-term rental accommodations have caused dissatisfaction among high-rise residents due to noise and the misuse of shared utilities. Guidelines on Short-Term Residential Accommodation (STRA), encompassing Airbnb and other short-term rental accommodations, were introduced in late 2019 to address issues related to short-term rentals in residential areas, especially in a home-sharing economy(Malaysia Productivity Corporation, 2019). According to the guidelines, the parties involved in the operations and enforcement of rules and regulations are the host or homeowner, the guest, and the STRA platform, such as Airbnb, which provides the service of online accommodation booking.

One of the key debates surrounding the permissibility of STRA is whether the nature of the building's use has significantly changed due to the operation of such businesses. This raises the issue of whether planning permission is required, particularly in cases where the building undergoes a "material change of use", as typically mandated under local planning regulations (Chua Abdullah & Ramly, 2024a). Planning permission may be necessary if the use of a property for STRA services constitutes "development" in planning terms, particularly when the scale of the STRA operations becomes commercial in nature.

This study aims to achieve the following research objectives:

1. To examine the impacts of Airbnb accommodation service on neighbourhoods and cities from the perspective of urban planners.
2. To determine the benefits and implications of STRA guidelines for future implementation.

LITERATURE REVIEW

Sharing Economy Concept

A sharing economy is characterised as a peer-to-peer system for obtaining, providing or sharing access to goods and services, often facilitated by a community that is based on an online platform in the sense of sharing economy (Guttentag, 2013). The term "sharing economy" encompasses various non-ownership modes of consumption, including swapping, bartering, trading, lending, sharing, and exchanging. The duration of the sharing access is for a short period, typically on a daily basis. These online-based products and services often involve the exchange of underutilised assets or services from individuals, either for free or for a fee (Rachel Botsman & Roo Rogers, 2010). Airbnb's so-called

sharing economy is a controversial phenomenon based on the peer-to-peer exchange of products and services created by recent developments in information technology. Opinions about this phenomenon vary, with free-market proponents supporting the sharing economy (Hopkins, 2016), and liberal-progressive defenders viewing it as a means to destabilise market-oriented consumerism and individual ownership (Hoffmann et al., 2016).

Concept and Background of Airbnb

Airbnb is a website allowing regular individuals to rent their homes as tourist accommodations. It has developed rapidly and currently sells millions of room nights annually due to its focus on cost-cutting, domestic amenities, and the opportunity for more authentic local experiences (Bao & Shah, 2020). The emergence of this sharing economy business model, which includes short-term rentals such as Airbnb, Grab and others, has been extensively practised globally in the tourism and business sectors. Airbnb has become dominant in the short-term rental market in Malaysia, particularly in high-rise accommodations known as strata titles. Airbnb creates innovative solutions to address common travel and accommodation challenges, launching its latest brand positioning through a new logo, website, and a user-friendly mobile application (Hartmans, 2017; King, 2015; Oskam & Boswijk, 2016). The procedure for using Airbnb is straightforward. It operates as an online community marketplace that allows individuals to book short-term accommodations from a list of verified hosts worldwide, without requiring users to own property. Those with a spare room or apartment can register on Airbnb's platform, offering their space for a specified period at a set price (Evans & Evans, 2019; Oskam & Boswijk, 2016; Zervas et al., 2018) To ensure safety and trust, Airbnb implements peer-to-peer interactions and verifies the identities of all users. Before booking or listing accommodations, users are required to provide legitimate phone numbers, photo identification, and links to their Facebook profiles (Cohen & Sundararajan, 2017). Property owners who list their accommodations are known as "hosts", while the individuals who stay in these spaces are called "guests", and the available properties are termed "listings". The process of becoming an Airbnb user or posting a listing is accessible and simple, making Airbnb a cost-effective and user-friendly alternative to traditional hotel bookings and vacation rentals.

Short-Term Rental Accommodation Concept

Short-term rental accommodations (STRA) are commonly described as dwelling units rented or leased for fewer than 30 days (Lee, 2016). However, state and federal authorities have yet to define them. Short-term rentals are an example of the sharing economy, in which individuals increasingly opt to share access to products and services through lateral or hierarchical trade often involving a

monetary exchange. This trend has been recognised as having positive and negative implications for communities nationwide.

Currently, many practices and regulations have been adopted worldwide to ensure the quality of life for residents and to avoid future problems related to unhealthy competition in industries, such as the hotel industry(Coyle & Yu-Cheong, 2016; Levendis & Dicle, 2017; Richards et al., 2019; Stollery & Jun, 2017; Wegmann & Jiao, 2017; Zamani et al., 2019). One restriction implemented for the short-term rental business is the nightcap, as described in Table 1 below, where entire home rentals are limited from 30 days to 90 days per year, depending on the country's regulations. Hosts must obtain permits to operate their business and pay taxes accordingly (BBC News, 2018), while the building's management committee sets the rules and regulations for high-rise buildings.

In Malaysia, the regulation of STRA falls under the jurisdiction of local authorities, as provided by the Town and Country Planning Act 1976 (Act 172). This act grants local authorities the discretion to either permit or prohibit property owners from engaging in commercial activities such as STRA within residential properties. However, the approach to regulating STRA varies across different local authorities, as each community has distinct needs and priorities, which continue to evolve due to changing societal expectations, the pursuit of an improved quality of life, and considerations of human rights (Lee Lik Meng et al., 2006). Moreover, legal and technical perspectives on STRA within strata premises emphasise the importance of clear regulations to address challenges related to property management, resident welfare, and enforcement mechanisms (Chua Abdullah & Ramly, 2024c).

Table 1: Restrictions on Short Term Rental Accommodations across the World

City	Restrictions
Amsterdam	Rentals of entire homes are limited to 60 days per year.
Barcelona	Short-term rentals require a license, but no new ones are being given currently.
Berlin	Landlords must get a permit to rent out 50% or more of their primary house for a certain period.
London	Rentals of entire residences are limited to 90 days per year.
New York City	Renting for an apartment for less than 30 days is usually prohibited unless the host is present.
Paris	Rental for less than a year is limited to 120 days a year.
San Francisco	Hosts are required to register as businesses and obtain short-term rental certifications. Rentals of the entire property are limited to 80 days per year.
Singapore	For public housing six-months minimum rental duration is required.
Tokyo	Home sharing was only permitted in 2017. The number of days each property can be rented is limited to 180 days.

Source: Gurran & Phibbs (2017); Zervas et al. (2017)

As shown in Table 1, the practices and restrictions implemented in various countries are designed to protect residents' quality of life while benefiting all stakeholders. In light of these practices, this study aims to explore the potential impact of STRA guidelines that are expected to be introduced in the near future. The viewpoints of town planners are crucial, as they serve as key decision-makers in managing both urban and rural areas.

RESEARCH METHODOLOGY

The data for this research were collected using a qualitative research method, designed to address issues related to social structures or individual experiences (Hilary P. M. Winchester & Matthew W. Rofe, 2010). The data gathering process involved a combination of public reports, credible supporting documents, and interviews with relevant stakeholders. In addition to secondary data, primary data were collected through semi-structured interviews with town planners and planning officers. Semi-structured interviews are known for providing in-depth responses, enabling researchers to explore participants' experiences, perceptions, views, feelings, and knowledge (Patton. M. Q., 2002).

This study involved a range of significant stakeholders, including local government officials and representatives from government-linked companies. The participants were provided with a topic guide in advance to prepare comprehensive and informed responses to the discussion points. Purposive sampling was employed to select participants with specific characteristics that aligned with the study's objectives. Additionally, snowball sampling was used, where initial participants recommended other individuals who met the selection criteria. The final sample consisted of eight respondents, all of whom had a minimum of five years of experience in the planning industry. This selection was based on their expertise in urban planning and their academic background, ensuring that the views shared were informed by both professional experience and academic knowledge. Thematic analysis, an iterative process that simultaneously involves data collection and analysis (Cassell & Symon, 1994), was employed to analyse the data from the semi-structured interviews. The findings from these interviews will be presented and analysed in the sections that follow.

FINDINGS

The findings in this section are based on a semi-structured interview with eight respondents who were recognised as being actively involved in the planning profession. The interview was then transcribed and thematically analysed based on the themes that emerged. Codes, or labels, were assigned to specific parts of the data that contributed to the themes. Table 3 shows the codes, categories, and themes from the interview sessions.

Table 2: Key Themes and Codes

Category	Themes	Codes
Impacts of STRA on neighbourhoods and cities	Increase in property value in the neighbourhood	• Rezoning the housing to commercial use • More short-term rental owners in high-rise buildings • Cater for short-term service apartments • Revenue for developers
	Diversity in tourism accommodation options and staycation	• Cheaper prices for accommodations
	Safety and quality of strata title management	• Cleanliness of the accommodations • More outsiders stay in the neighbourhood • Procedures for guests
Benefits and implications of STRA guidelines from planners' perspective	Guidance for local authorities	• Planning control: Control the zoning for commercial use
	Management operations of high-rise accommodations (strata title)	• Proper SOP for managing guests, owners, and the management of high-rise accommodations

Source: Codes from the interview

This study has identified several impacts of Airbnb, such as stimulating the state's economy through the tourism sector and serving as an alternative business for the residents to generate income. The second objective is to determine the benefits and implications of STRA guidelines to be implemented in future. STRA guidelines can be used to streamline regulations and businesses that are related to the sharing economy in residential areas. The existence of STRA guidelines helps ease the process and address key issues that need to be tackled in order to reduce the impact on residents and create a harmonious strata neighbourhood.

Impacts of STRA on Neighbourhoods and Cities

Theme 1: Increase in property value in the neighbourhood

The implications of STRA like Airbnb can have a double-edged impact, affecting different stakeholders in various ways. On the one hand, the rise of STRA creates opportunities for investors and property buyers who can afford to purchase units for investment purposes. This demand boosts revenue for developers, as they can sell units at higher prices to potential investors. Homeowners who wish to sell their property to an investor can expect a better return, as the property may be seen as more valuable due to its potential for short-term rental income. However,

the negative side is that homeowners looking to sell to a regular buyer who may not wish to operate an Airbnb unit may not receive as high a return.

> "…The implication will surely affect the housing price where the price will increase because of rezoning from residential to commercial." (R2)

> "…The housing prices will increase due to rezoning from residential to commercial use which is also good for the investor for its house selling price because of its higher value…" (R6)

> "…For homeowners of strata housing schemes, on the other hand, the implications can be both positive and negative. Ownership of high-rise buildings, especially with great amenities, will be targeted more for short-term rental rather than for owners residing in the unit/premise." (R5)

Furthermore, the proliferation of STRA in certain neighbourhoods can provide financial benefits to developers and building owners. Unsold units in apartment complexes can be converted into Airbnb units, generating additional revenue. As one respondent said: "…But there is also a positive impact on the neighbourhood unit where the unsold units in the apartment can turn into Airbnb units, and it can give revenue to the developer or building owner." (R1)

This phenomenon is supported by the findings of studies conducted in the U.S. The research suggests that the growth of Airbnb listings in Boston was associated with increased rental prices, particularly in neighbourhoods with a high concentration of short-term rentals, contributing to rent inflation in urban areas. The rise of home-sharing platforms, such as Airbnb, results in a decrease in the availability of long-term rental units(Bao & Shah, 2020; Karen Horn & Mark Merante, 2017). As property owners increasingly convert their properties to short-term rentals, the supply of long-term rental housing shrinks, exacerbating housing shortages. Additionally, both studies suggest that the proliferation of short-term rentals can accelerate gentrification and displacement. In areas with high concentrations of Airbnb listings, rising rents make it increasingly difficult for long-term residents to afford housing.

Theme 2: Diversity of tourism accommodation options or staycation

The conversion of permanent homes to tourism, especially in suburban areas, appears to be highest when the supply of tourist accommodation is constrained, and a high proportion of the rental stock is available for tourists rather than residents due to an increase in demand for Airbnb outside of city areas. This reduces the affordable rental market.

According to R1, "…. Airbnb could stimulate the tourism sector by encouraging tourists to stay longer at affordable prices. Most tourists are with families, so selecting Airbnb is the best choice with abundant facilities and discount prices if staying longer". Additionally, R8 mentioned that "…. Short-term rentals have been accepted for big families for staycations and are also an alternative option for international and domestic tourists. The spacious and homey environment in short-stay rental accommodation like Airbnb has boosted the local economy and generated income for investors."

The rise of Airbnb has created a shift in the tourism accommodation landscape, providing tourists with affordable, flexible, and convenient lodging options. According to Gurran & Phibbs (2017), Airbnb offers a viable alternative for families and longer-staying tourists, with the platform's lower prices and diverse accommodation types enabling tourists to access budget-friendly options that were previously unavailable in traditional hotels. Furthermore, Zervas et al. (2015, 2018) highlighted that Airbnb is particularly attractive for tourists looking for affordable accommodations that offer more space, amenities, and the potential for longer stays. The ability to book entire homes with kitchens, living areas, and multiple bedrooms makes it a popular choice for tourists travelling with families or in groups. Additionally, Evans & Evans (2019), Guttentag (2015), and Guttentag et al. (2018)supported this observation by emphasising how Airbnb's personalised offerings cater to tourists seeking an experience that is closer to local life. This experience, combined with cost-effective pricing, has made Airbnb a significant player in the accommodation market, especially for those looking for a more "home-like" environment than what traditional hotels provide.

Theme 3: Safety and quality of strata title management

The respondents emphasised that the impact of Airbnb operations in high-rise or strata-title properties largely depends on how well the property is managed. Proper management is essential for ensuring the safety, cleanliness, and overall well-being of residents, which in turn encourages more positive socio-economic activities in the area.

According to R2, "…. proper management will lead to safety, cleanliness thus allowing more socioeconomic activity upon this activity but if poor management on this Airbnb activity will resulting in more negative impacts such as broken facilities and unhappy residents." This highlights the importance of experienced property management in maintaining the quality of the living environment.

However, when the property management is inadequate, the negative impacts are more pronounced, affecting the neighbourhood's facilities, amenities, and social dynamics. R3 further explained that "……if the property management has experience in managing the property, they should not have a lot of negative

impact on the housing in terms of facilities and amenities. If the property management poorly manages the residential, it will also affect the social activity including safety and cleanliness." This suggests that a lack of effective management can undermine the quality of life for residents and create unsafe or unpleasant environments.

Additionally, R1 drew attention to a concerning trend where Airbnb activities are sometimes operated illegally, bypassing necessary regulations and taxes. R1 noted, "……Airbnb activity nowadays is illegally operated because they want to avoid paying taxes and avoiding some obligations in Airbnb and this had caused some disturbance to the neighbourhood making local authority cannot detect this kind of illegal activity." This indicates that unregulated Airbnb activities can create disturbances in the neighbourhood, including issues related to safety, cleanliness, and the overall integrity of the community. The inability of local authorities to detect these illegal operations further exacerbates the problem, making it difficult to enforce proper regulations and ensure the quality of life for permanent residents.

These findings underscore the importance of effective property management and regulatory oversight to mitigate the negative impacts of Airbnb on residential areas. When properly managed and regulated, Airbnb can contribute positively to the local economy, but when left unchecked, it can lead to significant disruptions.

Benefits of STRA Guidelines

Based on the findings, a theme has emerged to describe the benefits and implications of STRA guidelines in the future.

Theme 1: Guidance for local authorities

The respondents (R1, R2, and R3) highlighted the dual impact of STRA guidelines, recognising both their positive and negative aspects. On the positive side, the guidelines offer a structured approach to regulating short-term rental activities, especially for platforms like Airbnb, within residential-zoned areas. This can help streamline business operations and ensure compliance with existing regulations, thus balancing tourism activities with residential concerns.

R1 emphasised the importance of the STRA guidelines in planning control, noting that it can serve as a reference for parties looking to convert residential units into commercial properties for Airbnb. According to the respondent,

"…. STRA guideline will mostly help in planning control other than Strata Titles Act 1985 because it involves Airbnb units in an apartment, so all parties who involved either they want to convert their residential into a commercial for Airbnb will refer to this guideline as an obligation." (R1). This

shows that the guidelines are essential for ensuring that conversions are regulated and do not disrupt the intended use of residential spaces.

R2 acknowledged that the STRA guidelines can ease regulatory burdens, particularly in high-rise residential areas where tourism-related businesses operate. According to R2, "……STRA guideline will help in easier regulations, especially in tourism-related businesses which conducted high-rise residential."

This highlights the role of STRA guidelines in making it easier for both businesses and local authorities to navigate the complexities of short-term rentals. R3 further emphasised the role of STRA guidelines in controlling business activities, especially in residential neighbourhoods. R3 stated, "…. STRA guideline will help in controlling the business activity (Airbnb) which were operating in residential areas. In terms of social aspects, neighbourhood and tourism, STRA helps to control unhealthy competition due to Airbnb in the residential area."

This statement underscores how the guidelines can mitigate negative social impacts, such as unhealthy competition and the conversion of residential properties into commercial ventures, which may disrupt the local community. These insights suggest that STRA guidelines are a critical tool in balancing the growth of the short-term rental market with the need to protect the integrity of residential communities.

Theme 2: Management operations of high-rise accommodations (strata title)

It is important for the operation to have comprehensive guidelines to ensure residents' safety, security, health, public good and welfare. Moreover, these clear guidelines of STRA can also benefit developers, as STRA falls within the commercial sector and fulfils Airbnb's requirement to reduce issues and problems arising in residential areas. In addition, "……to help create clearer guidelines for short-term rental activities, the government must engage external professionals to assist in drafting the guidelines. STRA serves as a platform for regulating Airbnb activities in housing zoning and controlling unhealthy competitions resulting from the presence of Airbnb premises in residential buildings" (R7).

> "…even though the guideline may lack in many ways because what they provide only covers a small part for short-term rental, but it is still useful for its purpose." (R8)

Without STRA, residential buildings that are converted without permission to be Airbnb accommodations will cause social disruption to existing residents. However, on the negative side, the guidelines may have significant shortcomings. What they study covers only a small part of Airbnb's operations.

Moreover, the guidelines themselves are not comprehensive enough to cover the operations adequately, benefiting the platform but not the residential community, as agreed by R7 and R8. The Strata Title Act empowers local authorities to oversee and regulate land development to ensure orderly and sustainable urban growth (Chua Abdullah & Ramly, 2024b).Planning permission serves as a crucial mechanism in managing land use and mitigating conflicts between residential and commercial activities, including the regulation of STRA within high-rise developments.

CONCLUSION

The study highlights the implications of Airbnb for high-rise neighbourhoods and cities, including the benefits of STRA guidelines in controlling or managing shared economy activities in the future. Urban planners should approach STRA with a perspective that recognises both the economic benefits and the potential challenges it poses to housing markets. While short-term rentals contribute positively to tourism and local economies and provide flexibility for property owners, urban planners must prioritise the long-term sustainability of residential neighbourhoods. Without proper regulations, the proliferation of STRA listings can lead to a reduction in the availability of affordable long-term housing, driving up rents and displacing vulnerable residents (Gurran & Phibbs, 2017).

To ensure balanced urban development, planners should advocate for clear, well-structured regulations that address the demand for short-term rentals while safeguarding housing affordability, neighbourhood integrity, and social equity. This approach allows cities to harness the positive aspects of platforms like Airbnb while minimising negative impacts such as gentrification and housing shortages (Bao & Shah, 2020; Karen Horn & Mark Merante, 2017). However, policymakers entrusted with regulating the remarkable growth of home-sharing platforms lack sufficient information to make effective policy decisions, as highlighted in recent scholarly studies of Airbnb's influence on the rental market (Karen Horn & Mark Merante, 2017). This demonstrates how scholarly suggestions have frequently been used to limit Airbnb's influence on neighbourhoods while maximising the economic activity it provides (Lee, 2016).It is crucial to emphasise that, if Airbnb's operations are properly regulated, they may benefit some neighbourhoods. Policies should be structured to encourage homeowners to advertise "shared room" or "whole room" listings rather than "entire unit" listings, as these short-term rentals can assist local individuals generate extra money by renting out their excess capacity. Such regulations would align with Airbnb's initial mission and would help in the protection of the local rental market from commercial operators. Therefore, it is essential to implement strict monitoring systems like those used in the hotel industry within the home-sharing economy.

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IMPACT OF POST-COVID 19 ECONOMIC CRISES ON AFFORDABILITY OF RENTAL HOUSING IN RAJSHAHI: AN ANALYSIS BASED ON RESIDUAL INCOME

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Abstract

Housing has always been a consistent and globally recognized urban challenge that remains largely unresolved. Meanwhile, affordability lies at the heart of most housing issues. The post-COVID global economic uncertainty has further enhanced this problem, as the living costs continue to rise at an alarming rate. In countries like Bangladesh, the situation is even more complex due to its large population. As being the third-largest metropolitan city, Rajshahi faces severe challenges in addressing housing affordability. In most of the cases household incomes and living standards have remained constant, but rising inflation and other post-COVID economic pressures have increased the cost of living. This has a direct impact on the rental housing affordability in Rajshahi. After paying for the unavoidable non-housing costs, the remaining amount is insufficient for house rents or expenditures, leading to a significant housing cost burden for renters. This paper employs a residual income-based method to examine the effect of the economic crisis after COVID on rental affordability in Rajshahi, offering a comparative analysis of the pre-COVID situation. It is anticipated that this paper will broaden future research opportunities and contribute to the implementation of the required policies to address this issue.

Keywords: Housing Affordability, Post-COVID Economic Crisis, Non-Housing Expenditures, Residual Income Approach, Housing Induced Poverty

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INTRODUCTION

The concept of housing is more than just a shelter as it serves as an indicator of social safety, tenure security and economic status also. Consequently, owning house has always been a top priority all over the world, including Bangladesh. However, due to its shear population, rapid urbanization and rural-to-urban migration, housing remains a critical concern for this developing country.

This housing issue also comes with the question of affordability, as purchasing a home is often the most expensive lifetime investment for most citizens. Moreover, there is a lack of supply than demand, thus the housing affordability stakes are always in the rise. As a result, most of the families find it almost impossible to afford a house of their own (Giti, 2018) . Adding to this, there are some non-negotiable mandatory expenses as a part of daily life. These expenses are there to meet the need of food, clothing, transportation cost, education, treatments, medicines and other basic human needs. And these expenses cannot be compromised.

Keeping the economic condition of the common in mind, it is very difficult for the mass people of Bangladesh to meet these expenses. Even when these expenses are managed, the amount left over is often negligible. On the other hand, the post covid scenario has worsened this situation. This pandemic has resulted in a global economic regression, which has been particularly detrimental to developing countries like Bangladesh. While developed nations may have the resources to tackle such crises, developing countries face significant hurdles. Due to this economic imbalance the expenses of all the daily necessities and commodities have increased. On the contrary, the income of the mass people in most of the cases has remained the same and even in some cases, decreased. Furthermore, the devaluation of local currency in international market has also added fuel to this burning scenario.

In the opinion of the general population, they are now spending nearly 1.5 times more to maintain a minimum standard of living than they did before the economic downturn. They claim that, as a result, it has become extremely difficult for them to cover regular expenses, let alone afford homeownership. While higher-income groups can manage these changes, middle- and lower-income groups believe they have fallen into a financial trap (Asaduzzaman & Hameem, 2021).

So, affordability of housing has drastically changed, it is far beyond their capacity. In consequence, a noticeable percentage of people had migrated from the metropolitan small towns or rural areas failing to meet the living cost. Therefore, this paper aims to investigate the impact of post covid economic crisis on the housing affordability level of the different economic group of Rajshahi, Bangladesh

METHODOLOGY

This article focuses on analysing the housing affordability scenario after COVID, driven by the economic crisis. There are few models of measuring affordability but this paper adapts residual income-based approach. As this approach measures the income left for housing after meeting all the essential living expenses, making it well-suited to the research focus.

However, this scenario cannot be generalized necessitating the selection of a specific study area. The existing scenario of the selected area should be thoroughly analysed. Using the data, reports and field survey the average household sized income should be identified. Subsequently, the non-housing compulsory living cost must be analysed of the pre covid and post covid scenario. This can be done by survey, questionnaire, secondary data of economic inflation and price rising of daily necessities. This analysis of household expenses will provide the insights of residual income for housing of the pre- and post-COVID situation and also reveal the variation of affordability level of the selected study area.

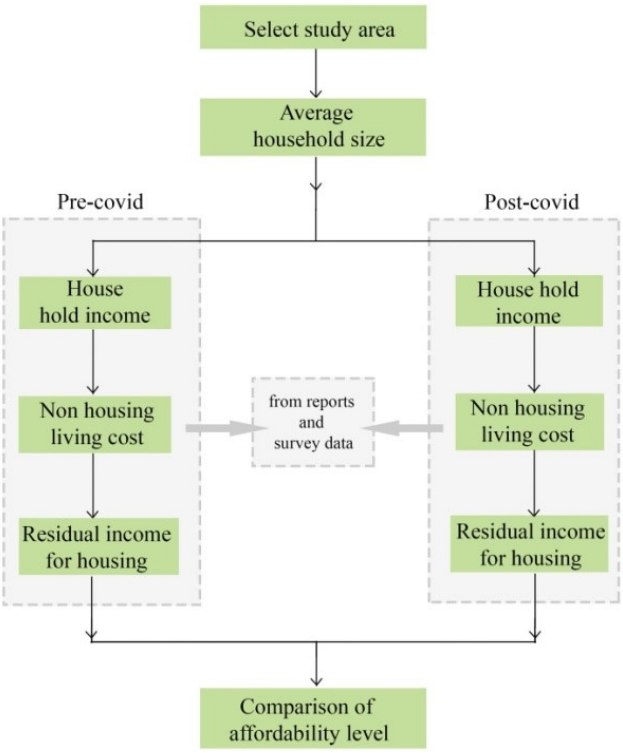

Figure 2: Methodology Flow Chart
Source: Author

STUDY AREA PROFILE

The aim of this paper is to assess the impact of the post-COVID economic instability on housing affordability. However, this problem cannot be generalized and for this reason a particular study area is selected specifically on Rajshahi to conduct the study. Selecting Rajshahi was triggered by some background consideration, as it is the third metropolitan of Bangladesh (Hameem et al., 2023). And being one of the most prominent cities in the northern region people keep migrating. Thus, this city is rapidly expanding and leading to a growing demand for housing.

On the other hand, the living cost of Rajshahi compared to the other cities is at a considerable level. But this scenario was greatly affected by the COVID pandemic. The living expenses have not remained the same as before. During these 2 years living cost has increased a lot. This has an immense impact in the housing affordability level of the people of Rajshahi. These factors align with the objectives of this study, making Rajshahi an ideal area for examining the impact of economic instability on housing affordability.

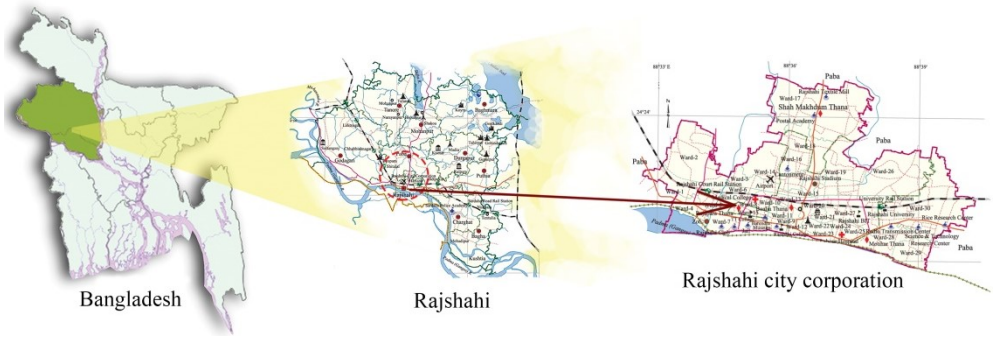

Figure 2: Location of the study area
Source: Author

HOUSING SCENARIO IN RAJSHAHI

Over the last decade, Rajshahi has faced rapid housing demand. The urban population in Rajshahi district increase from 2595197 in 2011 to 2915013 in 2022 (Census, 2022). As a result the density has increased from 1070 to 1202 per kilometre (Census, 2022). Also the number of households has increased from 633758 to 775260 within the same period (Census, 2022).

Table 1: Rent index

Year	Rent Index
2018-2019	5038.53
2019-2020	5339.74
2020-2021	5610.64

Source: Bangladesh Bureau of Statistics (BBS), 2021

So, both the housing demand and urban area of Rajshahi is expanding simultaneously. This housing need comes with the question of affordability. Because on field ownership pattern indicates that majority of the houses are not owned by the users, rather rented. But the economic instability continuing from the covid situation added more to this problem. As an impact of the global economic regression most of the house rents have gone up. So, the renters have to pay more than what they were paying before this economic condition.

Similarly, individuals aspiring to own a house are facing comparable challenges. House prices have gone up within the past few years. The construction materials price and the labour cost have raised a lot. As a result, many potential buyers or builders are unable to afford to purchase or construct new homes.

Table 2: Building Price Index

Time	Building material price index
20-Jun	624.67
20-Jul	626 74
20-Aug	627.4
20-Sep	628.78
20-Oct	630.21
20-Nov	632. 01
20-Dec	633 .94
21-Jan	640. 87

Source : Bangladesh Bureau of Statistics (BBS), 2021

So, there is an always increasing housing demand. But the supply is not up to the mark. Additionally, post-COVID global economic regression has fuelled the raising rents and housing prices and made it very difficult to afford for the people of Rajshahi. Thus, there should be a thorough investigation of the impact of the housing cost increase on the affordability level of Rajshahi.

AFFORDABILITY ANALYSES

This increase of house price and rents has reached such a rate that it is shifting beyond the affordability level of the mass people of Rajshahi. There should be a proper assessment to reveal the on-field impact of this sudden inflation over housing affordability. In this paper, the residual income approach is followed to measure the affordability level. The residual income approach to assessing housing affordability considers it in terms of households' ability to maintain a minimum standard of living. This is reflected in their capacity to meet non-housing needs at an adequate level after covering housing costs. (Nwuba, C. C., & Kalu, 2018). The residual income approach stems from the understanding that housing costs are typically inflexible and take precedence over other expenditures, making the first claim on the disposable income of most households. (Stone, 2006).

It calculates the portion of income available for housing (mortgage payments or rents) after accounting for relevant non-housing expenditures for different household types. If the remaining amount is insufficient to cover housing costs, the household is considered to be facing a housing affordability issue. (Burke et al., 2011). For this purpose, a thorough investigation of income and expenditures of the target group must be done as these two are the key factors of affordability.

Economic Condition

In any given scenario the key determinant of the affordability is monthly income. Because income defines the ability to spend for any goods or service. Survey data and on filed investigation was conducted to find out the income range of the people of Rajshahi.

This investigation indicates that:

- A majority of the people is service holders and their income has more or less remained the same.
- There has been no such event of salary increase both in government and private sector.
- Those who run business or shop owners also claims of their business profit declining.
- Workers and labors wage index has gone up a bit but their work frequency has decreased.
- Goods and agricultural producers sell their products with a low profit margin in the local market or to the middle man.

So, the income of the target area has remained the same or changed an inconsiderable amount. On the basis of income, the people of Rajshahi can be categorized into:

Table 3: Different Income groups of Rajshahi

Income group	Monthly income range BDT
Low income	<30000
Middle income	30000-120000
• Lower middle income	• 30000-50,000
• Middle - middle income	• 50000-80000
• Upper - middle income	• 80000-120000
High income	120000+

Source: Asaduzzaman and Hameem, 2021

Non-Housing Expenditures

There is a considerable amount of population growth and economic inflation. The living cost has also increased with the same acceleration. Stats show that almost all sort of goods and necessities were affected by the post covid inflation. The table below provides data on price increases and inflation rates:

Table 4: Inflation rate of non-housing expenditures

Expenditure Items	2018-19	2019-20	2020-21
Food	281.33	296.86	313.86
(Inflation)	5.51	5.56	5.73
Non food	229.58	243.00	255.85
(Inflation)	5.43	5.85	5.29
Clothing & footwear	277.64	290.00	298.14
(Inflation)	8.78	4.45	2.81
Gross rent, fuel & lighting	206.98	220.70	228.29
(Inflation)	3.36	6.63	3.44
Furniture, furnishing, household equipment's & operation	265.25	282.67	298.15
(Inflation)	6.24	6.57	5.48
Medical care & health expenses	215.31	230.07	247.86
(Inflation)	2.88	6.86	7.73
Transport & communication	235.23	248.48	271.45
(Inflation)	7.51	5.63	9.24
Recreation, entertainment, education & cultural services	186.72	190.13	193.61
(Inflation)	1.67	1.83	1.83
Misc. goods & services	239.87	259.27	288.53
(Inflation)	7.18	8.09	11.28

Source: Bangladesh Bangladesh Bureau of Statistics, 2022

People are struggling to keep up with the rapid rise in the cost of living. The higher income group can somehow cope with it. But the middle-income group who shares the majority of the population finds it very difficult to meet their monthly expenses let alone the lower-income tier.

These stats and data also aligned with the on-field scenario. Survey was conducted to find out the pre-COVID and post covid living cost of the households of Rajshahi. Household size in Rajshahi district 4.09 in 2011 and 3.76 in the year 2022 (Census, 2022). So, four-member families from those different income categories were taken into considerations and their monthly expenses were carefully considered. This analysis included expenses from utility bill, transportation, food, clothing, medicine, accessories, education, recreation and others. Additionally, personal vehicle expenses, support staff expenses add with the higher and higher middle-income group and a comparison made of the pre covid and post covid prices of these items to find out the gross amount of the increased living costs.

Affordability Evaluation

The living cost has risen incredibly high within these last few years. And these expenses cannot be compromised as all these items falls upon daily commodities. In these circumstances, the only area where compromises are often made is housing. Housing affordability has had a downfall in respect to the increased living cost. So, the comparison of affordability over these pre- and post-COVID situation is presented below:

Table 5: Residual income of different income groups of Rajshahi

Time frame	Income group	Monthly income (BDT)	Expenditures (BDT)	Residual income (BDT)
Pre covid	Low income	<30000	18000	12000
	Lower Middle income	30000-50,000	18000-32000	12000-17000
	Middle - middle income	50000-80,000	32000-55000	17000-25000
	Higher - middle income	80000-120,000	55000-85000	25000-35000
	High income	120000+	85000+	35000+
Post covid	Low income	<30000	24000	6000
	Lower Middle income	30000-50,000	24000-37000	6000-13000
	Middle - middle income	50000-80,000	37000-60000	13000-20000
	Higher - middle income	80000-120,000	60000-90000	20000-30000
	High income	120000+	90000+	30000+

Source: Field survey and Author's Calculation

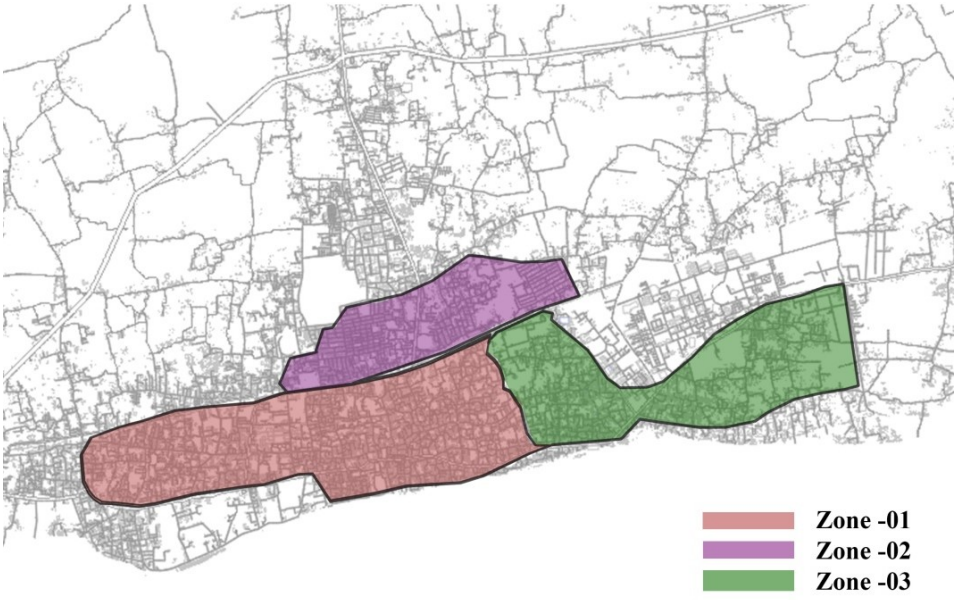

Figure 3: Different zones of Rajshahi on basis of house rents
Source: Author

In order to evaluate rental affordability in Rajshahi, the study took into account the variations in house rents across different zones and income groups. Rajshahi, like any other city, has diverse rental prices depending on the location and size of the houses, as well as the income levels of residents. To obtain a comprehensive understanding of rental affordability, the study collected data on house rents from various zones and categorized them based on income groups. By comparing these rental rates with the residual income, the study aimed to determine how affordable housing was for different segments of the population in Rajshahi. That is why different zone was identified in respect to the house rental level. Where "Zone 01" consists of area between Shaheb Bazar to Laxmipur, "Zone 02" consists of Uposhohor Residential area and Padma Residential area and finally "Zone 03" includes Sagarpara to Rajshahi university area. Moreover, the denatal data has been collected from those areas. This analysis shed light on the affordability dynamics in the city, considering the financial constraints faced by residents in relation to the rental prices they encountered. The findings contributed to a better understanding of the housing market in Rajshahi and could inform policy decisions and interventions aimed at improving rental affordability for the local population.

Table 6: Affordability level of different income groups of Rajshahi

Zones	Income group	Residual income (BDT)	House rent (BDT)	Affordability level
Zone 1	Low income	6000	7000-10000	Unaffordable
	Lower Middle income	6000-13000	10000-15000	Unaffordable
	Middle - middle income	13000-20000	12000-15000	Moderately unaffordable
	Higher - middle income	20000-30000	15000-20000	Affordable
	High income	30000+	20000+	Affordable
Zone 2	Low income	6000	8000-12000	Unaffordable
	Lower Middle income	6000-13000	12000-18000	Unaffordable
	Middle - middle income	13000-20000	18000-20000	Unaffordable
	Higher - middle income	20000-30000	20000-25000	Affordable
	High income	30000+	25000+	Affordable
Zone 3	Low income	6000	6000-8000	Moderately unaffordable
	Lower Middle income	6000-13000	8000-12000	Moderately unaffordable
	Middle - middle income	13000-20000	12000-15000	Affordable
	Higher - middle income	20000-30000	15000-20000	Affordable
	High income	30000+	20000+	Affordable

Source: Field survey and Author's Calculation

RESULT AND DISCUSSION

Housing affordability remains a persistent issue in Rajshahi, and the post-COVID economic crisis has further worsened the situation. The analysis conducted reveals that the economic inflation caused by the pandemic has rendered housing unaffordable for the lower- and middle-income groups in Rajshahi. Conversely, the higher middle- and higher-income groups have managed to cope more effectively, demonstrating the uneven impact of economic fluctuations on different income segments.

Traditionally, it is recommended that individuals allocate approximately 30% of their monthly income to their housing costs. However, due to the prevailing economic uncertainty, other essential non-housing expenses, such as food, transportation, and utility bills, have experienced significant increases. These non-negotiable expenses are crucial for individuals and cannot be compromised. As a result, the residual income left after meeting these expenses is far below the recommended 30% threshold for the lower- and middle-income groups in Rajshahi.

This phenomenon, commonly known as housing cost burden, highlights the challenges faced by the lower- and middle-income groups in meeting their housing needs amidst the post-COVID economic uncertainty. The above analysis further indicates that in zone 01 and zone 02 the rental amount is a burden for lower- and middle-income people. But in zone 03 the rent is comparatively lower. The burden of housing costs, coupled with the rising non-housing expenses, has put a considerable strain on their financial well-being and overall quality of life.

CONCLUSIONS

The findings indicate that the post-COVID economic climate has had adverse implications for housing affordability, particularly for lower to middle income group of Rajshahi. Addressing this issue requires comprehensive strategies that take into account the unique challenges faced by these income groups. It is crucial to implement measures that mitigate the housing cost burden and ensure access to affordable housing options for these segments of the population.

Promoting equitable and sustainable housing in Rajshahi necessitates a multi-faceted approach. This includes exploring avenues for increasing the supply of affordable housing units, enhancing financial assistance programs, and fostering partnerships between government agencies, private sector stakeholders, and non-profit organizations. Additionally, investing in infrastructure development and urban planning initiatives that prioritize affordable housing can contribute to long-term solutions. By acknowledging the specific housing needs and financial constraints of the lower- and middle-income groups, Rajshahi can strive towards creating a more inclusive and affordable housing market. This will

not only improve the well-being of individuals and families but also contribute to social and economic stability within the community.

DISCLOSURE STATEMENT

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IDENTIFYING THE DRIVERS OF HOUSEHOLD WATER USAGE EFFICIENCY IN TERENGGANU: THEORY OF PLANNED BEHAVIOR (TPB) APPROACH

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Abstract

In the contemporary era, the issue of water scarcity has emerged as a critical concern on a global scale. Factors such as rapid population expansion, urbanization, and the uncertainties associated with climate change have exerted significant influence on water availability, particularly in the context of domestic consumption. Regions including Klang Valley, Selangor, Johor, Perlis, Melaka, and Negeri Sembilan are currently grappling with water shortages. Despite Malaysia's reputation for substantial rainfall, the nation is increasingly confronted with freshwater scarcity concerns. Consequently, the primary objectives encompass an examination of water consumption patterns and the identification of determinants driving water conservation within households. The study sample encompasses 271 households. Results indicate that both attitude and subjective norms are significantly correlated with water use efficiency, with corresponding p-values of 0.076 and 0.86, respectively. The insights gleaned from water usage patterns can serve as valuable tools for water operators in the management and educational efforts targeted at households, including campaigns promoting sustainable water usage and conservation practices.

Keywords: Water Scarcity, Pattern, Water Usage, Consumer Behaviour

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INTRODUCTION

In the 21st century, water scarcity has become a crucial issue worldwide. Rapid population growth, urbanization, and uncertainties related to climate change are some of the factors influencing water availability, particularly for domestic consumption. Additionally, domestic water consumption in Malaysia is high and increasing annually. It is vital to understand water use behavior to effectively manage and promote water use efficiency in daily activities such as toilet use, laundering, showering, car washing, gardening, and both interior and exterior cleaning. Currently, Malaysians consume 220 to 250 liters of water per person per day, exceeding the 165 liters recommended by the World Health Organization. This is higher than the daily per person consumption in Thailand (160 to 170 liters), Singapore (130 to 150 liters), and Indonesia (140 to 160 liters), indicating that consumers' behavior and attitudes toward water consumption in Malaysia are inefficient (Kamarudin, K. 2020). In general, water use patterns can be divided into indoor and outdoor activities such as bathing, showering, toilet, household cleaning, car washing, gardening and many more.

