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A PRELIMINARY STRATEGIC FRAMEWORK FOR IMPROVING PUBLIC ASSET MANAGEMENT IN MALAYSIA

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Abstract

Public asset management in Malaysia faces persistent financial challenges, including poor revenue collection, weak budgeting, outdated asset registers, limited digital integration, and delays in asset disposal. This study develops a document-based preliminary strategic framework to improve the financial management of public assets in Malaysia. Its novelty lies in integrating audit findings, policy documents, academic literature, and international asset management guidance into a finance-driven framework that links key financial issues with practical strategic responses. Using qualitative document analysis, 30 purposively selected documents published mainly between 2015 and 2025 were reviewed, including Auditor General's Reports (2020–2024), DPAK, MPAM, TPATA, ISO 55000-related guidance, institutional reports, and academic articles selected based on relevance to public asset management, financial management, lifecycle costing, digital asset systems, asset disposal, and public sector governance. Thematic content analysis identified seven recurring financial issues: poor revenue collection, lack of lifecycle-based budgeting for operation and maintenance, inadequate digital tools, inefficient asset disposal, weak financial governance training, manual and outdated asset registers, and inconsistent policy implementation across agencies. These issues were matched with strategic responses, including smart payment systems, lifecycle costing, CMMS adoption, structured asset disposal, workforce financial training, digitalised asset registers, and standardised compliance monitoring. The framework is presented as a preliminary conceptual output derived from document analysis.

***Keywords**:* Public Asset Management, Financial Management, Strategic Framework, Lifecycle Costing, Asset Disposal, Malaysia

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INTRODUCTION

Public asset management is essential for effective government service delivery, infrastructure maintenance, and protection of public wealth. In Malaysia, public asset management continues to face recurring weaknesses, including outdated asset registers, poor maintenance practices, weak enforcement of asset-use policies, delays in disposal, and limited digital integration (Auditor General's Report, 2024; Sapri, 2021; The Edge Malaysia, 2025). Although these problems appear operational, they are closely linked to financial management weaknesses such as poor revenue collection, inadequate operation and maintenance (O&M) budgeting, weak cost control, and limited financial monitoring.

Financial management is therefore a critical part of public asset management. Without effective revenue collection, structured budgeting, and expenditure control, public agencies may struggle to maintain assets, update asset records, adopt digital systems, or recover value from obsolete assets. Previous studies show that weak financial planning can create liquidity pressure, fiscal uncertainty, and long-term asset deterioration (Kaw et al., 2020; Grozdanovska et al., 2017). In Malaysia, audit findings have repeatedly highlighted weaknesses related to rent and lease arrears, incomplete asset records, improper disposal procedures, and weak reporting practices (Auditor General's Report, 2023; Auditor General's Report, 2024). Media reports on rental and lease arrears provide recent public context, but the core evidence of this study is drawn mainly from official audit reports, policy documents, and academic literature (The Star, 2024; The Star, 2025).

These weaknesses have important financial implications. Inadequate O&M planning may increase future repair costs and shorten asset lifespan, while weak asset data limits agencies' ability to forecast expenditure and make evidence-based decisions. Limited digital integration also reduces transparency in maintenance spending and asset performance monitoring. Tools such as Computerized Maintenance Management Systems (CMMS) can support cost tracking, maintenance planning, and financial oversight, but their adoption and integration remain uneven across public agencies (Wienker et al., 2016; Ismail et al., 2019; Tajudin et al., 2022).

Malaysia already has several policy instruments for public asset management, including the Dasar Pengurusan Aset Kerajaan (DPAK), Manual Pengurusan Aset Menyeluruh (MPAM), and Tatacara Pengurusan Aset Tak Alih Kerajaan (TPATA). However, recurring audit findings suggest that policy availability has not fully translated into consistent financial control, lifecycle budgeting, digital asset monitoring, or value-based disposal practices. Existing studies have identified issues such as inaccurate asset data, delayed maintenance, weak enforcement, and poor disposal processes, but these issues have not been

sufficiently integrated into a finance-driven strategic framework for Malaysian public agencies (Ismail et al., 2019; Tajudin et al., 2021)

Therefore, this study aims to develop a preliminary strategic framework to improve the financial management of public assets in Malaysia. Specifically, it identifies key financial management issues affecting public asset administration and proposes strategic financial responses to enhance efficiency, accountability, and sustainability. This study adopts a qualitative document analysis approach by reviewing national audit reports, government policy documents, academic literature, and international asset management guidance, particularly ISO 55000. The paper proceeds with a review of relevant literature, followed by the methodology, findings and proposed framework, and conclusion with recommendations.

LITERATURE REVIEW

Definition of Terms

Public Asset Management (PAM) refers to the systematic planning, acquisition, use, maintenance, and disposal of public sector assets to maximise value throughout their life-cycle (OECD, 2025). In the public sector, PAM also supports transparency, accountability, service delivery, and efficient use of public resources (Hanis et al., 2010).

Financial management is central to PAM because each asset life-cycle stage involves financial decisions, including acquisition budgeting, O&M funding, revenue collection, expenditure control, valuation, and disposal value recovery. Earlier public sector practices often focused on acquisition cost while overlooking recurring O&M costs, which can lead agencies to underestimate the true cost of owning and maintaining assets (Hanis et al., 2010).

This study adopts a life-cycle financial perspective. Life-cycle costing requires agencies to consider the full cost of an asset from acquisition to disposal, not only its initial cost (Oh et al., 2023; Kneifel & Webb, 2022). This is consistent with ISO 55000 principles, which emphasise value creation, risk control, cost optimisation, and life-cycle decision-making in asset management (International Organization for Standardization, 2018; Parra et al., 2020; Institute of Asset Management, 2021). Therefore, this study treats financial management as the mechanism through which public assets can be planned, maintained, monitored, and disposed of more effectively.

Issues in Public Asset Management in Malaysia

Studies and audit findings show that Malaysia's public asset management continues to face several recurring weaknesses, particularly in financial governance, budgeting, digital integration, disposal, staff capacity, asset records, and policy implementation.

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Poor Revenue Collection and Weak Financial Governance

Weak revenue collection remains a major financial issue in public asset management. Audit findings have reported arrears involving public assets, including land lease, quit rent, and public housing rental collections (Auditor General's Report, 2023; Auditor General's Report, 2024). This is consistent with studies showing that local governments often face weaknesses in revenue management, enforcement, and long-term asset financing (Kaw et al., 2020; Salleh & Yusof, 2011). Poor collection reduces cash flow, weakens fiscal stability, and limits funds that could be reinvested into maintenance, upgrading, or service improvement (Grozdanovska et al., 2017; Mohd et al., 2018; Ismail et al., 2019; Teo et al., 2022). Media reports on rental and lease arrears provide recent public context, but the core evidence remains audit and academic sources (The Star, 2024; The Star, 2025).

Lack of Lifecycle-Based Budgeting for Operation and Maintenance

Public agencies often budget for assets through annual allocations rather than full life-cycle needs. This weakens long-term O&M planning and may lead to premature asset deterioration (Kaw et al., 2020). Life-cycle cost methods are important because they estimate costs from acquisition to maintenance, renewal, and disposal (Oh et al., 2023). Without lifecycle-based budgeting, agencies may underestimate future maintenance liabilities, leading to emergency repairs, service disruption, and higher long-term costs (Campbell & Reyes-Picknell, 2016; RICS, 2025; Mohd Tombel et al., 2024). Therefore, the absence of lifecycle budgeting shifts asset management from preventive financial planning to reactive expenditure.

Inadequate Digital Tools and Weak System Integration

Digital systems are important for tracking asset performance, maintenance costs, and financial accountability. Although Malaysia has introduced systems and frameworks such as mySPATA, iGFMAS, DPAK, MPAM, and TPATA, integration between financial data and technical asset data remains limited (Jabatan Akauntan Negara Malaysia, 2019). CMMS can support maintenance planning, work orders, cost tracking, inventory control, and resource management (Wienker et al., 2016). However, uneven adoption and weak integration reduce transparency over maintenance expenditure, limit cost forecasting, and increase the risk of inefficient spending (Abu Bakar & Kamaruzzaman, 2023; Mahamad Subri et al., 2025; Rustanto, 2019).

Inefficiency in Asset Disposal and Low Value Recovery

Asset disposal is often handled as an administrative process rather than a financial strategy. Delayed disposal of idle, obsolete, or damaged assets can reduce resale

value, increase storage costs, and prevent value recovery (Ismail et al., 2019; Tajudin et al., 2022). Audit-related reporting has also shown that poor asset decisions may result in avoidable financial waste (Bernama, 2023). From a life-cycle perspective, disposal should involve clear criteria, valuation, audit trails, skilled personnel, and value-based decision-making (International Organization for Standardization, 2018; Obicci et al., 2021; Joseph-Lara & Maharajh, 2024). Inefficient disposal therefore weakens financial recovery and reduces funds available for reinvestment.

Weak Staff Capacity in Financial Governance

Financial governance also depends on staff competency. Recurring issues such as irregular payments, delays in collection, non-compliance with procedures, procurement weaknesses, and weak internal controls suggest gaps in financial knowledge and institutional oversight (Ismail et al., 2019; Tajudin et al., 2021; Tajudin et al., 2022). Training can improve staff performance, compliance, budgeting accuracy, and asset-related decision-making (Lima & Costa, 2019; Singh et al., 2023). The Institute of Asset Management (2021) also identifies competency development as an important condition for effective asset management. Without adequate training, agencies face higher risks of misallocation, leakage, audit findings, and poor financial decisions.

Manual and Outdated Asset Registers

Accurate asset registers are necessary for financial tracking, valuation, maintenance planning, and auditability. However, many agencies still rely on manual, fragmented, or outdated records. This limits visibility over asset location, condition, value, ownership, and usage. As a result, agencies may struggle to plan maintenance budgets, identify idle assets, calculate depreciation, or prepare reliable financial reports (Grubišić et al., 2009; Theron, 2016). Integrated digital asset registries can strengthen fiscal accountability and support evidence-based planning (Razali et al., 2021; OECD, 2025; The Edge Malaysia, 2025).

Inconsistent Implementation of Asset Management Policies

Malaysia already has major public asset management policy instruments, including DPAK, MPAM, and TPATA. However, recurring audit findings suggest that implementation remains inconsistent across agencies (Auditor General's Report, 2024; JPAK, 2024). The issue is therefore not only policy availability, but the gap between policy design and actual practice. Inconsistent implementation creates uneven financial control, weak compliance, and fragmented reporting. Stronger standardisation, monitoring, and accountability mechanisms are needed to translate existing policies into measurable financial outcomes (Abdullah et al., 2011; Grubišić et al., 2009; Tajudin et al., 2022).

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Key Financial Solutions for Strategic Public Asset Management

The literature identifies several financial strategies for improving public asset management. These strategies can be grouped into governance standardisation, revenue optimisation, lifecycle budgeting, digitalisation, disposal management, capacity building, and asset data improvement.

In addition to identifying strategic responses, this section also presents possible KPIs for each solution. The KPIs are treated as indicative monitoring measures derived from the reviewed audit reports, policy documents, academic literature, and institutional guidance. They are included to show how each proposed strategy could be assessed in practice, but they are not presented as final or empirically validated performance indicators. Their role is to support the development of the preliminary framework and to provide measurable links between financial issues, strategic responses, and implementation outcomes.

Standardised Financial Governance Procedures

Standardised financial governance procedures can reduce variation in how agencies collect revenue, approve expenditure, monitor arrears, and report financial performance. Clear procedures strengthen consistency, accountability, and compliance across agencies (Ball, 2002; Ismail et al., 2019; Tajudin et al., 2022). Implementation requires clear operating procedures, defined roles, enforcement rules, internal audit checks, digital monitoring, and alignment with DPAK, MPAM, and TPATA (Tajudin et al., 2021; Joseph-Lara & Maharajh, 2024). Possible KPIs include arrears reduction, collection rate, number of audit findings, average time taken to act on arrears, and percentage of agencies complying with standard procedures.

Smart Payment Systems for Revenue Collection

Smart payment systems can improve revenue collection by making payments easier, traceable, and enforceable. Online billing, automated reminders, digital payment tracking, incentives, and penalty enforcement can reduce manual errors and improve payment compliance (Ball, 2002; Mahamad Subri et al., 2025). Wider evidence also supports the role of digital systems in strengthening fiscal transparency and accountability (The World Bank, 2023; OECD, 2025). Implementation requires online payment infrastructure, updated debtor records, integration with financial systems, clear arrears policies, and staff capability to monitor payment data. Possible KPIs include arrears reduction rate, digital payment uptake, average collection period, payment compliance rate, number of automated reminders issued, and percentage of accounts with updated debtor information.

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Lifecycle Costing for O&M Financial Stability

Lifecycle costing supports financial planning by estimating the full cost of an asset from acquisition to disposal. Instead of relying on reactive repairs, agencies can allocate funds based on expected maintenance, renewal, replacement, and disposal needs (Kaw et al., 2020; Oh et al., 2023; RICS, 2025). Implementation requires asset condition data, cost histories, maintenance schedules, risk assessment, and multi-year budget planning (Matos et al., 2015; Mahamad Subri et al., 2025). Possible KPIs include percentage of assets with lifecycle cost plans, percentage of O&M budget based on lifecycle costing, reduction in emergency maintenance expenditure, maintenance cost variance against forecast, asset downtime rate, and preventive maintenance completion rate.

CMMS for Cost Control and Transparency

Computerized Maintenance Management Systems (CMMS) can improve cost control by linking maintenance activities with financial information. CMMS records work orders, maintenance history, spare parts, labour costs, asset condition, and expenditure, allowing agencies to identify high-cost assets and justify budget requests using data (Wienker et al., 2016; Beniacoub et al., 2021). Implementation requires system selection, data migration, staff training, asset coding, integration with finance systems, and clear responsibility for updating records (World Health Organization, 2011; Meira et al., 2020; Ali & Khalid, 2021). Possible KPIs include percentage of assets recorded in CMMS, reduction in unplanned maintenance, average response time, maintenance cost per asset, and accuracy of maintenance cost records.

Asset Disposal as a Financial Strategy

Asset disposal should be treated as a financial strategy rather than a routine administrative task. Agencies can recover value by identifying obsolete, idle, or uneconomic assets early and disposing of them before their value declines further. This approach is consistent with ISO 55000's life-cycle view and previous studies on public asset disposal (Obicci et al., 2021; Tanui & Moronge, 2020; Joseph-Lara & Maharajh, 2024). Implementation requires disposal criteria, valuation procedures, market assessment, approval timelines, audit trails, trained officers, and linkage between disposal decisions, asset registers, and financial planning. Possible KPIs include average disposal time, percentage of obsolete assets disposed within target period, value recovered, reduction in holding costs, complete disposal audit trails, and percentage of disposal proceeds reinvested into asset needs.

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Workforce Financial Training

Workforce training strengthens financial governance by improving staff knowledge in budgeting, compliance, valuation, cost control, and asset-related decision-making. Better-trained officers are more likely to follow procedures, detect risks, maintain accurate records, and make financially sound decisions (Lima & Costa, 2019; Singh et al., 2023; Institute of Asset Management, 2021). Implementation requires structured training modules, competency standards, refresher courses, certification pathways, and evaluation of learning outcomes (Institute of Asset Management, 2014; Fegade & Sharma, 2023; Caterino et al., 2025). Possible KPIs include percentage of asset officers trained, training completion rate, post-training assessment scores, number of certified personnel, reduction in audit findings linked to non-compliance, and improvement in budget preparation accuracy.