Household behaviors can be measured using the Theory of Planned Behavior, which can determine water use efficiency (Ajzen, I.,1991). Intention toward efficient water use can be influenced by attitudes, subjective norms, and perceived behavioral control. Therefore, this study examined water use patterns and explored the relationship between the Theory of Planned Behavior (TPB) and water use efficiency. The questionnaire includes items related to water use patterns and TPB elements on water use efficiency, and it was administered to 300 residential customers. This research gap needs to be addressed to comprehend consumer behavior toward water use, provide insight into domestic use patterns, and identify TPB elements influencing water use efficiency.

This paper commences with an introduction, followed by a literature review on household water usage and consumer behavior based on the Theory of Planned Behavior (TPB). Section three discusses the study's methodologies and materials, while section four focuses on the results, findings and conclusions.

LITERATURE REVIEW

Drivers of Household Water Use Behavior

There are various factors that influence water conservation behavior, such as psychological aspects including values, beliefs, trust, emotional reactions, and attitudes. While previous behavioral studies have examined the relationship between psycho-social factors and household water use behavior, there has been a lack of a profiling approach to understand the barriers and drivers of household water conservation within behavior-change theory (Corral-Verdugo et al., 2002; Syme et al., 2004).

Earlier studies have linked attitudes toward gardening to overall household water consumption rather than just outdoor water use, but the findings of this research have been inconclusive. For instance, in a study conducted in Perth, Syme et al. (1990/1991) found significant relationships between spouses' opinions regarding their gardens and their household's total annual water consumption. Families who perceived their gardens as adding more value to their homes used more water throughout the year, as did families who valued their garden's recreational amenities.

Aitken et al. (1994) discovered in a study in Melbourne that attitudes toward water consumption were not reliable predictors of household water use when tested twice a week for 2.5 months during the winter. Many psychological and social factors can encourage positive behavior in households when implementing water-saving solutions (Fielding et al., 2012). Water conservation intervention solutions are typically delivered through communication and understanding and directing the psychological and social predictors of home water use behavior adds further depth to this area of study. Additionally, the understanding of the capability, opportunity, and motivation (COM) dimensions can be beneficial for identifying behaviors that affect water usage (Addo & Thoms, 2018). These factors, their impact on household water consumption, and their interaction with other potential factors that may hinder behavioral change are currently under investigation.

Behavioral Drivers

Behavioral factors encompass perceptions, thoughts, feelings, and beliefs that influence behavior. One popular theory for examining environmental behaviors is the Theory of Planned Behavior (TPB) developed by Ajzen in 1991, and it encompasses various aspects such as water use (Fu and Wu, 2014; Harland et al., 2006; Mosler, 2012; Steg and Vlek, 2009; Stern, 2000; Yuriev et al., 2020). According to the theory, beliefs have the power to influence norms, and in turn, norms will influence behavior among individuals (Roobavannan et al., 2018). Values can also influence beliefs, norms, and conduct.

Several studies have investigated the impact of individual behavior on water efficiency, including studies on water use efficiency (WUE) and regulations. These studies have involved various groups such as farmers and rural residents, and they have considered contextual elements including an individual's background and physical environment (Dreibelbis et al., 2013).

Behavioral aspects are influenced by a variety of factors, some of which may encourage or inhibit behavior (Contzen and Mosler, 2012). Contextual elements including environmental, technological, economic, social, institutional, and individual factors are significant in predicting water consumption (Russell et al., 2020). Environmental factors relate to geographical experiences associated

with sustainable learning (Dean et al., 2016), while institutional factors encompass linkages between water users and water delivery systems and relevant regulations (Khair et al., 2019).

Consumer Behavior Toward Water Usage Efficiency

The Theory of Planned Behavior (TPB) is an advancement of the Theory of Justified Action. TPB includes decision elements such as attitudes and subjective norms (Ajzen, 1991; 2006; Botetzagias et al., 2015). According to this theory, when consumers feel positive about buying a product or adopting a certain consumer habit, receive encouraging feedback from their environment (subjective norm), and have the means to purchase the product (perceived behavioral control), they are more likely to buy the product or engage in the promoted practices (Klockner, 2013; Lopez-Mosquera, and Sanchez, 2012). Figure 2 illustrates the three elements contributing to water usage efficiency intention in this study.

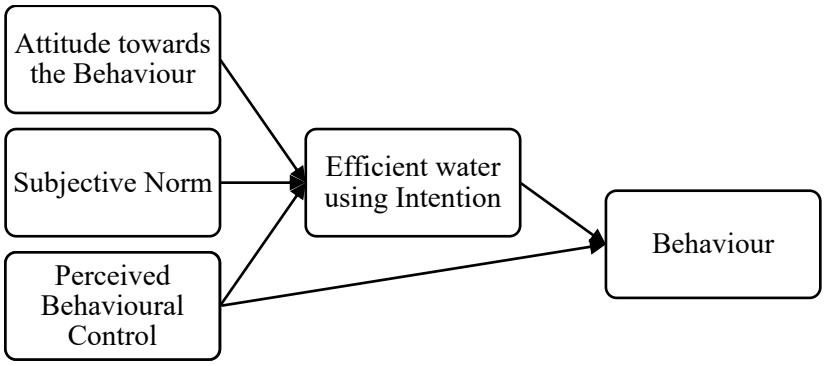

Figure 1: Adopted Theory of Planned Behaviour (Ajzen, 1985)

To create more accurate forecasts of behavioral intentions than previous models, the theory of planned behavior has been expanded to include attitudes, subjective norms, and perceived behavioral control as variables. An individual's attitude toward action is the extent to which the behavior is positively or negatively evaluated. Attitudes are determined by two factors: the instrumental factor (if the behavior can achieve something) and the experiential factor (how the individual feels while performing the behavior). The perceived positive or negative outcomes of engaging in a behavior, as well as people's evaluations of these outcomes, are referred to as behavioral beliefs.

These factors come together to form a person's attitude toward the behavior, reflecting the individual's positive or negative evaluations of a specific behavior (Abrahamse, 2019). Attitudes are determined as a set of probabilities

regarding the likelihood that the behavior will lead to desired consequences. These probabilities are based on personal experiences, opinions, information sources, and deductions. Subjective norms are perceived social pressures to engage in a particular behavior based on the opinions of a significant individual or a group of individuals (Ham, 2015).

Two types of clauses can be used to evaluate subjective norms: imperative clauses and descriptive clauses. Imperative statements refer to people's beliefs that others think "it should be done," and descriptive statements refer to what most people do. This also involves considering what is likely to be common in the social environment. Normative beliefs are the set of beliefs that other people (such as family, neighbors, or friends) may have about the behavior the person wishes to perform. Compliance motivation is an individual's awareness of complying with behavior based on what those around them think about performing that behavior.

Normative beliefs and motivation to comply are two factors, along with statements, that should be used to determine a person's subjective norms for behavior (Midden & Ritsema, 1983). Perceived behavioral control, the third element after attitudes and subjective norms, refers to a person's perception of their ability to perform a certain behavior. If a person's behavior is completely under control, intentions alone are sufficient to predict behavior. However, if a person's behavior is not fully within their control, perceived behavioral control (PBC) can provide additional information to help predict behavior beyond the TPB model's capability (Madden et al., 1992). PBC consists of two parts: self-efficacy and controllability. Self-efficacy refers to an individual's belief in their ability to perform behaviors that affect their lives (Bandura, 2010). Controllability is the ability of individuals to control behavior, their thoughts on the behavior's importance to the people around them, and their ability to perform the behavior when factors are beyond their control. These items identify PBC as Control Beliefs, which refer to beliefs about the factors or circumstances that make the performance of the behavior difficult or better (Ajzen, 2002).

RESEARCH METHODOLOGY

Study Area

Kuala Terengganu is located on the East Coast of Peninsular Malaysia, about 440 kilometers northeast of Kuala Lumpur. The city is situated at the estuary of the Terengganu River, which borders the South China Sea. The population of Terengganu is around 1.2 million people, with 90% being Malays, and the remainder being Chinese and Indians.

Kuala Terengganu, the state capital, as well as other towns and villages in Terengganu, have a relaxed pace of life that is untouched by the noise and hustle of a big city. Over the last 30 years, Terengganu has experienced

significant development due to rapid industrialization and increased commercial activity following the discovery of valuable assets. Prior to this, farming and fishing were the primary economic activities in the state.

Data Collection and Profile of Participants

The study was carried out from December 2021 to February 2022 in two districts in Terengganu: Kuala Terengganu and Kuala Nerus. A total of 300 responses were collected through face-to-face surveys, and after data cleaning, 271 cases were used for sample analysis. The Theory of Planned Behavior (TPB) model, based on Ajzen (2006) and Moura (2017), was used to understand household behavior related to water usage.

The study explored how beliefs and attitudes influence people's behavior and their perceived control over that behavior. A structured questionnaire was developed to assess water usage patterns, household water use efficiency behavior, and the Theory of Planned Behavior (TBP) toward water use efficiency. The results were measured on a five-point Likert scale, indicating respondents' subjective norms on water use efficiency (1 = Strongly Disagree; 2 = Disagree; 3 = Neither Agree nor Disagree; 4 = Agree; 5 = Strongly Agree). Participants in indoor and outdoor activities were asked to indicate their level of agreement or disagreement.

The study focused on understanding the impact of TPB on water use efficiency. A survey instrument and measurement scales were designed to test the conceptual model using items representing TPB components, such as intention and attitude, behavioral beliefs, subjective norms, perceived behavioral control, and control beliefs, towards water usage efficiency as presented in Figure 2.

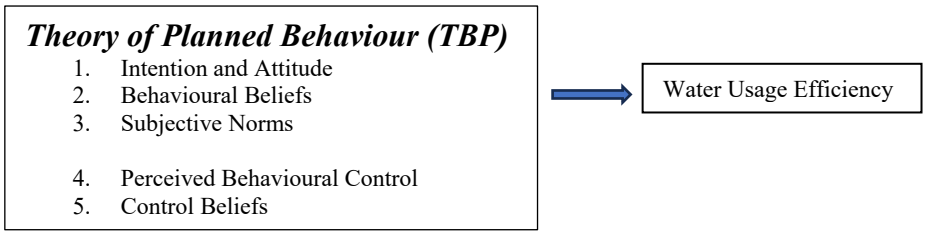

Figure 2: Conceptual model

Furthermore, descriptive analysis was used to evaluate domestic water consumption data. The factors influencing domestic water usage were determined using the following model:

$$\text{Water Usage } i = \beta_0 + \beta_1 \text{intention } i + \beta_2 \text{belief } i + \beta_3 \text{norms } i + \beta_4 \text{perceived behavioral } i + \beta_5 \text{ control } i + \varepsilon i \quad (1)$$

Here, "i" represents the individuals (with i ranging from 1 to N). The variable "water usage i" denotes water consumption, $\beta_1$intention represents intention and attitude, $\beta_2$belief represents behavioral beliefs, $\beta_3$norms represents subjective norms, $\beta_4$perceived behavioral represents perceived behavioral control, β_5 control represents control beliefs, and ε i represents the error term.

ANALYSIS AND DISCUSSION

Demographic Profile

The use of descriptive statistics helps to simplify and organize large amounts of data into a few numbers or graphs. This assists researchers in understanding the main features and patterns of the demographic profile of the data and identifying the important demographic characteristics of the study. the total sample for this study consisted of 300 residential customers. After data cleaning, 271 residential customers were used for further analysis, which represents 90.33% of the total sample. The main reason for this was that respondents needed to complete the TBP and water usage efficiency section in the questionnaire.

The majority of respondents were male (60.5%) and female (39.5%). The most common age group was 31 to 40 years (32.5%), followed by 20 to 30 years old (29.9%). Most respondents had 3 to 5 people in their households (49.8%) and lived in terrace houses (47.2%), followed by semi-detached and bungalow homes. The majority, approximately 77.9%, were married. In terms of education levels, most respondents had completed secondary school (19.4%) or college/university (38.7%).

Descriptive Analysis

Tables 1-5 present Cronbach's Alpha means, standard deviations, skew, and kurtosis for attitudes, behavioral beliefs, subjective norms, motivation to comply, perceived behavioral control, and control beliefs related to efficient water use. To ensure normal and univariate distribution, the values of skewness and kurtosis should fall within the range of -2 to +2 (George & Mallery, 2010). Other researchers such as Hair et al. (2010) and Byrne (2010) argue that data is considered normal if skewness is between -2 to +2 and kurtosis is between -7 and +7. Cronbach's alpha assesses the reliability and internal consistency of test items. Reliability refers to how consistently an item can measure a concept. Cronbach’s alpha value of .70 is considered good, .80 is better, and .90 is the best value for consistency in Cronbach’s alpha.

Table 1: Descriptive statistics for attitudes towards residential water use efficiently

	Mean	**SD**	**Skew**	**Kurtosis**	**Cronbach's Alpha**
I intend to manage and practice efficient water use at home in the future.	4.1439	.46103	.511	.993	.727
I am determined to manage and practice efficient water use at home.	4.1218	.44298	.565	1.473	
I plan to manage and practice efficient water use at home in the future.	4.2251	.56197	.007	-.297	
I recommend efficient water use practices to my family and friends.	4.2583	.53720	.119	-.374	
I have a positive view of this efficient water use practice.	4.2546	.50710	.329	-.334	
I think an efficient use of water at home would be good practice.	4.2804	.56005	-.026	-.503	
Overall Mean	4.2140				

Table 2; Descriptive statistics for behavioural beliefs toward residential water use efficiently

	Mean	**SD**	**Skew**	**Kurtosis**	**Cronbach's Alpha**
Efficiency in water use would lower my expenses on water bills.	4.2841	.48351	.560	-.722	.749
Efficiency in water use can reduce my water consumption.	4.3542	.52349	.138	-.992	
Efficiency in water use could improve the availability of water resources for other uses.	4.3247	.54916	-.014	-.691	
Efficiency in water use can reduce water wastage by using water efficiency equipment and changing water use habits.	4.4059	.53524	-.202	-.095	
Efficiency in water use can increase awareness and self-motivation to practice efficient water use in daily life.	4.2694	.50675	.335	-.460	
Efficiency in water use could make my daily routine at home easier.	4.2583	.51611	.098	.611	
More efficient water use practices can improve water conservation and the environment.	4.1661	.48506	.396	.540	
Efficiency in water use could raise awareness and motivation for myself to apply water use efficiency practices.	4.2362	.53363	-.001	.584	
Overall Mean	4.2874				

Table 3: Descriptive statistics for subjective norms towards residential water use efficiently

	Mean	SD	Skew	Kurtosis	Cronbach's Alpha
Most people think I should manage, and practice water use efficiency.	4.1365	.62048	-.192	-.070	.749
I expected to manage and practice water use efficiency at any time.	4.1661	.59482	-.068	-.325	
The people in my life whose opinions are that I would manage, and practice water use efficiency.	4.1365	.51621	.186	.439	
Most people around my neighborhood have started to practice or always practice water use efficiency in their households.	4.0812	.53129	.082	.479	
Overall Mean	4.1301				

Table 4: Descriptive statistics for perceived behavioural control towards residential water use efficiently

	Mean	SD	Skew	Kurtosis	Cronbach's Alpha
I am confident in managing and practicing water use efficiency.	4.2288	.49372	.421	-.092	.811
If I wanted to, I could manage, and practice water use efficiency at any time.	4.2841	.45183	.963	-1.081	
I can have full control over managing and practicing efficient water use.	4.2731	.51566	.263	-.473	
I have complete control over the decision to manage and practice efficient water.	4.2251	.50651	.320	-.087	
Overall Mean	4.2528				

Table 5: Descriptive statistics for control beliefs towards residential water use efficiently

	Mean	SD	Skew	Kurtosis	Cronbach's Alpha
I expect the government or non-government would offer water efficiency incentive programs (such as rebates and unit exchange programs).	4.2915	.48675	.529	-.782	.806
I expect the government or non-government would offer a water efficiency incentive program that would make it much more to manage and practice water use efficiency in the household.	4.2768	.55191	.022	-.481	
I expect the government or non-government would provide water management services related to water efficiency to help me manage water use efficiency in the household.	4.3542	.51637	.202	-1.064	
I expect the government or non-government would offer an educational program or awareness campaign to gain knowledge about the importance of water use efficiency.	4.2620	.59752	-.588	2.352	
Overall Mean	4.2961				

Data Analysis Behavior of Water Usage in Indoor and Outdoor Activities

Table 6 illustrates the breakdown of water usage for various indoor and outdoor activities such as bathing, laundry, dishwashing, cooking, drinking, aquarium care, pet bathing, toilet flushing, and general cleaning (indoor activities). It also includes outdoor activities like car washing, watering plants, maintaining landscapes, and swimming pool care. Most of these activities collectively contribute to over 60% of water usage both indoors and outdoors. The highest average water usage (4.11) is for bathing, followed by drinking (approximately 4.09) and laundry (about 4.03).

Table 6: Indoor and outdoor water usage

Indoor Water Usage								
No.	**Activities**	***Never use***	***Almost Never***	***Sometimes***	***Almost Every time***	***Frequently Use***	***Mean***	***Std. Deviation***
1	Bathing	-	-	14.0	60.5	25.5	4.11	0.61
2	Washing clothes	-	1.1	16.2	60.9	21.8	4.03	0.65
3	Washing dishes or kitchen appliances	-	0.4	27.3	47.2	25.1	3.97	0.73
4	Cooking	-	1.1	29.2	42.1	27.7	3.96	0.73
5	Drinking	-	0.7	19.9	47.6	31.7	4.09	0.75

Indoor Water Usage								
No.	**Activities**	***Never use***	***Almost Never***	***Sometimes***	***Almost Every time***	***Frequently Use***	***Mean***	***Std. Deviation***
6	Rearing fish in the aquarium	11.1	6.3	18.1	41.0	23.6	3.59	1.22
7	Bathing pets	11.8	7.0	15.1	47.6	18.5	3.53	1.21
8	Toilet flushing	3.0	7.4	22.1	46.5	21.0	3.75	0.96
9	Cleaning toilet and bathroom	1.8	8.9	22.1	42.8	24.4	3.78	0.97
Outdoor Water Usage								
No.	**Activities**	**Never use**	**Almost Never**	**Sometimes**	**Almost Every time**	**Frequently Use**	***Mean***	***Std. Deviation***
1	Cleaning the floor, windows, porch, and drain outside the house	1.5	15.5	13.3	50.2	19.6	3.70	0.99
2	Watering flowers, fruit, or vegetable plants	2.2	11.4	16.2	52.0	18.1	3.72	0.96
3	Washing the cars, motor vehicles, and bicycle	1.5	10.7	21.8	47.2	18.8	3.71	0.94
4	Business	15.9	4.4	19.9	43.5	16.2	3.39	1.26
5	Maintaining house landscape	14.4	5.2	18.8	43.9	17.7	3.45	1.25
6	Rearing fish at backyard fish pond	14.4	7.4	10.7	49.4	18.1	3.49	1.27
7	Swimming pool or portable swimming pool	18.5	4.1	12.9	46.1	18.5	3.42	1.34

Table 7: Water use efficiency and elements of TPB coefficients

Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	30.496	18.935		1.611	.108
	Attitude	-5.771	3.241	-.117	-1.781	**.076***
	Beliefs	-2.316	3.695	-.044	-.627	.531
	Subjective	4.073	2.365	.106	1.722	**.086***
	Behavioural	2.333	3.005	.056	.776	.438
	Control	1.856	2.748	.048	.675	.500

a. Dependent variable: Water bill

Note: * Significant at 0.10%

Table 7 displays water usage and its relation to elements of the Theory of Planned Behavior (TPB) including attitude, behavioral beliefs, subjective norms, and perceived behavioral control. The elements of attitude and subjective norms in TPB are statistically significant at 0.1%, indicating that a 1% increase in attitude and subjective norms leads to households intending to manage and practice water use efficiency.

In summary, this study utilized the Theory of Planned Behavior (TPB) to investigate how attitudes, behavioral beliefs, subjective norms, and perceived behavioral control influence residential water use efficiency through multiple regression analysis. The results indicated that both attitude and subjective norms significantly correlate with water use efficiency, with p-values of 0.076 and 0.86, respectively.

Households are inclined to manage and practice efficient water use at home, and they also encourage such practices among their family and friends, viewing it as beneficial for future water management. The study found that attitude strongly influences intentions for pro-environmental behavior and water-saving, consistent with the findings of Si et al. (2022), Okumah et al. M. et al. (2019), Daxiniet al. (2018), and .(Bamberg & Möser, 2007) (, 2019)

Concerning subjective norms, households believe it is important to manage and practice water use efficiency. They also observe that their communities are adopting similar practices, as highlighted in a study by Perren and Yang (2015). Both attitudes and subjective norms have a significant direct impact on the intention to use water efficiently, aligning with the findings of Si et al. (2022) and Gibson et al. (2021), who demonstrated that attitudes, subjective norms, and perceived behavioral control influence water use efficiency intention.

CONCLUSION

Understanding water usage behavior is crucial for developing efficient water usage strategies to align with SDG6 (Clean Water and Sanitation). Managing water resources, water recycling, exploring freshwater resources, controlling water pollution, ensuring water affordability, maintaining water quality, and promoting sustainability are all essential aspects. SDG-6 highlights several effective ways to address the water crisis. Insights into water consumption patterns can help water operators manage and educate households about sustainable water use and conservation. From a policy perspective, these findings suggest that policymakers and regulators should consider TPB variables when aiming to promote efficient water use behaviors. Therefore, water company operators and policymakers can propose suitable policies to ensure effective domestic water consumption in a sustainable manner and preserve water resources for future generations.

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THE IMPACT OF ENVIRONMENTAL RESPONSIBILITY ON THE WELLBEING OF UNIVERSITY STUDENTS

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Abstract

Despite growing awareness of environmental issues and the increasing integration of sustainability into educational settings, the relationship between environmental responsibility and the well-being of university students remains insufficiently explored. Presently, environmental issues pose challenges for Malaysia, becoming a global concern that demands serious attention. While the general displays a high level of awareness regarding environmental issues, conservation and preservation efforts remain low. This study aims to examine environmental responsibility's impact on university students' well-being. The study was conducted on 309 students, and the obtained data were analysed using SPSS version 20. The findings demonstrate a moderate positive relationship for all variables, including environmental knowledge, emotions towards the environment, self-efficacy, motivation, intention, and environmental behaviour toward the well-being of university students. Regression analysis results reveal that two variables, namely self-efficacy and environmental behaviour, exhibit a significant and positive influence on the well-being of university students. It is crucial to foster environmental consciousness among Malaysians, especially students, because this generation plays a crucial role in shaping the future of the environment. Also, the Malaysian government must prioritise addressing environmental challenges, as they are progressively worsening and concerning.

Keywords: Environmental Responsibility, Wellbeing, University

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INTRODUCTION

Environmental responsibility has emerged as a progressively significant determinant of an individual's well-being, especially among university students. In light of the increasing environmental issues the world is currently confronting, the recognition and adoption of proactive measures to ensure environmental sustainability are considered crucial elements for overall well-being (Jones & Kahn, 2023; Siron & Kasavan, 2023). University students, who embody the future leaders and catalysts of change, are especially vulnerable to the impacts of environmental problems, both directly and indirectly.

Recent research suggests that students who actively engage in environmentally responsible behaviours, such as recycling, lowering their carbon footprints, and participating in environmental activism, will experience favourable effects on their mental health and emotional well-being (Smith et al., 2024; Dooris et al., 2021). This connection can be attributed to the sense of purpose and community that comes from contributing to a larger cause, which helps alleviate feelings of anxiety and helplessness commonly associated with concerns about climate change (Rodriguez & Lee, 2023). Moreover, these individual actions not only foster personal well-being but also strengthen organisations such as educational institutions, community groups, and environmental NGOs that support these initiatives. This collective effort will then significantly contribute to the sustainable future of the destination as a whole (Azinuddin et al., 2023).

In addition, adding environmental responsibility to university courses and campus life has been demonstrated to improve students' entire educational experience and personal growth (Rezaei et al., 2022). As universities progressively implement sustainable measures, such as establishing environmentally friendly campuses and promoting eco-conscious initiatives, students' engagement and involvement in these practices not only enhance their education but also cultivate a deeper sense of connection to their surroundings, consequently enhancing their overall well-being (Giannetti et al., 2021).

This study seeks to investigate the precise ways in which responsibility for the environment affects the mental well-being of university students, considering the increasing significance of environmental challenges. Gaining a thorough understanding of this connection is essential for formulating tactics to improve students'well-being and foster a sustainable culture in higher education establishments (Ismail et al., 2023).

LITERATURE REVIEW

Environmental Knowledge

More people realise the importance of environmental knowledge in influencing individual opinions and behaviours toward sustainability. Inculcating individuals with a thorough grasp of environmental concerns is crucial for creating

responsible and informed citizens in the face of the world's mounting environmental challenges, which range from biodiversity loss to climate change (Radwan & Khalil, 2021). This notion is especially true in educational environments, where learners are being prepared to deal with challenging environmental issues in their personal and professional lives down the road.

Recent studies highlight the significance of environmental awareness in encouraging environmentally conscious behaviour. Zhao and Cheah (2023) discovered that students at universities are more inclined to participate in sustainable behaviours, such as cutting back on trash and energy use if they have a higher degree of environmental knowledge. Gaining information improves people's capacity to evaluate environmental policies critically and push for the needed changes, enabling them to make well-informed decisions (Johnson et al., 2024; Yusof et al., 2023).

Furthermore, enhanced mental wellness has been associated with environmental understanding, especially when it comes to worry related to climate change. Clayton et al. (2024) explained that, people who have a greater comprehension of environmental issues are better able to handle the psychological effects of environmental degradation. The relationship between knowledge and well-being emphasises how crucial it is to include comprehensive environmental education in academic courses, particularly in higher education.

Despite the increased focus on this topic, a gap remained in the efficiency of environmental education teaching and application. Although students may acquire theoretical knowledge, there is frequently little opportunity for this knowledge to be applied practically in real-world situations. To adequately prepare students for the complex environmental difficulties they will encounter, more multidisciplinary approaches are required that combine environmental knowledge with other subjects, such as economics, politics, and social sciences.

Environmental Emotion

Environmental emotions refer to the various experiences that humans have in response to changes and challenges in the environment. These emotions highlight the deep relationship between human psychology and the natural world. With the growing urgency of climate change and environmental degradation, there is a heightened need to comprehend the emotions associated with these issues, including eco-anxiety, eco-guilt, and environmental bereavement. Recent studies highlight how these emotions can deeply impact individuals' behaviour (Xiong et al., 2023).

Self-efficacy

Environmental self-efficacy refers to the belief in one's ability to take effective actions that positively impact the environment. This belief is increasingly

recognised as a crucial factor in promoting sustainable behaviours and addressing environmental challenges. Individuals with high environmental self-efficacy are more inclined to engage in behaviours like recycling, conserving energy, and advocating for environmental policies (Sh. Ahmad et al., 2022). Their confidence in making a meaningful difference drives their actions. Recent studies emphasise the importance of enhancing environmental self-efficacy, especially among young people, to foster a more sustainable future. For example, Yang et al. (2024) found that students who participated in environmental education programs focused on building self-efficacy were significantly more likely to engage in pro-environmental actions than those who did not receive such training.

Motivation

Environmental motivation encompasses intrinsic and extrinsic factors encouraging individuals to factors like societal expectations, regulations, and rewards. Personal values and beliefs form the foundation of intrinsic motivation, which is highly effective in cultivating enduring dedication to environmental behaviours (Budzanowska-Drzewiecka & Tutko, 2021). Individuals who experience a profound affinity for the natural environment will be inclined to engage in conservation endeavours and diminish their impact on the ecosystem. Recent research has indicated that environmental education and awareness initiatives that prioritise intrinsic motivation are more successful in encouraging sustainable habits compared to programs that exclusively focus on external rewards (Radwan & Khalil, 2021).

Extrinsic motivation, although significant, typically encompasses external stimuli or obligations, such as monetary incentives, social acknowledgement, or adherence to regulations. These variables can significantly promote pro-environmental behaviours, particularly when complemented by legislation that endorses sustainable practices (Budzanowska-Drzewiecka & Tutko, 2021). Gibovic and Bikfalvi (2021) conducted a study that showed how offering monetary incentives for recycling greatly boosted the number of people participating, especially in areas with low levels of environmental awareness. Nevertheless, the durability of actions influenced by external motivation may be compromised when the external rewards are eliminated. Thus, a blend of inherent and external reasons is frequently the most efficient approach to promoting long-lasting involvement in environmental matters, with educational programs playing a vital part in nurturing a more profound and personal dedication to environmental responsibility.

Environmental Intention

Environmental intention refers to an individual's conscious and intended choice to participate in behaviours that have a beneficial effect on the environment. This idea is frequently regarded as a preliminary stage to tangible environmental

conduct, functioning as a link between consciousness and implementation. Environmental intentions are influenced by multiple factors, such as individual attitudes toward the environment, perceived ability to manage behaviour, and societal norms (Ismail & Amin, 2020). The Theory of Planned Behavior (TPB), commonly used in environmental research, suggests that individuals are more inclined to form strong intentions to engage in pro-environmental behaviours when they have favourable attitudes towards these behaviours, perceive a sense of control over their actions, and believe that their social circle supports such actions (Ajzen, 1991). Ismail et al. (2023) have verified that these elements have a substantial impact on environmental intentions, particularly among young individuals who are displaying growing apprehension towards climate change and sustainability.

Environmental Behaviour

Environmental behaviour refers to the acts that individuals perform that have a direct impact on the environment, whether that impact is beneficial or harmful (Ismail & Amin, 2020). These behaviours involve a wide variety of actions, such as recycling, conserving energy, minimising water usage, and supporting policies that are designed to protect the environment. To promote sustainable behaviours, it is essential to have a solid understanding of the factors that influence environmental behaviour. Recent research showed that, environmental behaviour is influenced by a variety of factors, including personal beliefs, social standards, perceived behavioural control, and, increasingly, the emotional and psychological ties that individuals have with nature. Individuals who have a deep emotional connection to the natural environment are more likely to engage in actions that are beneficial to the environment, such as lowering their carbon footprint and participating in conservation initiatives, as Ismail et al. (2023) demonstrated.

Well-being

Environmental knowledge equips pupils with the comprehension required to identify and address environmental concerns, cultivating a feeling of accountability and consciousness. When students possess a deep understanding of environmental challenges, they are more prone to experiencing feelings like eco-anxiety or environmental bereavement. Although these emotions can be painful, they can also serve as a catalyst for them to engage in significant and impactful actions. Emotional involvement frequently results in a heightened feeling of attachment to the natural world and a stronger drive to participate in actions that safeguard and maintain the environment (Clayton & Manning, 2018). Furthermore, students who possess a strong sense of environmental self-efficacy, meaning they have confidence in their ability to make a difference, are more inclined to convert their environmental knowledge and emotions into proactive

actions. This sense can lead to an increased sense of purpose and satisfaction, ultimately resulting in improved overall well-being.

METHODOLOGY

This study employed a quantitative research method to gather and analyse data. Using a simple random sampling technique, 309 university students from Universiti Sultan Zainal Abidin (UniSZA) and Universiti Malaysia Terengganu (UMT) were selected as respondents. The data collection process was conducted through the distribution of questionnaires, both in physical form and via Google Forms, to ensure a broad and accessible reach among the participants.

The collected data were then analysed using the Statistical Package for the Social Sciences (SPSS) software. This software was utilised to perform descriptive and inferential statistical analyses, allowing for a comprehensive examination of the data. The analysis included various statistical tests to identify relationships and patterns relevant to the objectives, ensuring the reliability and validity of the findings.

ANALYSIS AND DISCUSSION

Respondent's Profile

The respondent profile provides an overview of the demographic and educational characteristics of the 309 university students from Universiti Sultan Zainal Abidin (UniSZA) and Universiti Malaysia Terengganu (UMT) who participated in the research. Table 1 shows the sample is composed of 133 male respondents, representing 43.0% of the total, and 176 female respondents, accounting for 57.0%, indicating a slightly higher participation of female students in the study.

The age distribution shows that the majority of respondents are between 21 and 25 years old, with 170 individuals in this category making up 55.0% of the total. This category is followed by 115 respondents (37.2%) in the 18 to 20 age group. A smaller percentage of respondents fall into the 26 to 30 age group (7.2%), and only 2 respondents (0.6%) are aged 31 and above.

The educational background of the respondents reveals that 221 participants (71.5%) are pursuing a degree, making it the predominant educational level among the sample. This is followed by 77 respondents (25.0%) who are enrolled in diploma programs. A minority of respondents are pursuing higher degrees, with 9 individuals (2.9%) working towards a master's degree and 2 respondents (0.6%) pursuing a PhD.

The respondents are fairly evenly distributed between the two institutions, with 163 students (52.8%) from UniSZA and 146 students (47.2%) from UMT. This balance ensures that the data reflects perspectives from both universities, contributing to the study's overall representativeness. Table 1 shows the summary of the respondents'profiles.

Table 1: Respondents' Profiles

Characteristics		No. of respondents	%
Gender			
	Male	133	43.0
	Female	176	57.0
Age			
	18 to 20	115	37.2
	21 to 25	170	55.0
	26 to 30	22	7.2
	31 above	2	0.6
Education level			
	Diploma	77	25.0
	Degree	221	71.5
	Master	9	2.9
	PhD	2	0.6
Institution			
	UniSZA	163	52.8
	UMT	146	47.2

The Descriptive Analysis

The descriptive analysis of the study's variables in Table 2 provides insight into the respondents' overall levels of environmental knowledge, emotions, self-efficacy, motivation, intention, behaviour, and well-being. The mean scores and corresponding levels indicate how the respondents generally perceive and engage with environmental issues and their overall well-being.

Table 2: The descriptive analysis of variables

Variables	Mean	Level
Environmental Knowledge	3.69	High
Environmental Emotion	4.38	High
Self-efficacy	3.70	High
Motivation	4.07	High
Environmental Intention	4.13	High
Environmental Behaviour	3.48	Moderate
Well-being	3.81	High

The respondents demonstrated a high level of environmental knowledge, with a mean score of 3.69. This suggests that the students are well-informed about environmental issues, which likely influences their attitudes and behaviours towards sustainability. Next, environmental emotion, with a mean score of 4.38, is the highest among all the variables. This indicates that the respondents have strong emotional responses to environmental issues, reflecting a deep concern and connection to the natural environment. Such strong emotions

can be a powerful driver for environmental action. Meanwhile, the high level of self-efficacy, with a mean score of 3.70, suggests that the respondents feel confident in their ability to make a positive impact on the environment. This confidence is crucial for translating environmental knowledge and emotions into tangible actions.

Motivation toward the environment also scored highly, with a mean of 4.07. This high level of motivation indicates that both internal and external factors drive the respondents to engage in behaviours that benefit the environment. Besides, the high mean score of 4.13 for environmental intention suggests that the respondents are committed to engaging in pro-environmental behaviours. This strong intention is a key precursor to actual environmental action.

Despite high levels of knowledge, emotion, self-efficacy, motivation, and intention, the mean score for environmental behaviour is 3.48, which is at a moderate level. This suggests that while respondents are knowledgeable and motivated, there may be barriers or challenges that prevent them from fully engaging in pro-environmental behaviours. Lastly, the overall well-being of the respondents is at a high level, with a mean score of 3.81. This indicates that, on average, the respondents feel positive about their lives, and their engagement with environmental issues may contribute to this sense of well-being.

The Relationship Between Environmental Responsibility on the Wellbeing

The Pearson correlation coefficients (r) presented in the analysis in Table 3 indicate the strength and direction of the relationships between various environmental variables (knowledge, emotion, self-efficacy, motivation, intention, behaviour) and well-being among the respondents. All correlations are statistically significant at the $p < .005$ level, as indicated by the p-values of .000.

Table 3: Pearson Correlation Coefficient (r)

Variables	Pearson Correlation (r)	P
Environmental Knowledge	.493**	.000
Environmental Emotion	.257**	.000
Self-efficacy	.558**	.000
Motivation	.446**	.000
Environmental Intention	.422**	.000
Environmental Behaviour	.515**	.000

Significant level $p<0.05$

The findings show a moderate to strong positive correlation between environmental knowledge and well-being, with a Pearson correlation coefficient of .493. This result suggests that as students' environmental knowledge increases, their sense of well-being tends to improve significantly. Understanding environmental issues may enhance students' sense of control and connection to

the world around them, contributing positively to their overall well-being. Meanwhile, the correlation between environmental emotion and well-being is weaker, with a coefficient of .257, but still statistically significant. It indicates that while strong emotional connections to the environment are associated with better well-being, the effect is less pronounced compared to other variables. Emotional engagement with the environment can contribute to well-being, but it may also lead to stress or anxiety if not balanced with action or coping strategies.

Next, self-efficacy shows the strongest positive correlation with well-being among all the variables, with a Pearson correlation coefficient of .558. This strong relationship suggests that students who feel capable of taking effective environmental action also tend to have higher levels of well-being. This may be because a strong belief in one's ability to influence positive change can enhance a sense of purpose and personal satisfaction, thereby boosting overall well-being.

The findings indicate a moderate positive correlation between motivation and well-being, with a coefficient of .446. It indicates that higher levels of motivation toward environmental issues are associated with better well-being. Motivated individuals are likely to feel more engaged and purposeful, which can contribute positively to their mental and emotional health. Environmental intention also shows a moderate positive correlation with well-being, with a coefficient of .422. This suggests that students who intend to engage in pro-environmental behaviours are likely to experience higher levels of well-being. Having clear intentions to act in environmentally responsible ways can provide a sense of direction and fulfilment, which supports overall well-being.

Lastly, the correlation between environmental behaviour and well-being is moderate to strong, with a coefficient of .515. This result suggests that students who actively engage in pro-environmental behaviours tend to report higher well-being. Engaging in these behaviours may provide a sense of accomplishment and align with personal values, thereby enhancing life satisfaction and well-being.

The Impact on the Wellbeing of University Students

The multiple regression analysis assesses the influence of various environmental responsible factors including knowledge, emotion, self-efficacy, motivation, intention, and behaviour, on the well-being of university students (refer to Table 4). The model's overall effectiveness is indicated by an R-value of 0.652, suggesting a strong collective relationship between these variables and well-being. The Adjusted R Square value of 0.413 means that approximately 41.3% of the variance in well-being can be explained by the combined effect of these predictors. The F-value of 37.129 is significant, confirming that the model as a whole is statistically significant.

Table 4: Impact Wellbeing

Variables	Beta	t	P
Environmental Knowledge	.109	1.776	.077
Environmental Emotion	.043	.770	.442
Self-efficacy	.357	6.583	.000
Motivation	-.010	-.136	.892
Environmental Intention	..081	1.275	.203
Environmental Behaviour	.254	4.371	.000

R = 0.652; F = 37.129; Adjusted R Square = 0.413

Environmental knowledge has a positive but non-significant impact on well-being. The beta coefficient of .109 indicates a weak relationship, with a p-value of .077. Thus, it does not meet the conventional threshold for statistical significance ($p < .05$). This result suggests that while knowledge contributes somewhat to well-being, its impact is not strong enough to be considered a major predictor in this model. Next, the impact of environmental emotion on well-being is also positive but not significant, with a beta coefficient of .043 and a p-value of .442. This result suggests that the emotional response to environmental issues does not have a strong or significant influence on the well-being of university students in this sample.

Self-efficacy stands out as the strongest predictor of well-being, with a significant beta coefficient of .357 and a p-value of .000. This result indicates that students who feel confident in their ability to take effective environmental action are likely to experience significantly higher levels of well-being. The strong relationship underscores the importance of fostering environmental self-efficacy as a key factor in enhancing student well-being. Surprisingly, motivation has a negative and non-significant impact on well-being, with a beta coefficient of -.010 and a p-value of .892. Thus, motivation, in isolation, does not significantly contribute to well-being, and its slight negative beta indicates that other factors may overshadow its direct effect.

Meanwhile, environmental intention has a positive but non-significant impact on well-being, with a beta coefficient of .081 and a p-value of .203. It indicates that while having intentions to act pro-environmentally is associated with better well-being, the relationship is not strong or significant in this model. Environmental behaviour is the second strongest predictor after self-efficacy, with a significant positive impact on well-being (Beta = .254, p = .000). This finding highlight that actively engaging in environmentally responsible behaviours contributes meaningfully to students' well-being, reinforcing the idea that practical action is key to enhancing life satisfaction.

CONCLUSION

This finding underscores the critical role of environmental self-efficacy and behaviour in enhancing the well-being of university students. While students exhibit high levels of environmental knowledge, emotion, motivation, and intention, a moderate level of environmental behaviour indicates a possible gap between what they intend to do and their actual actions. This gap presents an opportunity for further research to explore the barriers preventing students from translating their environmental intentions into behaviours.

The positive correlations between all environmental variables and well-being, with self-efficacy showing the strongest correlation, highlight the importance of fostering confidence in students' ability to effect positive environmental change. This confidence, coupled with actual environmental behaviour, emerges as a key predictor of well-being, suggesting that strategies to empower students to act on their environmental knowledge and intentions could significantly enhance their overall quality of life.

In summary, the study suggests that while knowledge, emotion, motivation, and intention are important, translating these factors into action supported by a strong belief in one's ability to make a difference is essential for promoting both pro-environmental behaviours and the well-being of university students. Therefore, initiatives that enhance self-efficacy and encourage active participation in environmental efforts are likely to be the most effective in fostering a sustainable and well-balanced student life.

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SPATIAL AUTOCORRELATION ANALYSIS OF THE FISCAL IMPACTS OF THE COVID-19 PANDEMIC ON PHILIPPINE LOCAL GOVERNMENT UNITS: A STUDY OF LUZON ISLAND

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Abstract

The COVID-19 pandemic has disrupted economic activities across Philippine Local Government Units (LGUs), resulting in significant fiscal implications. This study applied spatial autocorrelation analysis to a dataset covering around 15,480 data points from 645 LGUs (cities and municipalities) spanning 2009-2021, focusing on Locally-sourced Revenue (LSR) and Internal Revenue Allotment (IRA) dependencies. It assessed the fiscal impact of the pandemic by comparing actual 2021 LSR and IRA dependencies with their predicted levels. Pre-pandemic analysis identified "high-high" and "low-low" areas, revealing pronounced clustering of local economic advantages and disadvantages. During the pandemic, the majority of LGUs experienced negligible (36%) or slightly negative (27%) impacts on LSR dependencies with no spatial pattern found (Global Moran's I=0.001). Conversely, severe positive (49%) and negative (46%) impacts occurred on IRA dependencies with clear spatial autocorrelation (Global Moran's I=0.319). To address these disparities, policymakers are urged to implement proactive measures, including (a) targeted resource allocation and investments, (b) incentives for marginalized districts, (c) establishment of growth poles in lagging regions, and (d) enhance economic interconnectivity among LGUs.

Keywords: Community Resilience, Disaster Preparedness, Pandemic recovery, Spatial Analysis, Urban and Regional Planning

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INTRODUCTION

Fiscal decentralization in the Philippines commenced in 1991 with the legislative enactment of the Local Government Code (LGC). This has allowed the Local Government Units (LGUs) autonomy in their resource spending decisions based on the revenues they receive (Manasan, 2005). Republic Act No. 11964 defines Annual Regular Income (ARI) as the annual earnings, encompassing fees, and receipts, that local government units (LGUs) actually get from regular sources. This encompasses the National Tax Allotment (NTA) and additional portions of national wealth while excluding non-recurring revenues like national aid, grants, financial assistance, loan proceeds, asset sales, miscellaneous income, and analogous sources. In general, the two largest components of ARI an LGU obtains are Internal Revenue Allotment (IRA) and Local Source Revenue (LSR). IRA is an intergovernmental fiscal transfer of shares obtained from the national government. Meanwhile, LSR includes revenues obtained internally by an LGU. Both IRA and LSR are vital in the operations, deliverance of essential public services, and economic growth.

LGUs receive a fair share of IRA in accordance with the provision of LGC. However, several studies have shown disparities in economic growth. For instance, provinces remain highly dependent on the share they obtain from the national government despite the Philippines achieving overall economic growth. The growth has not reached the areas where it is intended (Cuaresma, 2019). Meanwhile, fiscal decentralization in the form of unconditional transfer has induced LGUs' overdependence on the national government (Panao, 2021). This heavy reliance on IRAs causes unpredictability and instability in local finances (Uchimura & Suzuki, 2009). There are also evidences that income generated locally are lesser in cities and municipalities that are more dependent on IRA. It is also alarming that LGUs that are reliant on the central government are more likely to allocate less budget on social and economic programs, which then fuels the cycle of dependency and underdevelopment (Panao, 2023). In contrast, those who are less reliant on the IRA are able to generate local income and spend a larger portion of their budget on public welfare initiatives (Panao, 2021). These observations raise doubt about one of the primary purposes of fiscal decentralization, which is to make the LGUs more fiscally autonomous.

This recurring fiscal issue has been further aggravated by the emergence of the COVID-19 pandemic, which has disrupted economies and societies on an unprecedented scale. In the Philippine context, hard and mild lockdowns were implemented from March to May of 2020. This resulted in negative repercussions on the economy, including a record-high decrease in the Philippine GDP and an increase in unemployment, affecting 90% of the labor workforce (Abueg, 2020; Lim, 2020). Despite government efforts to reduce the impacts of the pandemic on public health, the Philippines recorded the greatest

number of COVID-19 cases in Southeast Asia in the fourth quarter of 2020, according to the John Hopkins University Coronavirus Resource Center. Six months after the March 2020 lockdown, the Philippine economy commenced its recovery phase. Nonetheless, micro, small, and medium-sized firms (MSMEs) continue to grapple with substantial declines in demand and revenue, as seen by Shinozaki and Rao (2021). This reduces the recovery potential since most LGUs host MSMEs.

This report analyzes the financial effects of the COVID-19 outbreak on local government units in Luzon, the Philippines' largest and most economically vibrant island. Spatial and temporal trends in pre-pandemic LSR and IRA dependencies were essential in predicting the pandemic levels. Through the spatial autocorrelation analysis, areas where clusters or dispersion of fiscal dependencies and localized patterns of economic resilience or vulnerability are identified.

RESEARCH METHODOLOGY

Research Design

The research utilized a quantitative methodology, applying spatio-temporal analyses to examine the IRA and LSR connections of Philippine local government units on Luzon Island. A statistical technique known as spatial autocorrelation was applied to discern any noteworthy spatial patterns within these fiscal variables. The analysis was conducted using annual data spanning from 2009 to 2021, with resultant maps interpreted to detect clustering and dispersion patterns. To elucidate temporal trends, the Global Moran’s I index—a metric for spatial clustering—was utilized. Furthermore, the study evaluated the impact of the COVID-19 pandemic by measuring the deviation between actual and predicted values of IRA and LSR dependencies. LGUs exhibiting the most substantial deviation were identified as those most greatly affected by the pandemic's fiscal repercussions.

Study Area

Luzon stands as the Philippines' largest and most densely populated island, with coordinates at 16°N 121°E. It is home to seven regions encompassing 33 provinces, 72 cities, and 626 municipalities. It notably encompasses Manila, the capital of the nation and a significant metropolis, as well as Quezon City. Luzon, situated in the northern region of the Philippine archipelago, is bordered by the Philippine Sea to the east, the Sibuyan Sea to the south, and the South China Sea to the west. The Luzon Strait delineates its northern boundary from Taiwan. The island is vital to the nation's economy, functioning as the domicile of the National Capital Region, where most economic activity flourishes. The location map of Luzon Island is in Figure 1.

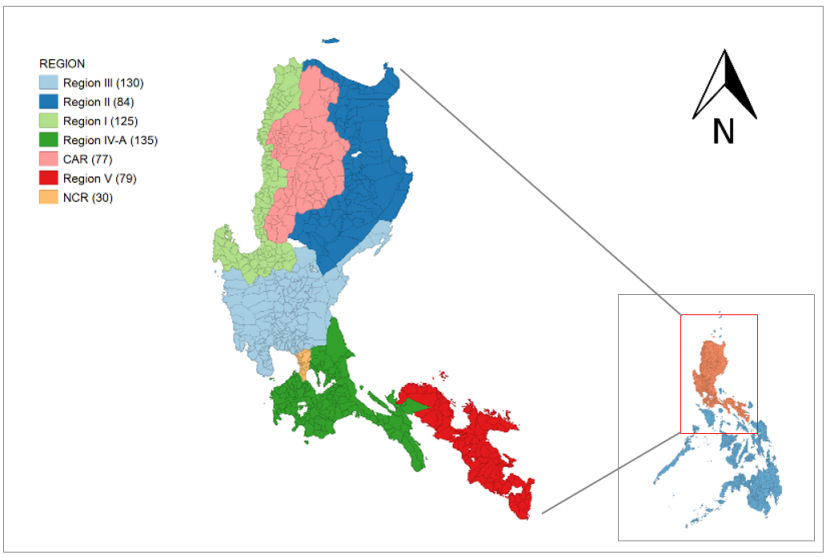


Figure 1: Location Map of Luzon Island, Philippines
Source: Map produced using GeoDa software (version 1.20)

Measure of Fiscal Impacts on Local Government Units

The basis for evaluating the fiscal impacts of the COVID-19 pandemic on the local government units are A) Locally Sourced Income (LSR) Dependency and B) Internal Revenue Allotment (IRA) Dependency.

A. Locally sourced Income (LSR) Dependency

Locally sourced income refers to the revenue generated by the local government unit (LGU) from taxes on real estate and local enterprises, as well as non-tax revenues derived from fees and charges associated with governmental activities. The Philippine Bureau of Local Government Finance (BLGF) states that the LSR can be calculated using the following formula:

$$\begin{aligned} &Locally\ Sourced\ Revenue\ (LSR) \\ &\quad = Real\ Property\ Tax + Tax\ on\ Business + Other\ Taxes \\ &\quad + Regulatory\ Fees\ (Permit\ and\ Licenses) \\ &\quad + Service\ or\ User\ Charges(Service\ Income) \\ &\quad + Income\ from\ Economic\ Enterprise\ (Business\ Income) \end{aligned}$$

LGUs that are highly dependent on LSR are more capable of obtaining income independently and are generally less dependent on the income shares they receive from the national government.

B. Internal Revenue Allotment (IRA) Dependency

The Internal Revenue Allotment (IRA) serves as the principal intergovernmental fiscal transfer in the Philippines (Senate Economic Planning Office, 2022). The IRA denotes the portion assigned to Local Government Units (LGUs) from the income produced by the Philippine government. LGUs receive IRA to sustain their government operations and finance projects, contributing to overall societal growth. The formulas for calculating IRA are provided in Section 284 of RA 7160, also known as the Local Government Code of the Philippines. The computation of IRA relies heavily on factors such as the type of government entity (province, city, municipality), the land area, and the population of its constituents. LGUs with larger land areas and populations are expected to receive larger IRAs.

IRA serves as a major funding source for many LGUs, with some heavily reliant on it. In fact, IRA can account for up to 98% of the budget for many LGUs (Cuaresma, 2019). High levels of IRA dependency are often observed in LGUs with limited capacity to generate local income. Additionally, IRA dependency tends to correlate with poverty incidence (Cuaresma, 2019).

Data Collection and Management

This study utilized fiscal data for the years 2009-2021, obtained from the Bureau of Local Government Finance (BLGF) of the Philippines, accessible at https://blgf.gov.ph. Only the municipal and city LGUs were considered in the study. In instances of missing data entries, linear interpolation was applied to estimate values for LSR and IRA dependencies. LGUs with at least three missing data points related to dependency were excluded from the analysis. Only 645 LGUs were analyzed after the pre-processing of the dataset. To visualize the results of the analysis, administrative boundary shapefiles sourced from the Humanitarian Data Exchange (https://data.humdata.org/) were employed.

Descriptive Statistics of LSR and IRA Dependencies

The interpretation of LGUs' LSR and IRA dependencies followed the categorization outlined in Table 1. For instance, LGUs with dependencies exceeding 5% are considered non-reliant on LSR and are likely dependent on the budget allocated by the national government. In contrast, LGUs with dependencies exceeding 50% are generally heavily reliant on LSR and are thus more self-sufficient in funding their expenses. Chloropleth maps were generated to visualize these dependencies in the pre-pandemic years of 2009, 2013, and 2017, as well as the pandemic year of 2021.

Table 1: Interpretation of LSR and IRA dependency

LSR/IRA Dependency	Interpretation
>5%	Not reliant on LSR/IRA
5%-20%	Slightly reliant on LSR/IRA
20%-50%	Significantly reliant on LSR/IRA
>50%	Heavily reliant on LSR/IRA

Source: Author-made Interpretation Scale

Spatial Autocorrelation of LSR and IRA Dependencies

The Moran's I statistic was employed to measure global spatial autocorrelation, which is a valuable tool for assessing the relationships among neighboring observations. This statistical method allows for the identification of interesting patterns and clustering among nearby observations. Moran's I shares similarities with the Pearson correlation coefficient and can be computed using the following formula:

$$I = \frac{N \sum_i \sum_j w_{ij} \frac{(x_i - u)(x_j - u)}{\sum_i (x_i - u)^2}}{\sum_i \sum_j w_{ij}}$$

In this context, N signifies the number of observations, w_{ij} indicates the spatial weight associated with the location of pair $_{ij}$, while x_i and x_j represent the variable values at positions i and j, respectively. This study employed the queen criterion of contiguity to ascertain spatial weight. This criterion delineates neighbors as spatial units that possess a shared edge or vertex. Moran's I values typically vary from +1 to -1. Moran's I values approaching +1 signify positive spatial autocorrelations, indicating that observations with like values are likely to cluster together. On the other hand, Moran's I of -1 typically suggests negative spatial autocorrelation, indicating dissimilarity among neighboring observations. Values near 0 imply the absence of spatial autocorrelation.

Spatial autocorrelation results are commonly visualized using a Local Indicators of Spatial Association (LISA) cluster map, which provides insights into spatial patterns and clustering of data. The LISA cluster map visualizes areas with clustering or association patterns, which can be classified as either High-High, High-Low, Low-Low, or Low-High. High-high and low-low clusters represent regions with positive and negative global autocorrelation, respectively. Conversely, High-Low and Low-High regions may be described as spatial outliers where neighboring locations exhibit dissimilar values. Spatial autocorrelation was performed on data covering the years 2009 to 2021 using GeoDa software (version 1.20).

Impacts of COVID-19 Pandemic on LSR and IRA Dependencies

The LSR and IRA dependencies of each LGU from 2009 to 2019 were utilized to predict the 2021 LSR dependency values. These values were forecasted using the exponential smoothing algorithm. The forecasted 2021 dependencies were then compared with the actual 2021 dependencies. The deviation from the predicted value served as the measure of the fiscal impact of the COVID-19 Pandemic on the LGUs and was interpreted using the scheme in Table 2.

Table 2: Interpretation of the deviation of LSR and IRA dependency

Deviation	Interpretation
>10%	Severe negative impact
2%-10%	Slight negative impact
-2%2%	Negligible impact
-10%-2%	Slight positive impact
< -10%	Severe positive impact

Source: Author-made Interpretation Scale

ANALYSIS AND DISCUSSION

Descriptive Statistics: LSR Dependencies

The chloropleth maps of LSR dependencies (Figure 2) show that a significant proportion of Philippine LGUs (ranging from 42% to 49%) exhibit a slight reliance on LSR. These LGUs are scattered throughout Luzon but are primarily concentrated in the central and coastal regions of the island. LGUs with a substantial dependence on their LSR include those in the National Capital Region, as expected, and urban centers and cities in each region. Notably, LGUs are surrounding these areas with a significant reliance on their LSR. Conversely, LGUs that do not heavily rely on their LSRs are concentrated in the north-central part (the Cordillera region) and the southeastern part of the island. This pattern is not surprising, as both regions face geographic disadvantages, such as mountainous topography in the Cordillera and distance from the urban capital. Such disparities may be accounted to the past patterns on investment allocation where concentrations of investment are evident in few metropolitan centers, causing high levels of poverty in rural regions (Rondinelli, 2011)

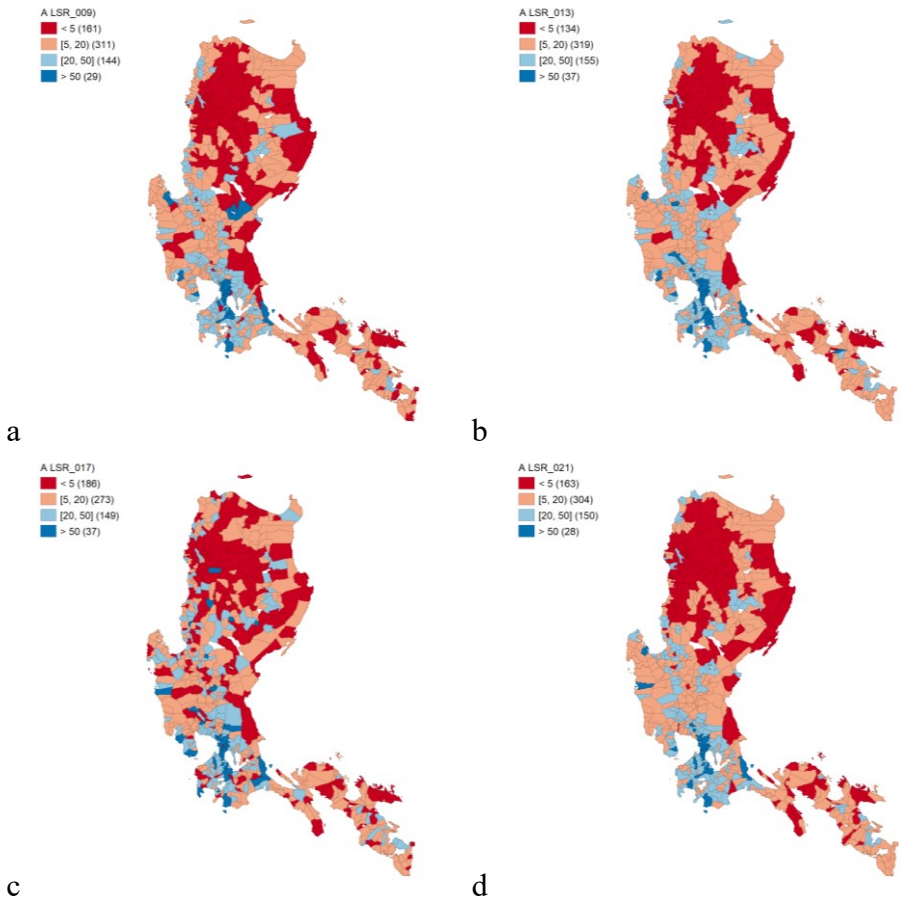


Figure 2: LSR dependencies of LGUs in Luzon Island during (a) 2009, (b) 2013, (c) 2017, and (d) 2021
Source: Map produced using GeoDa software (version 1.20)

Descriptive Statistics: IRA Dependencies

Most of the Philippine LGUs (ranging from 41% to 50%) are significantly reliant on their IRAs (Figure 3). LGUs that are consistently not reliant on their IRA include those of the National Capital Region and the surrounding municipalities belonging to Regions III and IV-A. Interestingly, some LGUs in Ilocos Sur and Pangasinan were generally not reliant on their IRAs in 2009 but have become more reliant on their IRAs as the years pass by. To explain the findings, further analysis of the Annual Regular Income (ARI) data from BLGF is necessary. It was revealed that some municipalities received significant shares of national tax collection, including (a) Tobacco Excise Tax (RA 7171) and (b) National Wealth

shares, both part of ARI but not categorized under LSR or IRA. RA 7171 grants Virginia Tobacco-producing provinces 15% of excise tax revenues, significantly boosting the finances of LGUs in Ilocos Sur and Pangasinan and reducing their IRA dependency. In contrast, LGUs heavily reliant on IRA and not on LSR are generally found in Regions Cordillera, II, III, and V. These observations hold true throughout the study period, with one exception being the year 2017, when LSR dependencies appear more scattered. Additionally, several municipalities consistently exhibit a heavy reliance on LSR, particularly those located on the eastern coastal areas of the island, including Regions II, III, and V.

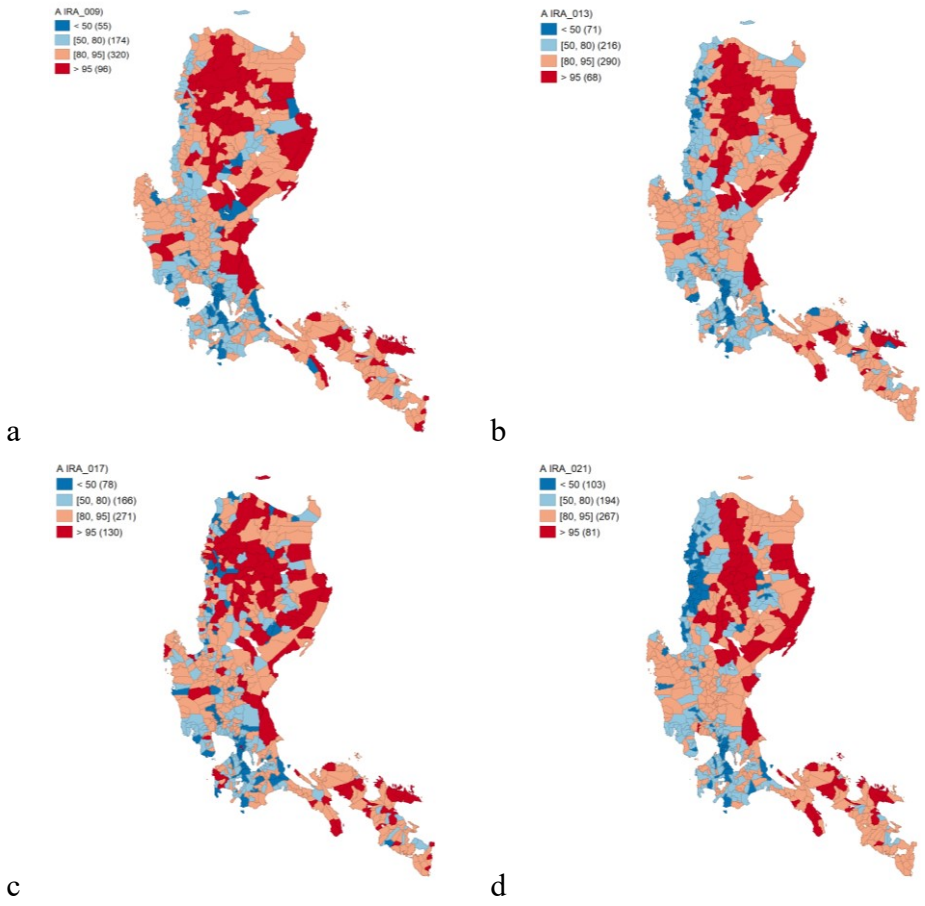


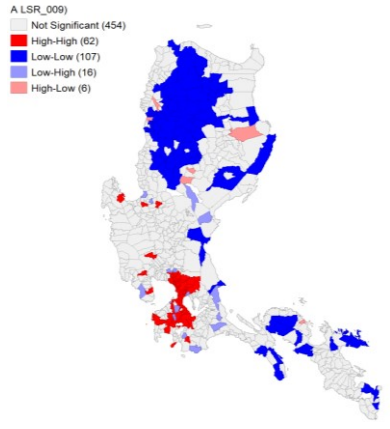
Figure 3: IRA dependencies of LGUs in Luzon Island during (a) 2009, (b) 2013, (c) 2017, and (d) 2021
Source: Map produced using GeoDa software (version 1.20)

Spatial Autocorrelation: LSR Dependencies

LISA cluster maps of LSR dependencies for the years 2009, 2013, 2017, and 2021 are presented in Figure 4. These LISA maps provide further evidence that aligns with the trends observed in the descriptive statistics. Areas classified as 'low-low' exhibit a relatively extensive presence throughout Luzon, which is indeed a cause for concern. Most of these areas are situated in the Cordillera region, but some can also be found in the eastern parts of Region III and Region V. These LGUs have low values of LSR dependencies and are surrounded by other LGUs with similarly low values. These areas demonstrate spatial autocorrelation, suggesting that this clustering of low LSR dependency is not merely the result of random chance. Consequently, these areas may be regarded as spatial clusters of socioeconomic disadvantage or localized poverty.

The extent of these areas gradually decreased and became more scattered from 2009 to 2017. Furthermore, several 'high-low' areas emerged, as expected from regional centers. Both of these trends indicate a more robust local economy during the 2009-2017 period. However, this trend was disrupted in 2021, when 'low-low' areas became more concentrated and expanded. Moreover, 'high-low' areas, where local economic development was anticipated to flourish, reverted to 'low-low' areas. This shift is highly likely associated with the ongoing freeze of economic activities during the onset of the pandemic.

Meanwhile, high-high areas are found on the NCR and nearby regional centers of Region III and IV. The trend has remained consistent throughout the 2009-2021 period. In an economic context, a "high-high" pattern might indicate that areas with strong economic activity or high incomes are concentrated in close proximity to each other, suggesting the presence of economic clusters or prosperous regions.



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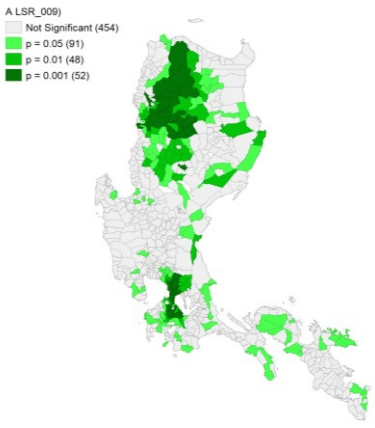

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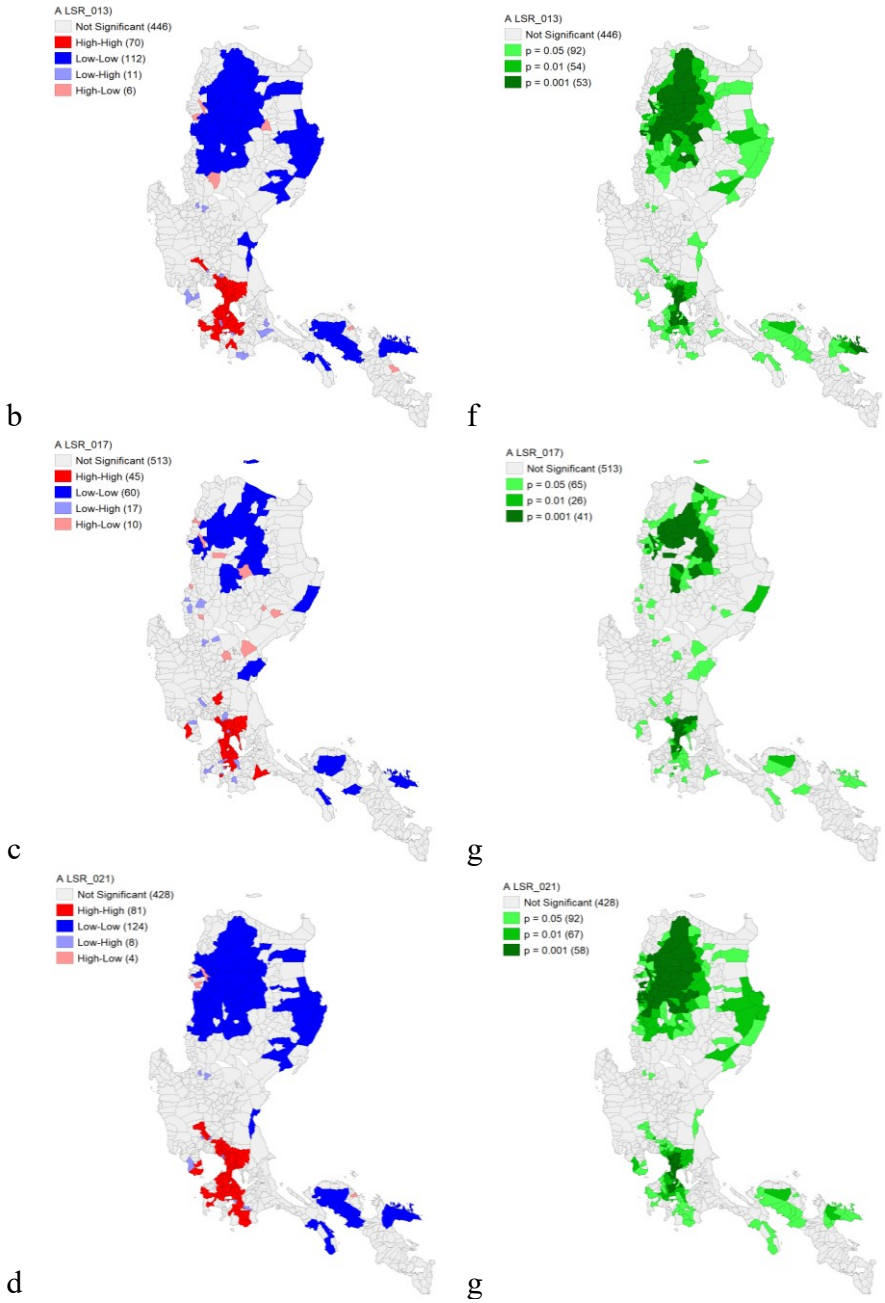
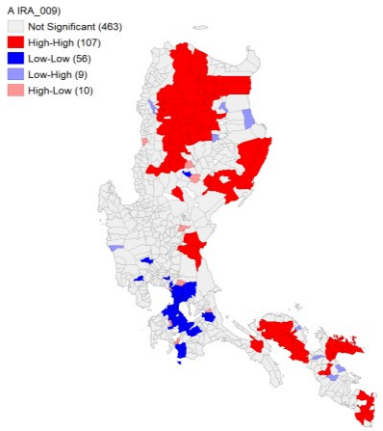


Figure 4: LISA cluster maps of LSR dependencies of LGUs in Luzon Island during (a) 2009, (b) 2013, (c) 2017, and (d) 2021, and their corresponding significance maps (e-h)
Source: Map produced using GeoDa software (version 1.20)

Spatial Autocorrelation: IRA Dependencies

LISA cluster maps of IRA dependencies (Figure 5) indicate that there are clusters of 'high-high' areas that are generally scattered but are concentrated in the Cordillera region, Region II, and Region V. Spatial autocorrelation results suggest that in these areas, local economies are not robust enough to reduce LGUs' reliance on the shares allocated to them by the national government. This is quite expected since LGUs that are located far from Manila are generally disadvantaged in many aspects, including economic, poverty, and human development (Tusalem, 2019). The trend appeared to be improving from 2009-2017, when there was less concentration and extent of high-high areas, which may suggest improved local economies. In fact, the number of LGUs in high-high areas has reduced from 107 down to 71. However, the occurrence of the pandemic has worsened the economic situation, resulting in a sudden increase in the number of affected LGUs to 120.

In contrast, 'low-low' areas, which are considered economically advantageous, are consistently found in the National Capital Region (NCR) and neighboring LGUs in Region IV-A. These areas are known to host highly urbanized cities and independent component cities, which are known to have the most dynamic and most resilient economies, respectively (Abner, 2020). Similar to the observations regarding LSR, the IRA situation improved from 2009 to 2017, with fewer areas classified as 'high-high.' However, this trend was disrupted in 2021 when areas became more concentrated and expanded. The primary cause of these changes in the fiscal landscape is attributed to the pandemic. It is also noteworthy that regions with 'low-low' areas have appeared, particularly in LGUs belonging to the provinces of Ilocos Sur and La Union. These LGUs receive shares from the Tobacco Excise Tax (RA 7171), which has been increasing throughout the period.



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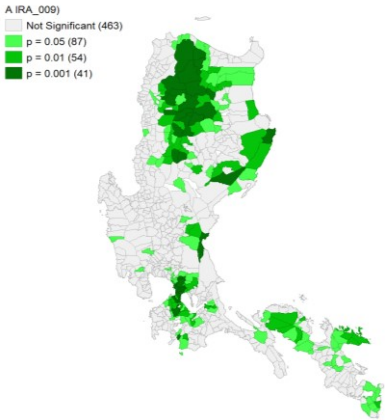

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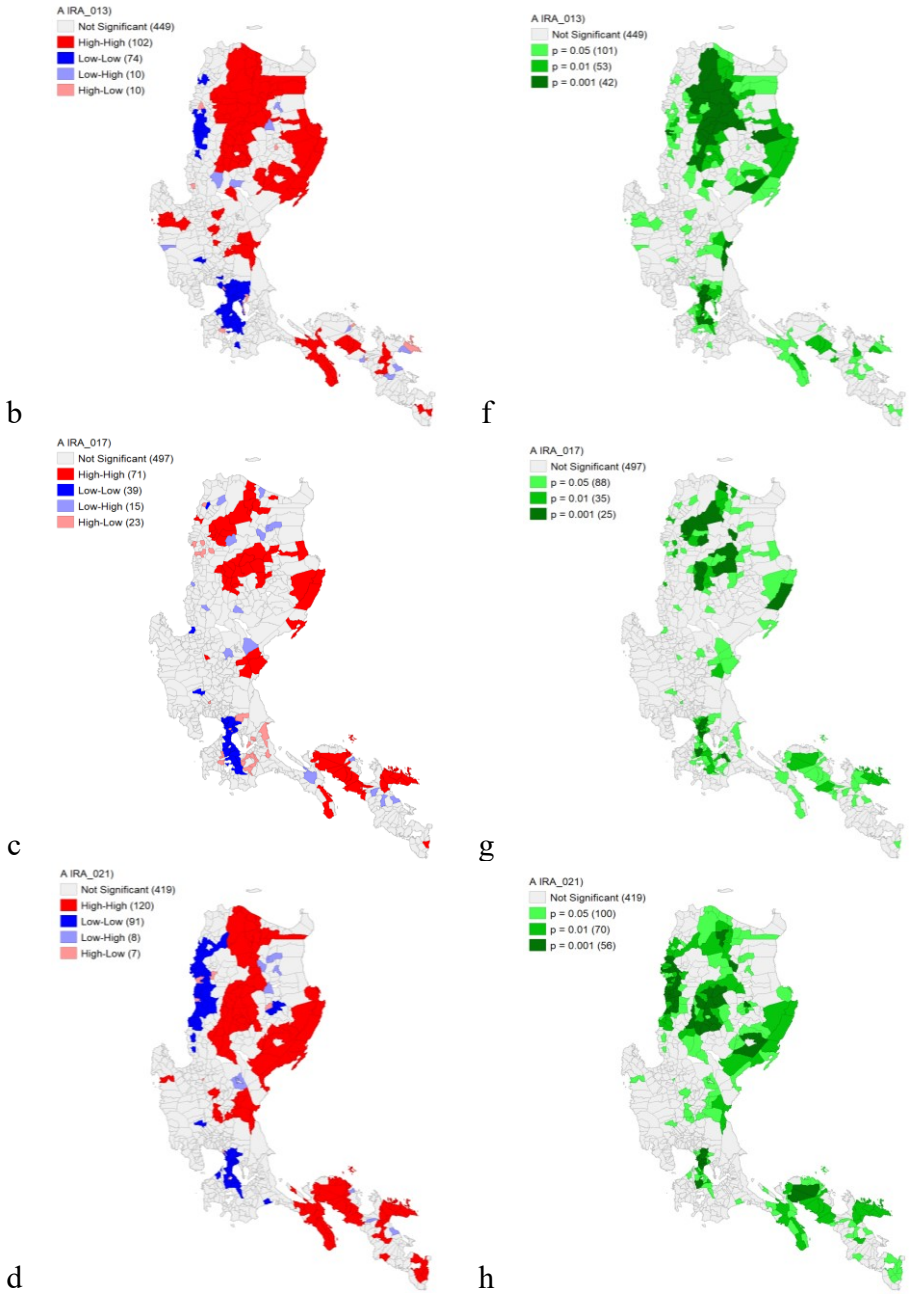

Figure 5: LISA cluster maps of IRA dependencies of LGUs in Luzon Island during (a) 2009, (b) 2013, (c) 2017, and (d) 2021, and their corresponding significance maps (e-h)
Source: Map produced using GeoDa software (version 1.20)

Trend in the Global Moran's I

The time series graph (Figure 6) of Global Moran's I for both LSR and IRA dependencies reveals values ranging from 0.214 to 0.614 for LSR dependencies and from 0.309 to 0.587 for IRA dependencies. All Global Moran's I values are positive, indicating that similar values tend to cluster together spatially, suggesting the presence of clusters.

The time series data shows that spatial clustering remained generally consistent from 2009 to 2021, aligning with Yeeles' (2015) findings of steady spatial income inequalities among LGUs over the past decade. However, a notable dip in clustering occurred in 2017, when Luzon experienced a scattering of the spatial trend, possibly indicating decentralization in LSR and IRA dependencies. This variation in Global Moran's I may be attributed to policy and economic changes following an administration shift, but further research is needed to confirm this.

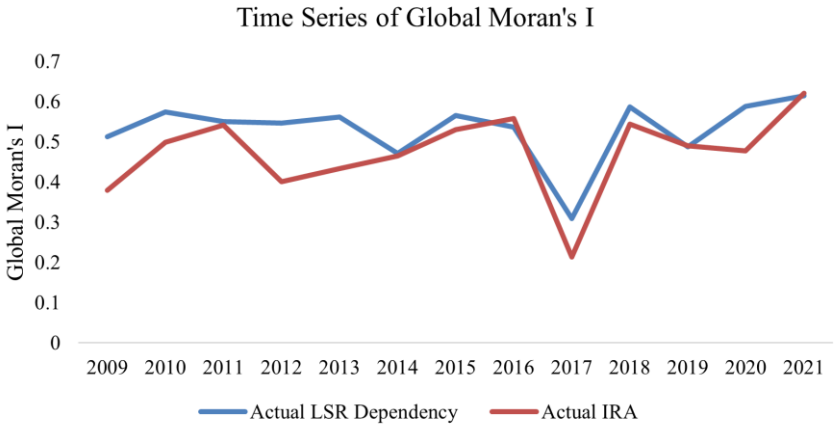

Figure 6: Time Series of Global Moran's I
Source: Author's own work

Impacts of COVID-19 Pandemic on LSR dependencies

The chloropleth map (Figure 7) illustrating the deviation from predicted LSR dependency values identified that the majority of LGUs have experienced negligible impact (36%), slight negative impact (27%), and slight positive impact (18%) on their LSR dependencies due to the ongoing COVID-19 pandemic. There is no apparent spatial pattern on the impact of the pandemic on LSR dependency. Furthermore, the LISA cluster displays a few areas classified as 'high-high' and 'low-low.' 'Low-low' areas are predominantly found in LGUs in the Zambales area, suggesting their fiscal resilience, despite the pandemic. In contrast, 'high-high' areas are generally scattered but are likely to be local urban

centers that have been heavily affected by the suspension of economic activities. Additionally, Global Moran's I value is 0.001, indicating that no spatial autocorrelation was found in the fiscal impacts of the pandemic on LSR dependencies.

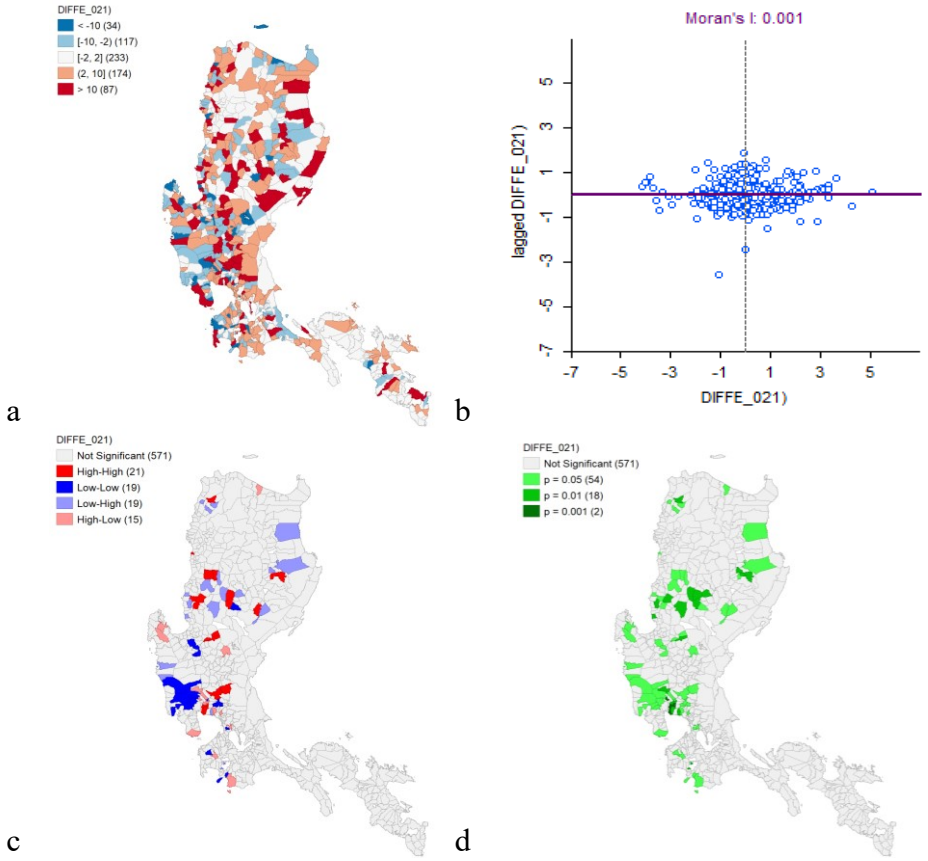

Figure 7: Deviation from the predicted LSR dependency of LGUs in Luzon Island during 2021 (a) Chloropleth Map, (b) Moran's Scatterplot, (c) LISA Cluster Map, and (d) Significance Map

Source: Map produced using GeoDa software (version 1.20)

Impacts of COVID-19 Pandemic on IRA Dependencies

The majority of LGUs have experienced severe positive impact (49%), and severe negative impact (46%) on their IRA dependencies due to the ongoing COVID-19 pandemic. Clusters of areas with similar values are now evident (Figure 8) but remain distributed throughout the region rather than being concentrated in a few areas. The LISA cluster map displays a few areas classified as 'high-high' and

'low-low.' 'Low-low' areas are mostly found in LGUs in Regions II, III, and IV. Meanwhile, 'high-high' areas are primarily limited to Region I but may also be found in Region II. Global Moran's I value is 0.319, indicating spatial autocorrelation in the fiscal impacts of the pandemic on IRA dependencies.

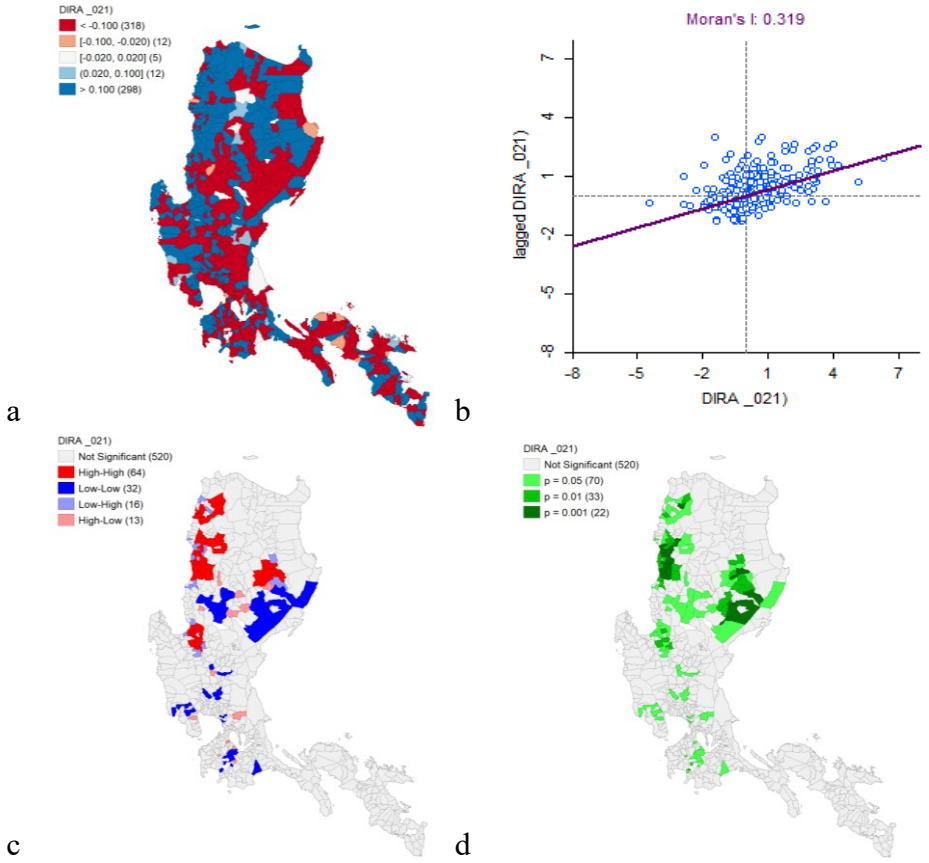

Figure 8: Deviation from predicted IRA dependency of LGUs in Luzon Island during 2021 (a) Chloropleth Map, (b) Moran's Scatterplot, (c) Cluster Map, and (d) Significance Map

Source: Map produced using GeoDa software (version 1.20)

CONCLUSION AND POLICY RECOMMENDATIONS

The results of this study provide an overview on the fiscal situations of LGUs in Luzon, both before and during the pandemic. For instance, the identified "low-low" areas provide evidence of the presence of regions facing economic disadvantages. Consequently, policymakers are encouraged to allocate resources

and investments to uplift these areas and improve their economic conditions. Carlos et al. (2023) underscored the government's responsibility in allocating the nation's resources to fulfill human needs. In the context of the pandemic, the healthcare system is above any other type of spending and could be focused on reducing loss in the country's GDP (Monsod and Gochoco-Bautista, 2021). Furthermore, the intervention of the Philippine government to give incentives to tobacco-producing provinces has improved the IRA dependencies of the recipient and the adjacent LGU. This instance suggests the effectiveness of targeted intervention to economically marginalized districts. Additionally, it may also catalyze the diversification of revenues due to improved local economies and a reduction of reliance on intergovernmental transfers.