Digitalised and Centralised Asset Register

A digitalised and centralised asset register improves financial tracking by providing accurate information on asset location, condition, value, ownership, maintenance history, and disposal status. Better asset data supports budgeting, auditability, maintenance planning, and evidence-based financial decisions (Grubišić et al., 2009; Tajudin et al., 2022). Integrated digital asset registries also support fiscal accountability and preventive maintenance planning (Razali et al., 2021; OECD, 2025). Implementation requires asset verification, standardised asset coding, data cleansing, access control, regular updates, and integration with finance systems and CMMS. Possible KPIs include percentage of assets verified and digitised, completeness of financial data, frequency of register updates, reduction in duplicate or missing assets, audit accuracy rate, and percentage of asset records linked to finance or CMMS systems.

Based on the reviewed literature, audit reports, policy documents, and institutional guidance, several recurring financial issues in public asset management were identified. Table 1 synthesises the main themes found in the literature and links each theme to its financial implication, proposed strategic response, and indicative KPI. This synthesis provides the conceptual basis for the subsequent document analysis and the development of the preliminary strategic framework.

Table 1: Evidence Trail, Financial Implications and Strategic Responses

Theme	Main evidence type	Financial implication	Strategic response	Indicative KPI
Revenue collection	Audit reports; public finance studies	Weak cash flow and arrears	Smart payment and enforcement	Collection rate; arrears reduction
O&M budgeting	Lifecycle costing literature; policy manuals	Reactive repairs and higher cost	Lifecycle costing in budget planning	Emergency maintenance reduction
Digital tools	CMMS studies; government manuals	Poor cost tracking	CMMS and finance-system integration	Assets recorded in CMMS
Asset disposal	Audit and disposal literature	Lost recovery value and holding cost	Structured value-based disposal	Average disposal time; value recovered
Staff capacity	Governance and training literature	Non-compliance and weak decisions	Financial governance training	Training completion; audit issue reduction
Asset register	OECD; asset register studies	Weak valuation and auditability	Digitalised central register	Record completeness; duplicate reduction
Policy implementation	DPAK, MPAM, TPATA; audit reports	Uneven control and repeated findings	Standardised compliance monitoring	Compliance rate; corrective-action closure

RESEARCH METHODOLOGY

This study used qualitative document analysis to develop a preliminary finance-driven framework for public asset management in Malaysia. Document analysis is appropriate where existing texts are systematically reviewed to identify patterns, meanings and relationships (Bowen, 2009; Clarke & Braun, 2017). The study is conceptual and did not involve interviews, surveys, Delphi validation, case testing or pilot implementation.

Documents were identified through targeted searches in academic databases, Google Scholar, official Malaysian government portals, audit report portals and institutional websites. Search terms included public asset management Malaysia, government asset management, financial management public assets, lifecycle costing, operation and maintenance budgeting, CMMS, asset disposal public sector, asset register, DPAK, MPAM, TPATA and ISO 55000. Documents were included if they were relevant to public asset management, financial management, asset maintenance, disposal, digitalisation, asset records or public sector governance. Documents were excluded if they were unrelated to the public sector, duplicated other sources, lacked clear authorship

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or had unverifiable publication details. Media reports were used only as contextual examples and not as the core evidence base.

A total of 30 documents were selected through purposive sampling. The document corpus covered official audit reports, government policies, technical manuals, international guidance and peer-reviewed studies. Table 2 summarises the corpus to make the selection traceable and reproducible.

Table 2: Document Corpus Used for Analysis (N = 30)

No.	Document/Source	Type	Main Relevance
1	Auditor General's Report 2021	Audit	Federal financial statements
2	Auditor General's Report 2022	Audit	Public-sector weaknesses
3	Auditor General's Report 2023	Audit	Revenue and asset issues
4	Auditor General's Report 2024	Audit	Recent audit findings
5	DPAK Version 2.0	Policy	Asset management policy
6	MPAM Version 2.0	Manual	Whole-life asset management
7	TPATA Version 3.0	Procedure	Immovable asset procedures
8	iGFMAS Asset Accounting Manual	Manual	Financial-system linkage
9	ISO 55002 guidance	Standard	Asset management system
10	IAM SSG 21	Guidance	Asset decommissioning and disposal
11	OECD Government at a Glance 2025	Institutional	Digital and fiscal accountability
12	World Bank public asset guidance	Institutional	Public asset management
13	RICS lifecycle costing guidance	Institutional	Lifecycle costing
14	Kneifel & Webb (2022)	Manual	Life-cycle costing method
15	Hanis et al. (2010)	Article	Public asset management framework
16	Ismail et al. (2019)	Article	Government asset management practices
17	Tajudin et al. (2021)	Article	Factors affecting asset management performance
18	Tajudin et al. (2022)	Article	Malaysian government agency asset issues
19	Kaw et al. (2020)	Book/report	Urban public assets and financing
20	Oh et al. (2023)	Article	Lifecycle costing
21	Mohd Tombel et al. (2024)	Article	O&M challenges
22	Abu Bakar & Kamaruzzaman (2023)	Article	CMMS acceptance
23	Wienker et al. (2016)	Article	CMMS functions
24	Beniacoub et al. (2021)	Article	CMMS evaluation
25	Obicci et al. (2021)	Article	Public asset disposal
26	Joseph-Lara & Maharajh (2024)	Article	Disposal process
27	Razali et al. (2021)	Article	Preventive maintenance data
28	Grubišić et al. (2009)	Article	Asset records and financial reporting
29	Lima & Costa (2019)	Article	Regulatory asset management
30	Singh et al. (2023)	Article	Training and performance

The selected documents were analysed using thematic content analysis. The coding protocol involved five steps including;

1. familiarisation with the documents.
2. extraction of text segments related to financial issues and solutions.
3. initial coding using categories such as revenue collection, O&M budgeting, CMMS, disposal, staff capacity, asset register and compliance.
4. grouping of codes into themes; and
5. synthesis of themes into a preliminary framework.

A coding matrix recorded the source, evidence segment, theme, financial implication and proposed strategic response. Trustworthiness was strengthened through triangulation across audit, policy, academic and institutional sources. Coded segments were checked against original documents, overlapping codes were refined and the interpretation was discussed through peer debriefing with supervisors (Nowell et al., 2017). The study does not claim empirical validation. The output is a preliminary framework derived from document analysis and should be tested through expert review.

FINDINGS/RESULTS

The thematic analysis produced seven financial issues and seven corresponding strategic responses. The themes appeared across different document types, which suggests that the issues are not isolated observations but recurring patterns in Malaysian public asset management. The evidence trail in Table 1 shows how each theme is linked to financial implications, strategic responses and indicative performance measures.

The findings indicate that financial weaknesses in public asset management operate as a connected system. Poor revenue collection limits funds available for maintenance. Weak lifecycle budgeting shifts agencies toward reactive repairs. Outdated registers and weak digital integration reduce visibility over asset condition and expenditure. Delayed disposal prevents value recovery. Staff capability gaps and inconsistent policy implementation allow the same weaknesses to recur. Therefore, the proposed framework treats public asset management reform as a finance-driven governance process rather than a purely administrative exercise.

Figure 1 positions audit findings, national policies, financial records, asset data and ISO 55000-related principles as inputs. These inputs support seven mechanisms such as smart payment systems, lifecycle costing, CMMS integration, structured disposal, financial governance training, digitalised asset registers and standardised compliance monitoring. The mechanisms produce

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measurable outputs and contribute to financial efficiency, accountability, asset value retention, reduced wastage, and sustainable public asset management. The feedback loop allows KPI results, audit findings, CMMS reports, register updates, budget reviews and compliance reviews to inform future decisions.

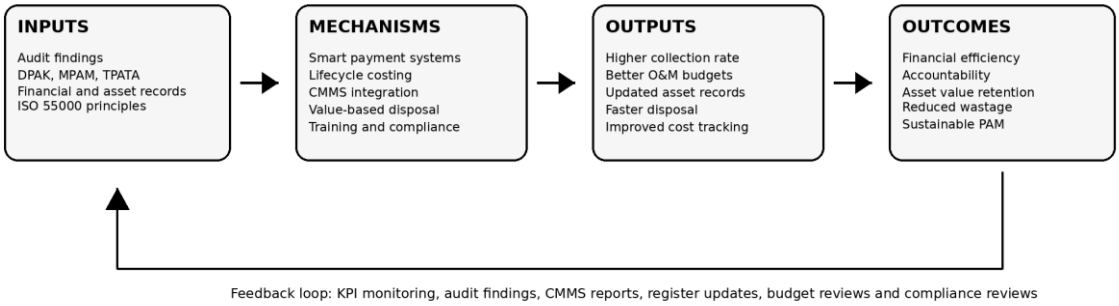


Figure 1: Finance-driven Strategic Framework for Public Asset Management

Table 3 translates the proposed strategies into an implementation matrix. It identifies the main issue, strategic response, responsible parties, key implementation steps, timeframe, and KPIs for each financial management issue. The timeframes are presented as indicative implementation phases rather than fixed deadlines. This phasing is adapted from the NSW Integrated Planning and Reporting Framework, which links annual operational planning, a four-year delivery programme, and long-term financial, workforce, and asset management planning (Office of Local Government NSW, 2025). Therefore, short-term actions refer to improvements that can begin within an annual planning cycle, while medium-term and longer-term actions refer to reforms requiring stronger coordination, budgeting, data preparation, system integration, and continuous monitoring.

Table 3: Strategic Implementation Matrix

Issue	Strategy	Responsible parties	Key steps	Timeframe	KPIs
Poor revenue collection	Smart payment and enforcement	Finance units;	Update debtor records; issue digital bills; automate reminders; monitor arrears; enforce penalties	0-12 months	Collection rate; arrears reduction; digital payment uptake
Weak lifecycle O&M budgeting	Lifecycle costing	Asset owners; finance units; technical departments	Assess condition; estimate lifecycle cost; prioritise critical assets; link to annual	1-3 years	Assets with lifecycle plans; emergency maintenance reduction; budget variance

Issue	Strategy	Responsible parties	Key steps	Timeframe	KPIs
			and multi-year budgets		
Weak digital integration	CMMS adoption and integration	ICT units; asset managers; maintenance and finance units	Select CMMS; migrate data; train users; record work orders; link costs to assets	1-3 years	Assets in CMMS; work orders completed; maintenance cost per asset
Inefficient disposal	Value-based disposal	Disposal committee; asset managers; finance and audit units	Identify obsolete assets; value assets; approve disposal; record proceeds; maintain audit trail	0-24 months	Average disposal time; value recovered; complete audit trail
Weak staff capacity	Financial governance training	HR; finance; asset units; training institutes	Develop modules; train officers; assess competency; conduct refresher training	0-24 months	Training completion; assessment scores; reduction in audit findings
Outdated asset registers	Digitalised central register	Asset registry; ICT; finance; agency management	Verify assets; cleanse data; standardise coding; update records; link to finance and CMMS	1-3 years	Verified assets; complete records; duplicate/unrecorded asset reduction
Inconsistent policy implementation	Standardised compliance monitoring	Ministries; agencies; internal audit; central monitoring bodies	Standardise SOPs; assign compliance owners; audit periodically; monitor corrective action	1-5 years	Compliance rate; repeat audit findings; corrective-action closure

The framework summarises the relationship between the main financial issues, proposed strategic responses, implementation actions, and possible KPIs for improving public asset management in Malaysia. Therefore, the framework serves as a preliminary guide for public agencies to strengthen financial accountability, improve cost control, and support more sustainable public asset management practices.

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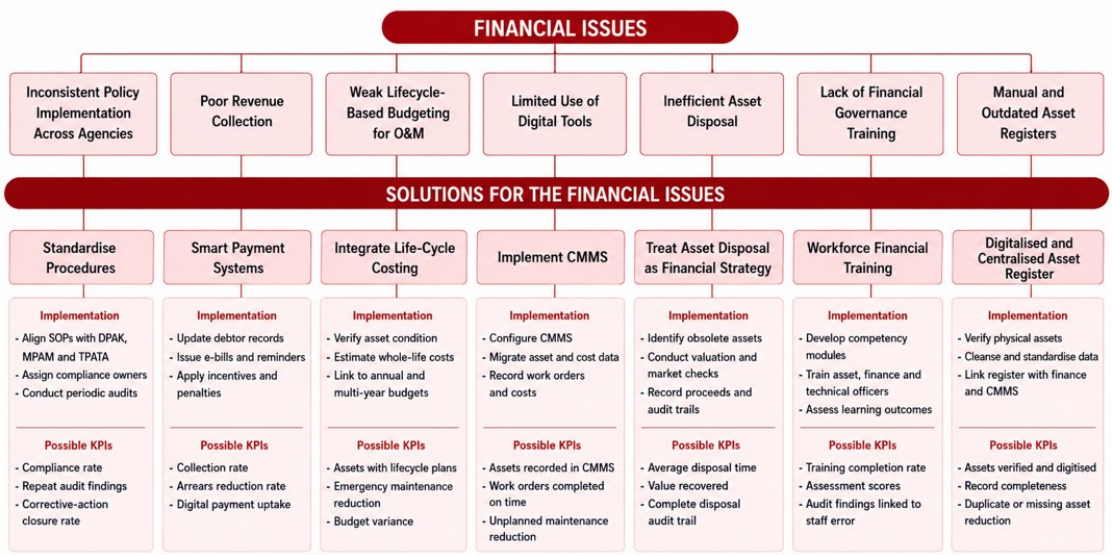


Figure 2: Strategic Framework for Improving Public Asset Management in Malaysia

CONCLUSION AND RECOMMENDATIONS

Summary of Findings

This study examined the financial challenges affecting public asset management in Malaysia and developed a preliminary strategic framework based on document analysis. The findings show that weaknesses in public asset management are strongly linked to financial governance issues, particularly poor revenue collection, limited lifecycle-based budgeting for operation and maintenance, weak digital integration, inefficient asset disposal, weak staff capacity, outdated asset registers, and inconsistent policy implementation across agencies. The study proposes seven corresponding strategies: smart payment and enforcement systems, lifecycle costing for O&M budgeting, CMMS adoption, structured asset disposal, targeted financial governance training, digitalised asset registers, and standardised compliance monitoring. These strategies form the basis of the proposed preliminary strategic framework for improving public asset management in Malaysia.

The findings suggest that public asset management should not be treated only as an administrative or technical function. It should also be managed as a financial governance function. Better revenue collection, lifecycle budgeting, asset data, disposal planning, and compliance monitoring can help public agencies reduce wastage, improve accountability, and protect asset value. The proposed framework provides a practical guide for public agencies to connect financial issues with implementation mechanisms and measurable performance

indicators. It can support decision-making by helping agencies identify priority reforms, assign responsibilities, and monitor progress through KPIs.

This study has several limitations. First, it is based only on document analysis and does not include primary data from interviews, surveys, Delphi panels, or case studies. Second, the documents were selected through purposive sampling, which may create selection bias even though the sources were chosen based on relevance and credibility. Third, the proposed framework has not yet been empirically validated with practitioners, policymakers, or public asset managers. Therefore, the framework should be treated as a preliminary conceptual output rather than a fully tested implementation model. Future research should validate the proposed framework through a Delphi study involving experts in public asset management, public finance, auditing, local government, and infrastructure maintenance. In addition, the framework should be tested through a pilot application in one or two local authorities. A pilot study would allow researchers to assess whether the proposed strategies, responsibilities, timeframes, and KPIs are practical in real administrative settings. The results could then be used to refine the framework before wider application across public agencies in Malaysia.