It is suggested to establish a growth pole in lagging regions, aligning with Andriesse's (2017) recommendation. Policymakers should focus investments in these areas to cascade economic progress and address disparities in LGU fiscal dependencies, which are regional and national concerns. Regional development initiatives should aim to evenly distribute economic activities, reduce "high-high" concentrations, and enhance social services and infrastructure. Policies to improve economic interconnectivity among LGUs are also essential to link isolated districts with metropolitan areas.

The disruptions in 2021 warrant the need for robust pandemic preparedness and economic contingency plans at the LGU level. LGUs should proactively mitigate fiscal impacts from external shocks by adopting data-driven strategies and continuously monitoring regional economic trends. This study could be a basis for developing and refining such strategies. Regular spatial analysis updates can support adaptive policymaking, while sudden fiscal changes may require investigation into underlying causes such as policy shifts and economic decisions.

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COMMUNITY PARTICIPATION IN URBAN AGRICULTURE (UA): DOES STAKEHOLDER COLLABORATION ENHANCE EMPOWERMENT?

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Abstract

Urban agriculture (UA) is recognised as a solution to urban food insecurity and a driver of economic development. Success of UA initiatives largely depends on careful design, planning, and the active involvement of urban communities. Understanding the motivational values of UA for community participation is crucial for achieving UA's broader social and economic goals. This study aims to investigate the values driving community participation in UA within the Klang Valley, Malaysia, and assess their contributions to social and economic empowerment. The study surveyed 180 participants involved in UA programmes using a multistage random sampling method. To examine the complex relationships among the variables affecting UA outcomes, Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied. A mediating effect analysis was also performed to identify indirect relationships, particularly the role of linking social capital between planning, implementation, and empowerment outcomes. In conclusion, the study highlights the crucial role of implementation and evaluation in urban agriculture (UA) programmes for social and economic empowerment. Evaluation processes revealed successes and potential drawbacks, emphasizing the need for improved methodologies. Linking social capital emerged as a key mediator that connects effective planning to empowerment outcomes, offering insights to enhance UA frameworks for sustainable and resilient communities.

Keywords: urban agriculture, participation, empowerment, community, linking

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INTRODUCTION

Urbanisation embodies a global pattern characterised by an extensive shift of individuals from rural settings to urban areas. This trend largely stems from the pursuit of superior economic prospects, advanced education, enhanced healthcare facilities, and improved living standards (Nath, 2021). In 2021, the world's population living in urban areas surpassed 50%, and it is expected to reach 68% by 2050. In Malaysia, urbanisation has rapidly increased, with 78% of the population living in cities, making it one of the fastest urbanising nations in Southeast Asia (World Bank, 2021). As cities grow, they rely more on imported food, which raises concerns about food security and affordability. In Malaysia, 80% of food is imported, leading to higher costs and dependence on external sources (Bank Negara Malaysia, 2020). Urban dwellers often spend a significant portion of their income on food due to limited local production and high supply chain costs (Ruel et al., 2017).

In recent decades, the recognition of Urban Agriculture's (UA) impacts has prompted the creation of policies and initiatives aimed at encouraging Malaysians to participate in this activity. The government has launched various initiatives and policies to support the promotion of UA programmes. For instance, the National Agrofood Policy 2021-2030 (NAP 2.0) plays a significant role in serving as a guideline for development of the agricultural sector in Malaysia. These initiatives concentrate on the promotion of sustainable farming practices, improvement of fresh and wholesome food accessibility, and the cultivation of more resilient communities. The primary goals of Urban Agriculture (UA) encapsulate the augmentation of local food production, boosting of access to nutritious food, endorsement of sustainable agricultural techniques, and bolstering of both local food systems and economic growth (Payen et al., 2022).

In Malaysia, various initiatives geared towards fostering Urban Agriculture (UA) activities have been launched by local authorities and governmental bodies. As highlighted by Chong et al. (2024), effective collaboration between government agencies and farmers is crucial to ensure urban food security. These actions encompass land provision, extension of technical backing and training, supply of financial subsidies, establishment of policy-related countermeasures, along with commissioning educational initiatives and awareness campaigns (Murdad et al., 2022). The agencies involved include the Department of Agriculture (DOA), the Ministry of Housing and Local Government, the Department of Irrigation and Drainage, the Ministry of Agriculture and Food Industries, as well as city and municipal councils. These authorities provide land, technical assistance, and training to support sustainable agricultural practices. Additionally, they are responsible for creating policies and programmes designed to promote sustainable agriculture. UA can also facilitate the development of social networks and partnerships which offers several

benefits, such as access to resources, knowledge exchange, community engagement, advocacy, and promotion (Murdad et al., 2022). UA can alleviate poverty and become a source of food security for the urban poor (Ramaloo et al., 2018) Connections with organisations, institutions, and financial contributors can provide members of UA programmes with crucial resources including funding, technical support and expertise which are essential for sustaining and expanding the programmes (Parkes et al., 2023). UA programmes in Malaysia promote economic empowerment by creating jobs, reducing costs, and fostering entrepreneurship (Ali & Vaiappuri, 2022). They lower household expenses by providing fresh produce and encouraging self-reliance through small-scale ventures. Successful programmes require partnerships, funding, and effective management (Murdad et al., 2022).

LITERATURE REVIEW

Community Participation

A literature reviewed emphasized that community participation is critical throughout the development process, i.e., during planning, implementation, monitoring, and evaluation. This ensures that the development projects planned are aligned with the needs and aspirations of the local population, leading to more successful outcomes (Margareta & Salahudin, 2022). A study in Japan explored the role of public health nurses (PHNs) in healthcare planning and found that collaboration with community residents from the planning phase is crucial. This involvement helps address medium- to long-term community health issues, therefore enhancing the effectiveness and sustainability of the projects (Yoshioka-Maeda et al., 2021). Similarly, research in Rwanda on stakeholder participation in project planning and execution found that involving stakeholders, especially beneficiaries, significantly impacts project success. The study highlighted that projects with higher stakeholder involvement during the planning phase are more likely to achieve their objectives (Bazimya, 2023).

This paper addresses the critical gap in research on community participation in urban UA within Malaysia. While global studies from countries like Japan, Rwanda, and Germany have highlighted the importance of involving communities in the planning, implementation, monitoring, and evaluation phases of development projects, there is limited understanding of how these principles apply to UA in Malaysia. With the rapid acceleration of urbanisation in Malaysia, challenges such as food insecurity, restricted access to fresh produce, and rising living costs are becoming increasingly urgent. UA offers a sustainable solution to address these concerns. This study investigates how community engagement can boost the effectiveness of UA initiatives and help overcome obstacles related to resource limitations, land availability, and technical expertise.

The purpose of this paper is to examine how UA can serve as a tool for social and economic empowerment, particularly for marginalised communities, by fostering stakeholder collaboration and promoting community involvement. Additionally, aligned with SDG 2 (Zero Hunger) and SDG 11 (Sustainable Cities and Communities), the study investigates how UA can improve local food systems, enhance food security, and build resilience for the community. Involving local communities in the planning, execution, and evaluation phases of development projects is essential for ensuring their relevance, sustainability, and success. Engaging communities helps align the projects with local needs and fosters ownership, leading to better and more enduring social and economic outcomes. The study hypothesizes that planning, implementation, and evaluation each have a positive impact on both social and economic empowerment.

Linking social capital

Linking social capital, introduced by Woolcock in 2001, is the third dimension of social capital. It encapsulates the interplay between individuals or collectives with pertinent stakeholders such as institutions, governmental entities, and non-governmental organisations (NGOs). This symbiotic cooperation facilitates the attainment of programme objectives (Woolcock, 2001). Previous literature emphasized linking social capital as particularly crucial as it provides access to resources (Jiang & Wang, 2020; Ratnam et al., 2024; Po & Hickey, 2020). This can include access to funding, expertise, and other resources that are essential for community development. For example, a community organisation that has a strong linking relationship with a government agency may be able to secure funding or support for a project that they would not have been able to obtain on their own.

By forging alliances with entities and organisations beyond their immediate network, communities can tap into resources and possibilities that may otherwise remain elusive within their own circles. Such connecting relationships permit underrepresented factions to interact with more powerful counterparts, thereby fostering channels to express their needs and interests effectively. Compared to bonding or bridging social capital, linking social capital often has a broader impact on a community. Such relationships have the potential to inspire collaborative endeavours between diverse organisations or collectives, which, despite embodying divergent goals or prerogatives, can converge to strive towards a shared objective (Díaz-Gibson et al., 2017). In the context of UA, local governments can support farming communities by granting access to land, water, and other necessary resources. Additionally, they can provide technical assistance, give training on sustainable farming practices, and facilitate the exchange of knowledge and resources among community members (Halden, 2019). Given this context, the study seeks to evaluate the success of government

and stakeholder interventions in supporting urban farming communities in Malaysia. The study hypothesizes that linking social capital mediates the relationships between planning, implementation, and evaluation with both social and economic empowerment.

Empowerment theory

This study uses the empowerment theory to examine the link between participation in urban agriculture (UA) programmes and community empowerment. Empowerment involves gaining authority over life's decisions in economic and social domains, thus enhancing decision-making, resource mobilisation, and planning (Israel et al., 1994). Social capital, emphasizing trust, reciprocity, and shared norms support this framework by fostering cooperation and productive actions (Evans, 2000). By exploring how empowerment and social capital interact, the study aims to reveal mechanisms through which UA programmes improve community well-being, drive economic growth, and achieve sustainable development by focusing on collaboration and self-reliance within communities.

RESEARCH METHODOLOGY

The study was conducted in Klang Valley which is recognised as Malaysia's most evolved urban expanse, with particular attention on communities engaged in the Urban Agriculture (UA) initiative, which falls under the stewardship of the Department of Agriculture (DOA). From 2,970 participants across seven districts, 180 respondents were selected using multistage random sampling, guided by a G-Power analysis (Faul et al., 2007). After obtaining community leaders' approval, self-administered questionnaires requiring 20 minutes to complete were distributed. Data collection followed a pre-scheduled plan, and the responses were analysed using descriptive statistics and Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess model fit and test hypotheses, summarise demographic insights and validate research objectives.

In this research, the researchers employed a self-administered survey as their primary tool to assess three crucial facets of involvement in the UA programme: planning, implementation, and evaluation. The questionnaire comprised five (5) items related to planning, six (6) items focused on implementation, and four (4) items addressing evaluation. These items were adapted from a previous study conducted by Riwalnu (2014). Furthermore, the researchers included four (4) items from Ibrahim (2016) to measure the level of linking social capital, while social and economic empowerment were assessed using a six-item scale adopted from Ndaeji (2014) and Rezai et al. (2014). All items in the questionnaire were rated on a 5-point Likert scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). To ensure the validity of

the questionnaire items used to evaluate UA programme participants, the researchers conducted a content validity assessment with expert researchers. Furthermore, a preliminary pilot test was executed, which consequently led to revisions in the phrasing and structural composition of the questionnaire as guided by the critiques received. The questionnaire which was initially conceived in English was translated into the Malay language once complete to adhere to the convenience and comprehension levels of the participating individuals. This study utilised Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine relationships among six (6) key constructs: planning, implementation, evaluation, linking, economic empowerment, and social empowerment. PLS-SEM was chosen for its predictive capability, suitability for small samples, and ability to analyse direct and indirect effects by incorporating one mediator and one moderator (Hair et al., 2020).

ANALYSIS AND DISCUSSION

Table 1 presents the demographic profile of the respondents. The data revealed that a significant majority (66.1%) of participants were aged between 41 and 60 years, with only 10.6% falling within the 21 to 40-year-old category. The average age of the respondents was 53.63 years, indicating a predominance of older participants in the study. This trend suggests that programme participation is higher among the elderly, who, having retired, can devote more time to community engagement. Their extensive experience and knowledge are often utilised, positioning them as role models to encourage younger individuals to participate in the programme. As noted by Riwalnu (2015), older adults' experience and wisdom enable them to contribute more effectively, foster stronger community connections and provide valuable insights.

The research additionally unveiled that 63.9% of respondents possessed either secondary school certifications or vocational training qualifications, hinting at the programme's inclusivity towards individuals hailing from varied educational realms. Moreover, with 30% of the respondents holding either diplomas or degrees from high-ranking colleges and universities, it intimates the programme's appeal to well-educated individuals harbouring a keen interest in sustainable community advancement. Contrastingly, a mere 6.1% of respondents had only primary school education under their belts. Regarding employment sectors, the study revealed that 45.6% of participants were categorised as self-employed individuals. This indicates that the programme attracts participants with diverse work experiences, particularly those who can dedicate time to sustainable community development projects. Furthermore, 33.3% of respondents were employed in the private sector, demonstrating that the programme also appeals to individuals working in private industries. In contrast, only 21.1% of respondents were government employees. When considering the

duration of participation, majority of the respondents (53.9%) had participated in the programme for a period extending beyond a year, whereas 46.1% had been associated for less than a year. This trend stands testament to the sustained commitment most participants have demonstrated towards the UA programme, highlighting their unwavering dedication towards propelling sustainable community development. The demographic characteristics of the respondents offer valuable insights into the factors influencing their involvement in the UA programme, which can help shape targeted and effective strategies for promoting sustainable community development.

Table 1: Demographic profile of respondents

Variable	Frequency	Percentage (%)
Age Group		
21–40	19	10.6%
41–60	119	66.1%
61 and above	42	23.3%
Average: 53.63		
Gender		
Male	116	64.4%
Female	64	35.6%
Marital Status		
Single	11	6.1%
Married	169	63.9%
Level of Education		
Primary school	11	6.1%
Secondary school/Vocational	115	63.9%
College/University	54	30.0%
Working Sector		
Government	38	21.1%
Private	60	33.3%
Others (self-employed or retired)	82	45.6%
Years of Participation		
<1 year	83	46.1%
>1 year	97	53.9%

Source: Present study

Measurement model

For the measurement model, we evaluated the loadings, average variance extracted (AVE), and composite reliability (CR). The criteria required loadings to be ≥ 0.5, AVE to be ≥ 0.5, and CR to be ≥ 0.7. As presented in Table 2, all AVE values exceed 0.5, and all CR values are above 0.7. The loadings were also generally acceptable, with only one or two falling below 0.708 (Hair & Alamer, 2022). In step 2, we evaluated discriminant validity using the HTMT criterion as recommended by Henseler et al. (2015) and later refined by Franke and Sarstedt

(2019). According to the HTMT guidelines, values should be ≤ 0.85 for the stricter criterion, and ≤ 0.90 for the more lenient criterion. As indicated in Table 3, all HTMT values were below the lenient threshold of 0.90, suggesting that respondents perceived the six constructs as distinct. Overall, these validity assessments demonstrate that the measurement items are both valid and reliable.

Table 2: Measurement Model

Construct	Item Code	Loading	CA	CR	AVE
Planning (PLAN)	PLAN1	0.956	0.969	0.976	0.889
	PLAN2	0.955			
	PLAN3	0.946			
	PLAN4	0.942			
	PLAN5	0.915			
Implementation (IMP)	IMP1	0.857	0.954	0.963	0.812
	IMP2	0.897			
	IMP3	0.920			
	IMP4	0.925			
	IMP5	0.913			
	IMP6	0.892			
Evaluation (EV)	EV1	0.951	0.960	0.974	0.927
	EV3	0.976			
	EV4	0.961			
Linking (LINK)	LINK1	0.809	0.933	0.949	0.789
	LINK2	0.880			
	LINK3	0.903			
	LINK4	0.923			
	LINK5	0.923			
Social Empowerment (SE)	SE2	0.942	0.958	0.969	0.858
	SE3	0.848			
	SE5	0.940			
	SE6	0.943			
	SE8	0.926			
Economic Empowerment	EE1	0.825	0.939	0.951	0.764
	EE2	0.846			
	EE3	0.844			
	EE4	0.912			
	EE5	0.905			
	EE6	0.909			

Source: Present study

Table 3: Discriminant Validity

	EE	EV	IMP	LINK	SE	EE
EE						
EV	0.333					
IMP	0.506	0.855				
LINK	0.807	0.475	0.619			
PLAN	0.352	0.896	0.872	0.422		
SE	0.720	0.642	0.819	0.779	0.657	

Note: Evaluation (EV); implementation (IMP); linking (LINK); planning (PLAN); social empowerment (SE), economic empowerment (EE).

Source: Present study

Structural model

Following the recommendations of Hair et al. (2020) and Cain et al. (2017), we assessed the multivariate skewness and kurtosis of the data. The results indicated that the data were not multivariate normal, as evidenced by Mardia's multivariate skewness ($\beta = 8.380$, $p < 0.01$) and Mardia's multivariate kurtosis ($\beta = 65.463$, $p < 0.01$). Consequently, in line with Becker et al. (2023), we reported the path coefficients, standard errors, t-values, and p-values for the structural model using a 10,000-sample bootstrap re-sampling procedure (Ramayah et al., 2018). Additionally, considering Hahn and Ang's (2017) critique that p-values alone are insufficient for testing hypothesis significance, we employed a combination of criteria, including p-values, confidence intervals, and effect sizes. Table 4 summarises the criteria used to test the developed hypotheses. This study tested the effect of the 3 predictors on SE.

The R^2 for SE was 0.748 which shows that all the 3 predictors explained 74.80% of the variance in SE. The result proved that planning shows no significant impact on social empowerment ($\beta = 0.133$, $p > 0.05$), while implementation has a positive effect ($\beta = 0.480$, $p < 0.05$) and evaluation has a negative impact ($\beta = -0.174$, $p < 0.05$), with both being statistically significant. Next, we tested the effect on 3 predictors on EE, with an R^2 of 0.609 which indicates that EE explains 60.9% of the variance in EE, giving support for H6. The confidence intervals bias corrected at 95% also did not show any intervals straddling a 0 for H2, H3 and H6, thereby supporting all the mentioned hypotheses.

Table 4: Significance of path coefficients for all direct relationships

Hypothesis	Relationship	Standard Beta	Standard Error	t value	p value	f^2	BCI LL	BCI UL
H1	PLAN□SE	0.133	0.086	1.554	0.060	0.014	-0.159	0.019
H2	IMP□SE	0.480	0.106	4.513	0.000	0.244	0.165	0.165
H3	EV □SE	-0.174	0.084	2.071	0.019	0.017	0.048	0.156
H4	PLAN□EE	0.161	0.147	1.093	0.137	0.009	-0.328	0.099
H5	IMP□EE	0.149	0.129	1.161	0.123	0.012	-0.347	0.089
H6	EV □EE	-0.271	0.121	2.240	0.013	0.035	0.138	0.164

Note: Evaluation (EV); implementation (IMP); linking (LINK); planning (PLAN); social empowerment (SE), economic empowerment (EE).

Source: Present study

Mediating effect

In this research, linking (LINK) is hypothesized to mediate the relationships between planning (PLAN), implementation (IMP), and evaluation (EV) on social empowerment (SE) and economic empowerment (EE). The principal aim of this analysis was twofold. It aimed not only to pinpoint significant path coefficients, but also to uncover noteworthy and significant indirect effects nestled within these established relationships.

Table 5: Significance of path coefficients for all direct relationships

Hypothesis	Relationship	Standard Beta	Standard Error	t value	p value	BCI LL	BCI UL
H7	PLAN□LINK□SE	-0.145	0.061	2.376	0.009	-0.260	-0.059
H8	IMP□LINK□SE	0.343	0.067	5.108	0.000	0.245	0.469
H9	EV □LINK□SE	0.041	0.069	0.600	0.274	-0.064	0.159
H10	PLAN□LINK□EE	-0.246	0.101	2.435	0.007	-0.428	-0.100
H11	IMP□LINK□EE	0.583	0.114	5.102	0.000	0.399	0.774
H12	EV □LINK□EE	0.070	0.116	0.603	0.273	-0.119	0.259

Note: Evaluation (EV); implementation (IMP); linking (LINK); planning (PLAN); social empowerment (SE), economic empowerment (EE).

Source: Present study

The bootstrapping analysis revealed significant indirect effects, highlighting the mediating role of linking (LINK) in the relationships between planning (PLAN) and both social empowerment (SE) and economic empowerment (EE). Specifically, the indirect effect of linking (LINK) on the relationship between planning (PLAN) and social empowerment (SE) is negative, with a beta coefficient (β) of -0.145. Similarly, linking (LINK) negatively mediates the relationship between planning (PLAN) and economic empowerment (EE) with a beta coefficient (β) of -0.246. These results indicate that the presence of linking (LINK) diminishes the positive effects of planning (PLAN) on both social and economic empowerment. On the other hand, linking (LINK) had a positive and significant mediating effect on the relationships between implementation (IMP) and both social empowerment (SE) and economic

empowerment (EE). The beta coefficients were β= 0.343 for social empowerment and β= 0.583 for economic empowerment. This suggests that linking (LINK) enhances the positive impact of implementation (IMP) on both social and economic empowerment, amplifying the benefits of effective implementation within the programme. The bias-corrected confidence interval does not straddle a 0, thus, the result can conclude that the relationships mentioned in H7,8,10 and 11 are significant.

Social and economic empowerment in UA programmes is crucial in Malaysia. Effective implementation ensures programme sustainability, fosters self-reliance, and strengthens community capacity for long-term success and development strategies. Among the three components of participation—planning, implementation, and evaluation—both implementation and evaluation were found to have significant relationships with social empowerment. This suggests that the way activities are executed and subsequently assessed plays a vital role in empowering communities socially. A well-executed programme can significantly boost community empowerment by providing opportunities for members to actively participate in the process (Haldane *et al.*, 2019). When community members are involved in implementation, they can contribute their knowledge and skills, ensuring that the programme is aligned with their needs and priorities, which are crucial for the programme's relevance and effectiveness. Moreover, a well-implemented programme can empower community members by equipping them with the necessary skills, resources, and support to take control of their lives. This might involve providing training and educational programmes, access to financing, or opportunities to develop leadership and decision-making skills. This approach not only enhances the effectiveness of the programme, but also fosters long-term community empowerment.

Economic empowerment is significantly influenced by evaluation, highlighting the importance of reflective processes in refining strategies and driving economic growth. However, current evaluation methods negatively impact both economic and social empowerment, potentially exposing deficiencies that undermine empowerment efforts. This calls for a critical reassessment to ensure evaluations are constructive. Participatory evaluations involving community members can better reflect their experiences and goals, fostering trust and enabling real-time adjustments for improved outcomes. For instance, Mufti et al. (2020) found that evaluations in Indonesia's post-conflict community programmes failed due to low trust and inadequate support, emphasizing the need for tailored, robust mechanisms to enhance empowerment outcomes.

Linking social capital significantly mediates the relationship between planning, implementation, and empowerment, underscoring its critical role. By connecting communities to institutions or power structures, linking social capital

facilitates access to resources, information, and cooperation essential for project success. Studies in South Africa demonstrated its importance in agricultural projects, where it enables resource access and training, ensuring success (Taruvinga et al., 2017). Similarly, Rudito et al. (2022) highlighted how linking social capital enhances participation, reduces uncertainty, and fosters unity in community empowerment initiatives. This broader socio-economic influence emphasizes linking social capital as a vital mediator in achieving sustainable social and economic empowerment within development projects.

CONCLUSION

The findings highlight the importance of implementation and evaluation in fostering social and economic empowerment within community programmes, particularly in the context of UA in Malaysia. The execution phase holds substantial significance in fostering social empowerment as it actively integrates community members into the process, thus allowing room for their skills and expertise to make a real impact. This vibrant participation doesn't just safeguard the idea that the programme resonates with the community's needs and predominant focal points, but it also empowers community members with essential assets, such as skill sets, resources, and leadership capabilities needed to manage their livelihoods effectively. A well-executed implementation strategy thus becomes a catalyst for long-term community empowerment, enhancing both the effectiveness of the programme and the self-reliance of the community.

In contrast, evaluation is identified as a key driver of economic empowerment. The reflective and analytical nature of evaluation processes helps in refining strategies and informing future actions that can lead to economic growth. However, the current evaluation methods appear to have a negative impact on both social and economic empowerment. This may be due to evaluations exposing deficiencies or challenges that detract from empowerment efforts, suggesting a need for a critical reassessment of these methods. Effective evaluations should be constructive, providing insights that enhance the programme's ability to empower the community rather than undermine it. Moreover, the concept of linking social capital emerges as a significant mediator between planning and implementation, influencing both social and economic empowerment. Linking social capital, which connects individuals and communities to broader institutions and power structures, facilitates resource access and cooperation for empowerment initiatives. Overall, the findings underscore the need for a holistic approach that integrates effective implementation, constructive evaluation, and strong social capital to achieve sustainable social and economic empowerment in community development programmes.

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INFLUENCE OF CENTRAL COURTYARD'S DAYLIGHTING ON VISUAL COMFORT AT TAMARIND SQUARE SELANGOR, MALAYSIA: A CASE STUDY

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Abstract

Current commercial buildings are designed in a compact and massive form leading to an unhealthy environment. Courtyard is an effective daylight passive design strategy implemented in a building that can contribute to a healthier environment. Moreover, courtyards can also act as a multi-functional space that can enhance social activities. These two potentials make courtyards relevant in solving the issues which arise in current commercial building's design. However, Malaysia is a tropical country with bright sky condition. To make use of the potential of daylight in courtyards in a tropical climate, a design strategy is needed to adapt with the over exposure of sunlight. To study the influence of daylight in courtyards and the strategies needed to counter the issues of visual discomfort, Tamarind Square was chosen as a case study, as the building is considered as one of the best design practices in Malaysia, based on the recognitions given by the Pertubuhan Akitek Malaysia (PAM) and other notable bodies. Daylight design strategies are examined to verify whether courtyards in Tamarind Square do meet the criteria for good visual comfort. Visual comfort is analysed based on visual comfort parameters that include: available amount of light, light uniformity, shading strategy, risk of glare, choice of material, access to view, and colours. There were three courtyards involved in this study: the North Court, the Centre Court and the South Court. Each of these courtyards has its own strategies in adapting to tropical climate and providing good visual comfort, while at the same time meeting its purpose as part of the commercial space in Tamarind Square.

Keywords: Courtyard, Daylighting, Commercial building, Visual comfort, Tropical climate region

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INTRODUCTION

Modern mall that is enclosed, air-conditioned, with all spaces fit inside the building like a box, was invented for temperate climates, particularly in America. As it is enclosed, it creates a negative impact to the environmental, psychological, health and well-being of the building users. In response to these design issues, introducing courtyards is one of the best potential solutions as deep building plan can be punched by courtyards and thus creates a meaningful functional place for public activities (Madihah et. al, 2022). Besides, a courtyard is also an effective space in a building that can control, regulate and homogenize the luminous environment. The trilogy areas surrounding a courtyard building include indoor spaces, outdoor spaces, and the courtyard itself, interacting in systemic ways to optimize the building's luminous performances. However, natural lighting sources in a tropical climate region might require certain strategies and adaptation in facing the hot and intense solar radiation which consequently causes over exposure, leading to visual discomfort issues. With this concern, this research paper attempts to investigate courtyard influences in a tropical climate architecture focusing on commercial buildings.

Tamarind Square is one of the commercial buildings in Malaysia which integrated courtyards into its building layout design, located in a 14.54-acre land in Cyberjaya. What makes Tamarind Square more special than other commercial buildings is the fact that it was built with the the intention to break away from the air-conditioned box malls, by reinventing the building approach that can adapt with tropical climates, particularly in Malaysia. Hence, the idea of a 'mall in the garden', a retail centre in the tropics, suited to the climate, culture and context, was born. Although the concept is relatively new in Malaysia, the developer believes it is a good idea to embark on commercial developments while helping to preserve a part of the country's green environment, combining both shopping and nature. Overall, Tamarind Square offers what is not found in a typical air-conditioned mall; a building that integrates nature and a community centre as part of meeting the purpose of a commercial centre. With this bold and new approach, where the past and the present were reinvented, Tamarind Square had won the PAM Pertubuhan Akitek Malaysia's Gold Award 2019 for Commercial Low-Rise category.

By selecting Tamarind Square as a case study, this research paper aims to investigate luminous environment of the existing courtyards at Tamarind Square in meeting the needs of the activities involved. These needs are examined by identifying the daylighting strategies in the Tamarind Square courtyard areas; whether the illuminance level provided is adequate or not to achieve visual comfort. The findings of this research is hoped to raise the value of the internal courtyard's role in architecture, in meeting the human needs for visual comfort

and increase the possibilities towards the development of internal courtyard in commercial buildings in the future.

LITERATURE REVIEW

Courtyards are outdoor spaces typically enclosed on three or four sides, functioned as a unique way to bring the outside in (Sara, 2020). In the early years of its existence, courtyards functioned as the primary meeting places for specific purposes including gardening, cooking, working, playing, sleeping, or even in some cases as places to keep animals (Edwards et al., 2006). The function later formed into a space that has social, cultural, religious, and environmental usage (Rong and Azizi, 2023). The application of courtyards as a passive design strategy in architectural vocabulary may be one among the most suitable approaches to the attainment of passive buildings (Tablada et al., 2005). Besides, it also has an architectural design element that is adaptable to almost all building typologies in all the climatic zones due to its passive tendencies for low energy consumption in buildings (Markus, Malsiah and Lim, 2017). Other than architectural, social, climatic, cultural, and religious benefits, it also has potentials in creating economic benefits (Almhafdy et al., 2013).

Daylight is defined as direct daylight coming from sunlight. Indirect daylight diffuses or reflected (sunlight) in the atmosphere (Baker and Steamers, 2002). In this situation, direct sunlight produces heat and glare but is not suitable for task illumination as it creates visual problems for building users. Malaysia has the amount of daylight that is considered high with an average of 12 hours/day with the brightest hours for the west-coast between 0830 to 0930 hours and for east-cost between 0930 to 1030 hours (Fadzil and Sia, 2003), in which illuminance is about 80,000 lux, 70,000 lux and 60,000 lux respectively (Zain et al, 1999). Sky condition in Malaysia is predominantly intermediate sky as the sky is 0% clear sky, 85.6% intermediate sky and 14.0% overcast sky. Intermediate sky is defined as the sky that is neither clear nor overcast (Zain-Ahmed et al., 2002).

It is relatively easy to identify a comfortable environment. However, it becomes a challenge to describe a visually comfortable environment because the effect produced by ‘well-being’ and ‘satisfaction’ levels is not a single effect but a generic condition of well-being. If the space is well-lighted, then the subjects usually do not experience any significant visual discomfort (TERI, 2021. Guidelines for optimum visual comfort is derived from key performance parameters. Visual comfort is considered to be achieved once it meets its criteria. First, the criteria are to be able to fully describe light in terms of its source, its distribution, its tone and colour, and its intensity. Second, to be able to control light level. Both too little and too much light can cause visual discomfort. Third, to be absent in light sharp contrast. Sharp contrast or major changes in light levels

(which is perceived as glare) can cause stress and fatigue as the human eye is permanently adapting to light levels (The Saint Gobain Building Science Handbook, 2020).

METHODOLOGY

Inventory

Data collection of the study involved three courtyards located within Tamarind Square, Cyberjaya (2°55'10"N and 101°38'13"E) using an inventory and field measurement method. The three courtyards are the North court, the Centre Court and the South Court. An inventory was completed to investigate and study the courtyard criteria that have influence towards visual comfort.

Figure 1: Location of case study in Cyberjaya, Malaysia
(Source: Google Earth, retrieved on 5 February 2024)

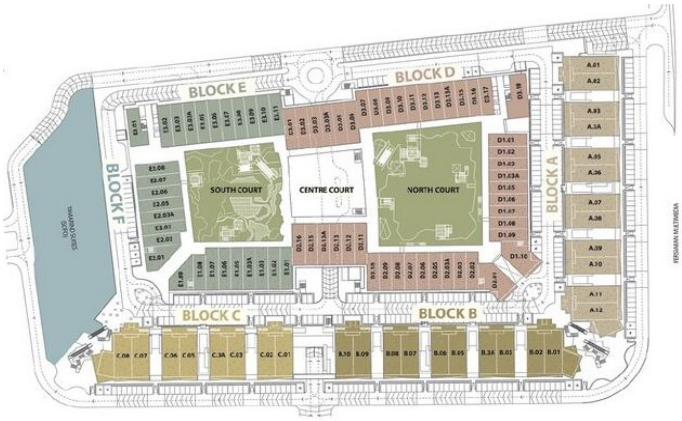

Figure 2: Location of North Court, Centre Court and South Court in Tamarind Square
(Source: tamarindsq.com)

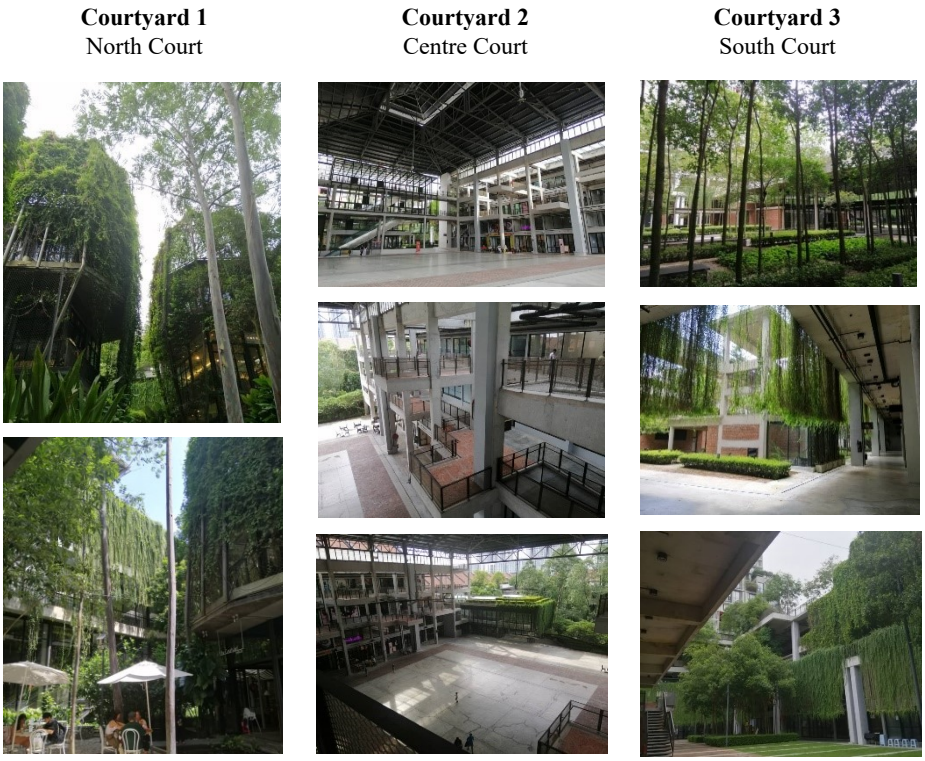

Figure 3: Courtyard's elements in three different court

Table 1: The parameters of courtyards case study at Tamarind Square

Item	Description	**Courtyard 1**	**Courtyard 2**	**Courtyard 3**
a.	Courtyard name	North Court	Centre Court	South Court
b.	Orientation	North	Center	South
c.	Courtyard size	52 m x 65 m	39 m x 39m	45.5 m x 65m
d.	Courtyard total area	3380 sqm	1521 sqm	2957.5 sqm
e.	Corridor Size	3.5 m	3.5 m	3.5 m
f.	Location	Center	Center	Center
Visual Comfort Parameter				
1.	Uniform distribution	X	√	X
2.	Optimal luminance	√	√	√
3.	Absence of glare	√	√	√
4.	Natural and artificial light	√	√	√
5.	Correct colours	√	X	√
6.	An access to views	√	X	√
7.	Adequate task lighting	√	√	√
	Assessment Score	6	5	6

Figure 4: North courtyard's sectional view and it's daylight design strategies

Figure 5: Centre courtyard's sectional view and it's daylight design strategies

Figure 6: South courtyard's sectional view and it's daylight design strategies

Field Measurement

Field measurement was conducted to collect illuminance levels data using a digital monitoring instrument, the lux meter. The instrument used for the field measurement study is a digital light meter known as SAUTER. This light meter is handheld with light-measuring levels ranging from 0.1 lux to 200,000 lux. The on-site measurements were intended to assess courtyard daylight strategies on

climate adaptation under local conditions. The important findings are related to the daylight strategies and the qualities of lluminous environments at the courtyard area.

The field measurement study was done by recording illuminance level of three different courtyards: the North Court, the Centre Court, and the South Court. Recording period was taken in 3 days on Sundays to get the average reading. Selections for time periods were based on the shops opening hours during daytime from 10 a.m. to 6 p.m. The timing is then divided into two period of time during daytime: Noon (Lunch) 01:00-2:00 and Evening (Tea) 5:00-6:00, as these two operational hours will have the negative affect of glare. P locations were positioned at the center of each grid as for along the East-West & North-south axis. P locations were arranged in linear formation perpendicularly to the grid. Sky illuminance according to the selected time period were captured at 100 000 lux – 90 000 lux (12 p.m. – 1 p.m.) and 30 000 lux to 10 000 lux (5 p.m. – 6 p.m.).

Figure 7: Digital light meter SAUTER

RESULT AND DISCUSSION

North Courtyard

Figure 8: Lux level at North courtyard at noon and evening

North courtyard has 97% of total reduction percentage of availability amount of light for noon and evening. According to MS 1525:2019, with reference to requirement of illuminance level, lux required is 750 lux for shops and 100 lux for corridor. Allowable illuminance level at the courtyard reached the highest reading at 3923 lux (more than required) and lowest illuminance level reading was 50 lux (less than required). This describes a fluctuation and inconsistency of illuminance level pattern at noon**.** Area shaded by trees has lower illuminance, while area exposed to the sun and unshaded have a rapid change in illuminance level. Meanwhile in the evening, illuminance level was stable and consistent as the sun already set to the west and has been filtered by the trees and shrubs. Most of the courtyard area was shaded by trees with different heights and random arrangement. Direct sunlight is filtered by trees creating a balance distribution of light. In the meantime, too many trees at certain area cause darkness.

The North courtyard used trees and shrubs as shading strategy. Creepers on tree house act as shading panel. This strategy allows the North courtyard to function as social activities area such as gathering place, photoshoot spot, resting area, and eating area. In terms of risk of glare, there is risk of glare but also risk of darkness in implementing trees as a shading strategy. Some areas become dark as the trees and shrubs blocked the sunlight. The North courtyard uses natural elements as choice of material. Pebble stones at walkway, steel at tree houses and concrete at floor and sittings areas are part of a strategy to reduce glare. In term of access to view, the North courtyard has access to view towards tree houses and greeneries. The colours that dominate the North courtyard are green colours as it is filled with greeneries.

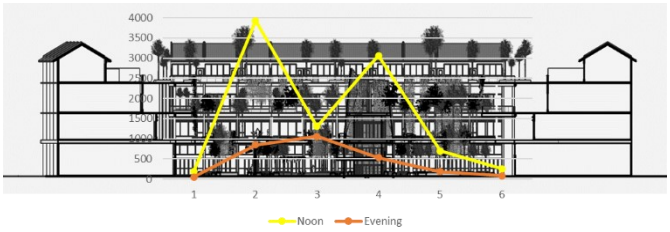

Figure 9: Comparison of average lux level noon and evening at North courtyard

Centre Courtyard

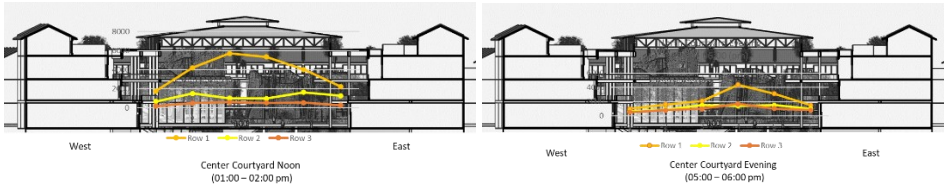

Figure 10: Lux level at Centre courtyard at noon and evening

The Centre courtyard has a total reduction percentage for noon and evening sun exposure of 98% - 93%, in terms of availability amount of light. According to MS 1525:2019 requirement of illuminance, maximum lux required is 750 lux for shops and minimum requirement of lux is 100 lux, that is applicable at the corridors. Allowable illuminance level at the courtyard recorded the highest reading at 2500 lux (more than required) and recorded lowest reading at 700 lux (more than required). This situation creates a stable and consistent uniformity of light at both noon and evening since the courtyard is covered by a roof and direct penetration of sunlight is thus controlled**.**

The Centre courtyard has a shading strategy by using a roof with side lit window at the roof tier. This allows the Centre courtyard to be utilized as an exhibition area, event space and recreational activities area. With this approach, it reduced the risk of glare from the sun. However, fully covered with cement floor with no trees planted around the courtyard area also cause some glare at the side area exposed to sunlight. Glare also happened at the open area exposed to sunlight in the evening as the sun is in a lower position than the roof. Neutral material is used as the chosen material at the Centre courtyard. The choice of material as in metal decking and steel roof structure, concrete with paint finish wall and column, and cement render floor do not help in reducing glare and providing a nice view at the courtyard. This approach also creates dull colours mood as in dominating colour effects.