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GREEN URBANISM: A COMMUNITY STUDY ON PERCEPTIONS OF URBAN REWILDING INITIATIVES AND MENTAL WELL-BEING IN IPOH, PERAK, MALAYSIA

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Abstract

Despite growing recognition of urban rewilding as a nature-based strategy to enhance urban resilience, empirical evidence on community perceptions of its contribution to mental well-being remains limited, particularly in rapidly urbanising Malaysian contexts such as Ipoh, Perak. This study examined Ipoh residents' perceptions of urban rewilding initiatives and their perceived association with mental well-being through three objectives: (1) assessing community awareness and understanding of urban rewilding, (2) evaluating perceived mental well-being and social benefits associated with rewilding initiatives, and (3) identifying implications for nature-based urban policy. A mixed-methods approach was employed, combining quantitative surveys (n = 50 residents) conducted using purposive sampling across diverse Ipoh neighbourhoods with semi-structured interviews. Data were analysed using descriptive statistics and thematic analysis. While the sample size necessitates caution in generalising the findings, the results indicated generally positive community perceptions toward urban rewilding initiatives, with community engagement receiving the highest average rating (M = 4.22/5). Additionally, 78% of respondents associated rewilded spaces with reduced stress and enhanced social cohesion. Qualitative insights further revealed that rewilded spaces were generally perceived as restorative urban environments, although awareness and appreciation varied across age and educational backgrounds. Overall, the findings suggest that urban rewilding may contribute positively to perceived mental well-being and community cohesion, while emphasising the importance of participatory planning and community co-design in supporting socially responsive and ecologically sustainable urban environments in Ipoh and similar urban contexts.

Keywords: Green Urbanism, Urban Rewilding, Mental Well-being, Community

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INTRODUCTION

Urban rewilding—"the restoration of self-sustaining ecological processes and native biodiversity in urban spaces through minimal human intervention" (Zhang et al., 2023)—is a vital nature-based solution to biodiversity loss and the urban human–nature disconnect. Unlike conventional greening, rewilding prioritises habitat connectivity, natural regeneration, and long-term ecological resilience (Carver et al., 2021). These principles align with Green Urbanism, which conceptualises cities as socio-ecological systems that integrate resilience, well-being, and cultural vitality (Beatley, 2000; Lehmann, 2010).

In Malaysia, rapidly urbanising cities face severe environmental pressures. Ipoh, Perak, experienced an 18.7% decline in green cover between 2010 and 2020 (Marzukhi et al., 2022), exacerbating urban heat island effects and diminishing daily interactions with nature. Consequently, urban liveability and mental well-being are under threat (Jabbar et al., 2022). While exposure to conventional, highly maintained green spaces is known to aid psychological restoration and stress reduction (Xingrui & Ibrahim, 2024; Bratman et al., 2019), the restorative potential of "managed wildness" remains underexplored (Hoyle et al., 2020). Furthermore, perceptions of urban wildness are culturally contingent; Asian urban populations often prefer tidy, structured landscapes (Hwang, 2025). As a result, community perspectives on rewilding in Southeast Asia are poorly understood.

Despite the profound ecological restoration potential of Ipoh's unique limestone karst ecosystem, empirical research on residents' views of rewilding and its mental health impacts is limited. To address this gap, this study explores community perceptions of urban rewilding in Ipoh, Perak, aiming to:

1. Assess community awareness and understanding of urban rewilding initiatives.
2. Evaluate residents' perceptions regarding the association between urban rewilding, stress reduction, and social cohesion.
3. Identify context-sensitive considerations for integrating rewilding principles into Ipoh's Green Urbanism framework.

RESEARCH BACKGROUND

Originating in the 1990s, Green Urbanism is a theoretical paradigm for sustainable city development designed to support both human well-being and ecological health (Beatley, 2000; Lehmann, 2010). Although frequently cited, its practical definition centres on zero-carbon initiatives, circular resource use, and waste elimination. Achieving these goals requires breaking down fragmented, traditional views of urban development and fostering multidisciplinary

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collaboration across architecture, engineering, sociology, and economics (Ayob, 2020; Hegazy, Hammad, Munshi, Alqurashi, & Bahreldin, 2024).

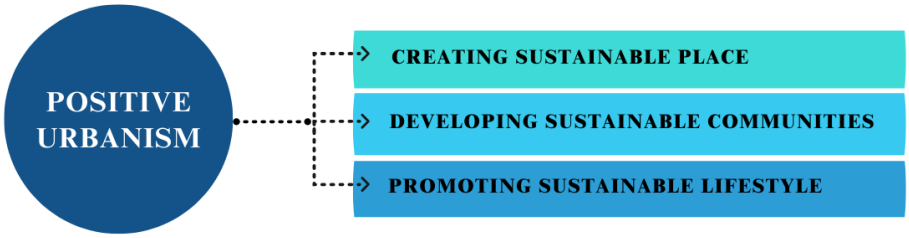


Figure 1: Green Urbanism as Positive Urbanism
Source: The Author (extracted from Beatley, 2000)

Methodologically, Green Urbanism optimises urban density through energy-efficient design, favouring the adaptive reuse of existing infrastructure and the ecological revitalisation of post-industrial cores over outward expansion. It provides a holistic foundation for sustainable modifications, ensuring urban systems maintain a healthy equilibrium with their surrounding hinterlands without degrading local ecosystems (Ayob & Amir, 2024; Lehmann, 2010). Rethinking existing infrastructure is therefore essential to creating compact, mixed-use, and polycentric urban centres.

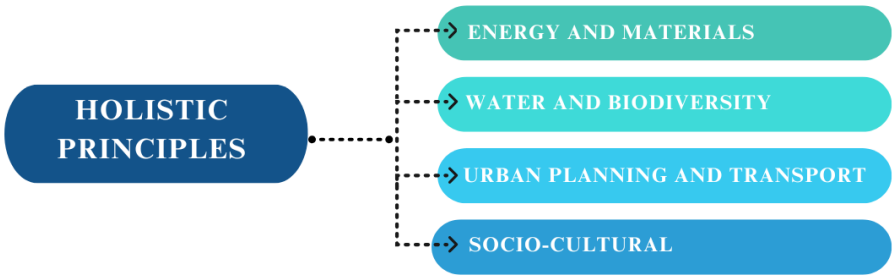


Figure 2: Green Urbanism Promotes Holistic Principles
Source: The Author (extracted from Lehmann, 2010)

This research is significant as it explores the vital intersection of urban development, mental health, and the emerging concept of urban rewilding within the rapidly urbanising context of Ipoh, Perak, Malaysia. Understanding community perceptions is essential to determine how urban rewilding practices might influence residents' mental health and well-being.

In Malaysia, the commitment for sustainable development is reflected in several key policy frameworks. The *National Urbanisation Policy* (NUP) and

the *National Physical Plan* (NPP) target the development of sustainable, resilient cities. Similarly, the *National Policy on Biological Diversity* and the *National Climate Change Policy* encourage ecosystem conservation and urban greenery. While these frameworks align closely with the principles of Green Urbanism, a crucial gap remains between policy goals and local implementation: rewilding is not yet incorporated as a clear, actionable strategy for improving mental health and well-being in urban planning.

The findings of this study contribute to the growing body of knowledge on green and sustainable urban development through the case of Ipoh. The findings can be used to inform community involvement programs and urban planning policies, resulting in a more comprehensive strategy that supports community mental health and environmental sustainability.

LITERATURE REVIEW

The Domain of Green Urbanism

Green Urbanism (GU) is a broad paradigm promoting sustainable, environmentally responsible city development. While defined in over 40 distinct ways across the literature, researchers generally agree on three core components that form the foundation of GU (Figure 3).

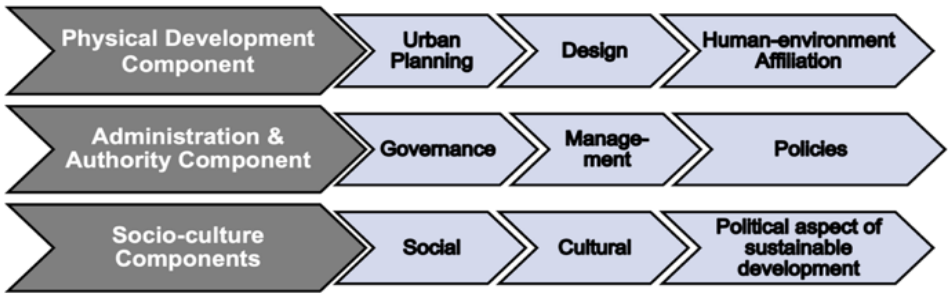


Figure 3: Green Urbanism: The Domain and Its Components
Source: The Author (extracted from Ayob, 2020

Green Urbanism and the Nature Dimension

Green Urbanism refers to an integrated urban planning approach that promotes ecological sustainability, biodiversity conservation, climate resilience, and human well-being through environmentally responsive design and nature-based urban strategies (Beatley, 2012; Lehmann, 2010). The concept emphasises the integration of green infrastructure, ecological restoration, and sustainable land-use planning to create healthier and more liveable urban environments.

Within this framework, urban rewilding represents a practical application of Green Urbanism by restoring natural ecological processes and

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increasing biodiversity within urban areas. Rewilding initiatives such as native vegetation restoration, ecological corridors, and naturalised public spaces contribute not only to environmental enhancement but also to social and psychological well-being through increased human interaction with nature.

Previous studies have shown that exposure to natural environments may reduce psychological stress, improve emotional restoration, and strengthen social cohesion among urban communities (Bratman et al., 2019; Hartig et al., 2014). In the Malaysian context, however, limited studies have explored community perceptions toward urban rewilding initiatives and their perceived influence on mental well-being, particularly in secondary cities such as Ipoh.

Urban Rewilding and Well-Being

Extensive research links exposure to biodiverse urban nature with reduced stress, lower anxiety, emotional restoration, and enhanced cognitive function (Bratman et al., 2019; Hartig et al., 2014). Crucially, naturalistic and semi-wild landscapes offer greater sensory diversity and ecological authenticity than highly manicured parks, often generating stronger restorative experiences (Carrus et al., 2015; Taylor & Hochuli, 2017).

Beyond individual health, rewilding fosters social well-being by encouraging outdoor recreation, social interaction, and community attachment. Environmentally, rewilded spaces improve urban liveability through cooling, air purification, biodiversity enhancement, and stormwater regulation (Castaño-Rosa, Pelsmakers & Järventausta, 2024). These compounded benefits are critical in rapidly urbanising cities, where a growing disconnect from nature exacerbates stress and mental fatigue (Bratman et al., 2019).

Despite growing international interest, empirical studies on urban rewilding predominantly originate from Western contexts. The applicability of these findings to Southeast Asian cities is uncertain due to distinct differences in climate, biodiversity, urban morphology, and socio-cultural perceptions of nature.

Local Context: Green Urbanism and Urban Rewilding in Malaysia

To bridge this geographical gap in the literature, urban rewilding is increasingly recognised as a critical strategy for restoring biodiversity and improving psychological well-being within rapidly urbanising Asian cities (Bratman et al., 2019; Taylor & Hochuli, 2017).

In the Malaysian context, urban rewilding explicitly focuses on the restoration of tropical urban ecosystems and ecological functions. This is achieved through native planting, rehabilitation of secondary forest patches, ecological river restoration, and biodiversity-sensitive, naturalised landscape planning. Crucially, these local approaches align directly with the sustainable

urban development goals outlined in Malaysia's *National Landscape Policy* and the *Low Carbon Cities Framework* (Nizarudin & Zakariya, 2025). Therefore, targeted investigation within these tropical urban settings is necessary to understand exactly how urban rewilding influences community well-being locally.

RESEARCH METHODOLOGY

This study employed a convergent mixed-methods exploratory case study design to examine residents' perceptions of urban rewilding and its perceived effects on psychological well-being in Ipoh. Quantitative and qualitative data were collected concurrently and interpreted collectively to provide a comprehensive understanding of community experiences.

Sampling and Data Collection: Purposive sampling was used to recruit 50 demographically diverse residents familiar with Ipoh's urban green spaces. While this relatively small sample size precludes broad statistical generalisation, it is appropriate for generating in-depth, contextualised insights.
Data collection consisted of two primary instruments:

- **Structured Questionnaires:** Utilised a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) to measure three main constructs: (i) awareness of urban rewilding, (ii) perceived psychological and emotional benefits (e.g., stress reduction, mood improvement), and (iii) perceptions of community engagement and environmental quality.
- **Semi-Structured Interviews:** Utilised open-ended questions to explore participants' lived experiences, emotional responses, and perceptions of rewilded spaces.

Instrument Validation and Ethical Considerations: To ensure reliability and validity, the questionnaire was piloted with 10 respondents to assess clarity and item suitability. Content validity was strengthened through expert review by academic professionals in urban design and landscape studies, while internal consistency was verified using Cronbach's Alpha. Standard ethical protocols were strictly observed: participants were briefed on the study's purpose, informed consent was obtained, and all data were anonymised and securely stored solely for academic purposes.

Data Analysis and Integration: Quantitative data were analysed using descriptive statistics (frequencies, means, and standard deviations; see Figures 5–10) to identify response patterns, rather than to establish causal relationships or broad statistical generalisations. Concurrently, qualitative interview data

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underwent thematic analysis—utilising open coding, categorisation, and theme development—to capture recurring lived experiences of urban rewilding. These themes directly informed the interpretations presented in Sections 5.1.2, 5.2.2, and 5.3.2. Integrating both datasets yielded a robust, comprehensive understanding of how residents perceive the ecological and psychological impacts of these initiatives. However, given the small sample size and potential for subgroup variations, these valuable local insights should be interpreted cautiously; future studies with larger, more diverse cohorts are recommended to validate and extend these findings.

Table 1: Research Method Procedures

Procedures	Implementation
Research Design	Mixed-methods exploratory case study integrating quantitative surveys and qualitative interview
Sampling Method	Purposive sampling of 50 residents representing demographic diversity in Ipoh
Data Collection	Surveys: 5-point Likert scale measuring awareness, psychological well-being, and community engagement. Interviews: Semi-structured questions on lived experiences and perceptions of rewilded spaces
Instrument Validation	Pilot testing with 10 respondents; expert review for content validity; internal consistency reliability assessed using Cronbach's Alpha
Data Analysis	Quantitative: descriptive statistics (frequencies, means, standard deviations). Qualitative: thematic analysis using open coding, categorisation, and theme development

The questionnaire instrument was reviewed by academic experts to ensure content validity and clarity. A pilot study was conducted prior to the actual data collection to test the suitability of the instrument. Reliability analysis was conducted using Cronbach's Alpha to assess the internal consistency of the questionnaire items. The instrument achieved a Cronbach's Alpha coefficient of 0.81, indicating good internal reliability.

RESULTS

This section presents findings from 50 residents in Ipoh regarding their perceptions of urban rewilding, its perceived influence on psychological well-being, and community engagement. Data were collected through structured questionnaires and semi-structured interviews. The integration of quantitative and qualitative findings provides a more comprehensive understanding of how residents perceive urban rewilding initiatives within the local context.

Demographic Profile of Respondents

The sample consisted of an equal number of male and female respondents (n = 25 each; 50%). Participants ranged in age from 16 to 70 years, with an average age of 34.6 years. The majority of respondents were aged 25–40 years (n = 30;

60%), followed by 41–55 years (n = 10; 20%), 16–24 years (n = 7; 14%), and above 55 years (n = 3; 6%).