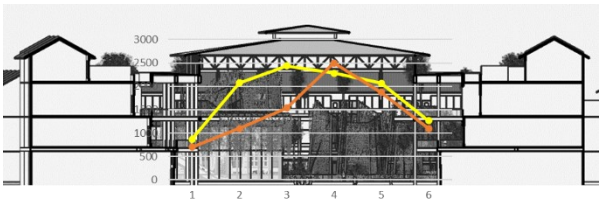

Figure 11: Comparison of average lux level noon and evening at Centre courtyard

South Court

Figure 12: Lux level at South courtyard at noon and evening

The South courtyard scores 90% - 78% of total reduction percentage of sun exposure for noon and evening. According to MS 1525:2019, illuminance requirement is 750 lux for shops and 100 lux for corridors. Allowable illuminance level at the South courtyard has the highest reading at 22500 lux (more than required) and the lowest reading at 473 lux (more than required). This pattern of readings affects the light uniformity at the South courtyard. At noon, the light uniformity pattern was fluctuated and inconsistent as the area shaded by trees has lower illuminance, while the area exposed to the sun and unshaded, has a rapid change in illuminance level. In the evening, the light uniformity pattern is more stable and consistent as the sun already set to the west and has been filtered by the trees and shrubs. Most of the South courtyard area is shaded by trees in a consistent height (5m) and in linear arrangement. Direct sunlight is filtered by trees which creates a balance distribution of light.

Shading strategy at the South courtyard are trees and shrubs. This strategy allows the center courtyard to function as social activities area such as gathering place, photoshoot spot and resting area. Choice of trees (vertical and monotonous in height) affect the glare control strategy as some areas are still exposed to glare. There is a risk of glare at areas exposed to sunlight. In terms of choice of material, exposed brick wall, and grass at ground level helps to reduce the risk of glare. The South courtyard has access to a view facing towards linear trees in the courtyard garden. The colour that dominates the South courtyard is green from the greeneries and earth colour from the walls.

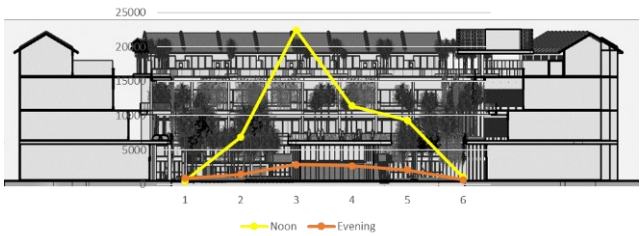

Figure 13: Comparison of average lux level noon and evening at South courtyard

Table 2: Comparison study on North, Centre and South courtyard in relation to visual comfort parameter

Visual Comfort Parameter	North Courtyard	Centre Courtyard	South Courtyard
Available amount of light	- Has appropriate brightness for performing task related to commercial building activities - Area that is too dense with greeneries causing darkness, need artificial light to help in achieving required illuminance.	- Has appropriate brightness for performing task related to commercial building activities.	- Has appropriate brightness for performing task related to commercial building activities.
Light uniformity	-A random planted of trees with a difference in height create an imbalance distribution of light around courtyard area.	-Covered with roof helps in creating a balance distribution of light especially during noon.	-Selection of trees higher than 5m in a linear arrangement create a more balance distribution of light around courtyard area.
Shading Strategy	- Good shading strategy - Sun exposure has been reduced up to 97%. - Selection of plants highly determined the effectiveness of the light filtered.	-Good shading strategy -Sun exposure has been reduced up to 98%.	-Good shading strategy. -Sun exposure has been reduced up to 90%. -Selection of plants highly determined the effectiveness of the light filtered.
Risk of glare	-Natural element absorbs light and reduce glare effect. -Leaf-green Reflection factor 20 - 25%, -Steel structure (black) Reflection factor – 0%, - Pebble stone – absorb light.	-Neutral colour of material absorbs light and reduces glare effect. -Bare concrete wall & column Reflection factor 30 - 35% -If painted white – Reflection factor - 100%, -Cement render flooring with glossy finish – produce glare.	-Natural element absorbs light and reduce glare effect -Leaf-green Reflection factor 20 - 25%
Choice of material	-Cooling environment effect	-Monochromatic environment effect	-Cooling environment effect

Visual Comfort Parameter	North Courtyard	Centre Courtyard	South Courtyard
Access to view	-Inward view all around courtyard -Create positive view -Heal visual fatigue	-Empty space with no view available -Create unpleasant view -No interesting visual experience	-Inward view all around courtyard -Create positive view -Heal visual fatigue
Colours	- Green – cooler colour -Relaxing to the eye -Psychological effect – Healing, calming, energizing -Cold colours help create the sensation that temperature is dropping.	-Bare concrete wall -- dull colour -Eye fatigue -Psychological effect - fatigue and boredom	-Green – cooler colour –Relaxing to the eye -Psychological effect – Healing, calming, energizing. -Cold colours help create the sensation that temperature is dropping.

CONCLUSION

To conclude whether the courtyard daylighting design strategy has the ability to provide good visual comfort or not is a challenge if it is justified according to the well-being of the users. Hence, this research paper decided to validate the visual comfort level through its parameters. Parameters are listed based on literature review that can specifically relate to courtyard criteria that influence daylight strategy in the courtyard areas. From the studies, it was found that the Tamarind's Square courtyards daylight strategy has two distinctive approaches. One is through greeneries, whereby multi-layered trees and shrubs are planted around the courtyard to reduce sun exposure and glare. This approach has been able to create a uniform distribution of light without having a direct exposure to the sun through the filtration from the tree leaves. The second one is through covered roof which is able to provide consistent shaded area at all times. However, this covered roof approach has limitations in terms of other aspects of visual comfort parameter as it only protects the courtyard from direct sun exposure.

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BUILDING CONDITION ASSESSMENT FOR SCHOOL BUILDING

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Abstract

This research explores the multifaceted domain of Building Maintenance Management (BMM), focusing on issues, challenges, and assessment methodologies. A comprehensive review of literature spanning various academic disciplines and professional fields was conducted to synthesize existing knowledge and identify gaps in understanding. The study investigates the impact of Building Condition Assessment (BCA) methodologies on sustainable asset management practices, emphasizing the need for integrated approaches to enhance efficiency and effectiveness. Key themes explored include Facilities Management (FM), and occupant satisfaction in the context of BMM. The research highlights the importance of strategic decision-making in allocating resources and implementing maintenance strategies to optimize building performance and ensure the well-being of occupants. Drawing on insights from diverse perspectives, this study contributes to advancing knowledge in the field of BMM and provides a foundation for future research endeavors and practical applications aimed at enhancing the sustainability and resilience of built environments.

Keywords: Building Maintenance Management, Building Condition Assessment, Life Cycle Costing, Facilities Management, Occupant Satisfaction

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INTRODUCTION

Building maintenance management in Malaysia, particularly for public buildings, has become increasingly important due to the aging infrastructure and the need for better upkeep. This is evident in public sectors, where schools require regular maintenance to ensure safety and functionality. Issues such as poor facility management, delayed repairs, and insufficient maintenance budgets have often plagued public buildings.

Recent studies have emphasized the need for systematic and proactive maintenance strategies, especially as reactive maintenance approaches remain predominant in Malaysia. For instance, Dzulkifli et al. (2021) highlight that maintenance in Malaysia tends to be reactive rather than preventative, often addressing issues after they arise, leading to higher costs and inefficiencies Furthermore, the public sector has seen significant challenges, including the deterioration of school facilities due to inadequate funding and oversight, contributing to unsafe conditions (Hauashdh et al., 2020)

The Building Condition Assessment (BCA) is increasingly viewed as a valuable tool for assessing and prioritizing maintenance in public buildings like schools. BCA helps in systematically evaluating building conditions to plan for preventive maintenance, which is more cost-effective and sustainable in the long run (Dzulkifli et al., 2021)

The need for effective building condition assessments in public schools across Malaysia has become increasingly important. Numerous studies have highlighted the frequency and causes of building defects, especially in government-owned structures, including public schools. A study by Syamilah Yacob et al. (2019), examined 300 school buildings and identified a range of defects, primarily due to factors such as poor maintenance, lack of supervision, and vandalism. The study found that most schools were in average to critical condition, underscoring the need for comprehensive maintenance strategies to ensure the safety of students and staff.

The three key problems are poor school building condition assessment, absence of specific guidelines for assessing school building conditions and lack of independent school building condition assessments. Regular inspections are infrequent, leading to reliance on complaints-driven maintenance. Implementing Building Condition Assessments (BCA) could facilitate regular maintenance planning and data collection. To address these issues, the research aims to develop a Building Condition Assessment (BCA) framework tailored to school buildings, enabling systematic assessment and maintenance planning to ensure safer and more functional educational environments.

The research aims to address the pressing need for a systematic approach to assessing and managing the condition of school buildings in Terengganu, Malaysia. With recurring instances of damages and deficiencies in

maintenance management, there is a significant gap in the guidelines for assessing school building conditions. Consequently, the study endeavours to develop a comprehensive School Building Condition Assessment (BCA) system tailored specifically to the context of public-school buildings in Terengganu.

The significance of this research lies in its potential to provide school management with a practical tool for assessing building conditions, aiding in informed decision-making regarding maintenance priorities and resource allocation. By filling the existing gap in guidelines, the proposed BCA system aims to facilitate more proactive and efficient maintenance planning, ultimately contributing to the safety and well-being of students and teachers.

The study is specifically targeted at public school buildings in Terengganu, with a focus on three schools in the Bandar Al-Muktafi Billah Shah area of Dungun, during the Movement Control Order period. Thus, it provides a localized and practical approach to addressing the identified challenges in school building maintenance management.

LITERATURE REVIEW

Building Condition Assessment (BCA)

Building Condition Assessment (BCA) is a crucial tool for evaluating building condition, aiding in effective maintenance planning and asset management. BCA involves assessing a building's physical condition and identifying necessary maintenance or improvement works. Definitions of BCA from various sources emphasize its role in measuring building performance and guiding future planning. Different countries utilize their own methods and components for BCA, tailored to their specific needs and standards.

BCA components typically include checklist building maintenance, defect identification, physical condition assessment, priority action assessment, and condition rating. Despite variations in components, the underlying philosophy remains consistent across countries. BCA processes are structured differently in various countries, with stages ranging from scoping services and procurement to implementation and reporting.

Condition Assessment Ranking Scales are vital in evaluating building quality, with various rating systems like three-point, four-point, five-point, and six-point scales being utilized. Each rating scale offers its own advantages and considerations, with factors like the number of rating points and the level of detail influencing their effectiveness. The choice of rating scale depends on factors such as the level of detail required and the ease of implementation.

Buidling Condition Assessment in Malaysia

Building Condition Assessment (BCA) has emerged as a crucial tool within Malaysia's built environment, particularly for managing government assets. The

country utilizes two main BCA systems: CP BS101 and JKR 21602 – 0004 – 13, both incorporating the Building Assessment Rating System (BARIS). Developed by the Royal Institution of Surveyors Malaysia (RISM) and the Public Works Department (PWD) respectively, these systems employ survey protocols for inspections and utilize BARIS to assess building conditions. The assessment process involves property description, inspection methods, and condition assessment, with detailed scales used for both condition and priority assessments. These ratings assist in prioritizing maintenance actions based on repair needs. Compared to overseas BCA systems, Malaysian BCA systems offer detailed descriptions and are more user-friendly. While they share similarities, such as using five-rating scales, variations exist in assessment processes and criteria, as shown in Table 1. Nevertheless, BCA in Malaysia plays a crucial role in asset management and maintenance planning, providing comprehensive evaluations of building conditions to guide decision-making processes effectively.

Table 1: Building Physical Condition Level used by Public Work Department

Grade	Inspection Scale	Description
1	Very Good	A new, no defect, performing as intended
2	Good	Minor defect, good condition, performing as intended
3	Fair	Major defect, moderate condition, still can functioning with supervision
4	Poor	Major or minor defect, critical, not functioning as agreed service level
5	Very Poor	Very critical, not functioning, risky to safety and health

Source: JKR (2013)

School Building in Malaysia

In Malaysia, school buildings serve as vital educational institutions for children, encompassing various facilities beyond classrooms such as administrative offices, counselling rooms, canteens, and libraries. Statistics reveal that Malaysia's school system comprises primary and secondary schools, with over 4.5 million students enrolled across approximately 10,000 schools nationwide. Primary schools alone account for 7,669 institutions, accommodating more than 2.6 million students, while secondary schools total 2,372, serving around 1.8 million students. The Ministry of Education ensures that schools meet essential infrastructure requirements outlined in the Malaysia Education Blueprint 2013-2025.

These guidelines mandate provisions like suitable physical structures, adequate classroom and toilet facilities, electricity and water supply, furniture, and technological resources. Over time, infrastructure requirements have evolved to incorporate elements such as improved internet connectivity, accessibility features, and advanced facilities to support modern educational needs. This

reflects the ongoing commitment to providing conducive learning environments for Malaysian students.

Design of School Building in Malaysia

The two main styles are identified: one-off design and standard design. One-off designs are unique, featuring distinctive layouts and façades not replicated elsewhere, while standard designs are characterized by repetitive use of façade design, layout, space planning, and materials (Norhaslin et al., 2019). Public school layouts in Malaysia typically adopt a linear spatial arrangement with single-sided corridors, featuring blocks of buildings facing each other with a courtyard in between (Farhana et al., 2022).

Additional physical structures within school buildings include halls, laboratories, workshops, canteens, and prayer rooms. The space planning of standard school designs adheres to the latest curriculum syllabus for primary and secondary schools set by the Ministry of Education. Furthermore, government school facilities in Malaysia are categorized into administration spaces, academic spaces, support facilities, laboratories, and open spaces, as per established standards and guidelines provided by the Department of Town and Country Planning (2012).

Maintenance of School Building

School building maintenance in Malaysia is crucial for ensuring a safe and conducive learning environment. However, despite its importance, the maintenance management of school buildings in Malaysia remains substandard (Hauashdh et al., 2020).

The condition of school buildings remains average, indicating a gap between theory and practice (Syamilah, 2019). The Educational Management Information System (EMIS) is an essential tool for managing school data, including infrastructure details, but challenges such as workload and competency issues among teachers hinder its effectiveness (John et al., 2022).

Furthermore, EMIS lacks specific features for building maintenance assessment, unlike formal building condition assessment (BCA) systems, such as BARS and BARIS, which are not specific to school buildings in Malaysia. The proper BCA system for schools is essential for efficient maintenance planning and cost-saving measures (Syahirah et al., 2020).

RESEARCH METHODOLOGY

The research aims to develop a School Building Condition Assessment system for schools in Terengganu, with objectives including the identification of school building components, Building Condition Assessment components, and the development of the assessment system. The research design involves both

quantitative and qualitative methods. Quantitative methods involve the analysis of numerical data using statistical techniques, while qualitative methods aim to understand and interpret social interactions. In this case, qualitative methods are employed to develop a deeper understanding of Building Condition Assessment and gather perspectives from respondents.

The research methodology chosen is qualitative, as it aligns to understand social interactions and perspectives related to Building Condition Assessment. The qualitative method allows for extensive interaction with respondents, typically involving a small group studied closely throughout the research. Case study research, characterized by investigating a contemporary phenomenon within its real-life context, addresses the research questions related to assessing school building conditions efficiently. Case studies provide comprehensive descriptions and analyses of individual cases, aiding in understanding “how" and "why" inquiries and contributing to theory development and generalization.

The research methodology involves data collection through interviews and literature review. Interviews are conducted using semi-structured approaches, with purposive sampling to select respondents with expertise in school building management. The interview questions are designed to gather insights on Building Condition Assessment (BCA) practices and building maintenance in schools. A pilot study is conducted to refine the interview questions, ensuring clarity and relevance for the respondents.

The research design incorporates grounded theory analysis to develop the BCA system for public school buildings. Grounded theory analysis involves data collection, initial coding, development of categories, theoretical sampling, and the development of core processes and relationships. The BCA system is developed based on components of school buildings identified through literature review and interviews. The components include roof, ceiling, wall, door and windows, floor, foundation, and utilities. The BCA system includes elements of the school building, condition assessment, total score, and recommended actions. Overall, the research aims to develop a comprehensive BCA system tailored for public school buildings in Terengganu, Malaysia, utilizing insights from qualitative data and grounded theory analysis.

In the analysis of interview sessions conducted for the field study, the demographic overview of respondents revealed a balanced representation in terms of gender, with an equal split between male and female participants. The age distribution across three categories—20-35 years, 36-45 years, and 46-55 years—highlighted diverse experiences. Regarding academic qualifications, respondents held a mix of diplomas and bachelor's or master's degrees, indicating a varied educational background relevant to building maintenance. Professionally, the majority were teachers, while others held roles in consultancy

or government positions related to maintenance. Most respondents had over five years of working experience, meeting the requirements for stakeholders in school maintenance.

Regarding familiarity with the Education Management Information System (EMIS), respondents exhibited varying levels of experience, with some having less than five years and others having more than 16 years. Moving to the analysis of respondents' knowledge of Building Condition Assessment (BCA), it was evident that they possessed a basic understanding, albeit with differences based on their involvement in maintenance activities versus teaching responsibilities. These findings provide valuable insights into the background and expertise of respondents, shedding light on their perceptions and experiences related to school maintenance practices in Malaysia.

ANALYSIS AND DISCUSSION

In discussing the research findings, the focus revolves around addressing the research questions concerning the components of school buildings, Building Condition Assessment (BCA), and efficient methods for assessing the condition of school buildings. Firstly, regarding the components of school buildings, the study confirms the importance of all elements listed, as respondents largely agreed on their significance for developing BCA systems. These components encompass various aspects such as architectural, structural, electrical, and utility components, all essential for the overall maintenance of school infrastructure. Consequently, the research successfully identifies these components, which are crucial for further investigation.

Secondly, the discussion delves into the components of Building Condition Assessment (BCA), emphasizing its importance in developing BCA systems. Respondents with backgrounds in building maintenance demonstrate an understanding of BCA components, which remain consistent despite variations across countries. The components include checklist building maintenance, defect identification, physical condition assessment, priority action assessment, and condition rating. This understanding lays the groundwork for the subsequent development of BCA systems tailored to school environments.

Additionally, the Ministry of Education's utilization of the Education Management Information System (EMIS) is a significant finding. The EMIS online system, managed by the Ministry, provides detailed information about school profiles, management, and facilities. While comprehensive, EMIS lacks the functionality to assess priority actions and rate conditions for damages or non-functional items, highlighting a gap that BCA systems could potentially address.

Lastly, the discussion touches upon the methodology for condition assessment in school buildings, with a five-point ranking scale identified as the standard approach. This standardized scale, supported by international

comparisons, facilitates consistent and efficient assessments, aligning with best practices in building maintenance evaluation. As a result, the study contributes valuable insights into the components of school buildings, the development of BCA systems, the role of EMIS in educational infrastructure management, and effective condition assessment methodologies.

Based on the data analysis and findings, a Building Condition Assessment (BCA) system tailored for school buildings is developed, utilizing a user-friendly format in Microsoft Excel for ease of use. This system comprises five key components, as depicted in Figure 1, which shows the components of BCA for school building, Sub-components of school building, Condition of school building, Score rating, and Action to be taken.

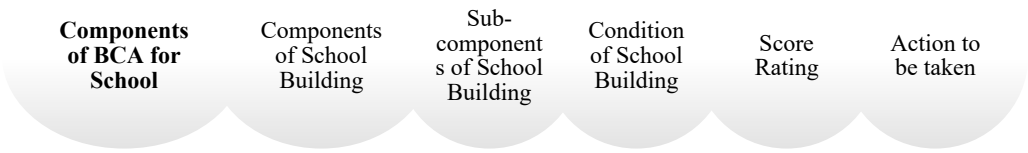

Figure 1: Component of BCA for school

Further examination of the Components of the School Building reveals two distinct sub-components: architectural components and structural components, respectively. These components are then categorized into Parts, including Components of school building, School facilities, and Sport facilities

Moving forward, each part is subdivided into specific Elements, representing essential aspects of school infrastructure maintenance. These Elements are identified through a comprehensive review of data analysis and literature, ensuring the inclusion of crucial factors for Building Condition Assessment for School systems. Table 2 outlines the Components and their corresponding Elements, covering critical areas such as Roof, Ceiling, Wall, Door and Windows, Floor, Utilities, School facilities, and Sport facilities. Each Element is meticulously defined to encompass various components of school buildings, facilitating a comprehensive assessment process.

Table 2: Components and Elements of School Building

No	Parts	Components	Elements
1	Components of School Building	Roof	Roof Cover Roof Truss Lisplank and Gutter
2		Ceiling	Ceiling frame Cover and ceiling trim Paint

No	Parts	Components	Elements
3		Wall	Column and Ring beam Brick/Filler Wall Paint
4		Door and windows	Frame Doors Windows
5		Floor	Lower structure Floor Cover
6	School Facilities	All school facilities	
7	Sport Facilities	All sport facilities	

Developing the Building Condition Assessment (BCA) system for school buildings incorporates a standardized approach to condition assessment using a five-point rating scale. This scale, selected for its simplicity and effectiveness, allows for an easy description of the building's condition without requiring complex formulas or equations. The decision to employ a five-point scale with color-coded indicators stems from its suitability for providing detailed assessments based on physical observations, as evidenced by literature findings.

Each component and element of the school building, as outlined in Table 2, is evaluated using this five-point scale, ensuring a comprehensive assessment process. The description and general condition overview further clarify the significance of each rating level, ranging from "Very Good" to "Critical," based on the extent of repairs or replacements required.

Subsequently, the score rating is determined based on the total score derived from the condition ratings of individual elements, as demonstrated in Table 3. This matrix system identifies the seriousness of each element and guides subsequent actions. Priority assessment, outlined in Table 4, further categorizes maintenance actions based on the total score, distinguishing between dilapidated, fair, and good conditions. This classification simplifies decision-making regarding the urgency and extent of repairs or replacements needed, streamlining the maintenance process for school buildings.

Table 3: Score for element

Score	**5**	**4**	**3**	**2**	**1**	
Cement Floor	**Very Good**	**Good**	**Fair**	**Poor**	**Critical**	**Total**
Ground Floor		4				4
1st Floor			3			3
2nd Floor				2		2
3rd Floor					1	1

Score	**5**	**4**	**3**	**2**	**1**	**Total**
Cement Floor	**Very Good**	**Good**	**Fair**	**Poor**	**Critical**	
Total	0	4	3	2	1	
Score	10					

Table 4: Priority Assessment

Priority Assessment	**Total Score**	**Description**
Dilapidated	4 – 8	The element of the building needs major repair or replace with new.
Fair	9 – 11	Only certain parts of the elements need to repair or replace.
Good	12 – 16	No maintenance action should be taken as the building is still in good condition

In the comprehensive Building Condition Assessment (BCA) process, each school building component undergoes a detailed condition assessment using a standardized five-point scale rating. This assessment is essential for accurately evaluating the state of the building and determining necessary maintenance actions. The assessment is then broken down further according to specific components, with detailed observations recorded for each element.

Starting with the Roof assessment, observations focus on physical indicators such as leaks or visible damage, with the overall condition graded based on a scoring system. Similarly, the Ceiling assessment involves inspecting ceiling frames, covers, trims, and paint quality to determine the condition of internal ceilings.

The Wall assessment entails observing the facade of the building, including columns, ring beams, brick or filler walls, and wall painting, to evaluate the condition of external wall elements. For Doors and Windows, assessments are made regarding door leaf, frame, knob, hinges, louvers, and frames, with attention to any signs of damage or deterioration.

Floor assessments cover timber, cement, and tile floors, with observations on their overall condition and any visible defects. Utilities such as rainwater downpipes are inspected to determine their functional state and any maintenance requirements.

Additionally, assessments extend to School Facilities and Sports Facilities, encompassing various amenities and infrastructure within the school premises. Each element undergoes thorough observation and evaluation to determine its condition and any necessary maintenance actions.

Through this meticulous assessment process, the BCA provides a comprehensive overview of the condition of each component and element of the school building. This information enables informed decision-making regarding maintenance priorities and actions to ensure the school infrastructure's safety, functionality, and longevity.

CONCLUSION

In conclusion, this research has culminated in developing a comprehensive School Building Condition Assessment (BCA) system specifically tailored for Malaysian school buildings. Through a systematic approach, the study has successfully addressed its aim and objectives, contributing valuable insights to the field of educational infrastructure management. Looking ahead, future research endeavours could focus on validating the developed BCA system through real-world implementation and assessing its effectiveness in improving building maintenance practices and enhancing educational outcomes. Additionally, exploring opportunities for technological enhancements, such as integrating building management software and IoT sensors, could further optimize the efficiency and effectiveness of the BCA process. By continuing to innovate and refine infrastructure management practices, stakeholders can ensure the long-term sustainability and resilience of Malaysia's educational facilities, ultimately benefiting students, educators, and communities alike.

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AN EVALUATION OF THE ROLE OF PHYSICAL LAYOUT IN CAMPUS MASTERPLAN DESIGN TO PROMOTE SUSTAINABILITY

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Abstract

Many of the current campus design development tends to be more ad-hoc and focus more on free-standing buildings in the landscape settings that do not respond to the environment of the local contexts. Those designs have been criticized for creating a high dependency on automobiles, sprawling and segregating campus outdoor spaces with roads and large parking lots that pose challenges to meet sustainability goals. This paper aims to evaluate the role of physical layout in the design of campus masterplan at Malaysian Public Universities (MPUs) to promote sustainability. Using a qualitative method of a multiple case study, a connection between physical layout and sustainability was evaluated based on document reviews, morphological studies, visual surveys, and semi-structured interview techniques. The finding reveals that the physical layout plays an important role in promoting a sustainable campus environment. It is recommended to emphasize the design of physical layout in the MPUs' campus masterplan to ensure compactness and structured configurations, which enhance design sustainability. These are important attributes in the design approaches that should be taken by MPUs for it to be agents of sustainability.

Keywords: Campus design, campus physical layout, urban form, morphological study, sustainability

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INTRODUCTION

Universities have a great responsibility to integrate sustainable design strategies for campus development. Universities should be the hubs for sustainability (Abdullah et al., 2024; Muhiddin et al., 2023; Sugiarto et al., 2022) and become communities with high potential for pursuing and promoting sustainability (Dawodu et al., 2022). Although most universities worldwide implement various strategies to address sustainability in higher education, Muhiddin et al. (2023) argue they vary substantially and remain fragmented due to several challenges. Among the challenges relate to the design of campus masterplans, which have been criticised for creating a high dependency on automobiles, sprawling and segregating campus outdoor spaces with roads and large parking lots. Sugiarto et al. (2022) emphasize that physical planning and the design of campus masterplans play an important role in achieving sustainability. However, Muhiddin et al. (2023) argue that the horizontal expansion of physical forms on campuses has changed the mode of transportation to motor vehicles, thus contributing to traffic congestion, a decrease in air quality, and an unhealthy environment on campus. Most university campuses have significant carbon footprints, primarily from motor vehicles, which negatively impact campus sustainability (Dawodu et al., 2022). Accordingly, campuses increase demand and supply to develop parking lots, posing a significant land-use problem and leading to a reduction of green spaces on campuses (Dawodu et al., 2022; McKenna & Altringer, 2021).

Furthermore, the design of campus masterplans tends to be more ad-hoc and focus on free-standing buildings in landscape settings. Campuses were built piecemeal, scattered and less integrated with the earlier development that caused a high- dependence on automobiles, traffic congestion and wasted campus land (Carmona, 2021; Samsudin et al. (2018). Additionally, these spatial arrangements reflect a jumble of isolated buildings that create disorientation (Trancik, 1986; Krier, 1979). Accordingly, the sprawl of physical forms often covers large areas of land that become 'lost-space' in low density (Trancik, 1986). In fact, Malaysian Public Universities (MPUs) that foster sustainable campus growth have also encountered these challenges. The previous studies found that most MPUs are sprawling in campus layout, where students' hostels are isolated and faculties are scattered over campus sites (Muhiddin et al., 2023; Nia, 2016; Abd-Razak et al., 2012; Shamsuddin et al., 2007b). Correspondingly, evaluating the physical layout of campus masterplans is crucial for promoting sustainability in MPUs.

LITERATURE REVIEW

Campus sizes have a direct impact on the physical layout of campus masterplans. Gehl (2011) claims that a small-scale campus is typically located in a compact environment. However, on a large-scale, people are dispersed in times and spaces because places are separated in a sprawling physical form with a high-automobile

dependency. On a medium-scale, people and activities disperse when buildings are placed at great distances apart, with entrances and residences oriented in opposite directions. Hajrasouliha (2017) classifies the elements of compactness and configuration in campus layout to establish a well-designed campus where buildings and spaces are interconnected through a hierarchical arrangement of spaces (Figure 1).

Compactness The density of campus and proximity of buildings.			
	Dense-Campus	Nucleus-Campus	Dispersed-Campus
Configuration The strength of campus spatial structure. Buildings are defining open spaces, campus spaces are connected through main corridors, campus main central space.			
	Structured-Campus	Ad-Hoc Campus	Hybrid-Campus

Figure 1: Compactness and configuration of a well-designed campus
Source: Hajrasouliha, 2017

The compactness in a campus layout serves to reduce automobile dependence on the road by minimizing travel distances, encouraging walking and facilitating social interaction (Samsudin et al., 2018; Nia, 2016; Matloob, 2016; Shamsuddin et al., 2007a). Matloob (2016) defines compactness as the degree to which the physical form reduces the distance between campus areas to encourage walking. Dober (1992) suggests that the most effective design for a walkable environment is a 150-acre enclosed campus. In general, pedestrians average walking radius is between 400 to 500 metres (Mehaffy et al., 2020; Gehl, 2011). Hajrasouliha (2017) defines compactness as the density of a campus and the proximity of buildings. He categorizes campus compactness into three types namely dense, nucleus and dispersed. A dense-campus design incorporates closely situated buildings and spaces to enhance a walkable environment for social interaction and safety. People feel safe when they see other people, which encourages walking (Hajrasouliha, 2017). Walking will encourage social interaction because it creates opportunities for contact during which individuals are at ease and able to engage, pause or become involved with others (Gehl, 2011). Compactness facilitates the concentration of activities and people on a large-scale (Gehl, 2011) and increases vitality in areas without relying on automobiles (Jacobs and Appleyard, 1987). Next, a nucleus-campus is

characterized by a concentration of compactness on a portion of the campus area. Shamsuddin et al. (2007a) argue that the development of a large campus should focus on a selected area to ensure easy access and movement, safety and to prevent traffic congestion, rather than utilising the entire site. Similarly, Dober (1992) suggests that both small and large campuses locate most of their buildings within five-minute walking distance from the campus centre. Whereas, a dispersed-campus is characterized by scattered and sprawling development on campus. This dispersed-campus development related to disorganized campus expansion, which caused shared facilities to be isolated and difficult to access by users, limited usage for those without vehicles and created fragmented outdoor spaces.

Hajrasouliha (2017) defines configuration as the strength of a campus's spatial structure, with buildings defining open spaces and campus spaces being connected by main corridors and a central spine. He categorizes campus configuration into three categories namely structured, hybrid and ad-hoc. Structured-campus refers to an organized hierarchy of spaces that are enclosed by buildings and interconnected. This type emphasizes constructing new buildings along the main spatial structure, creating enclosures with many entrances and focal-points, and providing a change in scale to distinguish different hierarchies of outdoor spaces (Hajrasouliha, 2015). Structured-campus provides building arrangements that define and enclose spaces, which is important to bring more people together and encourage social interaction (Gehl, 2011; Jacobs and Appleyard, 1987). Enclosure is an important quality in outdoor spaces for well-defined boundaries and forms that provide a distinct character and function (Alexander et al., 1977; Matloob and Alsoofe, 2018).

In turn, an ad-hoc campus is characterized by unorganized spaces filled with free-standing buildings that are not well-connected to one another (Hajrasouliha, 2015). Ad-hoc configuration tends to create more left-over spaces (Trancik, 1986) and is rarely utilized (Alexander et al., 1977). They are defined as negative spaces, which are shapeless, as compared to structured configurations as positive spaces, which have a distinct and definitive form and are enclosed. Alexander et al. (1977) suggest providing a degree of enclosure for negative spaces by adding small buildings, building projections or walls, transform them entirely into positive spaces. Carmona's (2021) emphasizes that this ad-hoc configuration reflects 'modernist urban spaces' that are contained within the free-standing buildings in landscape settings, large scale with a coarse grid and road network that segregates the urban spaces. Conversely, the structured configuration reflects 'traditional urban spaces' that are the spaces within urban blocks that define and enclose the outdoor spaces, small scale, fine grid meshed street that is well integrated and connected. Finally, a hybrid-campus is characterized by a combination of structured and ad-hoc configurations.

RESEARCH METHODOLOGY

This research employed multiple case studies to evaluate the physical layout of campus masterplans in Malaysian Public Universities (MPUs). As stated in the *Pelan Tindakan Pendidikan Tinggi Malaysia 2022-2025*, public universities are the main higher institutions in Malaysia, with the highest enrolment of students (MoHE, 2022). MPUs have been established since the early 1900s. MPUs play an important role due to their strong historical significance and the remarkable success of their academic achievements and educational quality. This research evaluated three early Malaysian campuses based on their evolving physical layout (Figure 2). The first campus is University Malaya (UM), which is the oldest public university in Malaysia. UM was built as a university in a greenfield development entirely on a vacant site. The second campus is Universiti Teknologi Malaysia Kuala Lumpur (UTMKL) served as the original main campus of UTM until 1989, when the main campus shifted to a new greenfield campus in Johor, which was officially opened in 1985. Finally, Universiti Pendidikan Sultan Idris – Sultan Abdul Jalil Campus (UPSI-KSAJ) is the origin campus of UPSI, which currently has expanded to the new Sultan Azlan Shah Campus, 8 kilometres apart. Both UTMKL and UPSI-KSAJ are small campuses that were established prior to independence and were upgraded from colleges or lower-level institutions into universities on brownfield developments.

The three selected campuses were evaluated based on the triangulation of multiple qualitative techniques of data collection, namely document reviews, morphological studies, visual surveys and semi-structured interviews. The analysis applied figure-ground plans via solid and void to portray the spatial configuration. Figure-ground plans are a significant tool to 'communicate essential information about built form and urban spaces in a graphic that is readily intelligible' (Hebbert, 2016, p.721). It clearly distinguishes 'the patterns of built form (figure) and unbuilt voids (ground), with the voids encompassing a variety of streets, squares, gardens, parks and outdoor spaces' (Carmona, 2021, p.198). Figure-ground plans can represent the past history, the current disintegration of outdoor spaces as a result of abandonment and large carparks, and finally the future of how to fit the current layout (Hebbert, 2016). Additionally, Trancik (1986) argues that it is important to understand the historical evolution of the physical forms in order to understand the current condition of spatial design. Caliskan and Marshall (2011) highlighted that a lack of incorporation of urban morphology in design, particularly in the process of creating physical form compositions and without a good understanding of the existing urban fabric, can lead to the failure of the urban environment. Correspondingly, figure-ground analysis and morphological studies were performed on the campus masterplans to evaluate the change in physical layout of the selected case studies.

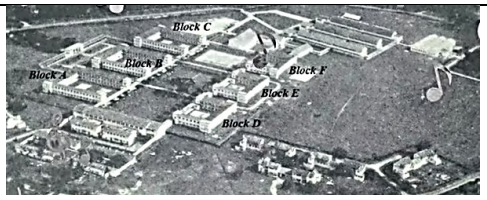
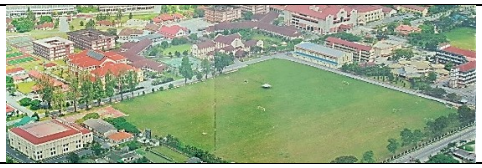
Campus Establishment	Campus Size	Physical Layout	
UM Established in 1961.	750 acres		Greenfield Development - Focus on the lake and *Rimba Ilmu*.
UTMKL Established in 1955 and upgraded to university in 1975.	47 acres		Brownfield Development - Focus on the open spaces.
UPSI-KSAJ Established in 1922 and upgrade to university in 1997.	81 acres		Brownfield Development - Focus on the padang.

Figure 2: Selected case studies with different design approach in campus layout.
Source: U-Malaya Library; UPSI, 2003.

RESULTS AND DISCUSSION

The discussion on the campus physical layout were based on the figure-ground analysis and morphological studies focusing on compactness and configurations as categorized by Hajrasouliha (2017).

Compactness

The findings show that UM is categorised as a dispersed-campus, while UTMKL and UPSI-KSAJ are categorised as dense-campuses (Figure 3). Both UTMKL and UPSI-KSAJ are within a circle 500-meter radius, which contributes to the compactness of the campus layout. The compact size of these two campuses was a result of their initial status as colleges, which were subsequently upgraded into universities.

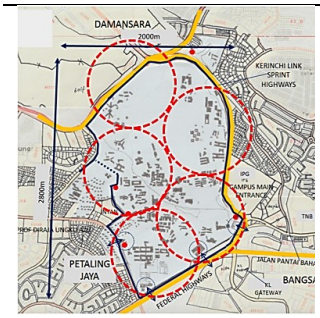
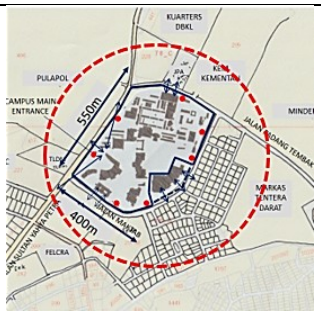
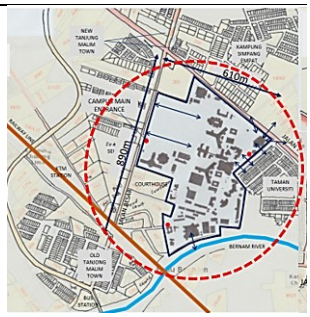
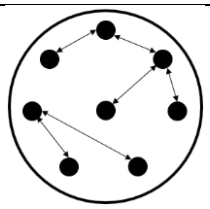
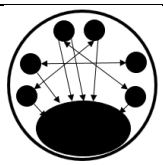
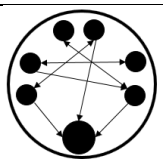
UM	UTMKL	UPSI-KSAJ
		
750 acres	47 acres	81 acres
Dispersed-campus	Dense-campus	Dense-campus
Approximately 5 circulars of 500m radius	Within 1 circular 500m radius	Within 1 circular 500m radius
		
Large Walking Radius	Small Walking Radius	Small Walking Radius

Figure 3: The compactness in the campus layout of three case studies.

The compactness of UTMKL and UPSI-KSAJ allows for a walkable environment within a small walking radius that reduces dependency on automobiles on campus. The result of a visual survey indicates that a greater concentration of users within a walkable space provides a higher chance to meet up for social interaction and natural surveillance. This is in-parallel with Carmona (2021), who highlighted that compactness reduces capacity for private automobiles on the road by reducing travel distances, encouraging walking and fostering social interaction. On a compact campus, people feel safe when they see other people on the campus street, which encourages walking (Hajrasouliha, 2017). However, the results of a visual survey showed that parking space at UTMKL remains high because there is a high demand for private vehicles to go to the campus without effective public transportation.

In turn, UM is a dispersed-campus on 750 acres of land. The visual survey demonstrates that UM requires a larger walking radius, resulting in a high-dependency on private automobiles to travel from one location to another on campus, inadequate parking and pedestrian-vehicle conflict. In-line with the results of interviews, it appears that UM lacks adequate parking on campus. It reflects a study done by Keat et al. (2016) that indicate long distances from

residential-colleges to the faculty and poor shuttle transportation as the reasons for students using private vehicles.

This larger walking radius lowers the chance of meeting up or running into the same circle of people because pedestrians can travel on various routes in different directions. While users who highly depend on private vehicles to travel tend to travel directly from one location to another and rarely meet up on the journey. This is aligned with Gehl (2011), who indicates that on a larger scale, people are dispersed in time and space because places are separated by dispersed physical form and high-automobile dependency. Additionally, Shamsuddin et al. (2007b) argued that the development of a large campus does not require the entire site, but should instead focus on a specific area for ease of access to facilitate movement, safety and the avoidance of traffic congestion. While, Matloob and Alsoofe (2018) emphasized 'infill-development' as an effective strategy to limit the expansion and increase density of the existing built areas, thus creating a more compactness that improves accessibility and enclosure.

Furthermore, the morphological analysis at UM demonstrates that the green spaces on campus decreased over time due to increased demand for built spaces (Figure 4).

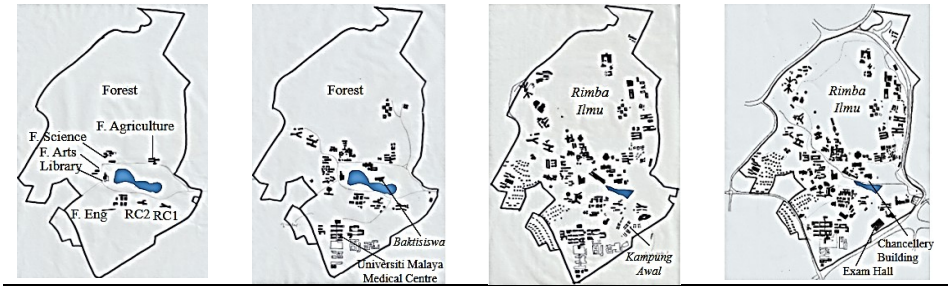
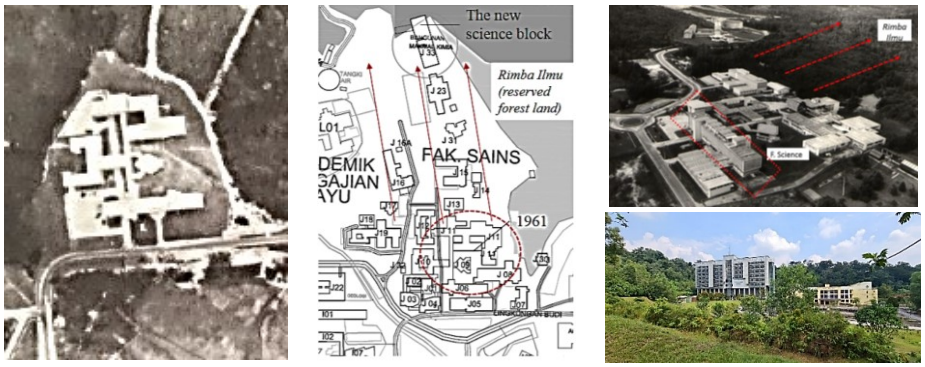


Figure 4: The evolution of physical layout in UM.

The lake served as the sole focal point for UM's development in the 1960s. However, the campus continues to expand around *Rimba-Ilmu* to build additional faculties, residential-colleges and shared facilities. This *Rimba-Ilmu*, was established in 1974 as a tropical rainforest botanical garden with more than 1600 species. It serves as a reserved-forest for conservation, research, education, and public awareness. The morphological analysis revealed that the growth and expansion of the campus are gradually consuming this reserved-forest land. In-line with the visual survey, the Faculty of Science recently built their chemistry-lab on part of the reserved-forest land (Figure 5). This is consistent with Abd-Razak et al. (2012), who highlight that the layout of the UM campus resembles a central core structure but is quite wide, and the campus's topography has a significant influence that results in a dispersed-campus.