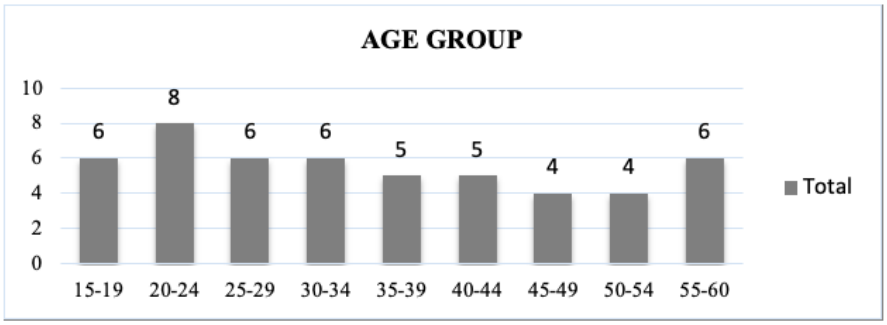


Figure 4: Distribution of Respondents by Age Group
Source: The Author

Regarding educational background, 15% (n = 8) held university degrees, 30% (n = 15) possessed diploma qualifications, 25% (n = 13) completed secondary education, 20% (n = 10) held vocational certifications, and 10% (n = 5) completed primary education. Employment backgrounds were also diverse, comprising government employees (n = 15; 30%), private sector employees (n = 14; 28%), individuals engaged in odd jobs (n = 10; 20%), self-employed participants (n = 6; 12%), and unemployed respondents (n = 5; 10%).

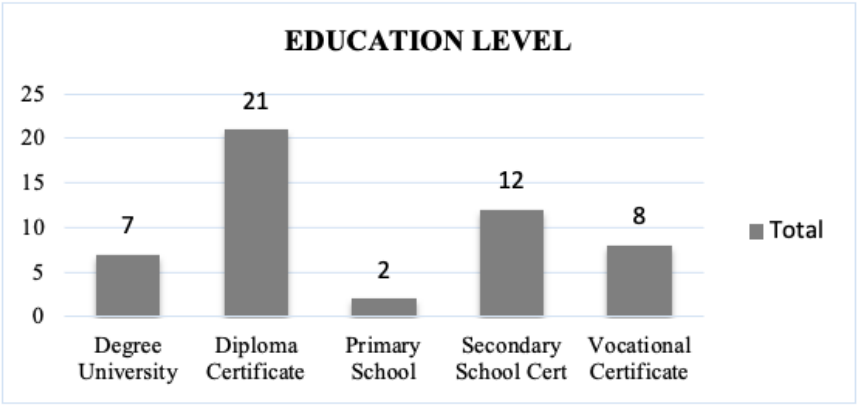


Figure 5: Distribution of Respondents by Education Level
Source: The Author

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Figure 6: Distribution of Respondents by Employment Type
Source: The Author

This descriptive analysis highlights the diverse demographic characteristics found in the sample of 50 respondents, including age, gender, educational attainment, and employment status. In addition to providing demographic data, the participants were asked to rate the following:

Perceptions of Urban Rewilding Initiatives Benefits:	Respondents were asked to rate, on a scale of 1 to 5, their perceptions of the benefits of urban rewilding initiatives, considering factors like green spaces, biodiversity, and community integration.
Perceived Impact on Mental Health and Well-Being:	Participants were requested to assess, using a 1 to 5 scale, the perceived impact of urban rewilding initiatives on their mental health, considering stress levels, relaxation, and overall well-being.
Community Engagement in Urban Rewilding:	Respondents were queried about their level of involvement in urban rewilding activities and their desire for increased community engagement and participation in decision-making processes related to these initiatives.

The combination of quantitative and qualitative responses provides a clear understanding of residents' perceptions and experiences with urban rewilding in Ipoh. This section also outlines the questions asked during data collection to give context for the following analysis.

Summary of Quantitative Findings

Table 2: Summary of Quantitative Findings on Urban Rewilding Perceptions (n = 50)

Constructs	Mean (M)	Standard Deviation (SD)	Key Response Patterns
Perceived Benefits of Urban Rewilding	3.60	0.80	72% (n = 36) rated benefits as moderate to significant
Perceived Impact on Mental Health and Well-Being	4.00	0.70	78% (n = 39) perceived positive mental health benefits
Community Engagement and Involvement	4.22	0.62	86% (n = 43) reported high involvement or desire for involvement

Perceptions of Urban Rewilding Initiatives

Quantitative Findings

Participants reported generally positive perceptions regarding the benefits of urban rewilding initiatives, with an average score of 3.60 out of 5 (SD = 0.80). Approximately 72% of respondents (n = 36) rated urban rewilding as providing moderate to significant benefits. The relatively low standard deviation indicates a moderate level of consistency in participants' responses.

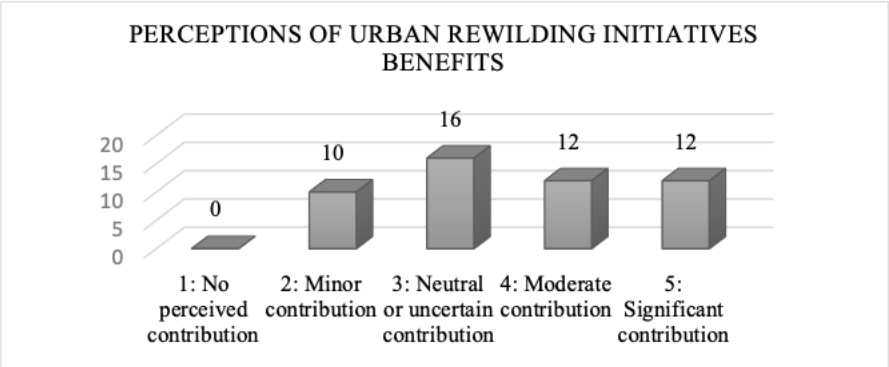


Figure 7: Respondents' Perceptions of the Benefits of Urban Rewilding Initiatives
Source: The Author

The bar graph presented in Figure 7 displays respondents' ratings regarding the perceived benefits of urban rewilding initiatives.

Qualitative Findings

Thematic analysis identified the theme of Perceived Environmental and Psychological Benefits. Participants frequently associated rewilded spaces with greener surroundings, stress reduction, improved emotional well-being, and enhanced community connections.

One participant explained: "*The presence of green spaces in the city contributed to a healthier environment and stress relief after a hectic day*." (Participant P1). These findings suggest that participants perceived urban rewilding as beneficial not only for environmental enhancement but also for psychological restoration and daily well-being.

Perceived Impact on Mental Health and Well-Being

Quantitative Findings

Participants generally perceived urban rewilding as positively influencing mental health and well-being, with a mean score of 4.00 out of 5 (SD = 0.70). Nearly half of the respondents (48%; n = 24) rated the relationship as moderate, while 30% (n = 15) perceived a significant positive impact.

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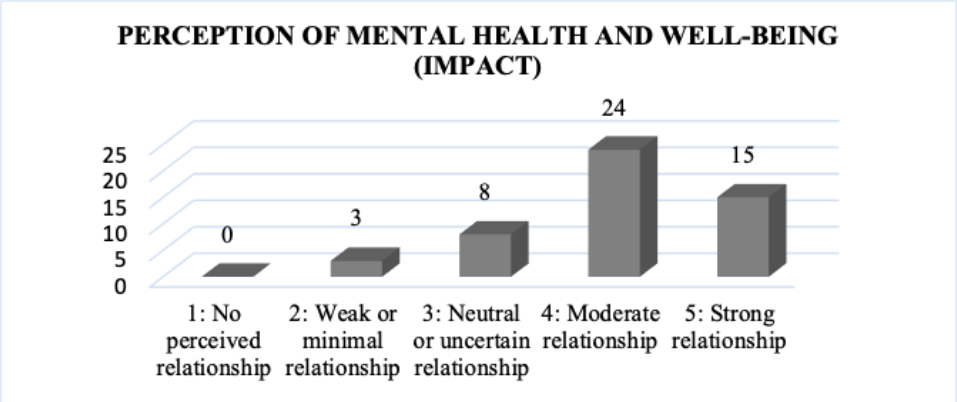


Figure 8: Perceived Relationship Between Urban Rewilding and Mental Well-Being
Source: The Author

Qualitative Findings

Thematic analysis revealed the theme of Psychological Restoration Through Nature Exposure. Participants commonly described experiences related to stress reduction, emotional comfort, and improved mental well-being when interacting with greener and more naturalistic environments.

As one participant stated: "*The greenery around parks and the kampung area has noticeably reduced my stress. It would be nice to have similar greenery in our Ipoh neighbourhood*." (Participant P12). Most participants perceived urban greenery as emotionally restorative, although several respondents who rarely visited rewilded spaces expressed more neutral views.

Community Engagement in Urban Rewilding

Quantitative Findings

Community engagement received the highest average score among all constructs ($M = 4.22$, $SD = 0.62$), indicating strong interest in participation and involvement. Approximately 86% of respondents ($n = 43$) reported high involvement or a strong desire to participate in urban rewilding initiatives.

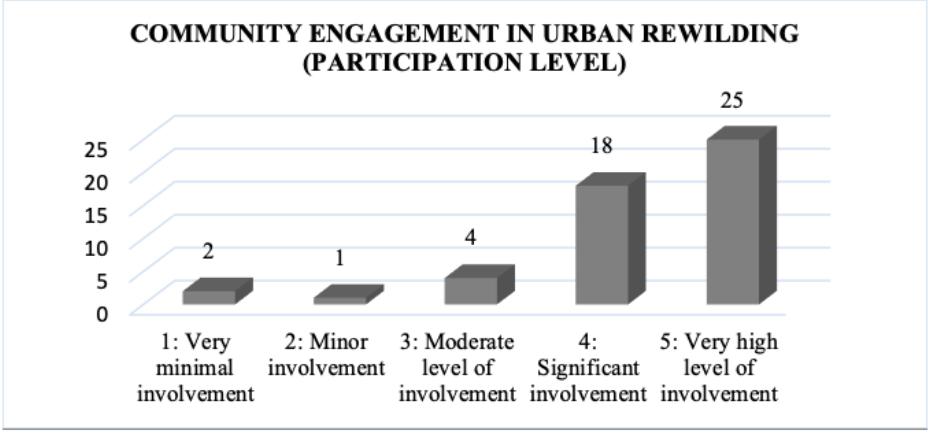


Figure 9: Community Interest in Participation in Urban Rewilding Initiatives
Source: The Author

Qualitative Findings

The thematic analysis identified the theme of Community Participation and Shared Responsibility. Participants emphasised the importance of involving local communities in planning and implementing rewilding initiatives.

One participant noted: "*While I occasionally join tree-planting drives, I wish to have more say in planning these initiatives*." (Participant P23). These responses indicate that participants not only supported urban rewilding initiatives but also desired more meaningful involvement in decision-making processes.

Integration of Findings

From Findings to Statutory Integration

The synthesis of quantitative and qualitative data reveals a robust consensus: urban rewilding in Ipoh is perceived not merely as an environmental upgrade, but as a catalyst for socio-psychological restoration. Quantitative metrics demonstrating moderate-to-high agreement on the benefits of rewilding are powerfully substantiated by qualitative narratives of emotional rejuvenation and community attachment. Analytically, this convergence underscores a reciprocal relationship between ecological health and human well-being. Participants identified specific interventions—such as native plantings and the naturalisation of public spaces—as direct contributors to both neighbourhood identity and environmental awareness. Consequently, these findings validate the necessity of embedding rewilding mechanisms, such as biodiversity corridors and ecological restoration zones, directly into statutory urban development frameworks. Furthermore, the strong desire for participatory planning indicates that collaborative governance is essential to maximise both ecological and social outcomes.

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Theoretical Implications: Biophilia and Green Urbanism

These findings offer crucial empirical validation for the biophilia hypothesis (Schiebel, Gallinat, & Kuhn, 2022) within a tropical, Southeast Asian urban context. The recurrent themes of stress alleviation and cognitive restoration experienced in naturalistic spaces suggest that participants perceived meaningful psychological value in ecological engagement. Beyond individual experiences, the findings reinforce the broader principles of Green Urbanism by highlighting the perceived relationship between biodiversity enhancement, environmental quality, and urban liveability. The emphasis placed on community involvement further suggests that sustainable urbanism may benefit from participatory and human-centred planning approaches alongside ecological design strategies.

Practical Implications for Urban Planning

For urban planners and policymakers in Ipoh, this research translates theoretical concepts into actionable, evidence-based mandates. The clear association between ecological restoration and public well-being dictates a shift away from highly manicured, conventional landscaping toward biodiversity-sensitive infrastructure. Crucially, the overwhelming preference for community involvement signals a need to transition from top-down municipal planning to collaborative stewardship models. Integrating rewilding principles into local planning guidelines, public space design, and green infrastructure policies will not only cultivate environmental resilience but also foster inclusive, psychologically supportive urban landscapes sustained by public ownership.

CONCLUSION

This study addressed an important gap in Southeast Asian urban sustainability discourse by exploring community perceptions of urban rewilding initiatives and their perceived relationship with mental well-being in the rapidly developing city of Ipoh, Perak. Through a convergent mixed-methods approach, the findings indicate that residents generally support the transition from conventional urban greening toward more ecologically functional and naturalised urban spaces.

The integration of quantitative survey findings and qualitative narratives suggests that “managed wildness” is positively perceived in relation to emotional restoration, cognitive refreshment, stress reduction, and environmental quality enhancement. The findings further reinforce existing literature on the biophilia hypothesis and the principles of Green Urbanism, highlighting the perceived interconnection between ecological health and urban liveability within urban communities.

From a practical perspective, the study indicates that the success of urban rewilding initiatives may depend not only on ecological planning strategies but also on meaningful community participation and social integration. The

strong interest in participatory planning among respondents suggests that collaborative and community-oriented stewardship approaches could support the implementation of native planting, biodiversity corridors, and naturalised public spaces within urban environments.

Overall, the study contributes to the growing discourse on nature-based urban planning approaches in Malaysia by highlighting public perceptions toward urban rewilding within the context of Green Urbanism. While the findings are limited to a relatively small sample size and perception-based responses, the study provides useful preliminary insights for planners and policymakers seeking to promote more ecologically resilient, climate-responsive, and socially restorative urban environments in Ipoh and similar rapidly urbanising cities.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The study focused exclusively on Ipoh, Perak, Malaysia. The impacts of urban rewilding are influenced by cultural, socioeconomic, and environmental contexts unique to Ipoh. The findings may not be applicable to other regions, even within Malaysia, thus limiting broader applicability.

Future studies on the role of technology and innovative urban design in enhancing the impact of urban rewilding on mental health could be particularly beneficial. Overall, these avenues of research contribute to a more comprehensive understanding of the potential benefits and challenges associated with urban rewilding initiatives and their implications for community well-being.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this research.

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UNDERSTANDING CONSTRUCTION DEFECT PATTERNS DURING THE DEFECTS LIABILITY PERIOD: IMPLICATIONS FOR RESIDENTIAL PLANNING IN MALAYSIA

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Abstract

Construction defects present a persistent challenge within Malaysian residential projects, impacting long-term sustainability and the goals of national housing policies. This paper moves beyond mere defect occurrence, examining lessons learned from their occurrence during the defects liability period. A case study of 160 terrace house units in Kuala Terengganu was chosen. The research adopted a mixed-method approach. First, a quantitative research method was adopted to identify the type of defects. These data were sorted and transferred into the SPSS software version 29 using frequency analysis to analyse the defect patterns. The qualitative research method involved analysing the defects sheet list and conducting semi-structured interviews with the project manager and the site supervisor to investigate the causes of these defects. The data were then transcribed and analysed using content analysis. Findings reveal that architectural works are predominantly affected, with poor material quality, substandard workmanship and inadequate supervision identified as primary contributors. These insights hold significant implications for urban and housing planning, informing the strategic integration of quality assurance into residential development. It also provides actionable recommendations for policymakers and industry stakeholders to enhance building standards, minimise defects and promote a more resilient and sustainable residential built environment.