1961 2020 The New Science Block

Figure 5: The expansion of the Faculty of Science towards the *Rimba-Ilmu*.
Source: U-Malaya Library.

Correspondingly, there is a need to design the campus layout to prioritize compactness by maximize construction within the existing development to minimize travel distances, promote walking and foster social interaction.

Configuration

The findings demonstrate that the configuration of campus layouts in UM and UPSI-KSAJ is categorised as ad-hoc campuses, while UTMKL is a hybrid-campus (Figure 6). The figure-ground analysis indicates that only UTMKL has a structured configuration on the old campus development, while the new development has an ad-hoc configuration. Hajrasouliha (2017) characterizes this type of layout that combines structured and ad-hoc configurations as a hybrid-campus.

UM	UTMKL	UPSI-KSAJ
		
Ad-hoc campus	Hybrid-campus	Ad-hoc campus

Figure 6: The configuration of campus layout in three case studies.

A visual survey found that the ad-hoc configuration of UM and UPSI-KSAJ are unorganized spaces filled with free-standing buildings that are not well-connected to each other and create lots of left-over outdoor spaces. It is aligned with previous studies indicating that poorly structured campus environments tend to create more left-over spaces between buildings and are rarely utilized (Alexander et al., 1977), which were defined by Trancik (1986) as 'lost-space'. Figure 7 shows UM's free-standing buildings, which significantly result in a great deal of 'lost-space' on their large campus.

Figure 7: Free-standing buildings that creates lots of left-over outdoor spaces in UM.
Source: U-Malaya Library.

Similarly, the campus layout in UPSI-KSAJ demonstrates ad-hoc configurations. The morphological analysis indicates that the campus layout is centred on the *padang* (Figure 8). The campus development began with three main buildings independently facing the *padang* in a symmetrical layout. The main building of Suloh-Budiman was built along the centre axis facing Jalan-Besar, with *Tadahan-Utara* and *Tadahan-Selatan* located side-by-side to the north and south, respectively. When the campus evolved as a result of its expandable function, this axis-line became blurred and eventually changed the earlier configurations. According to the interview results, the current campus environment is more congested and chaotic than it was in the 1950s. In-line with the visual survey, the infill of new free-standing buildings between old buildings creates an unorganized campus layout.

1922-SITC | 1960-MPSI | 1996-IPSI | 2020-UPSI-KSAJ

Figure 8: The change configuration of physical layout in UPSI-KSAJ.

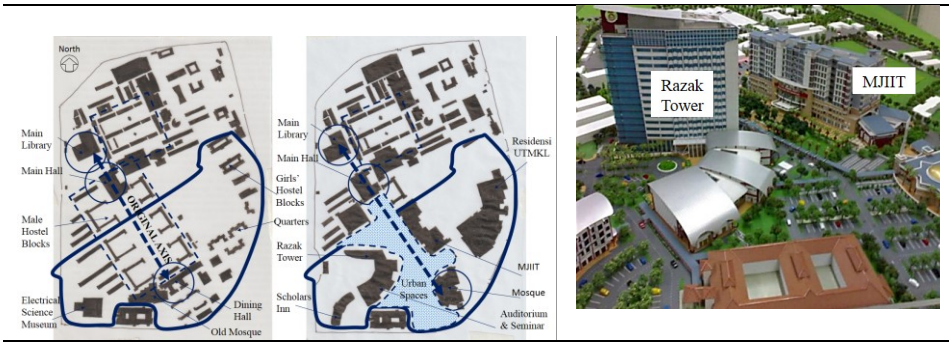
Moreover, the finding found that this ad-hoc configuration affects the local climate to provide users comfort. It creates issues to connect these free-standing buildings with covered walkways to suit the tropical climate. Providing covered walkways in all spaces causes budget constraints, and some spaces are not applicable. The result of the visual survey demonstrates that there are a lack dedicated covered walkways in UM that link the whole campus with faculties, hostels, and shared facilities. On this dispersed-campus, the only significant covered walkways from the hostel to academic blocks are from Residential-College 3, but they are just on sidewalks. This result is in line with Keat et al. (2016), who discovered that students choose to skip classes when it rains due to the lack of covered walkways to connect the residential-colleges and faculties. Moreover, the results of the interview indicate that covered walkways are difficult to implement in UM due to this ad-hoc configuration. Additionally, this free-standing building lacks shaded spaces on the ground floor that limit the activities for vitality (Figure 9). These buildings are limited to the building's primary entrances, which lead only directly to indoor spaces. Thus, it does not provide more space for transitions between internal and external campus buildings for social interaction compared to buildings in early campus development that connect several buildings on the ground floors.

Old buildings-connected ground floors.

New free-standing buildings - solely on individual entrances.

Figure 9: The configuration of the physical layout on the ground floor affects comfort and vitality.

In UTMKL, the morphological analysis discovered that changes in physical layout increase the image of ad-hoc configuration. The campus was originally designed as a structured-configuration centred on open spaces. The evolution and transformation of UTMKL has resulted in the demolition of a portion of the campus, thereby dividing the campus into two separate districts, the old and new developments of the hybrid configuration (Figure 10).



2000 – Old Development 2020 – New Development with less enclosure

Figure 10: The change in configuration of the physical layout in UTMKL.

The earlier layout of UTMKL provides smaller open spaces in each two-storey male hostel that connect to larger open spaces through an axis-line that anchors between the main hall and dining hall, demonstrating the hierarchy of spaces and being enclosed by buildings. This configuration provides a fine-grain, a sense of enclosure and high connectivity. In turn, the new development focuses on free-standing buildings in a coarse-grain landscape setting. When the campus was transformed to accommodate the 17-storey Razak-Tower, 10-storey MJIIT building, 4-storey Scholars-Inn, 2-storey Auditorium and Seminar, and 2-storey mosque, the changes in physical form had an effect on the enclosure, as buildings became objects in open spaces or open spaces that contained buildings. This reflects Carmona's (2021) argument that 'traditional urban spaces' have a small-scale, fine-grid meshed street that is well-integrated and connected, while 'modernist urban spaces' have a large-scale, coarse-grid and emphasize the road network that segregates the outdoor spaces. Besides, the earlier axis has been weakened due to the insufficient enclosure of the new free-standing buildings. UTMKL's early structured configuration enhances campus legibility, facilitating easy movement within easily controlled spaces. These configurations provide human wayfinding and indications to direct users from the starting point to the desired destination.

Moreover, the result of the visual survey found that the covered walkways in UTMKL can be divided into two types, attached to the building and independent (Figure 11). The covered walkways attached to the building are

mostly located in the old development of structured configurations, which provide better connectivity and provide multiple access points. However, the new developments provide covered walkways that are not attached to buildings, and certain parts must have elevated roofs to meet Fire Department requirements when passing through vehicle roads. The results of the interviews demonstrate that the users will get wet enough to move between the new free-standing buildings during rain. Typically, tropical downpours are accompanied by a strong wind that can assault from multiple directions, causing users of single, unattached covered walkways to become wet. Accordingly, structured configuration is a better design approach to reduce strong wind during rain and provide lots of shadow for a walkable environment in a tropical climate.

Structured configuration - old development

Independent covered walkways - new development.

Figure 11: The covered walkways between old and new developments in UTMKL.

Accordingly, there is a need to design the campus layout to reinforce structured configuration to provide a clear hierarchy of physical space in a campus environment. The structured configuration is a better design approach that enhances legibility, vitality and comfort in a walkable environment. A well-connected ground floor layout, typically in a structured configuration, promotes vitality that is accessible to the public for functions and climatic control.

CONCLUSION

The design of physical layout is the most crucial factor because it defines the pattern and structure of the street and buildings on campus. The evaluation of three campuses of Malaysian Public Universities (MPUs) shows that the large campus is expanded horizontally to utilized most of the campus land and finally creates a high dependency on automobiles and reduces green spaces. Sprawling necessitates more provision for campus streets and utility infrastructure. Additionally, the physical layout in MPUs mostly emphasizes the free-standing buildings with weak element that ties everything together. The physical layout must be direct, very clear, very defined and not scattered. Once the buildings are built, they cannot be relocated. The wrong design approach requires MPUs to create more solutions to the problems that have been created in the first place.

Therefore, it is recommended for MPUs to tackle their campus masterplans by designing the physical layout to provide compactness and structured configurations. These considerations contribute to the campus's legibility, vitality and comfort, which enhance a walkable environment. The implications of good design approaches in physical layout will ensure the design of campus masterplans to provide better outdoor spaces in campus development. MPUs need to take various actions to shape and reshape the campus over time as part of the process of shaping better places to promote sustainability.

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LIFE CYCLE COST (LCC) OF UNIVERSITY BUILDING MAINTENANCE: A SYSTEMATISED REVIEW

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Abstract

An effective maintenance management is predominantly important for university building, but commentators advocated it is more important for the maintenance strategies to be designed based on the efficient use of capital and resources. Commentators pointed out there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works. To overcome this, the life cycle cost (LCC) economic assessment technique has been recommended as an ideal solution that can facilitate the university agencies in the decision making to determine the most optimum building maintenance cost and financial capability over the anticipated study life. However, there is a need to identify any establishment link between the LCC with university building maintenance. Therefore, this paper is prepared with the objective to present the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance. A comprehensive review was conducted by searching databases, titles and abstracts screen, full-text analysis and data extraction on the targeted articles that have discussed the university building maintenance or indicated any form of building maintenance management elements with specific reference to LCC. The articles were identified from Google Scholar, Emerald, SAGE Scopus, My Cite, SpringerLink, as well as other databases. The findings indicate that many studies focused on building maintenance, however, there has been no specified guidelines concentrated on the LCC analysis of university building maintenance, which can be deliberated for practical guidance of maintenance management by the university agencies to attain value for money and making the university buildings and teaching and learning facilities economically wise use over the long term.

Keywords: University building, Life cycle cost, Maintenance

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INTRODUCTION

Education is a critical component in the Malaysian Strategic Thrust to drive the country to become a high-income and developed nation. The government is keen to improve Malaysian education sector to become a hub of education excellence that provides quality education throughout the learning life cycle, beginning from pre-school to university (Olanrewaju et al., 2010; Olanrewaju & Abdul-Rashid, 2015). Since independence, the Malaysia's economy has been guided by five-year economic development plans, and each economy plan shows that the education sector was given prioritize on development budget in terms of value and policy for education improvement. The education buildings in the universities are like any other buildings, that require various maintenance services for implementation to meet the intended purposes throughout the anticipated building life (Kim et al., 2016). The university buildings are designed and built for diverse faculties that have different specialisations with the objective to provide venue for favourable academic-related functions that include teaching, research, consultancy, and other related academic activities (Buys, 2009; Khalil et al., 2016; Kim et al., 2016; Palis, 2019; Odemakin and Abiodun, 2019). An effective maintenance management is predominantly important for university building, but commentators advocated it is more important for the maintenance strategies to be designed based on the efficient use of capital and resources (Abdul Lateef et.al., 2010; Zulkarnain et al., 2011; Kevin Chuks et.al., 2012; Campbell, Reyes-Picknell, et al., 2015; Kim et al., 2016; Puķīte & Geipele, 2017; Akomolafe, 2018; Afifah, 2019; Palis, 2019). Commentators pointed out there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works. To overcome this, the life cycle cost (LCC) economic assessment technique has been recommended as an ideal solution that can facilitate the university agencies in their decision making to determine the most optimum building maintenance cost and financial capability over an anticipated study life (Ayob et al., 2011, 2016a; PWD, 2023). However, there is a need to review and identify any establishment link between the LCC with university building maintenance, including how the LCC has been thought and discussed by scholars and researchers for university building maintenance practice. Therefore, this paper is prepared with the objective to present the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance.

OVERVIEW OF LIFE CYCLE COST (LCC) IN UNIVERSITY BUILDING MAINTENANCE

Maintenance is defined as a sequence of events that involves the implementation of various technical and administrative actions to take maintain the building

structure, systems and components to the intended functions and performance throughout the anticipated period. (Puķīte & Geipele, 2017). Good maintenance implementation will keep building's value and comfort living environment for building occupants. A well-maintained building requires minimum maintenance repair to remedy defects against deterioration and elongate life span at the optimum cost (Abdul Lateef et.al., 2010; Kim et al., 2016; Akomolafe, 2018; Abdullahi & Chinwendu, 2020; Zulkarnain et al., 2011; Shehu et al., 2020). Effective maintenance management is viewed from the feasibility perspective to ensure the building and its facilities will be operated and maintained in accordance with the consumer expectations and efficient use of capital resources (Afifah, 2019). The performance of building can refer to various meanings depending on the context, but it is commonly used to describe the routine act or regular operation in supporting the execution of tasks or activities in the building. All the maintenance activities of public assets and facilities in Malaysia are administrated by the Ministry of Works (MOW) through its technical agency i.e., Public Works Department (PWD). The PWD oversees the construction and maintenance of public assets and facilities, such as roads, government buildings, schools, hospitals, airports, harbours, piers, and related engineering work (PWD, 2023). Reports show that the Malaysia government has allocated high development fundings from the five-year economic plans to the education sector. However, the capital needed to operate and maintain the whole education buildings nationwide has significantly increased every year (Olanrewaju et al., 2010; Kim et al., 2016; Palis, 2019; Khalisah et.al., 2020). For example, in 2004, the Malaysian government spent RM304 million for the maintenance work of teaching and learning facilities in public universities. But it was reported the maintenance expenditure spent in 2008 had been highly increased double than the amount spent in 2004 to RM600 million (Olanrewaju et al., 2010: Khalisah et.al., 2020). Indeed, the education development budget had been increased by more than 42% over 20 years before 2010 (Olanrewaju, 2010). Nevertheless, the budgets allocation to public universities had been slashed to 70%, with 30% of the budgets were decided to be contributed by the universities from self-generated revenue. The budget cuts were particularly severe in in 2017, where the public universities received a total allocation of RM 6.12 billion, about 19.23 percent decreased from the RM 7.57 billion budget obtained in 2016. (Abdullah, 2017).

According to Khalil et al. (2016), and Odemakin and Abiodun (2019), the university buildings have to be maintained with effective maintenance management strategies by the in-charge agencies during the in-use phase to provide comfort indoor atmosphere for academic-related functions. However, there has been a critical demand to improve the traditional building maintenance policy that based on annual budget availability to prevent unforeseen restriction that can hinder a comprehensive implementation of building maintenance works

(Abdul Lateef et.al., 2010; Zulkarnain et.al., 2011; Kim et al., 2016). Life cycle cost (LCC) has been identified as ideal solution that can facilitate the university agencies in their decision making to determine the most optimum building maintenance cost and financial capability over the anticipated study life. However, there is a need to identify any establishment link between the LCC with university building maintenance. LCC is a useful economic assessment technique that can facilitate building owner or investor to estimate and determine the most optimum cost of owning, operating, maintaining, financial and disposing of buildings, facilities, or systems until the end of service life. In addition, LCC can compare the most cost-effectiveness between the competing maintenance methods or alternatives (Akomolafe, 2018; PWD, 2023).

In the Malaysia education sector, LCC economic assessment technique has been programmed as one of important topics in the economic subjects for the quantity surveying bachelor's degree programmes in several universities. Besides, the LCC has been enumerated as a subject matter in the postgraduate teaching courses including postgraduate research. This good development indicates a critical demand of LCC economic assessment technique to be delivered in undergraduate and postgraduate studies of the universities to prepare the students with theory, methodology and practical use of LCC, the benefits, including the LCC data, analysis and output knowledge for assisting them in the future decision making process with regard to economic viability to achieve the best value for money (ASTM International, 2010; BS ISO 15686-5, 2008; BSI, 2008; NATO Research and Technology Organization, 2009; Kelly & Hunter, 2009; Kirk & Dell, 1995, also as cited by Ayob, 2014; PWD, 2023).

Maintenance Management Models

Maintenance management is one of the important aspects in the institutional management of university strategic goals for providing a conducive learning environment that can enhance students' performance (Asiabaka; 2008, Hasbollah et al., 2018; Amaratunga and Baldry, 2000). As advocated by Karamera and Marion (2003), there is a considerable correlation between the students' performance and satisfaction level of educational setting and teaching and learning services they receive in the classes. The maintenance management for university building can be classified into following two categories:

i. Planned Maintenance: it is scheduled at fixed intervals of a certain number of days, months, quarters, seasons, years, or some other predetermined interval. The intervals are based on how much the service part in question has been used (Jenvald, 2020). In planned maintenance, the maintenance work is conducted according to the organization's recommended maintenance procedures. It does not require the consumer's request to preserve and

maintain the facilities. The purpose of planned maintenance is to determine what works need to be completed and how they need to be implemented. It is categorized as planned maintenance when the maintenance works on building and facilities are scheduled in advance to prevent damage and failure (Onawoga, & Akinyemi, 2010).

ii. Unplanned Maintenance: needed unexpectedly, not scheduled in advance, or based on user's request (Rahman, 2007). The unplanned maintenance is commonly executed when the defect or failure is not expected (Mobley2002, Jenvald and Hovmoller, 2020). The unplanned maintenance is preferred to be conducted when the element or part is damaged or defected that require new replacement (Onawoga, & Akinyemi, 2010). It is more difficult to estimate the unplanned maintenance rather than planned maintenance. This maintenance work is.

According to BS 3811:84, maintenance is the sum of all technical and related administrative actions meant to maintain or restore an object to a state in which it can the required functional performance. The literature study has identified several common models of building maintenance management. The identified models were reviewed and classified according to the two maintenance management categories, as presented in Table 1.

Table 1: Classification of Building Maintenance

Author	**Type of Maintenance**	
	Planned Maintenance	**Unplanned Maintenance**
British Standards Institution BS 8544: (2013)	Corrective maintenance, Preventive maintenance, Proactive maintenance	Reactive maintenance
Olanrewaju and Abdul-Aziz (2015)	Preventive maintenance, predictive maintenance, and proactive maintenance	Corrective maintenance
Salem M.A. Abuznaid (2018)	Preventive maintenance, Predictive maintenance, and Scheduling maintenance	Corrective maintenance
P. Palis (2019)	Planned maintenance, Predictive maintenance, and Preventive maintenance	Corrective maintenance
Nor Hapira Nadia et al. (2020)	Preventive maintenance, Statutory maintenance	Corrective maintenance Backlog maintenance.
N. Sipumelele et al. (2022)	Condition-based Maintenance, Reliability-centred maintenance	Total productive maintenance

Reactive maintenance or corrective maintenance

Reactive maintenance, also known as corrective maintenance or breakdown maintenance, is a maintenance approach in which repairs and maintenance works are carried out in response to the equipment failure or malfunction. According to GWilliam, (2022). reactive maintenance is the world's oldest method of maintenance. Reactive maintenance, sometimes known as "run-to-failure," is the process of performing maintenance chores after an asset has failed. The goal of reactive maintenance implementation is to restore the assets to operational status as soon as possible. Reactive maintenance, as opposed to planned maintenance, happens in response to unforeseen breakdowns or failures. Reactive maintenance is frequently utilized when the preventative maintenance resources are limited, or equipment failure is unpredictable. However, it is often seen as less efficient than proactive maintenance procedures, as it can result in higher expenditures, increased downtime, and lower overall equipment reliability. Corrective maintenance involves performing maintenance after a component or system has failed (Servio, 2015). Corrective maintenance involves finding, isolating, and fixing defects to ensure equipment, machines, or systems function properly (TWI, 2021).

Backlog maintenance

Backlog maintenance is the process of managing and updating a prioritized list of tasks, issues, or requirements that need to be addressed in the project or system (Department of Health Guideline, Queensland Health, 2017). Effective backlog maintenance management is essential for analysing maintenance demand, guiding maintenance programs, and identifying and managing hazards. For example, in road infrastructure, the is backlog maintenance defined as the cost of bringing the existing condition to a predetermined level, and hence has a monetary value. In the oil and gas industry, the backlog maintenance encompasses of a work package perspective that examines which work orders are not completed by the due date (Harald Rødseth and Per Schjølberg ,2017). This maintenance entails assessing, revising, and reprioritizing backlog items on a regular basis in response to shifting priorities, new information, feedback, and changing project objectives. By keeping the backlog maintenance current and relevant, greater focus can be given to the most important activities that can deliver value efficiently. This strategy is often employed in agile and iterative development methodologies.

Preventive maintenance

Preventive maintenance is a proactive approach that is often planned and scheduled in advance to minimize disruption or prevent failure to operations that can trigger unplanned downtime. Normally, the preventive maintenance is scheduled and then executed after a defined amount of time, or when a specific

system has been used to lower the probability of its failure (Basri et al., 2017). According to Tabikh and Khattab (2011), the preventative maintenance is a broad notion that encompasses all operations conducted on a machine to reduce unplanned downtime. According to Alhourani et al. (2021), the preventive maintenance was established in the 1950s to prevent unexpected failures of machines and equipment. It was designed and executed to prevent system breakdowns after prolonged use (Kimura, 1997). Such failures can create substantial delays and interruptions in the manufacturing lines, that had significantly increased costs and customer discontent (Al-Hourani et al., 2018). The preventive maintenance involves scheduled inspections, repairs, and upkeep of machinery, systems, or infrastructure to identify and address potential issues that can cause breakdown or failure. According to Olanrewaju and Abdul-Aziz, (2015), the preventive maintenance helps to identify any malfunctions and prevent failures or breakdowns before they occur. It may include routine inspections, replacement of components according to a predetermined schedule or based on usage metrics.

Proactive maintenance

According to Muganyi and Mbohwa (2018), proactive maintenance has been identified as a very useful method that can help to improve equipment reliability and performance. It prioritizes reliability and safety by reducing, automating, or simplifying maintenance tasks. It is also a preventative maintenance technique that focuses on finding and resolving possible issues before the occurrence of equipment failure or downtime Voisin et al. (2010). It entails methodical planning, scheduling, and execution of maintenance tasks to ensure equipment reliability and performance. The proactive maintenance solutions seek to increase equipment reliability, reduce downtime, and optimize maintenance costs by preventing problems rather than reacting to them after they occur.

Scheduling maintenance

According to Hasanuddin et. al., (2024), implementing scheduled maintenance practices within building facility management significantly mitigates risks, minimizes unplanned maintenance expenditures, and enhances overall building performance. The scheduling maintenance entails planning and coordinating maintenance tasks to ensure that they are completed at the proper times to minimize operational disruptions and increase maintenance efficiency. It includes the process of determining when the maintenance work should be completed, assigning resources, and coordinating activities to make the best and efficient use of time and resources. An effective maintenance scheduling is critical for guaranteeing the equipment reliability, availability, and performance while reducing downtime, costs, and operational disturbances.

Predictive maintenance

Predictive maintenance is an advanced maintenance plan that employs data analytics, sensor technologies, and machine learning algorithms to forecast when the equipment may fail, allowing repair to be performed proactively before the breakdown happens. According to Servio, (2015), the predictive maintenance anticipates damage/damages in future. The predictive maintenance can be periodic with fixed time intervals or predictive with forecasted failure times. Zhu et al., (2024) stated that the predictive maintenance, is also known as condition-based maintenance, that is implemented to prevent unexpected breakdowns that can increase building maintenance expenses. Almost all project management programs are time-based, and maintenance activities rely on elapsed time. The equipment's failure behaviour can be predictable. According to Fiix, (2021), the predictive maintenance uses data analysis to discover irregularities and potential problems of the equipment and its related process, allowing for early correction to prevent failure. Instead of following a set timetable or waiting for indicators of breakdown, the predictive maintenance uses real-time data and predictive analytics to uncover patterns and trends that indicate approaching equipment failure or degradation. The predictive maintenance is frequently used in the industries like manufacturing, energy, transportation, and utilities, where the equipment downtime can provide serious financial adverse effects. However, the predictive maintenance devices are more expensive to install, making them ideal for specialist building features, particularly in the manufacturing industry (Olanrewaju and Abdul-Aziz, 2015).

Condition-based maintenance (CBM)

Markus (2003) stated that the condition-based maintenance involves measuring an asset's condition and using the data to estimate necessary maintenance. The goal of CBM is to prevent breakdowns and extend preventive maintenance periods. This will boost the performance of the asset. The CBM analyses equipment status in real-time and uses diagnostics and prognostics to predict mechanical system failures. Telford et al., (2011). Condition-based maintenance is a maintenance method that involves the monitoring of equipment status in real time to decide when the repair work should be conducted. The condition-based maintenance assesses the health and performance of equipment using sensors, data analysis, and prediction algorithms, rather than following a fixed maintenance timetables or waiting for faults to occur. The condition-based maintenance helps to improve maintenance operations, increase equipment reliability, and maximize operational performance by leveraging real-time data analytics.

Reliability-centred maintenance

Reliability-centred maintenance is a comprehensive maintenance strategy that aims to increase the dependability, safety, and efficient use of equipment and systems at the optimum maintenance costs. The reliability-centred maintenance has created a decision model that emphasizes the importance of preventative maintenance to minimize costly repairs. Investing huge resources is not cost-effective as it exceeds the cost of errors (Nord et al., 1997; Liedberg, 2021). It is a one-of-a-kind tool used by reliability, safety, and/or maintenance engineers to create optimal maintenance plans that describe the criteria and tasks that must be completed to achieve, restore, or maintain a system's or equipment's operating capacity. (Brauer,1987). It is a systematic approach to ensuring that physical facilities function as intended. Reliability-centred maintenance is a key approach for regular preventative maintenance. (Sajaradj et al., 2019). Unlike traditional maintenance methods that focus on routine or reactive maintenance chores, the reliability-centred maintenance stresses a methodical and data-driven assessment of equipment reliability and maintenance requirements. Overall, the reliability-centred maintenance is a proactive and methodical maintenance management approach that can assist businesses in improving the dependability, safety, and efficient use of business assets, while preventing downtime. This method is adopted when the equipment dependability is crucial for business operations in certain industries, e.g., manufacturing, aviation, transportation, and utilities.

Total productive maintenance (TPM)

According to Liedberg (2021), defined total productive maintenance as an approach to reduce or eliminate downtime that allow maintenance and production operators to perform daily maintenance using autonomous maintenance. It emphasizes the importance of maintenance as a fundamental aspect of work (Liedberg, 2021). When the TPM and Total Quality Management (TQM) can be worked together to improve operational performance. The TPM will help to minimize costs by reducing scrap and producing fewer defective goods (Modgil and Sharma, 2016). The TPM is an improved maintenance strategy that is established to increase equipment efficiency, minimise failures and encourage autonomous maintenance through the involvement of employers and employees in the organisation (Bhadury, 2000; Cheong et al., 2021). It is one of the lean manufacturing approaches that can help to improve equipment performance by increasing the production rate, equipment availability and overall productivity of manufacturing. It helps to achieve zero breakdown, zero defect, zero accident that preserves the building functions (Azid, 2018).

METHODOLOGY OF STUDY

The study targeted articles that discussed on the Life Cycle Cost (LCC) and university building maintenance management. The identified articles for review were searched from Google Scholar, Emerald, SAGE Scopus, ISI Index, My Cite, SpringerLink, ISRA publications, as well as other databases.

Search Strategy

The searching strategy implemented in the study was designed with a systematized analysis of literature that evaluates the internal validity of each article following the advised given by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al., 2009; Booth 2009; Bello, 2021). The study looked for related academic publications covering all years until 15 March 2024 and covered all related studies based on Life Cycle Cost (LCC) and university building maintenance management. A structured approach was designed to categorize potentially important database research that in line with the best practices on the systematic literature review. The database search consisted of three components: (1) the identification of relevant terms relating to LCC (keyword quest), and the subject headings: 'Public Building maintenance,' 'educational or education building maintenance,' or 'university building maintenance. or (2). was identifying Malaysian research using keywords like "world country," and "Malaysia". Then those search strings were put together using Boolean operators such as "or" and "and" for all possible combinations. In addition to the database searches, the reference lists of the academic literature and the relevant papers were also searched (Bello et al., 2021)

Inclusion and exclusion criteria

All the publications of life cycle cost of university building maintenance that were found from the search activities, have been added to the list of articles in this paper. The search process is in line with the PRISMA as illustrated in Figure 2. A set of inclusion and exclusion criteria was established to select papers that eligible to be included in the systematized review, which includes as follows: 1. Identification of relevant studies by searching the databases; 2. Screening and removal of duplicate records; 3. Eligibility checks; and 4. Inclusion of articles that are most suitable in this systematized review (Bello et al, 2021). Based on the outcome of PRISMA assessment as presented in Figure 1, a total of 530 records were found by the research and other sources, 227 duplicate records were removed that left 303 records. Following that, 183 records were removed at the title screening stage, and the remaining 120 records were further assessed according to inclusion and exclusion criteria that has withdrawn 78 records. 42 records were found relevant for full text assessment, and therefore, as a result, 33 records were

found not relevant to withdraw, which finally left 9 records that are found eligible for inclusion in the systematized review.

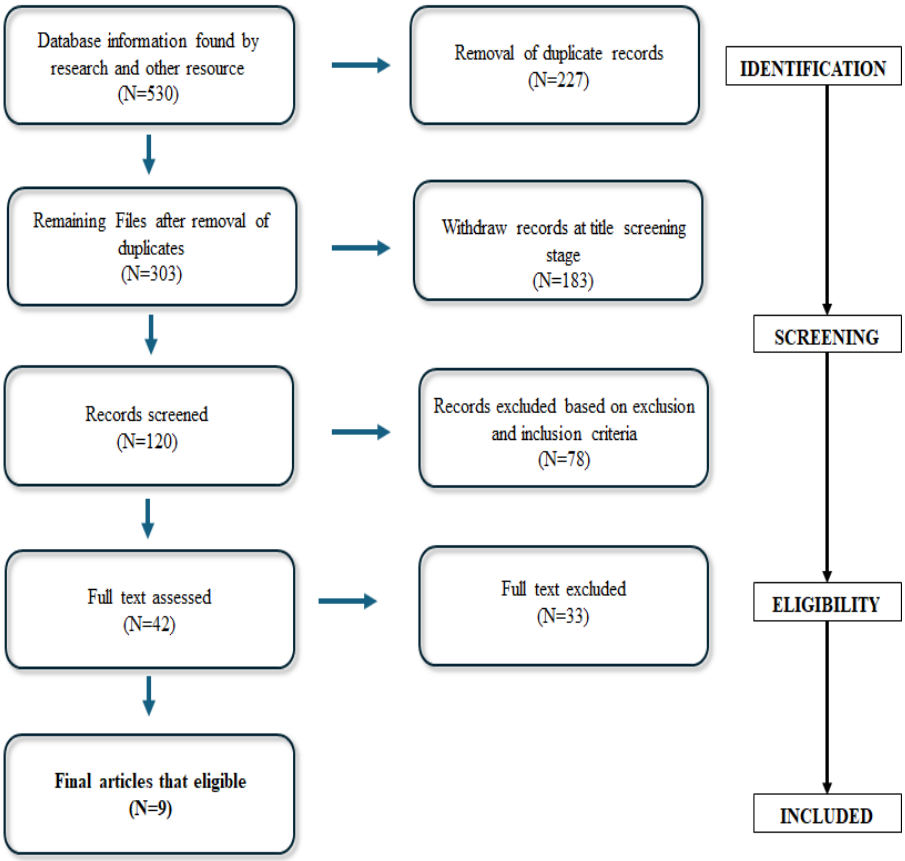

Figure 2: Prisma Flow Diagram (modified from Bello et al., 2021)

Data Extraction

The required data were extracted from each of the nine (9) qualifying papers that include the following details: name of the author(s), the title of the article, date of publication, name of publication journal/conference, research method adopted in the study and a summary of the findings. The details of extracted data from the nine (9) qualified articles are presented in the following section 4.0.

FINDINGS

Overview of Review Findings

Paper 1 (T. Puvaneswary (2014) focused on activity-based life cycle cost process model of facilities maintenance for public universities authors of corroborated that

to identified high-priority facilities and developed an Activity-Based Life Cycle Cost (AB-LCC) model for public facilities upkeep an effective cost management in building facilities maintenance must provide. On their part, the authors of Paper 2 (Ayob and Abdul Rashid, 2018) found that there is no model, system or guideline has been established in the Malaysian construction industry that can facilitate the LCC estimators to trace, define, collect, and update cost data as inputs into the process of producing reliable LCC outputs. Paper 3 (Huang et al., 2018) presents the outcome of study on reducing the environmental impacts caused by the Chinese university dormitories development. The study has identified two improving opportunities to reduce the said environmental impact: 1) improving building with deep renovation for current dormitories and implementing low energy buildings standards for new built dormitories; and 2) increasing the use of low environmental impacts building material by implementing carbon tax on main building material and timbers as structure material. Paper 4 (Chang-Sian Li and Sy-Jye Guo 2018) presents the outcome of study on life cycle cost analysis of maintenance costs and budgets for the university buildings in Taiwan using the BPN, MR and SLR models. The study outcomes have established that the BPN model is more superior cost prediction model of university buildings maintenance rather than MR and SLR to obtain the optimal life cycle maintenance scenario.

In Paper 5, (Dilawar Husain & Ravi Prakash (2018)), presents the outcome of study on the life cycle ecological footprint assessment of academic building. The study explains the ecological impacts of a building, the methodology used in the estimation of life cycle ecological footprint (LCEF total) of building, life cycle resources consumption (e.g., energy, water, building materials, manpower, etc.) and life cycle waste assimilation. Paper 6 (Bidi and Ayob, 2015) presents the outcome of investigation on the quality of cost data as inputs for LCC analysis of maintenance during the in-use phases of university building. The study has established the quality criteria of data required as inputs for producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building. In the paper 7 the title is to investigation of LCC analysis practice of university mosque maintenance during the in-use phase (Salem, 2018) found that the type of mosque maintenance during the in-use phase are scheduled maintenance, routine maintenance, and preventive maintenance where there is the common maintenance type that can be practiced in mosque maintenance works.

Table 2: The nine (9) qualifying papers included in the systematized review.

No	Author & Year Publish	Title	Key Findings/Conclusion
1	T. Puvaneswary (2014)	Activity-based life cycle cost process model of facilities maintenance for public universities	It presents the Activity-Based Life Cycle Cost (AB-LCC) model for public facilities upkeep.
2	Ayob, Mohd Fairullazi, Abdul Rashid, Khairuddin (2016a)	Protocol of Life Cycle Cost (LCC) data input requirements process	It presents the protocol that can facilitate the LCC estimators to trace, define, collect, and update cost data as inputs into the process of producing reliable LCC outputs.
3	Huang, Lizhen; Liu, Yongping: Krigsvoll, Guri: Johansen, Fred (2018)	Life cycle assessment and life cycle cost of university dormitories in the southeast China: Case study of the university town of Fuzhou	It presents environmental impacts caused by the Chinese university dormitories development and two improving opportunities to mitigate the impacts.
4	Chang-Sian Li & Sy-Jye Guo (2018)	Life Cycle Cost Analysis of Maintenance Costs and Budgets for University Buildings in Taiwan	It presents the LCC of maintenance costs and budgets for the university buildings in Taiwan using the BPN, MR and SLR models.
5	Dilawar Husain & Ravi Prakash (2018)	Life Cycle Ecological Footprint Assessment of an Academic Building	It presents the life cycle ecological footprint assessment (LCEF total) of academic building, resources consumption (e.g., energy, water, building materials, manpower, etc.) and waste assimilation.
6	Bidi, Nor Khalisah and Ayob, Mohd Fairullazi (2015)	Investigation of Quality of Cost Data for Life Cycle Cost Analysis in University Building Maintenance	It presents the quality required for the cost data as inputs for LCC analysis of maintenance during the in-use phases of university building.
7	Salem M.A. Abuznaid (2018)	Investigation of LCC Analysis Practice of University Mosque Maintenance During the In Use Phase	It presents scheduled maintenance, routine maintenance and preventive maintenance that are practiced in mosque maintenance works
8	Mysarah Maisham, Hamimah Adnan, Noor Akmal Adillah Ismail and Noor Aisyah Asyikin Mahat (2019)	Developing a Research Methodology for Life Cycle Costing Framework for Application in Green Projects	It presents the state of LCC in practice in green projects for both public and private sectors

No	Author & Year Publish	Title	Key Findings/Conclusion
9	Bidi, Nor Khalisah and Ayob, Mohd Fairullazi and Aripin, Srazali and Mat Noor, Noorsidi Aizuddin. (2020)	A study on quality of cost data in life cycle cost analysis of maintenance during the in-use phases of university building	It presents the quality state of cost data as inputs for each of the cost components in producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building

(Maisham 2019 et al.,) in their Paper 8, presents a research methodology for Life cycle costing framework for application in green projects. The study has established that the application of LCC practice is still limited in green projects, although the research trends of LCC are increasingly important in this green project areas. Both the public and private sectors are still wedged to the traditional procurement approach of project development, looking towards more on short term initial cost rather than the optimum long-term cost over the economic life. Lastly, Papers 9 Bidi et al., (2020) presents the outcome of study on the quality of cost data required as inputs for each of the cost components of LCC analysis of maintenance of university building. The study has established that the operation and maintenance cost data of the university building are not readily available, accessible, current and reliable to be used as quality inputs for producing a comprehensive and reliable LCC analysis of maintenance during the in-use phases of university building.

Thematic Areas

The thematic areas of the studies were categorized according to the key discussion points reported by the authors in their papers. According to the mode score in Table 3, the highest mode score in this variable is item 4 (M=3, item 4 – 33.33%, papers 4,6,9) which the authors discussed on the cost data issues and LCC analysis of university building maintenance. The second rank are shared by items 1 and 5, with 2 authors each respectively (M=2, items 1 and 5 – 22.22%, papers 1,2-item 1, papers 5,8-item 5) which the authors discussed on the administration and management of LCC, and framework for LCC analysis in university building maintenance.

Table 3: Thematic Focus of the studies and mode rank

No	Thematic areas	Paper	Mode rank
1	Administration and management of LCC	1,2 (22.22%)	2
2	Public Engagement and involvement in the development of LCC in maintenance	7 (11.11%)	3
3	Analysis of Case studies on LCC of building maintenance	3 (11.11%)	3
4	Cost data issues and LCC analysis of university building maintenance	4,6,9 (33.33%)	1
5	Framework for LCC analysis in university building maintenance	5,8 (22.22%)	2

DISCUSSION

The outcome of the study has proven the established links between the Life Cycle Cost (LCC) with university building maintenance. From the 530 review papers listed, only nine (9) papers met the requirements for inclusion of systematised review. All the 9 papers are research papers, but only two research papers presented framework for LCC analysis in university building maintenance, i.e., Papers 5 and 8 and the thematic areas is ranked second place of highest mode score. Therefore, based on the outcome of systematised review, it is not misconception to state that no specified guidelines or protocol concentrated on the LCC analysis of university building maintenance is currently available, including in Malaysia, which can be deliberated for practical guidance of maintenance management by the university agencies to achieve economic efficiency and value for money decision making in facilitating them to manage the building and teaching and learning facilities economically wise use over the long term. In addition, the findings show many literatures discussed on university building maintenance, but very limited literatures reported on the LCC of university building maintenance, i.e., only 9 papers.

CONCLUSION

This paper has presented the outcome of systematised review on life cycle cost (LCC) with specific reference to university building maintenance. Good maintenance management for education buildings is important to make Malaysia as the hub of education excellence. It prolongs the service life of university buildings to provide conducive learning environment that can enhance students' academic performance. It also helps to keep the university building's value economically wise use and makes staff and students' living comfort and enjoyable. On the contrary, neglecting maintenance will provide various adverse impacts to building owners and occupants. Although LCC has been identified as an ideal and useful economic assessment technique to facilitate the university agencies in their decision making to design and implement maintenance strategies based on the efficient use of capital and resources, it is deemed appropriate for

recommendation of further study to be carried to develop a specified guidelines or protocol concentrated on LCC analysis of university building maintenance that can revolutionize the traditional building maintenance policy based on annual budget availability for preventing unforeseen restriction that can hinder the comprehensive implementation of university building maintenance works.

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THE SOCIO-TECHNICAL SYSTEM FRAMEWORK FOR MAINTAINING THE SMART HERITAGE OF CHENGDU'S HISTORICAL AND CULTURAL VILLAGES

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Abstract

As the development of smart cities continues to advance, Smart Heritage has become an essential component of cultural preservation and inheritance. The cultural Heritage of Chengdu's historical and cultural villages possess significant cultural and social value and currently faces complex challenges in terms of conservation. Based on the actual situation of Chengdu's historical and cultural villages, employs qualitative research methodology, including semi-structured interviews with experts, to construct a socio-technical system framework supporting the implementation of smart Heritage in Chengdu's historical and cultural villages, aiming at effective management and conservation of Smart Heritage. The study first identifies the expertise areas and the number of experts involved. It is divided into three main parts: the socio-technical system's social, technological, and environmental dimensions. Based on the findings of this study, it is evident that the Smart Heritage of Chengdu's historical and cultural villages require interdisciplinary cooperation and coordination across various sectors. Additionally, there is a need for continually updated and improved technological support systems to adapt to changes in the era and demands. This framework is believed to provide valuable references and guidance for managing and conserving Smart Heritage in Chengdu's historical and cultural villages.

Keywords: Smart Heritage, Socio-technical system, Chengdu's historical and cultural villages

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INTRODUCTION

In the face of rapid urbanisation and technological development, the protection of cultural heritage faces complex challenges, particularly in regions with rich historical backgrounds like Chengdu. Chengdu's historical and cultural villages are treasure troves of tangible architecture and important carriers for preserving traditional culture and enhancing ethnic cohesion, possessing significant cultural and social value. In recent years, smart heritage has emerged as a promising approach to scientific management and widespread dissemination of cultural heritage through digital and smart means. (Khalaf, 2019; Poulopoulos & Wallace, 2022) . However, applying such technologies often lacks a comprehensive strategy, focusing primarily on technological development without fully integrating social, cultural, and environmental aspects.

This paper proposes a socio-technical system framework as a comprehensive approach to maintaining the smart Heritage of Chengdu's historical and cultural villages. Rooted in socio-technical system theory, the framework advocates for designing and developing social and technical elements within organisations or systems as interdependent wholes to enhance efficiency, satisfaction, well-being, and sustainability (Majchrzak & Borys, 2001). It provides a perspective that can address the complexity of implementing smart heritage. By adopting this framework, the study aims to harmonise intelligent technologies with the social, cultural, and environmental contexts of Chengdu's heritage sites, fostering a sustainable conservation model that benefits from technological innovation while enhancing the villages' social, cultural, and economic value. In this process, the research contributes to the growing discourse on sustainable heritage conservation practices, gaining insights into the potential of socio-technical systems in addressing the multifaceted challenges faced by historical and cultural villages in Chengdu and other regions. A detailed examination of social, technological, and environmental factors formulates comprehensive strategies for protecting and enhancing Smart Heritage in the context of rapid urbanisation and technological change.