Keywords: Construction defects, residential projects, defects liability period, quality

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INTRODUCTION

The rapid pace of urbanisation in Malaysia has elevated the construction sector to a significant position within the national economy. However, alongside this growth, construction defects—defined in this study as non-conformities or failures in workmanship, materials, or design that deviate from specified standards—have emerged as a persistent and critical issue (Sellakutty & Rajendran, 2017; (UiTM) et al., 2023). These defects undermine not only structural integrity and aesthetic quality but also long-term sustainability outcomes in residential developments.

Defects are frequently attributed to deficiencies in project planning and implementation, including inadequate coordination among stakeholders, failure to identify early warning signs, and weak quality control practices (Najihah et al., 2023). Importantly, construction defects are not merely technical issues; they directly affect planning implementation mechanisms, including delays in approvals and certifications, increased inspection burdens, enforcement actions during the Defects Liability Period (DLP), and weakened feedback loops for improving future developments. As a result, defects contribute to cost overruns and inefficiencies, with studies estimating that approximately 2%–6% of contract values are spent on rectification works (Muhammuddin et al., 2023; Olanrewaju et al., 2021).

Despite regulatory frameworks such as the Housing Development Act (which mandates a 24-month DLP) and broader national policies (e.g., National Construction Policy 2030 and National Housing Policy 2030), existing studies indicate a gap between policy intent and on-the-ground implementation, particularly in relation to governance, enforcement, and stakeholder accountability. Furthermore, while prior research has identified general causes of defects, there remains limited empirical integration between defect occurrence data and planning decision-making processes, especially how defect trends inform approvals, inspections, and continuous improvement mechanisms in residential projects.

Research Gap

Current literature tends to (i) examine defects from a technical or cost perspective, or (ii) discuss policy frameworks at a high level, but rarely connects defect occurrence with planning implementation processes and governance mechanisms in a structured and evidence-based manner. There is also insufficient clarity on how defect data can be systematically utilised to strengthen regulatory feedback loops and improve future project delivery.

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Research Questions / Objectives

Accordingly, this study addresses the following questions:

1. What are the most prevalent types and causes of construction defects in Malaysian residential projects?
2. How do these defects impact planning implementation processes, particularly approvals, inspections, and enforcement during the project lifecycle?
3. What gaps exist between regulatory frameworks and actual practices in managing construction defects?
4. How can defect occurrence data be leveraged to improve governance, feedback mechanisms, and sustainable residential planning outcomes?

By addressing these questions, this research aims to provide actionable insights for project teams and policymakers to enhance construction quality and strengthen planning implementation practices. Ultimately, improving defect management contributes to more sustainable, resilient, and high-quality residential development in Malaysia, aligning with broader national and global sustainability goals.

LITERATURE REVIEW

Definition of Construction Defects

Construction defects are generally defined as deficiencies in design, workmanship, or materials that result in failure to meet intended performance or contractual requirements (Isa et al., 2016; Lambers et al., 2023). They may occur during construction or after handover and include both visible (patent) and hidden (latent) defects (Alabi et al., 2024). In this study, construction defects refer to observable or latent non-conformities arising from design, materials, workmanship, or process failures that compromise building performance, quality, or compliance. This definition enables defects to be examined not only as technical issues but also in relation to planning implementation processes such as approvals, inspections, enforcement, and feedback mechanisms.

Types, Causes and Categories of Construction Defects

Existing studies show consistent patterns in defect types and causes within residential projects. Architectural defects are most frequently reported, followed by structural and mechanical defects, while electrical defects are less common (Olanrewaju et al., 2021). However, this trend may reflect visibility bias, as more noticeable defects are more likely to be reported by occupants (Amin, 2010). Defects are typically classified into patent defects, which are detectable during

inspection, and latent defects, which emerge during occupancy (Alabi et al., 2024).

The causes of defects are well established, including poor workmanship, inadequate supervision, substandard materials, design inconsistencies, and documentation errors (Sandanayake et al., 2021). Among these, workmanship and human-related factors are often the most significant, particularly in contexts with limited skilled labour. These upstream factors—workmanship quality, site supervision, and compliance with specifications—interact to influence defect occurrence. Weaknesses in these areas increase the likelihood of defects, which subsequently affect planning processes such as approvals, inspections, enforcement during the Defects Liability Period, and regulatory feedback loops.

Despite these insights, the literature remains fragmented, often separating defect types from their underlying causes and lacking integration with planning implementation. To address this, this study adopts and refines the classification by Najihah et al. (2023), which categorises defect causes into design, material, documentation, workmanship, lack of protection, maintenance, natural factors, vandalism, user abuse, and wear and tear. This framework is selected for its comprehensive coverage and its ability to distinguish between controllable factors and external influences, making it suitable for analysing governance and regulatory responses.

Defects Issues in Residential Projects in Malaysia

In Malaysia, construction defects remain a persistent issue in residential developments despite existing policies and regulatory frameworks. Homebuyer dissatisfaction continues, particularly in low- and medium-cost housing, with common defects affecting key building elements such as roofs and walls (Talib et al., 2015). While the number of completed housing units has increased, the prevalence of defects highlights a gap between housing delivery and quality outcomes.

These defects not only affect building performance and user satisfaction but also disrupt planning implementation processes, including delays in approvals and certifications, increased inspection requirements, and enforcement actions during the Defects Liability Period. Furthermore, the absence of systematic feedback mechanisms limits the ability of regulatory bodies to learn from defect trends and improve future developments.

Accordingly, this study contributes by integrating defect types and causes into a unified framework, prioritising key defect drivers, and establishing a linkage between defect occurrence and planning implementation processes. This provides a practical basis for improving construction quality and strengthening planning governance in residential development. This persistent

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issue underscores the need for a more robust understanding of defect characteristics and their underlying causes within the Malaysian context (Olanrewaju et al., 2021). Specifically, previous research on Malaysian residential projects indicates that faulty design, poor workmanship, and substandard materials are principal contributors to construction defects (Shooshtarian et al., 2024), with non-structural cracks being particularly prevalent (Najihah et al., 2023.). Further investigations into defects in Malaysian residential projects have also highlighted issues stemming from improper installation techniques and inadequate soil analysis, which contribute significantly to various structural and aesthetic deficiencies (Abdul-Rahman et al., 2012). The rapid development and demand for housing projects in Malaysia have led to increased reports of defects, indicating that latent defects, which often surface after the defect liability period, are frequently linked to poor workmanship, climate conditions, and design flaws, including material selection and supervision during construction (Sahi et al., 2022; Saufi et al., 2023).

METHODOLOGY

This study adopts a mixed-methods research design to provide a comprehensive understanding of construction defect patterns and their underlying causes in Malaysian residential projects. The integration of quantitative and qualitative approaches enables both statistical identification of defect trends and in-depth exploration of causal factors, thereby strengthening the overall analytical rigour
A case study of 160 units of terrace houses in Kuala Terengganu is chosen as the sample. Kuala Terengganu was chosen since it is among the states experiencing rapid growth for the construction of residential projects and the fastest district in terms of construction rate in Terengganu. The project defect sheet list reported by the home buyers was analysed manually to investigate the types of defect occurrence according to the work discipline i.e., architectural defects, structural defects, mechanical defects, and electrical defects. The data obtained was transferred into Statistical Packaging for Social Science (SPSS) Version 29 and analysed using frequency analysis.

Next, an online semi-structured interview with the project manager and site supervisor was conducted to ascertain the causes of each defect identified previously. Moreover, both had experienced managing projects for more than 28 years. The interviewees were contacted using phone calls to set the date and time for the interview. They agreed to be interviewed via Google Meet on 26 January 2023 at 3:00 p.m. This data was transcribed and analysed using content analysis.

FINDINGS

Types of Defects

Table 1 outlines the overall type and number of defects by element according to work disciplines. In addition, it also ranks the most defective element based on their work disciplines.

Table 1: Types and Numbers of Elemental Defects According to Work Discipline

Element/Work discipline	Total no of defects	Rank
A) Architectural		
1. Roof	132	5
a) Blockage of gutter system and rainwater downpipe	104	
b) Missing roof tiles	28	
2. Staircase	52	6
Peeling off paint	52	
3. Wall, Floor and Ceiling Finishes	2524	1
a) Peeling of paint at wall	558	
b) Dirty and stain mark	542	
c) Peeling of paint at ceiling	380	
d) Plaster crack	256	
e) Unevenness of paint	196	
f) Poor finishing of wall plaster	185	
g) Watermark at ceiling due to roof leakage	164	
h) Poor installation of floor tiles	158	
i) Plaster peeling	76	
j) Fungus on the wall	9	
4. Windows & Fittings	438	3
a) Poor fixing of window	222	
b) Dirty and stain mark at window	188	
c) Hairline crack	28	
5. Doors	670	2
a) Dirty and stain mark at door	200	
b) Door leaf damaged	182	
c) Door frame damaged	138	
d) Poor fixing of door	94	
e) Door leaf difficult to open	56	
6. Sanitary Fittings, Fixtures & Toilet Cubicles	288	4
a) Loose fittings / Improper installation of fittings	164	
b) Incomplete installation of plug socket	86	
c) Dirty and stain mark	38	
B) Structural		
1. Wall	138	1
Wall crack	138	

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Element/Work discipline	**Total no of defects**	**Rank**
2. Floor	114	2
Floor crack	114	
3. Ceiling	70	3
Ceiling crack	70	
4. Skirting	32	6
Skirting crack	32	
5. Floor trap	50	5
Blockage of floor trap	50	
6. Drainage	66	4
a) Drainage crack	32	
b) Blockage of drainage	34	
7. Pipe	10	7
Blockage of pipe	10	
C) Mechanical		
1. Pipe Installation	98	1
a) Wrong pipe installation	48	
b) Plumbing equipment damaged	26	
c) Overflow of pipe	24	
D) Electrical		
1. Electric Supply System & Fittings	96	1
a) Dirty socket	86	
b) Dirty ducting	6	
c) Unplugged fitting	4	

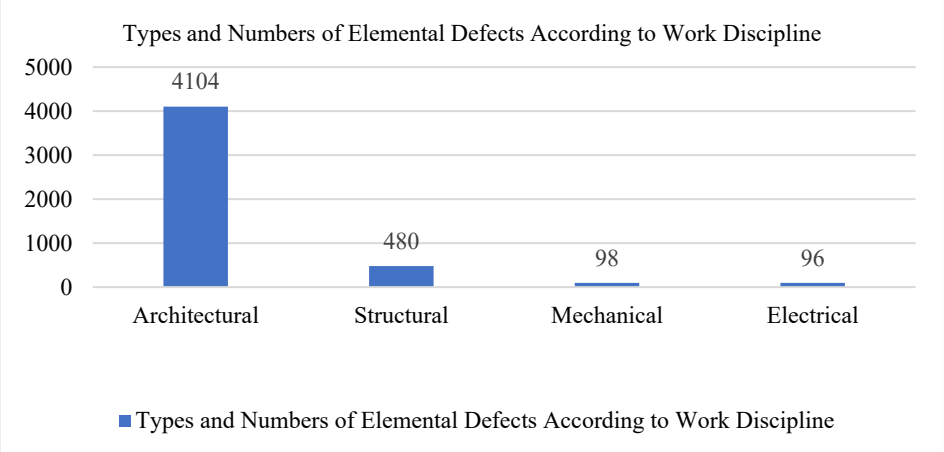


Figure 1: Types and Numbers of Elemental Defects According to Work Discipline

Figure 1 illustrates the distribution of elemental defects according to work discipline. Architectural defects recorded the highest number of cases (4,104), followed by structural (480), mechanical (98), and electrical defects (96).

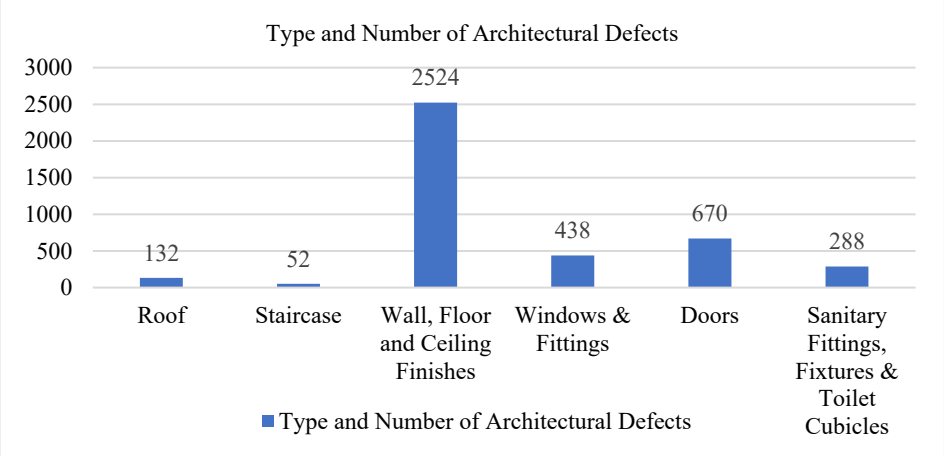


Figure 2: Type and Number of Architectural Defects

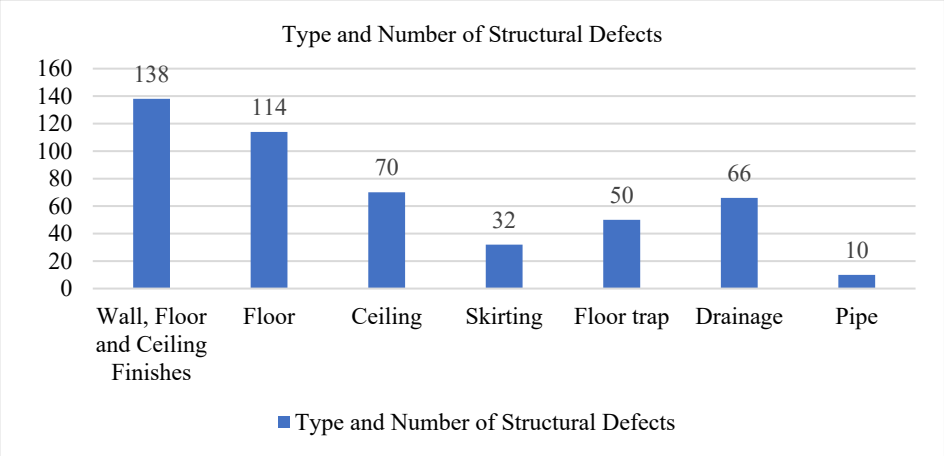


Figure 3: Type and Number of Structural Defects

As illustrated in Figure 2, architectural defects were predominantly associated with wall, floor, and ceiling finishes, accounting for 2,524 cases. This was significantly higher compared to other architectural elements such as doors (670 cases), windows and fittings (438 cases), and sanitary fittings, fixtures, and toilet cubicles (288 cases). Roof and staircase defects recorded the lowest frequencies, with 132 and 52 cases, respectively. The findings indicate that finishing-related works contribute substantially to the overall architectural defects during the DLP.

Figure 3 demonstrates the pattern of structural defects identified in the residential projects. The most frequently reported defects involved wall, floor,

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and ceiling finishes (138 cases), followed by floor defects (114 cases). Defects related to ceiling, drainage, floor traps, skirting, and pipes were comparatively lower. The low occurrence of pipe defects (10 cases) suggests that plumbing-related structural issues were less significant compared to finishing and flooring defects. Architectural works are disproportionately affected by defects when compared to other work disciplines such as structural, electrical, and mechanical elements. This suggests a critical area requiring intensified attention during the design, construction, and inspection phases, particularly concerning the finishing and aesthetic aspects of residential units. The prevalence of architectural defects may indicate deficiencies in detailing, material application, or supervision specific to these visible and often user-facing elements. Seven architectural elements were involved with Wall, Floor and Finishes being the most defective elements recorded. Meanwhile Staircase was identified as the least defective work. In structural works, building cracks as the most defective element and pipe works was identified as the least defective element in mechanical works. Only one element as involved in both mechanical and electrical works. For mechanical works, wrong pipe installation is the major defective works occurred and overflow of pipe is the least defective work. Meanwhile, only electrical supply system and fittings were recorded in electrical works.

Causes of Defects

Table 3 presents the 32 causes of defects in architectural works. Amongst these causes, four principal causes emerged: poor workmanship, works not accordance to specification, lack of supervision and a pervasive lack of supervision. These causes frequently interact to exacerbate the incidence of defects, underscoring critical areas where existing construction processes and their oversight require immediate and substantial modification (Najihah et al., 2023). Poor workmanship directly results in defects installations and finishes and inadequate construction management (Fromsa et al., 2020).

Table 2: Causes of Architectural Defects and Its Frequent Causes

Element	Causes of defects	The most frequent causes of defects
Wall, Floor and Finishes	Works not accordance to specification	1. Poor workmanship 2. Works not accordance to specification 3. Lack of supervision 4. Lack of protection
	Lack of protection	
	Poor workmanship	
Doors and Fittings	Works not accordance to specification	
	Inappropriate door material	
	Lack of supervision	
	Wrong measurement of doors and doors margin	
	Exposed to weather	
	Lack of protection	
	Poor workmanship	

Element	Causes of defects	The most frequent causes of defects
Ceiling finishes	Works not accordance to specification	
	Roof leakage	
	Poor workmanship	
	Lack of supervision	
Windows and Fittings	Lack of protection	
	Poor workmanship	
	Different floor level	
	Works not accordance to specification	
	Lack of supervision	
Sanitary Fittings, Fixtures and Toilet Cubicles	Works not accordance to specification	
	Poor workmanship	
	Lack of supervision	
	Lack of protection	
Staircase	Lack of protection	
	Works not accordance to specification	
Roof	Poor workmanship	
	Works not accordance to specification	
	Lack of supervision	

Works not accordance to specification can lead to premature failure and aesthetic compromises and is influenced by factors affecting the use of substandard materials (Faremi et al., 2020). Critically, the lack of effective supervision often allows both poor materials and workmanship to go unaddressed, perpetuating the cycle of defects. The inability of the supervisory team to identify and rectify poor-quality materials at critical junctures is a substantial contributing factor (Sin et al., 2024).

Table 3: Causes of Structural Defects and Its Frequent Causes

Element	Causes of defects	Frequent causes of defects
Building Crack	Poor workmanship	1. Poor workmanship 2. Works not accordance to specification 3. Lack of supervision 4. Lack of protection
	Works not accordance to specification	
	Lack of supervision	
	Roof design failure	
Blockage	Lack of protection	
	Poor workmanship	
	Works not accordance to specification	
	Lack of supervision	
Drainage	Lack of protection	
	Poor workmanship	
	Works not accordance to specification	
	Lack of supervision	

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Table 4 provides crucial insights into the nature of structural defects in residential projects. Like architectural works, poor workmanship, works not in accordance with specification, lack of supervision and lack of protection are the four most frequent causes of defects. The table consistently identifies poor workmanship as a frequent cause for building cracks, roof failures and drainage problems. This indicates that a significant portion of structural defects stems directly from the inadequate execution of construction tasks by labour. Work not in accordance with specification directly results in defects installations and finishes that can compromise the structural integrity and functionality of various building elements (Fromsa et al., 2020). Lack of supervision is due to the inability of supervisory teams to identify and rectify poor-quality materials (Sin et al., 2024). Thus, directly correlates with an increased incidence of defects. Addressing these overarching findings is paramount for developing robust quality assurance frameworks and fostering genuinely sustainable residential planning in Malaysia.

Table 4: Causes of Mechanical Defects and Its Frequent Causes

Element	Causes of defects	Frequent causes of defects
Pipe installation	Works not accordance to specification	Works not accordance to specification

Table 5: Causes of Electrical Defects and Its Frequent Causes

Element	Causes of defects	Frequent causes of defects
Electric Supply System and Fittings	Lack of protection	Lack of protection Works not accordance to specification
	Works not accordance to specification	
	Lack of supervision	

Table 5 and 6 indicates causes for both mechanical and electrical defects. It is found that works not accordance to specification is a primary cause of defects in both disciplines. This signifies a fundamental breakdown in translating design intent and technical requirements into built reality. When construction deviates from approved plans, material specifications, or performance standards, the resulting structures are inherently vulnerable to defects. Clear and carefully prepared specifications are crucial for conveying technical requirements, but their misuse or non-use can lead to disputes and defects. Problems with plumbing systems are commonly reported by residential building owners, and if left unaddressed, these defects can lead to significant damages and repair costs (Gurmu & Mudiyanselage, 2023).

DISCUSSION

This paper provides crucial insights for policymakers, industry practitioners, and all stakeholders involved in Malaysia's residential projects. It offers a

foundational understanding necessary to minimise defects and ensure the long-term durability and dependability of residential constructions. The persistent issue of construction defects, notably within architectural works and predominantly attributable to poor material quality, deficient workmanship, and inadequate supervision (Najihah et al., 2023), necessitates a fundamental re-evaluation of current planning and development paradigms.

From a planning perspective, these observed defects are not merely isolated construction failures but are indicative of broader systemic challenges embedded within the residential development lifecycle (Yarnold et al., 2023). The Malaysian government's focus on quality and durability, as articulated in the National Housing Policy 2030, clearly acknowledges the gravity of this issue The identified root causes suggest that existing planning regulations, building codes, and enforcement mechanisms may be insufficient or inadequately implemented Integrating comprehensive quality assurance proactively into the entire residential planning lifecycle is therefore paramount. This entails several key strategies:

a) Pre-Construction Planning and Design Review -This requires the implementation of more stringent reviews of proposed materials and construction methods during the planning permission application process. Patel et al., 2021 suggested that the developers should be mandated to submit detailed quality management plans outlining how materials will be sourced, quality checked and installed to meet national standards.
b) There is a need to enhance the capacity and frequency of independent site inspections and supervision by regulatory bodies, as current inspections often have limitations. This would ensure strict adherence to approved plans, established building standards, and quality management protocols throughout the construction period (Salvi & Kerkar, 2020). In developing countries, effective quality management practices are critical, and challenges are often attributed to ineffective quality management systems (Odiba et al., 2021).
c) Post-occupancy evaluation and feedback loops: Utilising data and feedback gathered during the DLP is essential to refine future planning guidelines and construction practices (Lee et al., 2020). Establishing a robust feedback mechanism allows "lessons learned" from defects to directly inform improvements in subsequent projects, creating a continuous improvement cycle within the planning and construction ecosystem. This can involve assessing the impact of defects to make sustainable decisions on continuous improvement activities (Milion et al., 2021). Defect reporting and building inspection processes are crucial before handover to new owners.

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Addressing construction quality directly contributes to Malaysia's overarching sustainable urban development goals. By ensuring the long-term durability and dependability of residential constructions, the nation fosters a more resilient and sustainable conscious construction industry. Government agencies and planning authorities must foster greater collaboration with developers, contractors, and homeowners to establish a shared culture of quality and accountability. This includes strengthening regulatory frameworks, providing clear and accessible guidelines, and promoting transparent communication channels (Al-Otaibi et al., 2025). Educational initiatives targeted at project teams can also significantly enhance both cost-efficiency and overall construction quality, as supported by academic understanding of effective project management (Aqlima et al., 2024: Fromsa et al., 2020). Ultimately, the strategic imperative is to shift the focus from reactive defect rectification to proactive defect prevention, thereby embedding quality assurance as a core principle of residential planning strategy across Malaysia.

CONCLUSION

The research critically underscores the imperative of effective management of construction defects in Malaysian residential projects, particularly during the DLP. By thoroughly examining defect occurrences, the research sheds light on underlying systemic issues that, if addressed, could foster a more robust and sustainable construction industry. The findings clearly demonstrate that architectural defects are the most prevalent, with their primary causes consistently identified as poor material quality, poor workmanship and inadequate supervision.

For residential planning in Malaysia, this research provides crucial evidence to inform and enhance existing quality assurance frameworks, policy interventions, and sustainable practices. The direct links established between construction defects and national policies underscore that construction quality is not merely an operational detail but an integral and foundational component of broader national development objectives. By strategically addressing the root causes of defects, Malaysia can proactively advance towards developing a resilient and sustainable construction industry, thus enhance the livability of its urban areas.

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BUILDING INFORMATION MODELLING (BIM) CONTRACT ADMINISTRATION: CURRENT KNOWLEDGE, PRACTICES, AND ROLE ENHANCEMENTS FOR MALAYSIAN QUANTITY SURVEYORS

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Abstract

Building Information Modelling (BIM) has significantly improved planning, design, and construction productivity, while also strengthening the roles and functionality of Quantity Surveyors (QSs) in contract administration. This study aimed to assess the extent of QS knowledge and practices regarding BIM-based contract administration, thereby suggesting prospects for enhancing QS roles in the modernised era of the construction industry. A quantitative research method, involving questionnaire surveys, was employed. The results and findings from the descriptive statistics and reliability analysis revealed that although QSs have a relatively high level of knowledge regarding BIM contract administration, there is a lack of standardisation and documented references for managing BIM contracts in local practices. The study further proposed the "three-level enhancement framework" based on the ranked-survey responses to further improve the existing QS roles in contract management, specifically during the pre-construction, construction, and post-construction stages. This, in turn, contributes to a better understanding of the importance of QS involvement during the planning stage of BIM integration. Overall, the study outcomes promote full collaboration through a conducive digital environment that values the QS functional roles in digital construction and serves as a strategic enabler for urban planning and sustainable developments in Malaysia.

Keywords: Building Information Modeling (BIM) contract administration, quantity surveying roles, governance and procurement, construction development projects, Malaysia context.

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INTRODUCTION

Globally, the construction industry is a significant contributor, generating substantial revenue with an annual production of nearly $10 trillion in construction-related goods and services (Chen et al., 2022). Thus, Building Information Modelling (BIM) has been established as a catalyst to support sustainable development, incorporating digital construction (CIDB, 2021). BIM plays a significant role in planning, designing, constructing, operating, and maintaining buildings throughout their entire life cycle (Alwee et al., 2023). As one of the leading parties in supporting sustainable development and digital construction, Quantity Surveyors (QSs) are well recognised for providing cost and contract management services from the initial stage until delivery completion.

Nevertheless, the published report by the Construction Industry Development Board (CIDB) demonstrates that the adoption rate of BIM accounted for 55% of its current uptake in the local construction industry (CIDB, 2021). Compared to the global players such as the United States (US), the current adoption rate achieved 80%, China at 52%, and India, which ranged at 10% to 18% (Zhen et al., 2025). These figures demonstrated that the current adoption in Malaysia remains lagging. These results further indicated that more opportunities can be learned from advanced global adopters to bridge Malaysia's policy needs and technological gaps. In countries such as the US and the United Kingdom (UK), strong government mandates have proven effective in accelerating BIM adoption (Chowdhury et al., 2024), creating industry-wide momentum. By contrast, in Malaysia, the high investment cost of BIM applications remains a notable concern, which continues to hinder broader uptake (Al-Ashmori et al., 2022).

In the current local context, many QSs still rely on conventional contract administration when managing cost and construction contract practices. This approach is hindered by a lack of technical interoperability when working with other parties, making it challenging to eliminate conventional working processes (Ahmed et al., 2022). Consequently, some QSs had difficulty understanding BIM practices and contractual approaches when managing actual construction projects (Shahid et al., 2025). Empirical studies further indicate that contractual impediments can lead to disputes, particularly during the implementation of BIM-based projects (Erpay & Sertyesilisik, 2021). Although BIM scholars acknowledge these emerging issues in recent literature, current empirical research exploring how the evolving roles of QSs, particularly in contract administration, is relatively unknown. Lack of standardised BIM guidance for current QS practices can hinder the effective contract and cost monitoring, in which both aspects are crucial for successfully delivering the project development.

In response to these issues, this study examines the extent of knowledge and practices among QS practitioners regarding BIM-based contract administration, which is critical for optimising BIM implementation in sustainable development construction projects. To achieve this aim, three research objectives are defined: (1) to identify the current knowledge on BIM contract administration amongst QS in Malaysia; (2) to investigate the current practices on BIM contract administration amongst QS; and (3) to propose enhancements to the QS roles on BIM contract administration to support the revolution of digital construction for future Malaysian construction industry.

Furthermore, a specific focus on the Malaysian context is necessary to align with recent efforts by the government and the CIDB. This is outlined in the National Construction Policy 2030 (NCP) and the new economic framework, *Ekonomi Madani*, which emphasises the need for future enhancements in BIM implementation and other technological tools in the built environment. Additionally, improvements in the contractual and governance aspects of BIM implementation in Malaysia are essential to enhance the practical usability of technology integrations in projects, particularly for QSs who also serve as contract administrators when managing construction contracts. Moreover, QS's expertise in governing the procurement policies and risk management facilitates the integration of digital technologies into planning and development, thereby empowering more resilient and sustainable developments for the future Malaysian construction industry.

LITERATURE REVIEW

Current Knowledge of BIM Contract Administration Among Quantity Surveyors

For the past two decades, BIM has emerged in the construction-related literature as a tool that can develop robust modelling systems integrating people, processes, and technology for various design, construction, and operation activities (Omar & Mohd Fateh, 2023). Gerbert et al. (2016) claimed that digital technologies such as BIM employed in urban development projects will significantly reduce project lifecycle costs by approximately 20% and improve project delivery timelines (Gerbert et al., 2016).

During the planning stage, BIM enables local authorities to review planning submissions using an automated compliance checking process, thus minimising human errors and increasing the effectiveness of the approval workflow (Fuzi et al., 2024). During the design stage, BIM is recognised as a platform that facilitates data and model exchange among stakeholders, thereby eliminating work duplication (Zainon et al., 2018). It has also been revealed to help reduce construction costs and increase work productivity, particularly during the construction phase. Thus, there is no doubt that the foundation of

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digitalisation in the construction industry is the information and mathematical modelling of end-to-end processes. This enables work to be optimised in terms of cost, time, business suitability, and with a minimum negative impact on the built environment (Honcharenko et al., 2021). As the cost estimator involved in estimating costs for the whole project lifecycle, QSs must understand that regulatory compliance through BIM-based planning processes can streamline data management and project monitoring during construction and operation. This is particularly true for large-scale projects that involve the strategic integration of township developments and multiple utilities and infrastructure considerations.

In construction development projects, QSs extend beyond managing costs and budgets. Their roles have also expanded to include governance, procurement and contract management tasks. Past scholars have criticised the scope of work associated with QSs as being time-consuming and prone to human errors (Alwee et al., 2023). An empirical study noted that applying BIM technology has resulted in more comprehensive and accurate drawings while reducing the workload of QSs and minimising assumptions and misinterpretations in measurement tasks (Ismail et al., 2021). By adhering to the proper BIM process and workflow, project stakeholders, including QSs, can enhance their knowledge of cost and contract administration tasks through seamless collaboration and reduce communication gaps with other project stakeholders.

QSs may find that assessing and analysing cost management procedures becomes much easier through BIM applications than with conventional techniques, provided they possess the right process and workflow knowledge (Keung et al., 2022; Soon et al., 2024). In line with this, the idea that the application of BIM in the construction industry is becoming increasingly recognised and utilised. For example, in Hong Kong, BIM has become commonly integrated for public and private projects (Keung et al., 2022). Although the rate of BIM usage is increasing, the involvement of QSs in BIM remains limited. This validates the argument that there is still limited knowledge on implementing BIM into reality, particularly when conducting cost estimation and other contract administration tasks by QSs (Alwee et al., 2023).