Smart Heritage of Chengdu's Historical and Cultural Villages

Chengdu, a renowned historical and cultural city in China and the birthplace of the ancient Shu civilisation, boasts a history of over 3,000 years. The "Chengdu Urban Master Plan (2016-2035)" emphasises the vigorous protection and development of cultural heritage. Chengdu has identified 13 historical and cultural villages and continues to expand this list (**Figure 3**). In October 2020, Chengdu proposed the "Smart City Construction Action Plan (2020-2022)" to develop smart infrastructure and cultural tourism services. In 2021, the Chengdu Municipal Government promulgated the "Regulations on the Protection of Historical and Cultural Famous Towns, Villages, and Traditional Villages of

Chengdu", advocating for smart protection through digital data collection, mapping, establishment of protection archives, integration into information management systems, and public disclosure. Moreover, it seeks to promote smart cultural tourism, including digitalising scenes and constructing internet-connected venues. Against the backdrop of China's digital rural development and Chengdu's smart city initiatives, historical and cultural villages are integral components of Chengdu's cultural heritage. Therefore, leveraging technology and intelligence to protect and develop the cultural Heritage of Chengdu's historical and cultural villages is crucial. Consequently, it is imperative to research the Smart Heritage of Chengdu's historical and cultural villages.

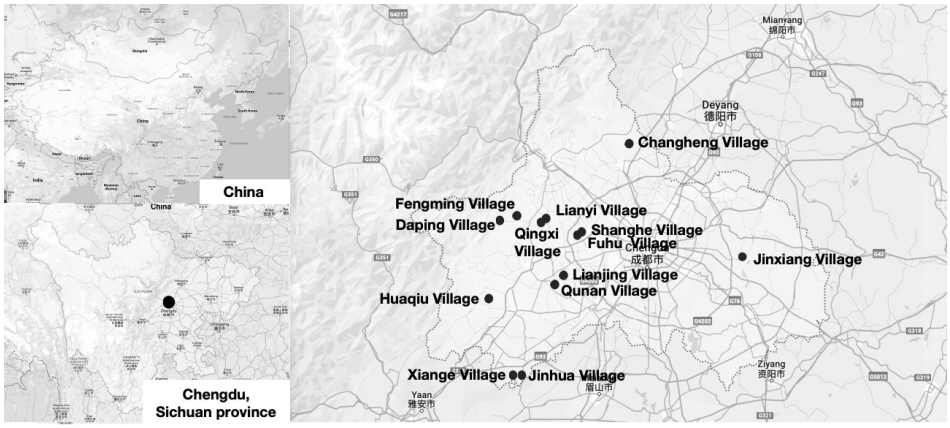

Figure 1: Chengdu's historical and cultural villages
Source: Google map

LITERATURE REVIEW

Smart Heritage

World Heritage refers to the invaluable and irreplaceable wealth recognised by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Heritage Committee (WHC), representing a universally recognised legacy of outstanding significance and universal value in natural and cultural landscapes. According to UNESCO, heritage is classified into three categories: natural heritage, cultural heritage (both tangible and intangible), and mixed heritage. Protection strategies have been formulated since 1972 and are continuously updated with social development. Smart heritage was initially proposed by the INTACH Heritage Academy (2007), aiming to address the challenges of cultural heritage protection in the era of smart cities by leveraging the advancements in Information and Communication Technology (ICT)(Adrian & Kurniawan, 2020). It is considered a relatively new system and management medium. Batchelor (2021) defined smart heritage as a complete ecosystem. Smart

heritage is the fusion of smart technology with the disciplines of smart cities and heritage, integrating smart technology's autonomy, automation, and innovation within the historical context and subjective interpretation(Batchelor et al., 2021). Smart heritage is a relatively new concept, intersecting smart city and heritage disciplines.

In 1992, UNESCO initiated the "Memory of the World" project, proposing digital technology for cultural heritage preservation. Since the 1990s, digital technology has rapidly developed and been utilised to protect and manage cultural heritage. Subsequently, the emerging field of cultural computing adopted methods such as reverse engineering and computer graphics to analyse, inspect, conserve, and visualise cultural heritage (Gonizzi Barsanti et al., 2015). After 2010, the field of cultural heritage preservation gradually shifted from digital recording to integrating and applying multiple technologies. It has evolved from simple information systems about cultural traditions to complex systems encompassing heterogeneous data sources (such as sensor networks and social networks), digital libraries, multimedia collections, and web-based data services. It includes geographic information technology, satellite positioning and measurement technology, remote sensing and high-definition imaging technology, information and communication technology, the Internet of Things (IoT), multimedia, network communication, cloud storage systems, and wireless sensor networks (WSN), facilitating digital preservation and dynamic monitoring of cultural heritage; sustainable utilisation and management of cultural heritage; as well as cultural heritage experience and services, promoting the dissemination of cultural Heritage (Borda & Bowen, 2017; Luo et al., 2024). Smart heritage integrates multiple disciplines, including archaeology, tourism, architecture, and those related to information technology and digital platforms(Batchelor & Schnabel, 2019). Furthermore, its application areas continue to expand, encompassing tangible and intangible cultural heritage.

Since 2013, with the revitalisation of rural areas in China in 2018, the application of Smart Heritage in the research of historical and cultural villages has gradually emerged. When the Smart Village Strategy was proposed in 2019, relevant studies surged, and research directions began diversifying. The core content and information of cultural heritage in historical and cultural villages are objectively and comprehensively recorded, preserved, and structured into data resources, which can be retrieved, learned, and disseminated through data platforms, 3D technology, human-computer interaction, virtual reality (VR), augmented reality (AR), and other technologies (Hongji & Yong, 2017; Jin & Haopeng, 2021; Rahmat et al., 2023; Ali et al., 2018). This initiative provides a solid data foundation and decision support for protecting, restoring, and disseminating cultural Heritage in Chinese historical and cultural villages. These technologies offer new possibilities for recording, participating, and interpreting

cultural heritage, but their implementation often lacks frameworks that fully consider the social and cultural dimensions.

Socio-technical system

The Socio-Technical System (STS) is a system involving complex interactions among human (social components), machine (technical components), and social-environmental components. It aims to design a system with characteristics of an open system, providing a robust analytical framework for complex systems and organisations to address better complexity, dynamism, new technologies, and competitive environments(Trist, 1980). Leavitt (1965) provided a research framework for socio-technical system theory. The framework shifted the discovery of entire organisations and focused on the relationships among people, tasks, structures, and technologies. Bostrom and Heinen (1977) advocated for the interrelatedness of these system components and the necessity of considering them together (**Figure 2**), proposing a socio-technical system framework. The social subsystem comprises structures and people, while the technical subsystem comprises technology and tasks. The environmental dimension refers to external dimensions that affect the system. On the one hand, there are complex political, economic, social, technological, environmental, and legal factors. On the other hand, architectural environments, physical environments, geographical locations, and natural disasters also constitute complex environmental factors.

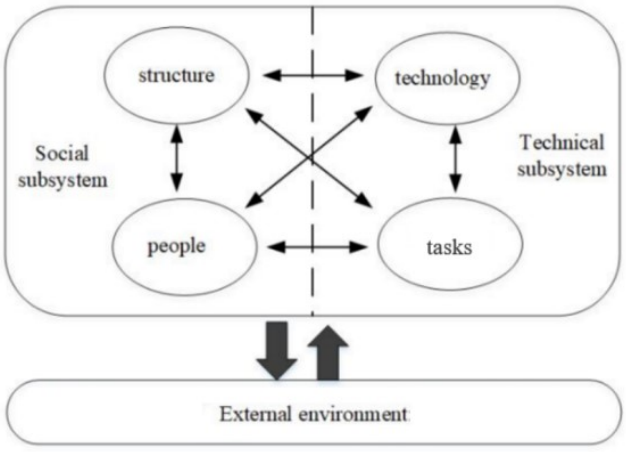

Figure 2: The Socio-Technical System Framework
Source: Bostrom & Heinen,1977

The Socio-Technical System (STS) was introduced by Emery and Trist in the 1950s in the British coal mining industry when mechanical technology was

introduced. It enhanced organisational efficiency and job satisfaction(Trist, 1980), emphasising the interaction between social systems and technological infrastructure. It has been developed and applied for over 60 years, successfully applied in many critical areas, especially in the design of new technologies and redesign of job roles (Geels, 2004; Li et al., 2018). It provides a comprehensive perspective on cultural heritage preservation, particularly in addressing the complexity of smart heritage's technological, social, and environmental interactions. Yakel (2007) discussed the application of STS in digital management, emphasising the importance of technological and social factors in implementing digital projects. Parry (2010) demonstrated the alignment of STS theory through case studies of digital transformation in museums and cultural institutions. Srinivasan (2012) explored how to promote diversity and inclusiveness in cultural heritage by integrating technology and social learning. This aligns with the core principles of socio-technical system theory, which considers social factors in technology design and implementation. Elisa Giaccardi (2012) focused on the role of social media as a technological tool in facilitating community engagement and dynamic preservation of cultural heritage, demonstrating the potential application of STS theory in Smart Heritage preservation.

Challenges facing the historical and cultural villages in Chengdu include pressure from urbanisation and the risk of losing tangible cultural heritage. Smart heritage has the potential to strengthen heritage conservation in this context. However, the approach we need should not only adopt smart technology but also consider how technological solutions can adapt to the socio-cultural environment of cultural heritage and engage local communities and stakeholders in meaningful ways. (Ab Dulhamid et al., 2023). Jointly protecting and developing cultural heritage can promote rural tourism (Dulhamid et al., 2023; Ismail Isa et al., 2022). Integrating Socio-Technical Systems into heritage conservation represents a paradigm shift, emphasising the importance of understanding and addressing social and technological dimensions in conservation work. For villages in Chengdu, this may mean developing conservation strategies with technological innovations that optimise technological, social, and environmental systems, leading to more comprehensive and sustainable heritage conservation approaches.

RESEARCH METHODOLOGY

This study will conduct qualitative research through semi-structured interviews with experts. Experts were selected from research domains, including the tangible cultural heritage of historical villages in Chengdu (4), Smart Heritage (2), and Socio-technical Systems (2). Purposeful sampling and snowball strategies were employed to select participants, and each interviewee was assigned a code (E1 to

E8). Information about the interviewees is presented in **Table 1**. Before collecting data, semi-structured interview questionnaires were prepared based on research questions, objectives, relevant literature, and theoretical frameworks. Detailed question lists were designed for the interviewees. These questions were open-ended, allowing interviewees to construct their answers, and they also had to be sufficiently engaging to prompt detailed discussions on specific topics for both researchers and interviewees. (Qu & Dumay, 2011).

Table 1: Interviewees' Information

Interviewees	Interviewees' Position / Agencies
E1	Associate Professor / Sichuan Agricultural University
E2	Professor / Southwest Jiaotong University
E3	Associate Professor / Southwest Jiaotong University
E4	Associate Professor / China West Normal University
E5	Project Director / Lifang Digital Technology Group Co., Ltd
E6	Associate Professor / Southwest University of Science and Technology
E7	Associate Professor / Sichuan University of Science and Engineering
E8	Associate Professor / Sichuan Agricultural University

The questionnaire framework was divided into three (3) sections. Part A included three questions about the technological dimension in the socio-technical system framework; Part B included three questions about the social dimension; Part C contained four questions about the environment. Efforts were made to communicate with and interview the eight experts through telephone calls, and interview locations were determined to be varied, including their workplaces and private offices. All interviews were conducted between July and September 2023 and were documented through written notes and audio recordings.

Study scope

The scope of this study focuses on the tangible cultural heritage of historical villages in Chengdu, which encompasses historical relics, historical buildings, and cultural sites. Chengdu's historical and cultural villages possess favourable natural conditions. Due to cultural history and geographical structure differences, a tangible cultural heritage has emerged, characterised by family settlements, religious culture, and traditional craft culture (**Table 2**). Overall, the tangible cultural heritage of historical villages mainly consists of three forms: historical buildings, historical relics, and cultural heritage conservation units.

Table 2: The Tangible Cultural Heritage of Historical Villages in Chengdu.

No.	History building	No.	Cultural relic protection units
1.	Li's courtyard	1.	The Imperial Tea Garden
2.	Xu's courtyard	2.	Daming temple
3.	Chongjiang Bridge	3.	Feixian Ge
4.	Yin Changheng's Residence	4.	Chongyang 1886 Ancient Cellar Pool
5.	He Lin's Residence	5.	
6.	Zhengjia courtyard	6.	
7.	Yu Jiapian residence	7.	
8.	Banmu Pond Cultural Courtyard		

Source: Author

ANALYSIS AND DISCUSSION

Figure 3 illustrates the survey results regarding the socio-technical system framework for maintaining the Smart Heritage of historical villages in Chengdu. It depicts three internal dimensions: social, technical, and environmental; each also outlines the requirements for sustaining the Smart Heritage of historical villages in Chengdu.

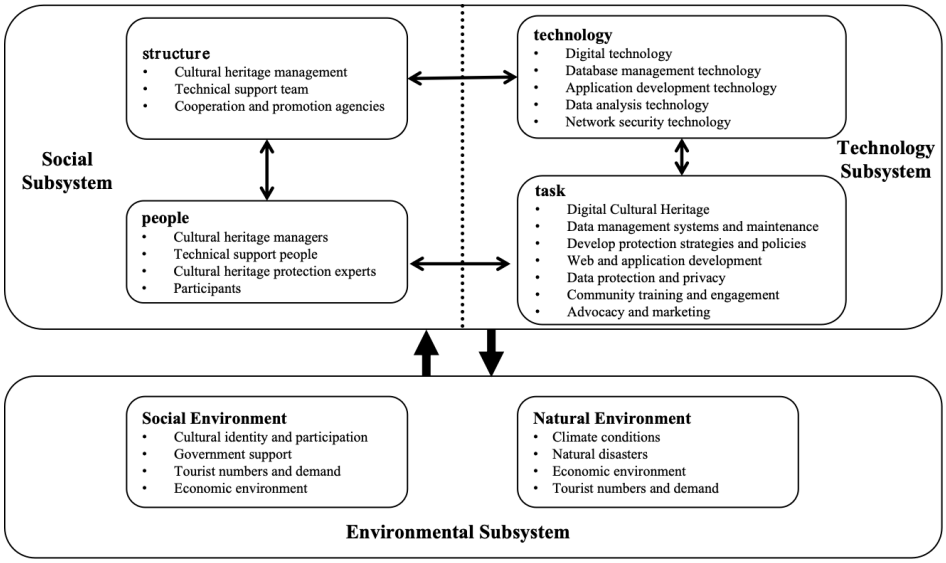

Figure 3: The socio-technical system framework of the Smart Heritage of historical villages in Chengdu.
Source: Author

Technology Subsystem

Tasks

Several experts emphasised the collaborative nature of multiple tasks required to maintain Smart Heritage, with application and development tasks paramount in promoting cultural heritage dissemination. The descriptions are as follows:

"Development of Smart Heritage applications, including guides, virtual exhibitions, and social media interactive features. A user-friendly interface and interactivity are required to provide a rich user experience". (E1).
"Development of websites and mobile applications to provide information and interactive experiences". (E2).
"Provision of a user-friendly interface and interactivity to create a profound and enriching user experience. This includes designing interactive maps, virtual exhibitions, narration features, etc., to help users explore and understand cultural heritage more deeply". (E5).
"Development of online platforms for Smart Heritage, including websites and mobile applications, to provide a user-friendly interface and interactivity. These platforms may include virtual tours, historical background information, interactive maps, and multilingual support to enrich users' cultural experiences". (E6).
"Creation of educational resources, including online courses, educational games, and teaching materials". (E7).

Furthermore, the experts emphasised the importance of comprehensive cultural heritage digitalisation, including digitising cultural heritage, establishing regular data management systems, maintenance updates, and extensive data protection and privacy measures. It is essential to develop appropriate smart heritage protection strategies and policies. Equally important is encouraging community training and participation, conducting publicity and marketing campaigns, promoting knowledge and application of cultural heritage, and increasing visibility to attract more tourists and researchers. By fulfilling these tasks, we can only better support the realisation of smart heritage.

Technology

Several experts mentioned the need for diverse technological collaborations to support task implementation, with technology support for application and development tasks being the most important in maintaining the protection and development of smart heritage. The descriptions are as follows:

"Virtual and augmented reality technologies are used to create virtual tours and educational experiences". (E2).
"Digital display technologies are used to produce multimedia content". (E8).
"Network and Internet technologies: support online access and interaction". (E7).
"Mobile application development technologies are used to create user-friendly mobile applications, providing guides, virtual exhibitions, and interactive experiences". (E5).
"Cloud computing and storage technologies are used to store and manage large amounts of data and content, including cultural heritage information. They allow for remote storage and access, providing highly scalable storage solutions for easy storage capacity expansion when needed. This contributes to the effective preservation and management of cultural heritage data". (E6).
"Geographic Information Systems: used for geolocation and map navigation functions". (E5).

Furthermore, experts pointed out that supporting task implementation requires digital technology for collecting, storing, and managing information related to historical and cultural villages, photos, documents, etc. Database management technology is essential for storing and managing large amounts of data and content. In contrast, data analysis techniques, artificial intelligence (AI), and machine learning are used for data analysis, task automation, and personalised content recommendations. Network security technology, including firewalls, data encryption, access control, malware detection, and vulnerability management, is equally important to ensure data security and user privacy. It is through the collaboration of these technologies that smart heritage can be realised. **Figure 4** illustrates three-level coding to analyse the expert interview data for the Technology Subsystem.

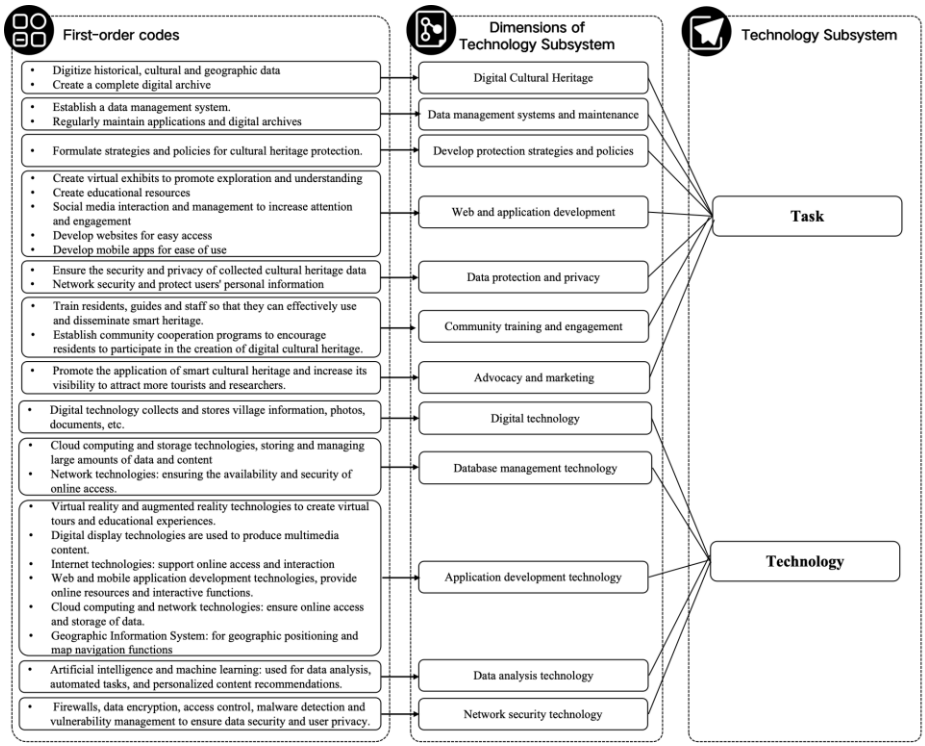

Figure 4: The Coding Scheme of the Technology Subsystem
Source: Author

Social Subsystem

Structure

Several experts emphasised the importance of organisational structure, with the technology support team being crucial in protecting smart heritage. Descriptions are as follows:

"Data Management Team: Responsible for collecting, storing, and maintaining cultural heritage data". (E3).
"Technology Team: This team is responsible for application development, database management, network maintenance, and security". (E6)
"Technology vendors: Provide digitalisation and application development technologies, assisting in system development and maintenance". (E4).

Experts also pointed out that establishing cultural heritage management, collaboration with multiple teams, and promotion are essential to better realising smart heritage.

People

Figure 5 illustrates three-level coding to analyse the expert interview data for the Social Subsystem. Several experts mentioned the need for collaboration among various professionals to sustain the operation of Smart Heritage in historical cultural villages. Descriptions are as follows:

"Technical developers are responsible for creating and maintaining digital systems; traditional village conservation and cultural heritage experts provide professional guidance on protection and display; data analysts process and interpret relevant data; government officials provide policy support and regulation". (E8).
"Suppliers provide equipment and technical support; representatives of residents communicate residents' needs and feedback". (E4).
"Tourists can collaborate to facilitate better execution". (E3).
"Investors provide financial support". (E5).

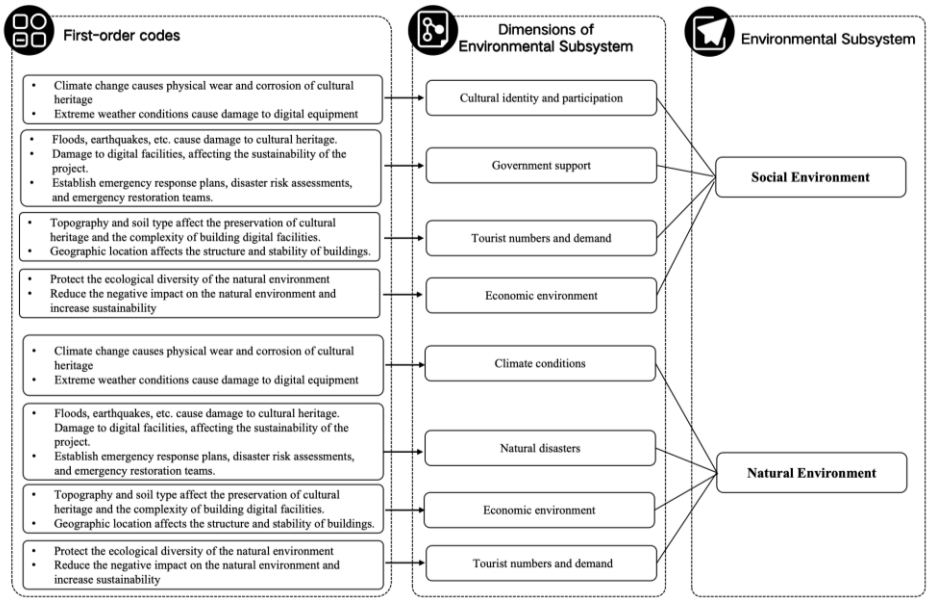

Figure 5: The Coding Scheme of the Social Subsystem.
Source: Author

Environmental Subsystem

Social Environment

Several experts emphasised the importance of government support, including government policies, funding support, and regulation, which significantly

influence the implementation and sustainability of Smart Heritage in historical cultural villages. Descriptions are as follows:

"National and local government cultural policies play a crucial role in protecting and inheriting cultural heritage". (E4).
"Government funding support can drive project development". (E3).
"Government regulation has a significant impact on project implementation and sustainability". (E7).

Experts also pointed out that community cultural identity and residents' active participation are crucial for project success. Active participation can enhance the preservation and dissemination of cultural heritage. The number and behaviour of tourists can affect the protection and sustainability of cultural heritage. Tourists' interests and needs can influence project content and experience design. Equally important is the economic environment, which affects sustainability.

Natural Environment

Several experts emphasised the impact of the natural environment on the feasibility and sustainability of Smart Heritage projects, where natural disasters can damage cultural Heritage, historical villages, and digital facilities, affecting the protection and maintenance of cultural heritage. Emergency response plans, disaster risk assessments, and emergency repair teams should be established. Descriptions are as follows:

"Natural disasters such as floods, earthquakes, and fires may threaten the physical preservation of cultural heritage, requiring measures to protect digital cultural heritage data and items". (E2).
"Extreme weather and natural disasters (such as floods, earthquakes) may damage historical villages and digital facilities, affecting project sustainability". (E1).
"Natural disasters such as earthquakes, floods, and fires may cause severe damage to cultural heritage. Emergency response plans, disaster risk assessments, and emergency repair teams are needed". (E5).

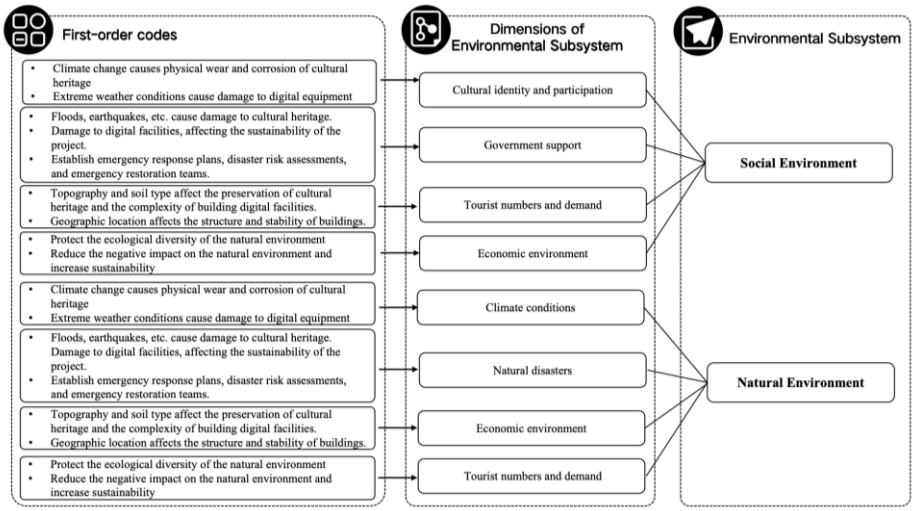

Figure 6: The Coding Scheme of the Environmental Subsystem
Source: Author

Figure 6 illustrates the process of using three-level coding to analyse the expert interview data for the Environmental Subsystem. Experts also pointed out that climate change and geographical conditions may affect the preservation of cultural heritage and the complexity of building digital facilities. Environmental protection is equally important to reduce negative impacts on the natural environment and increase the sustainability of smart heritage protection. These social and environmental factors are intertwined and collectively influence the success and sustainability of Smart Heritage projects.

CONCLUSION

This study conducted interviews with eight experts. Based on the research findings, a socio-technical system framework for the Smart Heritage of historical villages in Chengdu was constructed to promote sustainable development and protection. This framework integrates social, technical, and environmental factors organically, providing comprehensive and systematic guidance for the maintenance and management of Smart Heritage. Firstly, in the technical dimension, specific tasks and relevant technologies supporting their implementation must be clearly defined for the Smart Heritage of historical villages in Chengdu to achieve comprehensive protection and utilisation of Smart Heritage. Secondly, in the social dimension, a diversified organisational structure needs to be established, requiring collaboration among various professionals, including cultural heritage conservation experts, smart technology specialists, and government administrators, to ensure the better operation of the Smart

Heritage of historical villages in Chengdu. Lastly, significant natural and social environmental factors that impact the implementation and sustainability of smart heritage in historical villages in Chengdu need to be identified in the environmental dimension. The Smart Heritage of historical villages in Chengdu requires interdisciplinary and interdepartmental cooperation and coordination to integrate resources, optimise management, and continuously improve the technical support system to adapt to changing times and demands. Through continuous improvement and optimisation, this framework contributes significantly to protecting and developing the Smart Heritage of historical villages in Chengdu, leaving behind a rich and valuable cultural legacy for future generations.

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THE ENDURING LEGACY OF MASHRABIYA IN ISLAMIC ARCHITECTURE AND DESIGN

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Abstract

This research investigates the multifaceted significance of Mashrabiya, a traditional architectural element found throughout the Islamic world. Employing a design typology approach, it delves into its historical, social, artistic, and environmental aspects. The core focus lies in the typology's impact on functionality, including solar control, ventilation, and humidity regulation. Cultural and social values embedded within the design and craftsmanship are also explored. The study emphasizes design strategies for incorporating Mashrabiya in both historical and contemporary buildings, analysing its use as a primary decorative element. A comparative analysis with traditional Malay house screening is included. six case studies, encompassing traditional and modern applications, will be examined alongside the element's historical background, installation methods, material usage, and modern adaptations in hotels and boutiques. Finally, the artistic representation and construction techniques, particularly its connection to abstract geometry, will be explored. This comprehensive investigation aims to highlight the rich history of Mashrabiya, establish it as a valuable source of inspiration for future designers, and bridge the knowledge gap between traditional and modern forms.

Keywords: Mashrabiya, Architecture, Design, Traditional, Modern.

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INTRODUCTION

The Climate exerts a profound influence on architectural design. Each region's climatic characteristics leave an indelible mark on its built environment, shaping unique elements and fostering a distinct cultural identity (Ashour, 2018). The Islamic art and architecture is centuries old (Kamarudin et al., 2020). The Mashrabiya, a traditional component of Islamic architecture originating in the Arab world, exemplifies this intricate relationship (Dariyadi et al., 2022a, 2022b). Its intricate latticework design has captivated Western scholars for centuries, and its recent resurgence in contemporary projects like hotels and boutiques underscores its enduring appeal (Mohamed, 2015). Modern applications of the Mashrabiya vary in their adherence to the original design. Traditionally, it was a cantilevered structure with a lattice where water jars were placed to cool through evaporation as air passed through (Bagasi & Calautit, 2020). These days, the term refers to an aperture featuring a wooden lattice screen made out of tiny, circular-section wooden balusters spaced at precise, regular intervals, frequently forming an elaborate and aesthetically pleasing design as shown in figure 1.

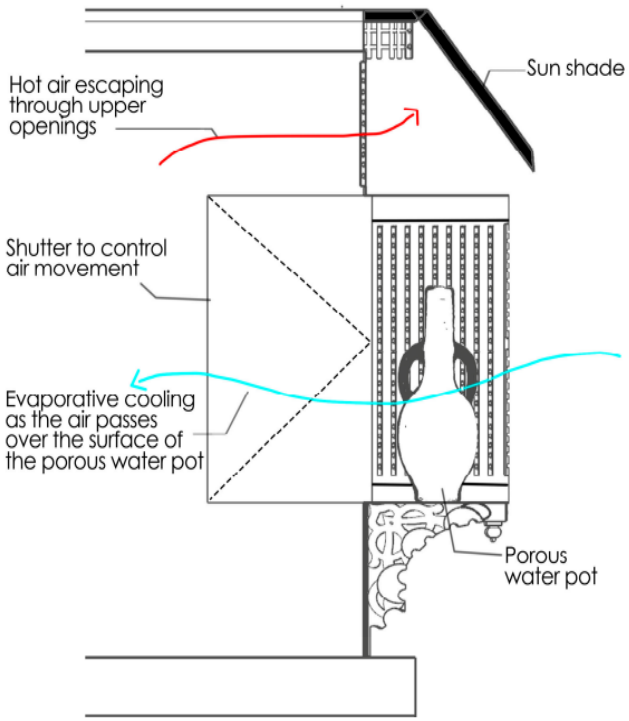


Figure 1: Indoor air-cooling system created by placing porous water jars in the Mashrabiya.
Source: (Taki & Kumari, 2023)

Originally, "Mashrabiya" referred to structures for cooling water jars, using an intricate lattice for evaporative cooling and air movement. This design tackled the harsh Middle Eastern heat and low humidity, while also serving as a means for social privacy and window closure (Headley et al., 2015). By strategically filtering sunlight and promoting natural ventilation, the Mashrabiya facilitated a comfortable "cold effect" within dwellings, a critical feature for inhabitants enduring extreme heat (Bagasi, 2022). Figure 2 shows the functions of Mashrabiya.

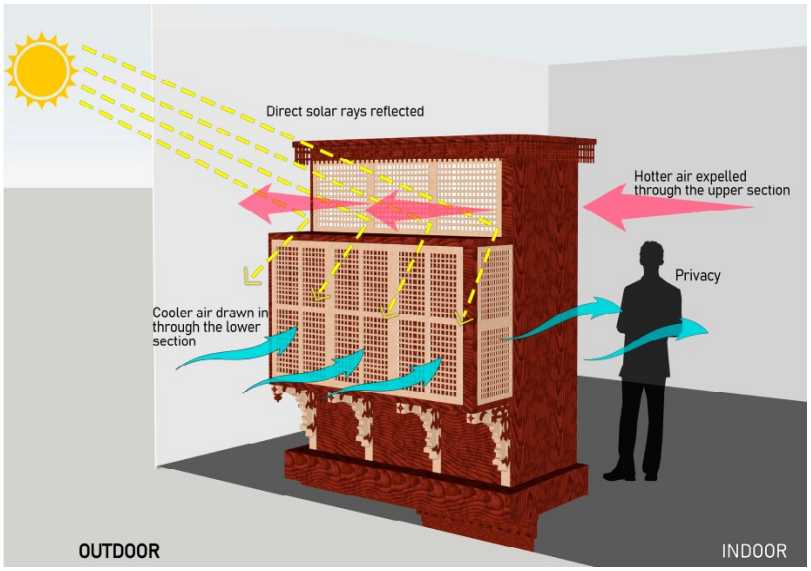


Figure 2. A schematic showing the main features of Mashrabiya.
Source: (Taki & Kumari, 2023)

The Mashrabiya has evolved from a functional element into a cultural symbol, reflecting various historical eras and imbuing buildings with unique identity. Its multifunctionality controlling light, airflow, humidity, and heat gain makes it a vital eco-friendly feature with remarkable adaptability (Amer et al., 2015).

This paper explores the evolution of the Mashrabiya, from its historical origins to its application in both traditional and contemporary architecture. Through case studies, it examines Mashrabiya's design principles materials, colours, and assembly highlighting its relevance in modern spaces, particularly hotels. The study bridges traditional understanding with contemporary use, focusing on successful examples in facades, windows, and interiors globally. It also addresses whether referencing the original form is vital for enhancing the tourism experience in modern hospitality design.

METHODOLOGY

This study explores the potential of Mashrabiya, a traditional Islamic architectural element, in contemporary building design. Using a qualitative approach, it employs two methodologies. First, six case studies both historical and contemporary hotels are analysed, categorized by installation location and historical context as shown in figure 3. The location criteria document where the Mashrabiya is used in the design (e.g., facades, windows, or interiors), while the historical context considers the era of the building's construction. This categorization offers insight into Mashrabiya's use across different periods and spatial contexts in hospitality design.

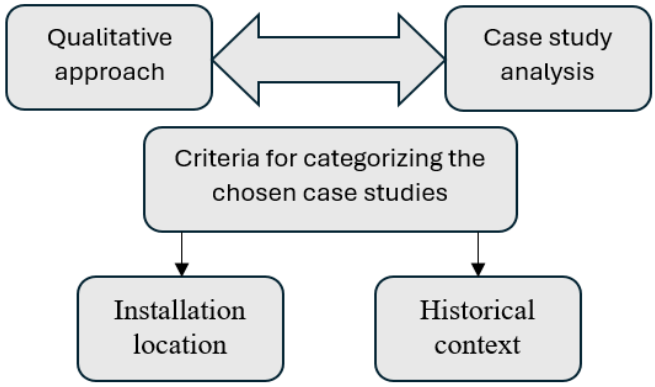


Figure 3. Categorization of case studies

The second approach focuses on data collection through semi-structured interviews and a comprehensive literature review. The review aims to clarify the concept of Mashrabiya, analyse its historical role, and connect it to its identity in Islamic architecture. Secondary data will provide an update on contemporary Mashrabiya styles and materials, presented in tables and graphs for critical evaluation. By combining case study analysis, literature review, and contemporary trends, the research offers insights into Mashrabiya's potential in modern hotel design.

Data collection

This research, employing a qualitative approach, delves into the potential of Mashrabiya, a traditional Islamic architectural element, for contemporary hotel design. Data collection centers on two primary sources: archival research and case study analysis.

Archival Research: Building a Strong Foundation

A thorough review of scholarly journals, theses, dissertations, books, and articles on Islamic architecture and design will form the study's foundation. This review has two main purposes: first, to gain a deep understanding of Mashrabiya's historical development, including its functional principles and cultural significance in Islamic architecture; and second, to provide insights into its traditional use. This knowledge will serve as a key reference for evaluating its integration into contemporary hotel spaces.

Case Study Analysis: Unveiling Mashrabiya's Potential

Six case studies will be documented to explore Mashrabiya's use in both historical and contemporary hotels as shown in Figure 4. Spanning from the Abbasid era to modern projects, these studies will track Mashrabiya's evolution and focus on public buildings, aligning with the study's goal of enhancing its role in hotels. The cases, selected from various countries, will include historical houses to understand its transition from domestic to public use. These insights will guide proposals for integrating Mashrabiya into contemporary hotel design.

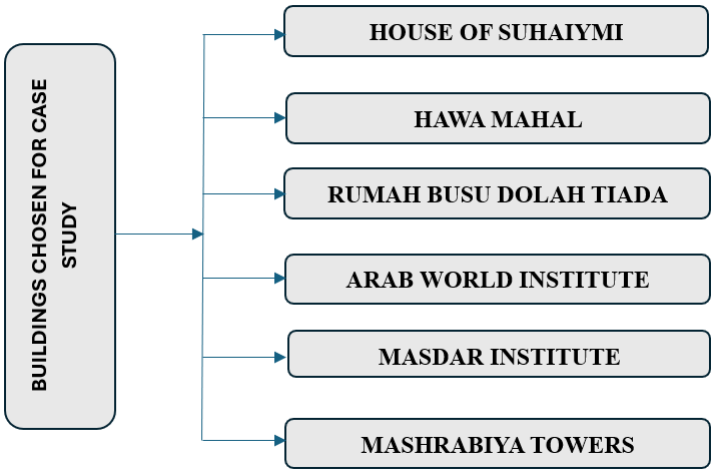


Figure 4. Chosen buildings for case study

Traditional case studies

House of suhaiymi

The Suhaymi House, located in Islamic Cairo, Egypt, serves as a valuable case study for understanding the historical application of Mashrabiya. Built in the 16th century by Abdul Wahab el Tablawy, this Ottoman-era residence, now a museum, exemplifies the integration of Mashrabiya within domestic architecture (Ocran et al., 2019). The house revolves around a central Sahn (courtyard) featuring a small

garden with palm trees. Notably, the Suhaymi House incorporates extensive Mashrabiya elements, particularly within windows as shown in figure 5.

The intricate latticework of Mashrabiya serves multiple functions. It controls sunlight, reducing harsh summer heat in Cairo, while allowing cool breezes to enhance natural ventilation. Additionally, it acts as a barrier against dust, maintaining airflow, and provides privacy without completely obstructing exterior views. The Suhaymi House illustrates Mashrabiya's vital role in traditional Islamic architecture by offering climatic comfort, privacy, and a decorative touch. This historical case study informs the exploration of integrating Mashrabiya into contemporary hotel design, which is the focus of this research.

Figure 5. Floral and geometrical patterns in the Egyptian Mashrabiya
Source: (Abdel et al., 2014)

The enduring appeal of Mashrabiya stems from both its functionality and aesthetic qualities, reflecting exquisite craftsmanship. Historical accounts, particularly in Egypt, emphasize the meticulous detail in creating Mashrabiya. The preservation of intricate marble flooring, timber furniture, and ceiling decorations in buildings like Suhaymi House demonstrates the high quality of materials and workmanship. Many historians consider Egyptian Mashrabiya the

pinnacle of this art form, showcasing the finest craftsmanship. Skilled Muslim artists expressed their engineering and artistic talents through Mashrabiya designs, featuring intricate latticework of small shapes assembled with wooden sticks. This interplay of mass, space, light, and shadow created a unique visual effect, as seen in the decorative configurations inside Al-Mashrabiya at Suhaymi House as shown in Figure 6 (a).

The dynamic interplay of light and shadow in Mashrabiya design created a "wonderful dramatic atmosphere" in the interior courtyards of Arab homes, enriching their character. Its craftsmanship and aesthetics made Mashrabiya more than just functional, elevating it to a key part of architectural and cultural heritage. This focus on aesthetics will be essential when considering Mashrabiya's integration into contemporary hotel design. While functionality is important, its ability to create a unique atmosphere and add visual distinction will be crucial for its adaptation in modern hospitality spaces as shown in figure 6(b).

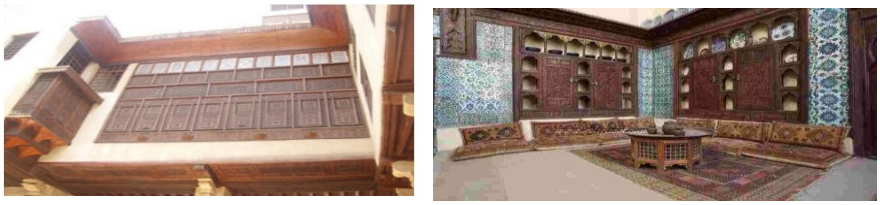


Figure 6 (a). Decorative configurations inside Al-Mashrabiya- Al Suhaimi House
Source: (Ocran et al., 2019) **(b)**Al Suhaimi House majlis
Source: (Bayt Al-Suhaymi | Know More About House of Suhaymi in Cairo, n.d.)

Hawa mahal

Hawa Mahal, known as the "Palace of Winds" in Jaipur, India, is a compelling case study that blends Rajput and Mughal architectural styles. Built in the 17th century by Maharaja Sawai Pratap Singh, it reflects an inspired vision influenced by the Khetri Mahal. The palace's striking five-story facade resembles a beehive, featuring 953 intricately decorated Jharokha windows with delicate latticework. These Jharokhas allowed royal women to observe street life and festivals while maintaining privacy, adhering to the "purdah" custom of female seclusion as shown in Figure 7 (a).

Hawa Mahal's architectural style reflects a harmonious blend of Rajput and Mughal influences. The red and pink sandstone construction, echoing the city's moniker as the "Pink City," is a signature Rajput element. The intricate latticework, geometric patterns, and small arched domes, however, showcase the undeniable influence of Mughal aesthetics. This precise repetition of these contrasting styles creates a visually captivating and historically significant structure. Figure 7 (b) shows the chambers with small windows.

Figure 7. (a) Jharokhas decorated with complicated latticework *Source: (taken by author)* **(b)** The chambers with small windows of the façade *Source: (About Hawa Mahal | Hawa Mahal, n.d.)*

Beyond its visual grandeur, Hawa Mahal's design integrates functional elements. The stone Mashrabiya, with strategically placed openings, facilitated natural air circulation through the Venturi effect, keeping the palace cool during India's hot summers as shown in figure 8. Fountains within the palace further enhanced the cooling effect, ensuring a comfortable environment for the royal residents.