Current Practice on BIM Contract Administration Among Quantity Surveyors

To achieve the project's goals and objectives, QSs can leverage the full potential of BIM to enhance their professional practices and improve the efficiency of cost and contract management. During the pre-design estimation phase, a QS will be required to produce a feasibility study to determine the building cost, utilising limited sketches and assumptions about the building (Alwee et al., 2023). This cost plan is crucial in determining the time and budget allocations for the

construction project. Considering this evidence, allocations of building cost data can be easily and automatically extracted from the model. Thus, BIM helps generate a reasonable and accurate cost estimation required by QSs, while also identifying potential risks of cost overruns (Halil et al., 2024). An e-tender can be a web-based platform (Azizi et al., 2021). Accordingly, BIM simplifies the tender process, reducing the time and workforce required to produce cost estimates while increasing the accuracy and reliability of the results (Rashidi et al., 2024). The contractor will only need to download the documents from the website and then submit the Bills of Quantities (BQ) with the pricing to the website for the following tender evaluation process. In the pre-construction stage, the production of QS can be conducted seamlessly using an automation process with BIM-plugged-in software. Updating BQ could be performed much more easily when there are changes in the model (Soon et al., 2024).

Once the contract was awarded between the client and contractor, important contract administration tasks involved site supervision and monitoring to assess project progress for interim payment certifications (Alwee et al., 2023). This construction stage also requires the QS to spend more time visiting the site every month to check the actual work progress against the planned schedule. Results from empirical data support that BIM can facilitate production and visualising work progress, as monitored using Unmanned Aircraft System (UAS) for tracking, monitoring, and site verification at construction projects (Chen et al., 2022). This can effectively increase the accuracy of data collection on-site progress and speed up the quantity of surveying work. Once the construction is completed, BIM information and data significantly aid maintenance purposes (Ismail et al., 2021) when developing maintenance plans and schedules. Taking these considerations together, BIM can also be utilised effectively to enable informed decision-making based on project performance, operational aspects, and economic factors.

Enhancements to the Quantity Surveyors' Roles in BIM Contract Administration

During the Pre-construction Phase

Improving the contract administration process is crucial to ensure transparency through early integration, such as in the BIM-based planning and designing stages. Detailed policy guidelines and BIM contract requirements should also be outlined in accordance with project standards and outcomes (Alwee et al., 2023). Clearly defined project standards and procedures can help parties utilise BIM effectively during the pre-construction stage to accurately estimate the project's financial costs and expenses, facilitating bidding during the tendering process (Rashidi et al., 2024). Additionally, Manzanares et al. (2023) proposed a more streamlined estimation process that provides real-time and up-to-date data lock-

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in, preventing missing items from occurring during the estimation process. Accordingly, clarifying rights and obligations among all contracting parties should be established and identified during the design phase to ensure a smooth workflow and prevent future conflicts between the design team and the construction company (Mohammadi et al., 2024).

During the Construction Phase

One of the advantages of 4D models is their ability to visualise the progress of construction activities, allowing for the monitoring and control of construction time (Alwee et al., 2023). Therefore, BIM can provide a clear understanding of comparing the planned schedule with the actual progress on site to ensure that the project aligns with the project timeline. Moreover, it could identify early risks to avoid delays, and corrective actions can be planned as soon as possible. Apparently, the role of BIM in managing conflicts and reducing disputes has been proven to help manage and resolve conflicts in the construction industry. This is further confirmed by Khawaja and Mustapha (2021), who remarked that BIM has been demonstrated to be highly effective in reducing the number of variations and Requests for Information (RFIs), which helps to achieve certainty goals in terms of time and cost.

During the Post-construction Phase

The significant benefit of BIM in this phase is the transfer of building data to a Facility Management (FM) system, which includes integration, allowing for more efficient and effective scheduling, building assessment, and maintenance history tracking (Zainon et al., 2018). Additionally, BIM can generate data directly from the cloud database for maintenance planning purposes, enabling it to create an optimal maintenance schedule tailored to the project's specific conditions. This process is crucial for QSs to understand, as multiple parties must comprehend how BIM operates as the centralised data system for the decision-making process (Alwee et al., 2023; Ismail et al., 2021).

To advance specific knowledge and elevate current practice among QS involved in BIM-based projects, it is evident that BIM facilitates information flow and project coordination from the pre-construction process through to the post-stage for future operational works. In the pre-construction phase, the results of the feasibility study and the tender process can be simplified in the estimation process. During construction, BIM is viewed as helpful in monitoring and controlling construction progress to avoid risks and disputes. Meanwhile, during the post-construction phase, BIM effectively plans maintenance scheduling for later operation and maintenance.

Conceptually, the synthesis from the literature review maps out three measurable constructs known as (i) Knowledge, (ii) Practice and (iii) Role enhancements that become the dimensions used in the data collection process.

RESEARCH METHODOLOGY

This study employs a quantitative research approach to assess the identified constructs and variables from the literature on the QSs' knowledge, current practices and future enhancements in BIM contract administration. The methodology is designed to systematically collect, analyse, and interpret data to provide empirical insights from the two components and propose potential improvements to the QS roles for future governance in managing BIM construction contracts.

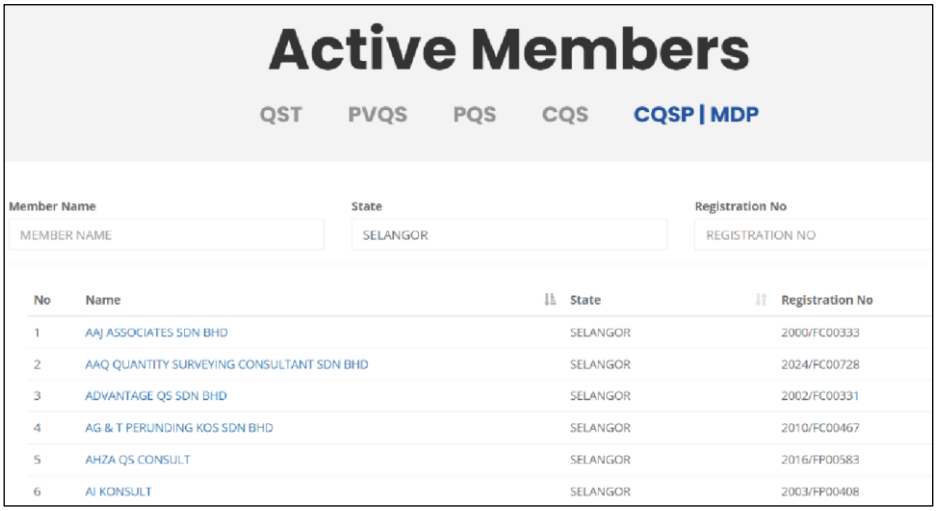


Figure 1: List of registered members of QSs with the BQSM
(Source: www.bqsm.gov.my)

In particular, the primary data was collected using structured questionnaires distributed to QSs in *Klang* Valley, Malaysia. The finalisation of the population is being collected through registration with the Board of Quantity Surveyors Malaysia (BQSM), which has produced a total of 2,505 members. After formulating the sample size calculation, the required number of respondents was reduced to 246. This sample size included QSs in various professions, such as QS technologists, provisional QSs, professional QSs, consultant QSs, and consulting quantity surveying practitioners (refer to Figure 1). The final data collection stage yielded 37 responses (R: 37, equivalent to a 15% response rate) following a series of online survey distributions and then proceeded to the data

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analysis stage. Note that low participation from the respondents presented a limitation in gathering replies and feedback, despite several reminders, follow-ups, and targeted emails being conducted to overcome this challenge in the data collection process.

Previous scholars have criticised the acceptance of modest participation (Dillman et al., 2014), which is unusual, particularly in industry-based and specialised respondent group surveys. This includes those in the construction-related field, where practitioners often have heavy workloads that lead to survey fatigue during the data collection process. Previous research (Fellows & Liu, 2015) also acknowledged that this issue is commonly faced by scholars in construction management research, whereby respondents are often inaccessible due to time constraints. Thus, a step was taken to reduce the risk of non-response bias. For instance, the study included cross-checking of the respondents' demographics against the broader target population (by referring to the BQSM website), which resulted in no substantial bias in the research sample size. Indicatively, the findings somehow remained reliable and informative as they were obtained from experienced QS practitioners across diverse categories (developers, contractors, consulting firms, and others).

The questionnaire included multiple-choice questions, Likert scale responses (scale1-4 to minimise neutral bias), and open-ended questions to capture a diverse range of perspectives. The collected data were analysed using the Statistical Package for the Social Sciences (SPSS) to ensure rigorous statistical interpretation. The analysis consisted of (1) descriptive analysis that is used to summarise the characteristics of the respondents, (2) frequency distribution that is applied to determine common responses, and (3) reliability test that is conducted to measure the internal consistency of survey responses, ensuring the validity of the results. A Cronbach's Alpha test was performed to assess the internal consistency of the questionnaire responses. The reliability coefficient aimed for a threshold of 0.7 or higher, ensuring data consistency.

Table 1: Results from the reliability test

Construct	Number of items	Cronbach's Alpha	Level
QS current knowledge	10	0.809	Good
QS current practices	10	0.887	Good
QS roles for future enhancements	15	0.947	Excellent

Based on Table 1 results from the reliability tests demonstrated that coefficient values for all three components are accurate, consistent and reliable for the subsequent interpretation of results and findings (Cronbach's Alpha coefficient of 0.809 for Objective 1 on the QS current knowledge coefficient of

0.887 for Objective 2 on the QS current practice, and the Cronbach's Alpha coefficient of 0.947 for Objective 3 on the QS roles for future enhancements).

RESULTS AND FINDINGS

Background of the Respondents

Demographic information refers to the background details of the target respondents. By referring to Table 2, the study revealed that the largest number of respondents had less than five years of experience in construction, accounting for 18 (48.6%) of the total.

This was followed by 11 to 15 years of experience, which accounted for seven (18.9%) of the total. Finally, the lowest experience in construction was six to ten years of experience and more than 15 years, which resulted in a total of only six for each (16.2%). Regarding the current professions of the respondents, the largest number of current professions are from consulting firms, which comprise a total of 13 (35.1%). This is followed by 11 QSs from contractors (29.7%) and seven from other fields (18.9%). The professions collected here include those from government agencies and claims consulting agencies. Lastly, the lowest profession among the respondents is that of developers, at six (16.2%).

Table 2: Information about the respondents

Item	Information	Number of Respondents	Percentage (%)
Experience in Construction Sector	Less than 5 years	18	48.6%
	6 – 10 years	6	16.2%
	11 – 15 years	7	18.9%
	More than 15 years	6	16.2%
Quantity Surveying Field	Developer	6	16.2%
	Contractor	11	29.7%
	Consulting Firm	13	35.1%
	Others	7	18.9%
Experience with BIM Implementation	Less than 3 years	30	81.1%
	4 - 6 years	5	13.5%
	7 -9 years	1	2.7%
	More than 10 years	1	2.7%

The above table also presents the respondents' years of experience in BIM implementation. The study results reveal that the largest number of years of experience in BIM implementation is less than three years, which accounts for 30 (81.1%) of the total. Then, it is followed by four to six years of experience, which accounts for five years (13.5%). Finally, the lowest experience in BIM implementation is seven to nine years and more than nine years, resulting in one each (2.7%). Therefore, respondents' involvement in BIM implementation is still relatively new. Nonetheless, the results suggest that strong theoretical

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understandings, embedded in formal education, help them in their early-career development, although they have limited hands-on practice in the construction industry.

Current Knowledge of BIM Contract Administration Amongst QS

A few significant results are presented in Table 3 regarding the current understanding of BIM contract administration among QSs in the local construction industry.

The requirement for a strong financial investment (K5) was ranked highest (mean score = 3.76) in implementing BIM and is also acknowledged as one of the challenges faced in the current industry. QSs are required to conduct additional cross-checking work (K6), ranked second, with a mean score of 3.65. The third-ranked group, with a mean of 3.51 regarding the current knowledge, indicated that updating design changes can be performed seamlessly (K2), as agreed upon by the respondents involved in the study. Fourth place (mean = 3.46) highlighted that BIM could assist decision-making, indicating that most QS agreed with that functionality when administering construction projects using BIM-based processes (K4). Additionally, ranked number five with a mean of 3.38, the study revealed that BIM helps prevent data loss and errors (K3) as part of the current knowledge widely agreed upon by QS when integrating with BIM.

Table 3: Current knowledge of BIM contract administration amongst QS

Item	Current Knowledge	Mean	Standard Deviation	Rank
K1	BIM technology provides comprehensive and accurate information, thus reducing QS workloads	3.35	0.58766	6
K2	The process of updating design changes can be done seamlessly with the help of BIM	3.51	0.60652	3
K3	BIM helps prevent data loss and errors	3.38	0.72078	5
K4	BIM assists the decision-making process throughout the project	3.46	0.60528	4
K5	Strong financial investment is required to successfully implement the BIM in practice	3.76	0.43496	1
K6	QSs are required to do additional cross-checking of data in the BIM cloud to ensure the accuracy of data	3.65	0.53832	2
K7	BIM models need to be updated regularly to deal with real-data changes from time to time	3.30	0.70178	7

With a mean score of 3.35, QS further suggested that comprehensive and accurate information could reduce the workload during collaboration with other project stakeholders (K1). Finally, with a mean of 3.30, many QS understood that regular updates on the BIM models are necessary to capture real-

world changes over time during project implementation (K7). Although respondents reported being relatively proficient in BIM-based knowledge, it may be inferred that major barriers such as high investment costs and added workload could contribute to their constraints in implementing BIM effectively.

Current Practices on BIM Contract Administration Amongst QS

As presented in Table 4, the analysis results revealed several key findings regarding the current practice of BIM contract administration among QSs in the local construction industry. With a mean score of 3.59, the highest, most respondents agreed that operations and maintenance for buildings after completion (P8) could be achieved using 5D models that support lifecycle costings for facilities management. The process of generating BQ can be automated when integrating the work process via BIM integration (P3), which is ranked second, thereby increasing productivity in completing work (mean score = 3.54). The third mean score, 3.54, indicated that BIM contract administration practices could be streamlined for e-tendering and digital documentation (P4), thereby simplifying the lengthy conventional tendering process, which can be time-consuming.

Table 4: Current practice of BIM contract administration amongst QS

Item	Current Practice	Mean	Standard Deviation	Rank
P1	Preparation of a feasibility study during the planning stage is more efficient compared to the conventional process	3.41	0.79790	6
P2	The extraction process of cost data can be done directly from the BIM models to produce an accurate cost analysis	3.41	0.68554	7
P3	The process of generating BQ could be done automatically, which can increase productivity	3.54	0.55750	2
P4	e-tendering and digital documentation can simplify the complicated and long process of the traditional tendering process	3.54	0.69100	3
P5	The tender evaluation process can be done easily with the help of BIM	3.19	0.90792	8
P6	The tracking of project progress, interim payments, and variation works can be done effectively	3.43	0.80071	5
P7	Analysing construction progress can be done remotely with the help of visualisation and progress monitoring using 4D models and simulations	3.51	0.50671	4
P8	Operations and maintenance can be achieved with the use of 5D models	3.59	0.55073	1

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The fourth-ranked group noted that most QS respondents believed progress at the site could be monitored remotely with the aid of visualisation (P7), especially when using 4D models to track site progress through model simulations (mean score = 3.51). The respondents further agreed that tracking work progress, particularly for tracking variation works and monitoring interim payments (P6), could be performed effectively using a BIM-based process. This fifth rank achieved a mean score of 3.43 from the analysis. Additionally, with a mean score of 3.41, the study revealed that work associated with preparing feasibility studies could streamline various QS tasks from the outset (P1), thereby increasing efficiency in meeting the client's needs. Therefore, BIM enhances the data extraction process to generate accurate cost data, facilitating effective cost analysis (P2). The final mean score from the analysis (3.19) revealed that many QS agreed that having the right knowledge about the BIM work process helped them conduct the tender evaluation process more easily (P5) compared to existing manual processes still used in the industry.