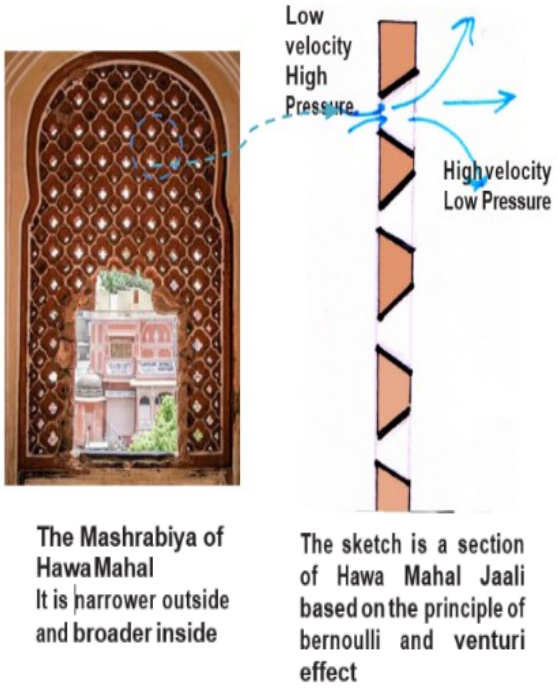


Figure 8. Bernouli and venturi effect in Hawa mahal

Hawa Mahal transcends its function as a palace, standing as a testament to the fusion of Rajput and Mughal architectural styles. The intricate facade, with its small windows, stone-carved screens, and arched roofs, continues to captivate

visitors. The contrasting use of red and pink sandstone, along with the play of light and shadow on the latticework, creates a mesmerizing visual experience. Hawa Mahal embodies the rich cultural and artistic heritage of Jaipur, serving as a landmark monument that continues to inspire architects and historians alike.

Rumah busu dolah tiada pendua

Rumah Busu Dolah Tiada Pendua in Melaka, Malaysia, is a key case study for exploring Malay architecture and its focus on passive design principles. As the only surviving traditional Melaka Malay heritage house, it exemplifies the region's cultural and artistic heritage as shown in Figure 9 (a). The defining feature of Rumah Busu Dolah is the extensive use of the Kerawang motif, an intricate floral pattern applied to the roof, stairs, windows, doors, and walls. This motif not only enhances the house's visual appeal but also symbolizes Malay cultural identity. The perforated Kerawang elements function similarly to Islamic Mashrabiya, allowing natural air circulation and light penetration, promoting thermal comfort. This aligns with Malay passive design principles, aiming to regulate indoor temperatures without mechanical means. Thus, the Kerawang motif serves both decorative and functional purposes as shown in Figure 9 (b).

Figure 9 (a). The entrance of Rumah Busu Dolah tiada Pendua
Source: (Keindahan Rumah Warisan Melaka Siri 1: April 2012, n.d.)
(b) The interior of the house showing the open wall screening
Source: (Keindahan Rumah Warisan Melaka Siri 1: April 2012, n.d.)

Rumah Busu Dolah reflects a commitment to traditional construction techniques and sustainable materials. Local builders used time-tested methods, crafting wooden carvings without nails. The primary material, Cengal wood, is known for its durability and weather resistance, ensuring the structure's longevity and ease of future repairs. Rumah Busu Dolah Tiada Pendua exemplifies the Malay people's cultural heritage and architectural ingenuity. The Kerawang motif integrates passive design principles effectively, making this case study a valuable resource for understanding cultural identity and passive design in contemporary architecture.

Modern case studies

Arab world institute

The Arab World Institute (Institut du Monde Arabe, IMA) in Paris, designed by Pierre Soria, Jean Nouvel, Architecture-Studio, and Gilbert Lezenes and completed in 1987, exemplifies the reinterpretation of traditional elements in contemporary architecture. Intended as a cultural bridge between Arab and French cultures, the building's design is inspired by the Mashrabiya, a traditional Islamic architectural element as shown in Figure 10 (a). Jean Nouvel drew significant inspiration from Mashrabiya, a traditional latticework element made from wood that provided cooling, privacy, and light control. Nouvel aimed to capture its essence using modern materials and technologies. The facade he designed features around 27,000 light-sensitive diaphragms that mimic Mashrabiya's functionality by regulating light entry. Figure 10 (b) illustrates these diaphragms.

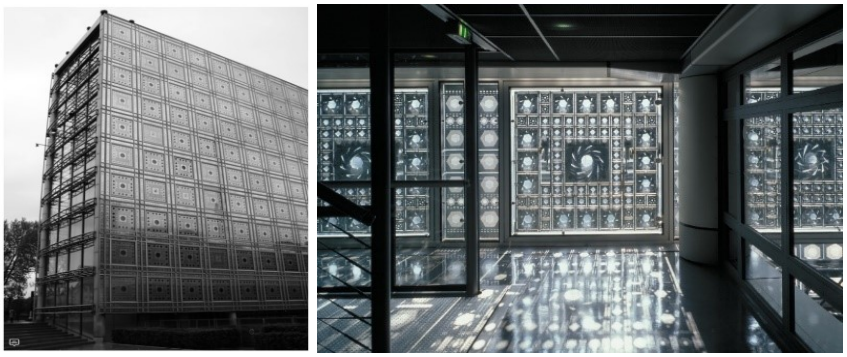


Figure 10 (a). The exterior view of the Arab World Institute
Source: (AD Classics: Institut Du Monde Arabe / Enrique Jan + Jean Nouvel + Architecture-Studio | ArchDaily, n.d.)
(b). Light sensitive diaphragms walls
Source: (قيبطتلا ةثادحو تركفلا ةلاصأ نيب ةيملاسلاا ترامعلا بف ةيبرشملا Mashrabiya in Islamic Architecture between Idea Authenticity and Applying Novelty Abstract: 2018)

The facade also includes a metal screen with dynamic geometric motifs behind the glass wall, featuring 240 photo-sensitive, motor-controlled shutters. These shutters act as sophisticated sunscreens, adjusting automatically to control daylight and regulate interior temperature. This system reflects the Islamic architectural tradition of filtering natural light to create specific atmospheres.

Nouvel's reinterpretation of Mashrabiya integrates modern light control mechanisms while presenting a challenge: the extensive use of glass walls limits natural ventilation, requiring HVAC systems for cooling. This case study of the Arab World Institute highlights both the potential and limitations of modern adaptations of traditional elements, emphasizing the need to balance functional

and aesthetic considerations. Future advancements may lead to more innovative and sustainable reinterpretations of traditional architecture.

Masdar institute

Masdar City in Abu Dhabi, completed in 2015 by Foster + Partners, exemplifies the integration of traditional elements into contemporary sustainable architecture. This project balances technological advancements with cultural heritage, addressing the challenge of preserving cultural identity amidst modern architectural trends.

The Mashrabiya, a traditional Islamic architectural feature known for its natural cooling, privacy, and light control, inspired Masdar City's design. The project's self-shading facade, made of metal screening with rotating panels, modernizes the Mashrabiya's functionality. Figure 11 (a) shows Mashrabiya-inspired elements on the residential units' walls and balconies, reflecting both environmental and aesthetic goals. The geometric patterns on the facade, derived from Islamic motifs, enhance the interplay of light and shadow, merging tradition with sustainability. Masdar City's sustainability efforts go beyond aesthetics, incorporating both technological and traditional methods to reduce heat gain. Techniques such as terracotta cladding, air-filled wall panels, and metal screening play a role in this. The large spacing and rounded profiles of the metal screening resemble traditional Mashrabiya balusters, reinforcing cultural heritage. Figure 11 (b) shows the terracotta facade on the windows, while the use of palm wood and terracotta in balcony areas reflects traditional moisture control methods. These elements maintain cultural continuity and apply proven techniques for humidity regulation. Figure 11 (c) illustrates the apartment facade detail before installation.

Figure 11 (a). The Residential Units in Masdar City having Mashrabiya on the wall and balcony.

Source: (قيبطتلا ةثادحو تركفلا ةلاصأ نيب ةيملاسلاا ترامعلا بف ةيبرشملا Mashrabiya in Islamic Architecture between Idea Authenticity and Applying Novelty Abstract, 2018)

(b). Terracotta façade covering the windows.

Source: (قيبطتلا ةثادحو تركفلا ةلاصأ نيب ةيملاسلاا ترامعلا بف ةيبرشملا Mashrabiya in Islamic Architecture between Idea Authenticity and Applying Novelty Abstract: 2018)

(c). A detail of one apartment façade before fixing it to the building

Source: (Masdar Institute / Foster + Partners | ArchDaily, n.d.)

Masdar City stands as a testament to the potential of reinterpreting traditional elements for a sustainable future. The project successfully utilizes the Mashrabiya as a source of inspiration for environmental solutions, showcasing how cultural heritage and technological advancements can work in tandem to create a sustainable future for the Arab world.

Mashrabiya towers

The Mashrabiya Towers in Abu Dhabi, completed in 2012 by Aedas Architects, exemplify the modern reinterpretation of traditional elements in sustainable architecture as shown in figure 12 (a). The towers integrate cultural heritage with innovative technology to create an environmentally responsive landmark. Inspired by the Mashrabiya a traditional Islamic architectural element known for its natural cooling, privacy control, and light filtration the design captures its essence using contemporary materials and technologies to achieve a sustainable and visually striking facade. The Mashrabiya Towers' defining feature is their innovative facade, a modern take on the traditional Mashrabiya. The facade includes an automated shading system with 2,000 umbrella-like modules per tower, controlled by photovoltaic panels. These modules adjust their angles based on sun exposure, mimicking the Mashrabiya's function of providing shade and regulating light. Figure 12 (b) shows the opening sequence of the Mashrabiya Towers facade.

Figure 12 (a). Al Bahar Towers/ Mashrabiya Tower in Abu Dhabi, UAE
Source: (Abdelkader & Park, 2018)
(b). The Opening Sequence of Mashrabiya Towers Façade
*Source: (*قيبطتلا ةثادحو تركفلا ةلاصأ نيب ةيملاسلاا ةرامعلا فب ةيبرشملا *Mashrabiya in Islamic Architecture between Idea Authenticity and Applying Novelty Abstract:, 2018)*

The Mashrabiya Towers highlight the integration of sustainability and aesthetics. Their dynamic facade reduces heat gain, enhancing comfort and potentially lowering air conditioning needs. However, unlike traditional Mashrabiya, this design does not address humidity control. The towers also

provide a visually captivating experience: when closed, the folded umbrella modules mimic intricate Arabic patterns, while when extended, they reveal the building's modern mass. This blend of tradition and modernity creates a striking architectural statement. Figure 13 shows the responsive facade.

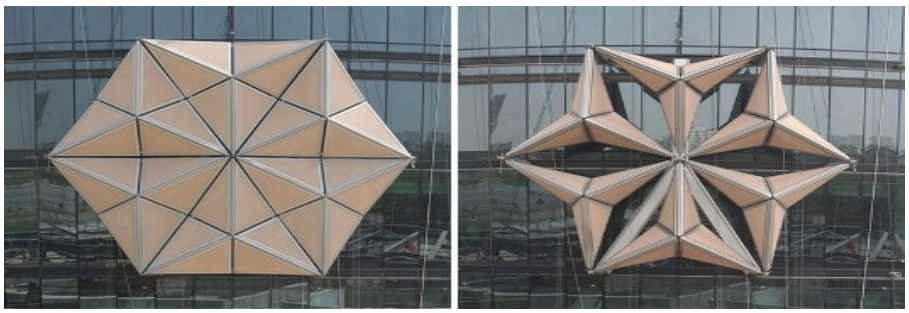


Figure 13. Umbrella Responsive Façade
Source: (Amrousi, 2017)

The Mashrabiya Towers offer an innovative approach to combining environmental and aesthetic considerations but come at a higher cost than traditional Mashrabiya designs. The project may still need air conditioning for optimal comfort. Despite the need for further exploration in areas like humidity control, the towers exemplify how modern technology can create responsive, visually compelling architecture while honoring cultural heritage. They serve as a significant example of how sustainable design can blend tradition with innovation, inspiring future advancements in the field.

IMPORTANT FINDINGS

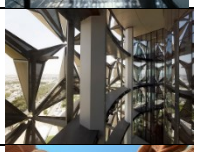
This study explores the evolution of Mashrabiya, a key element in Islamic architecture known for its versatility in decoration. Historically, Mashrabiya served both decorative and functional roles, adorning walls, windows, and ceilings with intricate patterns carved from wood or sandstone. It regulated light and ventilation, enhancing interior comfort in hot climates.

The study identifies a shift towards modern applications of Mashrabiya, where contemporary designers use new materials and techniques to create varied colors and forms. Mashrabiya now often functions as a structural component, forming double-skin facades or entire building envelopes, and visually expressing cultural identity. Additionally, modern Mashrabiya can incorporate kinetic mechanisms for dynamic control of light and airflow, improving environmental performance.

This exploration underscores Mashrabiya’s lasting significance, highlighting its transformation from a traditional decorative element to a dynamic, adaptable building component. It emphasizes the potential of

integrating traditional elements in innovative ways to achieve sustainable and culturally relevant architecture. Table 1 provides details about the case study buildings.

Table 1: Details about the buildings chosen for case studies.

Name	Location	Year	Construction	Material	Pattern	Picture
Suhaiymi house	Cairo, Egypt	1648	Adjacent to the wall & protruded With small delicate cubes, wooden balls, or rectangles and small squares connected by horizontal and vertical crossed wooden sticks	Timber	Square geometry grill Semi carved upper and lower panel linear seamless design and complex integration of floral nonperforated and geometrical perforated design.	
Rumah busu dolah tiada pendua	Melaka, Malaysia	1909	Adjacent to the wall structure Wall panels	Timber	Semi-carved floral motif and the perforated floral carved motifs.	
Arab world institution	Paris, France	1987	Adjacent wall structure A complete façade wall panel	Stainless Steel	The metallic screen unfolds with moving geometric motifs.	
Mashrabiya towers	Abu Dhabi UAE	2012	Umbrella-like modules Double skin façade	Stainless steel	Modules in the shape of an umbrella in the photovoltaic panels-controlled tower.	
Masdar institute	Abu Dhabi UAE	2015	Adjacent to the wall and balcony	Brick	Geometrical porous stars.	

Design strategies.

The discussed projects highlight the ongoing interplay between tradition and innovation in architecture. Islamic architecture is characterized by its emphasis on geometric patterns, symmetry, and the integration of natural elements to create harmonious and functional spaces (Baydoun et al., 2024). Islamic art often incorporates sustainable principles by using locally sourced materials and designs that promote durability and environmental harmony. (Baydoun et al., 2023). Analysing these projects provides insights into design strategies that balance sustainability with cultural identity.

The Mashrabiya Towers demonstrate advanced technology for sustainable design, with a dynamic facade managing heat gain effectively.

However, such solutions may sometimes lack distinct architectural identity. In contrast, the Sofitel and Mashrabiya House showcase a neo-traditional approach, incorporating Mashrabiya elements into modern designs to maintain local identity while ensuring sustainability. The Sofitel uses Mashrabiya screens, and the Mashrabiya House features a reimagined stone facade, both enhancing cultural heritage.

These projects suggest Mashrabiya's potential in hotel design globally, offering functionality in light control, ventilation, and privacy while allowing for modern reinterpretations. Modern Mashrabiya serves as a model for integrating traditional elements into contemporary, sustainable architecture. By adapting these strategies, architects can create buildings that are innovative, culturally relevant, and aesthetically pleasing. Figure 14 shows an organizational diagram of sustainability movements in hotel design.

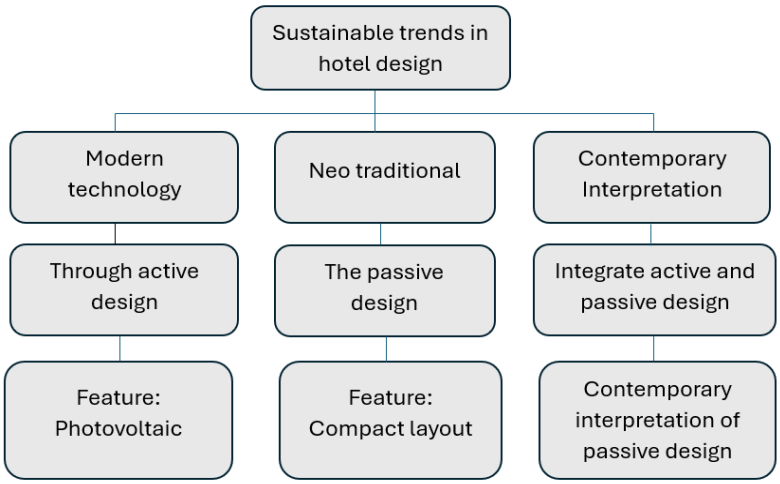


Figure 14. An organizational diagram of the sustainability movements in hotel design.

Aesthetic principles used in Masrabiya

Mashrabiya and windows are central to Islamic architecture, combining functionality with a distinctive aesthetic. This study explores their design principles, rooted in Islamic art's emphasis on unity and abstraction. The intricate geometric patterns of Mashrabiya, derived from simplified forms, reflect this focus on essential forms and harmony. The prohibition against depicting living organisms led to innovative decorative patterns, with geometric and abstract motifs often appearing as silhouettes when backlit. The principle of "horror vacui" is evident in the meticulous filling of surfaces with decorative elements, creating a visually captivating experience through intricate latticework and dynamic light and shadow interplay. Additionally, the manipulation of light

through the lattice enhances the visual complexity, while the principle of "ijtihad" fosters innovation with diverse geometric shapes and patterns. Together, these elements make Mashrabiya and windows not just functional but also a testament to the rich aesthetic values of Islamic art, continuing to inspire modern architecture.

CONCLUSION

This research highlights Mashrabiya's enduring appeal and its potential as a sustainable solution for contemporary architecture. By examining its functionality, the study shows how Mashrabiya provides natural cooling, controls light penetration, and enhances air circulation, reducing the need for mechanical air conditioning and contributing to energy efficiency. Particularly relevant for public buildings like hotels, Mashrabiya not only improves comfort and reduces energy consumption but also enriches the guest experience with its cultural aesthetic. The research, which includes six case studies of both traditional and modern Mashrabiya, provides valuable insights into optimizing design, selecting sustainable materials, and integrating cultural heritage into modern applications. Modern Mashrabiya designs, including double-skin facades, offer significant energy savings and improved building performance. Overall, Mashrabiya's evolution from historical to modern iterations demonstrates its continued relevance and potential for creating sustainable and culturally enriched environments.

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RETROFITTING GREEN INFRASTRUCTURE IN KUALA LUMPUR: A DOCUMENT ANALYSIS OF POLICY GAPS AND CLIMATE RESILIENCE

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Abstract

Urban green spaces play a critical role in enhancing environmental sustainability, climate resilience, and the well-being of urban populations. However, the fragmentation of green spaces in Kuala Lumpur presents significant challenges to sustainable urban planning and climate adaptation efforts. This study examines the policy gaps that hinder the effective integration of green infrastructure into Kuala Lumpur's urban planning framework. A qualitative document analysis is conducted to assess national policies, planning guidelines, and international best practices related to green infrastructure and climate resilience. The findings reveal that while Malaysia's policies accentuate the provision of green spaces, they lack comprehensive enforcement mechanisms, leading to inconsistencies in green infrastructure implementation. Key challenges include policy fragmentation, decentralised governance, inadequate financial incentives, and the absence of explicit regulatory frameworks supporting green infrastructure retrofitting. By analysing international models, such as the United Kingdom's Green Infrastructure Standards and Singapore's Green Plan 2030, this study identifies policy strategies that could enhance Malaysia's urban resilience. The study concludes that a systematic retrofitting framework is required to address the existing policy gaps and ensure the strategic integration of green infrastructure into urban development. It recommends adopting international best practices, strengthening regulatory enforcement, and fostering cross-sectoral collaboration to enhance climate adaptation and ecological connectivity. These measures are essential for improving urban sustainability and mitigating the adverse effects of rapid urbanisation and climate change in Kuala Lumpur.

Keywords: Green Infrastructure, Climate Resilience, Policy Gaps, Green Spaces and Networks, Urban Area

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INTRODUCTION

Urban green spaces play a critical role in enhancing environmental sustainability, economic viability, and the overall well-being of urban dwellers. These spaces contribute to biodiversity conservation and climate regulation by improving bioclimatic conditions, mitigating pollution, managing excessive heat, and facilitating rainwater retention and flood control. Additionally, urban green spaces stimulate local economies by attracting businesses, fostering tourism, and generating employment opportunities. Furthermore, research indicates that green spaces within urban residential areas significantly enhance physical health, mental well-being, and overall quality of life.

Despite widespread discussions and policy initiatives promoting urban green space development, the issue of fragmented urban green spaces remains a persistent challenge in Kuala Lumpur. Rasli et al. (2019) argue that ineffective policies have accelerated urban expansion, leading to the fragmentation of green spaces in the city. According to Yeo et al. (2022), this fragmentation is a result of Malaysia's policy emphasis on green space provision rather than the development of green infrastructure. Green infrastructure, as a nature-based solution, enhances climate resilience, ecological connectivity, and sustainable urban development (Anderson & Gough, 2021).

The absence of a comprehensive and coordinated approach to green infrastructure underscores the urgent need for a retrofitting framework to address the fragmentation of urban green spaces in Kuala Lumpur. Fragmented green spaces contribute to the urban heat island (UHI) effect, significantly impacting urban thermal comfort (Akbari et al., 2016). The continued degradation of the urban thermal environment due to rapid urbanisation necessitates robust mitigation strategies through the implementation of green infrastructure (Hou et al., 2022).

This paper aims to highlight the policy gaps and challenges related to retrofitting green infrastructure in Kuala Lumpur to enhance climate resilience. The specific objectives are (i) to analyse the policy gaps and inconsistencies hindering the integration of green infrastructure in Kuala Lumpur's urban planning framework, (ii) to examine the existing national policies in addressing urban green space fragmentation and climate resilience, and (iii) to examine international best practices in green infrastructure implementation that could inform policy improvements in Kuala Lumpur. To bridge the policy gaps and improve climate resilience, Malaysia can adopt international best practices such as the Green Infrastructure Standards, Planning and Design Guide from Natural England (UK), the Urban Green Infrastructure Handbook from the Australian Institute of Landscape Architects (AILA), and Singapore's Green Plan 2030. By incorporating lessons from these global frameworks, Kuala Lumpur can develop

an integrated and strategic approach to retrofitting green infrastructure, ensuring sustainable urban development and enhanced climate resilience.

LITERATURE REVIEW

Fragmented Urban Green Spaces

The fragmentation of urban green spaces presents a significant challenge in Malaysia, as evidenced by various studies. Yeo et al. (2022) and Rasli et al. (2018) highlight that inadequate policies and rapid urban expansion have contributed to the fragmentation of green spaces in Kuala Lumpur. This issue is not confined to the capital city; Kemarau (2021) examines spatial-temporal changes in urban green spaces in Kuching, Sarawak, demonstrating that green space fragmentation is a nationwide concern. Furthermore, the provision and establishment of urban green spaces in Malaysia face several obstacles, as outlined by Maryanti et al. (2016), who critically assess the implementation of green space provision standards and associated challenges. Li et al. (2019) further emphasise the role of urbanisation in exacerbating green space fragmentation, underscoring the need for a comprehensive understanding to inform effective planning policies.

Efforts to address urban green space fragmentation are evident in studies such as Nor and Abdullah (2019) and Nor et al. (2017), which focus on developing classification systems and ecological connectivity networks to enhance Kuala Lumpur's urban green spaces. Beyond ecological connectivity, fragmented green spaces may also contribute to increased levels of secondary air pollutants and associated health risks (Shen & Lung, 2017). The implications of fragmented green spaces extend beyond environmental concerns; Lee et al. (2015) underscore their role in promoting healthy living, while Rasidi et al. (2018) explore their influence on social interactions within urban neighbourhoods

Moreover, urban green space fragmentation has profound implications for biodiversity conservation and ecological connectivity. Nor et al. (2017) stress the importance of ecological connectivity networks in rapidly urbanising cities, emphasising the role of green space structure in sustaining wildlife habitats and enhancing biodiversity. Li et al. (2019) further explore the relationship between urbanisation and green space fragmentation, advocating for a spatiotemporal perspective to address the growing challenges associated with urban expansion. These dimensions collectively underscore the multifaceted significance of mitigating urban green space fragmentation in Malaysia to promote environmental sustainability, public health, and climate resilience.

Green Infrastructure for Urban Areas

Green infrastructure is a fundamental component of sustainable urban planning and environmental management in Malaysia. The integration of green spaces,

including parks, gardens, and green corridors, within urban landscapes plays a critical role in enhancing biodiversity, mitigating climate change impacts, and improving the overall quality of life for urban residents. Artmann et al. (2019) and Monteiro et al. (2020) emphasise the necessity of incorporating green infrastructure planning principles within spatial planning frameworks to promote urban sustainability and resilience. In the Malaysian context, green infrastructure development is essential for addressing environmental challenges and strengthening urban resilience. Faisal et al. (2022) identify green infrastructure as a sustainable and adaptive solution that delivers ecological, economic, and social benefits through nature-based approaches.

Similarly, Chen et al. (2022) highlight the importance of considering the spatio-temporal dimensions of green infrastructure implementation to effectively manage the impacts of rapid urbanisation and increasing impervious surface areas. On another note, softscape elements play a crucial role in enhancing environmental quality and increasing the value of the surrounding landscape which may contribute to the overall success of green infrastructure initiatives, ensuring sustainable urban development while meeting user expectations and promoting ecological well-being (Sani, et al., 2020). Mohammad Sabri & Ponrahono (2024) emphasise the importance of small urban parks in enhancing urban resilience to climate change by serving as green infrastructure for stormwater management while also offering recreational and social benefits.

The expansion of urban agglomerations in Malaysia has led to the fragmentation of green spaces, adversely affecting ecological connectivity and biodiversity. Studies by Chu et al. (2022) and Li et al. (2019) explore the link between urban expansion and green space fragmentation, underscoring the need for strategic planning to preserve and enhance green infrastructure networks. Yeo et al. (2022) and Nor et al. (2021) propose conceptual frameworks for green infrastructure and examine the transformation of urban green spaces in rapidly growing cities such as Kuala Lumpur. Their findings emphasise the role of green corridors and sustainable landscape development in mitigating the effects of urban expansion. Well-designed and well-maintained green spaces not only enhance urban residents' experience and mental well-being but also serve as vital green infrastructure, strengthening climate resilience by improving overall environmental quality (A.A, et al., 2021).

Beyond ecological and environmental functions, green infrastructure holds significant cultural and social value in urban settings. Research by Gómez-Villarino et al. (2020) and Riechers et al. (2019) highlights the diverse cultural ecosystem services provided by green infrastructure, contributing to community well-being and enhancing urban liveability. Additionally, urban green spaces serve as crucial adaptive measures for mitigating the adverse impacts of climate

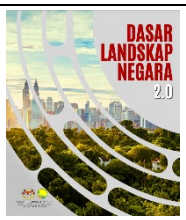
change, including extreme weather events such as heatwaves and droughts, which are becoming increasingly prevalent (Kraemer & Kabisch, 2022). Green infrastructure offers significant potential in enhancing urban resilience to climate-related challenges, such as urban heat islands, increased flooding, stronger wind patterns, and episodic rainfall, particularly in high-density urban areas where large green spaces are limited.

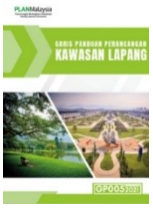
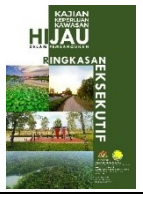
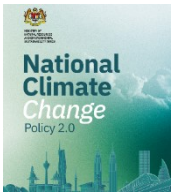
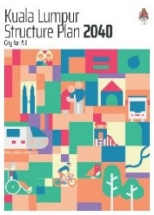
Furthermore, the effectiveness of urban greening initiatives depends on both the rate of greening and the spatial configuration of green spaces, which are pivotal factors in mitigating climate change impacts (Yin et al., 2021). By integrating green infrastructure into urban planning and design, Malaysian cities can enhance climate resilience while simultaneously promoting environmental conservation, social well-being, and economic sustainability.

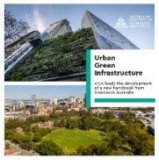
Policies and Guidelines on Green Infrastructure and Climate Resilience

Green infrastructure is integral to promoting urban sustainability, enhancing climate resilience, and safeguarding environmental well-being. A wide range of national and international policies and guidelines underscore its importance, offering valuable insights that Malaysia can adopt to strengthen its urban planning framework. The following official documents in Table 1 provide key examples of these frameworks:

Table 1: List of policies and guidelines on green infrastructure and climate resilience

National Policies and Guidelines	***Documents***
i) National Urbanisation Policy 2 (2019) – PLANMalaysia This policy underscores the need for enhancing both the size and quality of green spaces within urban areas. It advocates for sustainable urban expansion by integrating ecological networks and green spaces to improve environmental health and urban resilience.	
ii) Implementation Guidelines on Urban Regeneration (2023) These guidelines emphasise the importance of green networks and corridors in urban redevelopment projects. By incorporating green infrastructure into regeneration strategies, cities can improve air quality, reduce heat island effects, and enhance biodiversity.	
iii) National Landscape Policy 2.0 – National Landscape Department, Malaysia Under Thrust 3, Strategy 3.1, this policy calls for the provision of green infrastructure to mitigate climate change impacts. It promotes sustainable landscape planning, advocating for urban parks, green corridors, and ecological connectivity as essential climate adaptation measures.	

National Policies and Guidelines	***Documents***
iv) Garis Panduan Rancangan Kawasan Lapang – PLANMalaysia This guideline provides a framework for planning open spaces, emphasising their multifunctional benefits, including flood mitigation, urban cooling, and social well-being. It aligns with broader sustainability goals by integrating green infrastructure into urban development.	
v) Kajian Keperluan Kawasan Hijau dalam Pembangunan – Jabatan Landskap Negara This study assesses the necessity of green spaces in urban planning and their role in enhancing environmental sustainability. It supports data-driven decision-making in designing green infrastructure to optimise ecosystem services.	
vi) National Policy on Climate Change – Ministry of Natural Resources and Environment Malaysia This policy aims to bridge the gap between climate action and green infrastructure development. It emphasises the need for nature-based solutions to combat climate change, highlighting urban forests, permeable surfaces, and ecosystem-based adaptation as crucial components.	
vii) National Physical Plan 4 (RFN4) – PLANMalaysia RFN4 focuses on spatial sustainability and climate resilience, with a strong emphasis on green infrastructure as a strategy for urban climate adaptation. It promotes nature-based solutions to enhance urban liveability, flood management, and carbon sequestration.	
viii) Kuala Lumpur Structure Plan 2040 – Dewan Bandaraya Kuala Lumpur The Kuala Lumpur Structure Plan 2040 highlights the integration of green infrastructure in urban planning to ensure a sustainable, climate-resilient city. It emphasises the creation of green corridors, public parks, and sustainable water management systems as essential elements for mitigating climate change impacts and enhancing the city's environmental quality.	
International Policies and Guidelines	***Documents***
i) Green Infrastructure Standards – Natural England, UK These standards establish best practices for integrating green infrastructure into urban planning. They provide a reference for policymakers to ensure that green spaces contribute effectively to biodiversity conservation, climate resilience, and public health.	

ii) Green Infrastructure Planning and Design Guide – Natural England, UK This guide outlines design principles for effective green infrastructure, focusing on ecological connectivity, sustainable drainage systems, and urban heat mitigation.	
iii) Urban Green Infrastructure Handbook – Australian Institute of Landscape Architects (AILA) This handbook provides practical insights into designing and implementing green infrastructure within Australian cities, highlighting case studies on climate adaptation and resilience.	
iv) Singapore's Green Plan 2030 – Government of Singapore Singapore's national strategy integrates green infrastructure into urban planning to achieve sustainability and resilience. It prioritises nature-based solutions, urban greenery, and sustainable water management in response to climate challenges.	

RESEARCH METHODOLOGY

This study conducts qualitative research using document analysis, guided by the objective of assessing policy gaps, urban green space fragmentation, and climate resilience strategies related to green infrastructure in Kuala Lumpur. The analysis focuses on policy documents, government reports, and international frameworks published between 2015 and 2024, as tabulated in Table 1. This document analysis aims to determine whether Malaysia's current policies effectively integrate green infrastructure solutions and whether existing frameworks align with global standards for climate adaptation and urban sustainability. The study identifies policy strengths, gaps, and potential areas for improvement to support the development of a retrofitting framework for green infrastructure in Kuala Lumpur.

For data analysis, the documents are analysed using Quirkos, a qualitative data analysis tool that facilitates thematic coding and visualisation of recurring patterns within textual data. Additionally, policy comparison tables are developed to assess variations in green infrastructure integration across different policy documents. The findings highlight policy inconsistencies, regulatory limitations, and gaps in implementation, providing a structured basis for evaluating the effectiveness of Malaysia's green infrastructure policies in addressing urban resilience challenges.

The results of this document analysis are expected to reveal gaps in green infrastructure implementation, policy misalignment, and the need for a more integrated planning approach. The analysis highlights whether Malaysia's existing policies provide adequate regulatory mechanisms for enhancing green connectivity in Kuala Lumpur. Findings from this study aims to provide

evidence-based recommendations for policymakers and urban planners to strengthen green infrastructure integration within urban development strategies.

ANALYSIS AND DISCUSSION

This analysis examines key national policies, international frameworks, and planning guidelines that influence green infrastructure strategies in Kuala Lumpur. Specifically, it evaluates policy gaps, urban green space fragmentation, and climate resilience strategies, providing a comprehensive assessment of Malaysia's existing policies and their alignment with international best practices. Section 1 examines national policies that address green infrastructure planning and implementation, while Section 2 explores international frameworks and their relevance to Malaysia. Section 3 identifies key policy gaps related to green infrastructure, urban fragmentation, and climate change adaptation. Finally, this analysis aims to offer insights into how Malaysia can enhance its green infrastructure planning to improve climate resilience and urban sustainability.

Section 1: Key Insights from National Policies and Guidelines

Figure 1 is a visual representation from Quirkos, illustrating an analysis of various policies concerning green spaces and networks, biodiversity initiatives, open spaces and spatial multifunctionality, as well as regulations and financial initiatives. The following is a refined summary of the key findings:

Figure 1: National Policies and Guidelines Analysis on Green Spaces and Sustainability

Green Spaces & Networks emerge as the most significant category, comprising 62% (17 highlights). The analysis underscores the prioritisation of urban green spaces and integrated ecological networks. Policies such as the National Urbanisation Policy 2 (2019) by PLANMalaysia and the National Landscape Policy advocate for specific green space allocations, including a minimum of 10% of total development areas and at least two square meters per person in urban environments. Despite these provisions, challenges persist in implementation, particularly in high-density areas, due to weak enforcement and inadequate cross-sectoral collaboration. Biodiversity Initiatives, accounting for 18% (six highlights), emphasise the necessity of integrating urban green corridors and ecological elements into urban planning. The Implementation Guidelines on Urban Regeneration 2023 recommend incorporating green elements in 50% of new developments; however, the absence of stringent regulatory enforcement poses a risk to long-term sustainability. Open Spaces & Spatial Multifunctionality, representing 10% (three highlights), focus on establishing standards for multifunctional urban open spaces. The National Physical Plan 4 (RFN4) – PLANMalaysia advocates for sustainable urban resilience strategies, while the *Kajian Keperluan Kawasan Hijau* study reveals that Malaysia's 7.5% urban green space coverage falls below international benchmarks. The findings highlight a need for structured policy integration and stronger regulatory mechanisms to address this gap.

Regulation & Financial Initiatives, constituting 12% (four highlights), address the financial and policy frameworks supporting green infrastructure. The National Policy on Climate Change underscores the role of green infrastructure in climate mitigation, targeting a 40% reduction in greenhouse gas emissions by 2030. Nevertheless, the lack of a cohesive implementation framework across national, state, and local levels hampers effective execution. Additionally, the Kuala Lumpur Structure Plan 2040 aims to achieve 20% tree canopy coverage by 2040 yet requires clearer implementation roadmaps and alignment with national policies. Overall, while Malaysia has developed comprehensive policies promoting urban green infrastructure, significant challenges remain in enforcement, regulatory clarity, cross-sectoral integration, and financial incentives. Addressing these gaps will be critical in advancing sustainable and resilient urban development.

Section 2: Best Practices from International Policies and Guidelines

Figure 2 below shows an analysis of international green infrastructure policies and their relevance to Malaysia, particularly Kuala Lumpur. It highlights key contributions, quantitative measures, and how these strategies can be adapted to enhance urban resilience and sustainability in the Malaysian context.

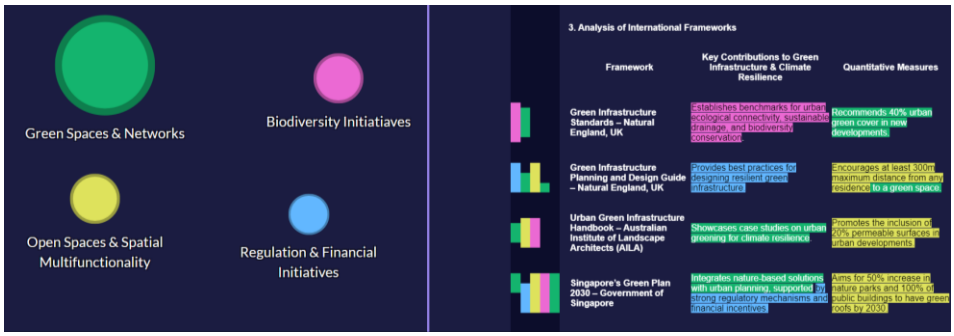


Figure 2: International Policies and Guidelines Analysis on Green Spaces and Sustainability Using Quirkos

The Green Infrastructure Standards by Natural England, UK, establish benchmarks for ecological connectivity, sustainable drainage, and biodiversity conservation, recommending 40% urban green cover in new developments. Implementing similar benchmarks in Kuala Lumpur could enhance ecological corridors, reduce urban heat island effects, and improve air quality, addressing the city's rapid urbanisation and environmental concerns. Additionally, the Green Infrastructure Planning and Design Guide from the UK promotes best practices for designing resilient infrastructure, advocating for at least 300 meters maximum distance from any residence to a green space. Adopting this strategy in Kuala Lumpur could enhance public access to green areas, improve residents' well-being, and support active urban lifestyles.

Meanwhile, the Urban Green Infrastructure Handbook by the Australian Institute of Landscape Architects (AILA) emphasises case studies on climate resilience, recommending the inclusion of 20% permeable surfaces in urban developments. This approach is particularly beneficial for Kuala Lumpur, where flooding and poor drainage systems are ongoing challenges. Increasing permeable surfaces would help manage stormwater, reduce flash floods, and promote groundwater recharge. Furthermore, Singapore's Green Plan 2030 integrates nature-based solutions with urban planning, reinforced by strong regulatory mechanisms and financial incentives. This model could serve as a blueprint for Kuala Lumpur, encouraging policy-driven urban greening and incentivising private sector participation in sustainability efforts.

Notably, Singapore aims for a 50% increase in nature parks and mandates 100% of public buildings to incorporate green roofs by 2030. Implementing similar targets in Kuala Lumpur could enhance biodiversity, create cooling microclimates, and support Malaysia's broader climate adaptation goals. These international policies highlight the importance of structured policy enforcement, cross-sectoral collaboration, and financial support in achieving urban sustainability. By integrating these best practices, Kuala Lumpur can

strengthen its resilience against climate change, improve liveability, and position itself as a leading green city in Southeast Asia.

Section 3: Policy Gaps, Limitations and Lessons Learned

This analysis highlights critical policy gaps, regulatory inconsistencies, and the need for an integrated planning approach to enhance green infrastructure in Kuala Lumpur. Current frameworks do not fully align with global standards for climate adaptation. To address these gaps, policymakers should prioritise cross-sectoral collaboration, develop enforceable regulatory frameworks, and integrate financial incentives for green infrastructure investment. Strengthening Malaysia's policy landscape can enhance urban resilience and promote sustainable development in rapidly growing cities.

Malaysia's urban and environmental policies, particularly in Kuala Lumpur, face significant gaps that hinder the effective implementation of green infrastructure and climate resilience strategies. Key issues include the lack of clear implementation mechanisms and weak enforcement across policies such as the National Urbanisation Policy 2 (2019), the Implementation Guidelines on Urban Regeneration (2023), and the National Landscape Policy. These gaps lead to fragmented and unstructured urban greening efforts, especially in high-density areas where space constraints and competing land-use priorities further complicate matters. Additionally, policies like the National Policy on Climate Change lack a cohesive framework to integrate national, state, and local planning processes, limiting the effectiveness of climate adaptation strategies.

Furthermore, land use policies and the National Physical Plan 4 (RFN4) lowly prioritise interconnected green corridors or enforce mandates for green infrastructure, restricting biodiversity conservation and the resilience of urban ecosystems. Kuala Lumpur's urban planning, as outlined in the Kuala Lumpur Structure Plan 2040, also lacks detailed implementation roadmaps and alignment with national policies. As mentioned by Seng Yeo, et al,. (2022), Malaysia aims to protect the environment, but its policies on green infrastructure remain fragmented, requiring a national-level framework with strategic, operational, and reflexive measures for effective implementation and continuous monitoring. To address these issues, stronger regulatory frameworks, cross-sectoral collaboration, and financial incentives are needed. Integrating best practices from international policies—such as mandating green space access, permeable urban surfaces, and private sector participation—could improve Kuala Lumpur's climate resilience and green infrastructure.

CONCLUSION

This study underscores the urgent need for a cohesive and enforceable framework to integrate green infrastructure into Kuala Lumpur's urban planning policies.

Despite the presence of national guidelines promoting green space development, the lack of clear enforcement mechanisms and regulatory inconsistencies impedes the effective implementation of green infrastructure strategies. The findings highlight that fragmented governance, financial constraints, and limited policy coherence hinder Malaysia's ability to develop resilient urban ecosystems. Drawing on international best practices, this study emphasises the importance of adopting structured green infrastructure standards, enhancing policy integration, and implementing targeted financial incentives to support sustainable urban development. A coordinated, cross-sectoral approach involving policymakers, urban planners, and stakeholders is essential to retrofitting green infrastructure and strengthening Kuala Lumpur's resilience to climate change. By aligning Malaysia's urban planning policies with global benchmarks, the nation can advance sustainable development goals, enhance ecological connectivity, and foster a more climate-resilient urban environment.

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