The data appears to suggest that BIM practices enhanced automation processes in preparing BQ, facilitated seamless tendering procedures, and improved site tracking and monitoring works. However, this should rely on their sufficient BIM experience to work effectively via digitalised working processes.

Enhancement to the QS Roles in BIM Contract Administration

The respondents were asked to propose enhancements to the QS roles in managing BIM contract administration for future projects (Table 5). For contract administration during the pre-construction stage, clear stipulations on roles and responsibilities, with a mean of 3.43, demonstrated the highest agreement, emphasising the need for all project stakeholders to understand their obligations regarding BIM implementation in various project implementations (R2). The second-highest mean (3.32) indicated that clear stipulations regarding contract requirements are essential, as they identify each party's roles, including BIM work specifications, to ensure that contractual responsibilities are clearly defined (R3). Thus, transparency in the BIM contract formation is also essential (mean score = 3.30) to ensure that the client determines their BIM needs and deliverables (R1), ensuring all parties involved in BIM design and construction comply with the BIM requirements.

For contract administration during the construction stage, the highest mean score from the analysis (mean score = 3.46) indicates that a proper risk mitigation process must be determined early before any conflicts and issues arise during construction (R5). This ensures that the minimisation of actual risk occurrence can be considered early during project implementation. The second rank, with a mean score of 3.35, concerns all parties in optimising construction scheduling for site monitoring using a real-time platform to enhance collaboration

and provide greater transparency in achieving work completion (R4). Many respondents also suggested that communication at various levels in BIM collaboration (mean score = 3.30) needs to be improved, thus preventing contractual disputes from occurring while managing the projects (R6).

Table 5: Enhancement to the QS roles in BIM contract administration

Item	Enhancement to the QS Roles	Mean	Standard Deviation	Rank
	During Pre-construction			
R1	Transparency and efficiency in the BIM contract formation	3.30	0.66101	3
R2	Clarification on the roles and responsibilities of all project stakeholders	3.43	0.55480	1
R3	A clear understanding of contract requirements by defining the roles, specifications, and BIM deliverables	3.32	0.62601	2
	During Construction			
R4	Optimisation of construction schedules via visualisation and monitoring through real-time progress	3.35	0.58766	2
R5	Conflicts and issues during construction must be resolved by mitigating the risks early	3.46	0.60528	1
R6	Communication and collaboration should be improved to reduce and prevent disputes during construction	3.30	0.70178	3
	During Post-Construction			
R7	The decision-making process for planning maintenance activities should be done by centralising all data in the asset model	3.35	0.67562	1
R8	Streamline the data transfer process for the maintenance and operation phase to minimise the risks of errors	3.16	0.86646	2
R9	Improving the resource allocations for maintenance and operations management	3.35	0.63317	1

For the contract administration during the post-construction stage, most respondents highlight the significance of improving the decision-making process or planning maintenance activities using a centralised data management system to conduct asset management (R7) after the project is handed over to the end-users. Most respondents further agreed that having clear resource allocations is necessary to manage people, processes, and technology (R9) for operation and maintenance post-construction (mean score = 3.35). Finally, with a mean score of 3.16, there is an urgency to ensure that the data transfer process for maintenance and operation is conducted accurately to minimise any risks of errors (R8). This is especially relevant when relying on technology to monitor the

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operational parts of maintaining building performance. Discussions on the overall results and findings will be elaborated on next.

DISCUSSIONS

Based on the data collected through questionnaire surveys and the findings discussed, a three-level enhancement framework of the study is proposed. As presented in Figure 3, the framework outlines three dimensions: "Knowledge," "Practice," and "Enhancement of Roles," which QSs must consider in supporting their roles as enablers that function in various project phases, including planning, design, construction, operation, and maintenance. The first dimension indicated that financial investment (K5), cross-checking for data accuracy (K6), and ease of updating BIM data and information (K2) are the three highest priorities in current knowledge. These conceptualise the cost feasibility, data reliability, and operational efficiency in BIM contract administration. Meanwhile, the second dimension demonstrated that 5D models for operations and maintenance (P8), automatic BQ generation (P3), and e-tendering using digital documentation (P4) are the most crucial practices being implemented among QS managing BIM-based projects. The findings suggest that process simplification via integrated processes can help streamline the QS workflow by utilising BIM models in a digital environment. Thus, the final dimension in Figure 5 demonstrated that clarifications about roles and responsibilities during the pre-construction (R2), risk mitigations on conflicts during construction (R5) and centralising all data using an asset model during post-construction (R7) are the most significant improvements that a QS, as a professional enabler, must elevate to improve governance mechanisms from existing conventional roles of BIM collaboration. Collectively, these findings indicated that additional training for QS that includes technical procedures and implementation guidelines is necessary.

Although the feedback from the study is relatively limited due to a small sample size, other practical implications can be observed in terms of finances, which may become a major barrier to BIM's implementation. This validates the argument that a significant investment is required for firms to adopt BIM technology, as it necessitates periodically upgraded hardware to ensure the software can run smoothly and efficiently deliver the work without difficulty (Ismail et al., 2021). Nevertheless, QS practitioners agree that BIM can streamline the lengthy and complicated process of updating design changes. This is attributed to the fact that quantities issued from the model are automatically synchronised and updated through the model (Zainon et al., 2018), which can indirectly help ensure the accuracy and consistency of data in real-time, reduce the risk of data transfer errors, and save time.

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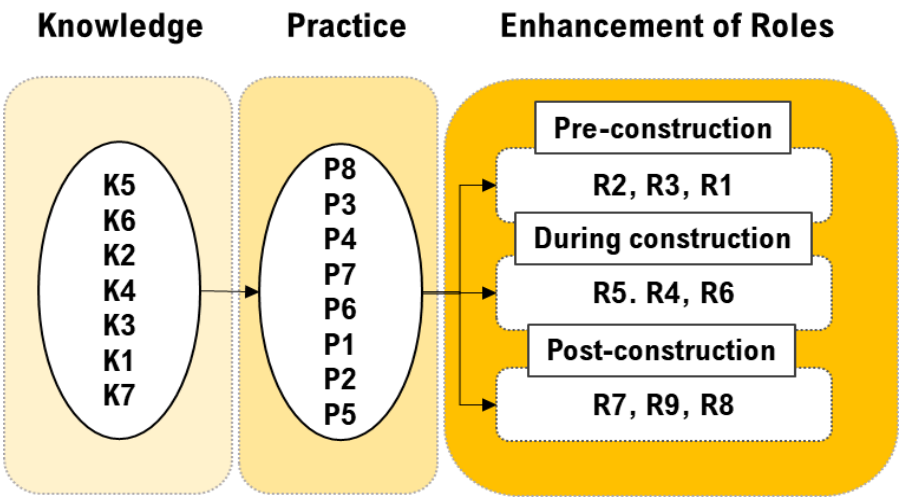


Figure 3: Three-level enhancement framework of the QS knowledge and practices and the roles for BIM contract administration

Considering the implications, it stands to reason that most QSs recognise the efficiency of BIM in maintenance operations, due to its data management and control capabilities, as well as its ability to provide better interpretation by linking real-time data in models. BIM can be integrated into various building systems to enable real-time monitoring of building performance, including lifecycle costs and energy consumption. Evidence strongly suggests that the use of paper in the e-tender system has been significantly reduced by up to 90%, resulting in a decrease in administrative and transaction costs associated with producing tender documents (Azizi et al., 2021). Therefore, implementing BIM into practice has provided a solution to time-consuming issues, such as introducing e-tenders, which are more time-saving (Halil et al., 2024).

From a policy perspective, a notable observation demonstrated that the roles and responsibilities of all stakeholders must be clearly defined and specified in the contract during the early stages of the BIM integration process. These roles should be clearly outlined during the pre-construction phase for the entire BIM contractual integration life cycle (Alwee et al., 2021). Note that the lack of clarity and adequacy in BIM contract guidelines will lead to more contract and regulatory issues (Alaitobi et al., 2024), especially during the construction collaboration process. Therefore, the study somehow revealed that BIM collaboration can minimise the occurrence of disputes, mitigate their impact, and manage them proactively (Khawaja & Mustapha, 2021). BIM can identify and resolve clashes at the early stages, preventing costly rework and delays, which are a major source of disputes.

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CONCLUSION

This study has comprehensively examined the participation and roles of QSs, particularly in BIM contract administration, focusing on current knowledge, existing practices, and potential areas for improvement despite the limited number of respondents who were involved in the study. The findings highlight that while QS professionals generally understand the significance of BIM, several gaps hinder its full integration into the contract administration process. The research findings indicate that Malaysian QS professionals have a fundamental understanding of BIM contract administration. However, a lack of standardised guidelines and legal frameworks tailored to BIM practices leads to implementation inconsistencies, although BIM is already utilised in QS practices, primarily for cost estimation, clash detection, and project tracking. To optimise BIM implementation in contract administration, this study proposes a three-level enhancement framework that can serve as a guide, such as for the BQSM, to align the needs for improving the QS competencies, thus bridging the current gaps through knowledge, practice, and role-based enhancements for the modernised Malaysian construction industry.

This study offers both theoretical and practical implications for the field of BIM contract administration, which is also vital in supporting the sustainable development goals of the construction industry. At the same time, the findings offer valuable insights for policymakers and industry stakeholders to develop standardised contractual guidelines, training modules, and regulatory frameworks that facilitate smoother BIM implementation.

While this study provides significant insights, it is not without limitations. The research was conducted primarily in the *Klang* Valley region, which may not capture the broader implementation of BIM in Malaysia. It is pertinent to note that this study relied on questionnaire surveys, which may not have fully captured the depth of the practical challenges faced by QS professionals and other practitioners, such as urban planners, architects, and other designers, who contribute to their roles in contract administration. Thus, qualitative methods, such as interviews and case studies, should also be considered to gain deeper insights into the challenges and best practices that involve multiple disciplines. Future studies can further bridge the gap between BIM theory and practice by addressing these areas, contributing to a more structured and efficient contract administration process in Malaysia's construction industry.

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ASSESSMENT OF SPATIAL PLANNING CRITERIA ASSOCIATED WITH INDOOR AIR QUALITY CONSIDERATIONS IN REFURBISHED KINDERGARTENS WITHIN SHOP OFFICE SETTINGS

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Abstract

Indoor air quality (IAQ) plays a role in the health, comfort, and cognitive development of young children. This issue is critical in early childhood education environments. In urban areas, many kindergartens operate in commercial buildings, particularly converted shop office units. However, these buildings often lack spatial planning features that support indoor environments. This study evaluates the compliance level of spatial planning features associated with IAQ-related planning considerations in refurbished kindergarten settings. A quantitative observational case study approach was adopted. The study involved six kindergartens located in refurbished shop office buildings in Selangor, Malaysia. Spatial planning criteria were synthesised from several Malaysian guidelines and standards. These included the Guidelines on the Establishment of Kindergarten and Child Care Centre (2017), Ministry of Education Malaysia Guidelines (2021), Uniform Building By-Laws (1984, Amendment 2021), ICOP IAQ 2010, and MS 1525:2019. The assessment focused on ten key spatial features. These features included floor area per child, window-to-floor ratio, open space provision, natural lighting and ventilation, back-up air-conditioning systems, operable windows, kitchen separation, zoning between clean and wet areas, building orientation, and room depth. Each feature was scored using a structured rubric. The scores were converted into percentages to determine the compliance level for each kindergarten. The compliance scores ranged from 57% to 87%, showing different levels of compliance among the case studies. Common weaknesses included insufficient operable windows, overcrowded classrooms,

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and poor kitchen zoning. The study recommends improving existing guidelines by integrating spatial planning criteria associated with IAQ considerations to support healthier refurbished kindergarten environments.

Keywords: Spatial Planning, Indoor Air Quality, Kindergarten, Refurbished, Shop Office

INTRODUCTION

Spatial planning in kindergarten environments is essential for supporting young children's health, safety, and developmental needs. As early childhood is a formative stage for cognitive, emotional, social, and physical growth, the physical arrangement of space can significantly influence children's learning experiences and overall well-being (Moreira *et al*., 2023).Well-designed kindergarten environment typically include clearly defined zones for key activities such as learning, play, eating, and resting, while also ensuring smooth circulation and easy supervision. Kindergarten environment also role as a "third teacher," shaping how children interact, explore, and construct meaning through their daily experiences. Therefore, spatial planning in kindergartens must be approached not merely as a functional design task, but as a fundamental component supporting the children's holistic development.

To ensure safe and developmentally appropriate environments, various guidelines and regulations have been established to guide the spatial planning of kindergartens. Key references in Malaysia include the Guidelines for the Establishment, Registration and Operation of Private Kindergartens (Ministry of Education, 2021), Guidelines on the Establishment of Kindergarten and Child Care Centre (2017), and the Uniform Building By-Laws (UBBL) 1984 (Amendment 2021). These documents provide recommendations on the minimum floor area per child, the inclusion of open spaces, natural ventilation and lighting, zoning between clean and wet areas, and the provision of safety measures. Nevertheless, while these guidelines outline important spatial considerations, they often lack emphasis on environmental performance, particularly IAQ.

Spatial planning is typically associated with functional layout and child engagement; at the same time, it plays a significant role in determining IAQ within educational settings (Salleh *et al.*, 2016). Poor spatial decisions such as insufficient window openings, ineffective zoning, high occupant density, and the use of pollutant-emitting materials can result in inadequate ventilation and elevated concentrations of indoor pollutants (Zainudin *et al.,* 2019*)*. This is particularly problematic in kindergartens, where children are more vulnerable to air quality issues due to their developing respiratory systems and longer indoor exposure times. The lack of proper integration of IAQ strategies into spatial

design could cause classrooms and common areas to be confined, poorly ventilated, and uncomfortable. Therefore, spatial planning must also consider environmental quality to ensure that learning environments are not only pedagogically supportive but also health-protective (Zhang *et al.*, 2021).

In Malaysia, the scarcity of affordable urban land has led many kindergarten operators to establish their centres within refurbished shop office units. These buildings were originally designed for commercial rather than educational purposes. While adaptive reuse of these structures offers a cost-effective solution, it also introduces spatial compliance challenges echo the 'dynamic space formation' described by Haryanto *et al.* (2020). These settings often lack adequate natural ventilation, appropriate spatial zoning, and compliance with the IAQ guideline. As a result, children in such environments may be exposed to higher levels of indoor air pollutants, as recently highlighted by Zakaria *et al.* (2025).

This study focuses on assessing the extent to which spatial planning features in refurbished kindergartens align with IAQ strategies and regulatory requirements. By evaluating elements such as floor area per child, ventilation provision, room configuration, and functional zoning, the research aims to identify compliance gaps and propose spatial improvements to support healthier indoor environments in non-purpose-built kindergarten settings.

LITERATURE REVIEW

Kindergarten Spatial Planning

In Malaysia, most resources related to kindergartens emphasize the quality of teacher teaching and the scope of the curriculum, while spatial planning receives insufficient attention (Chai & Mohidin, 2021). This is important because children at the kindergarten level are more sensitive to the arrangement of physical space (Matthews & Lippman, 2020). The design of an effective kindergarten environment needs to meet the needs and interests of children, and this can only be achieved through the provision of a quality physical learning environment (Shaari *et al*., 2016). Therefore, attention to global spatial planning under the manipulation of architectural design features should be the first focus to create an effective learning environment as a fundamental category of the physical learning environment, as shown in Figure 1.

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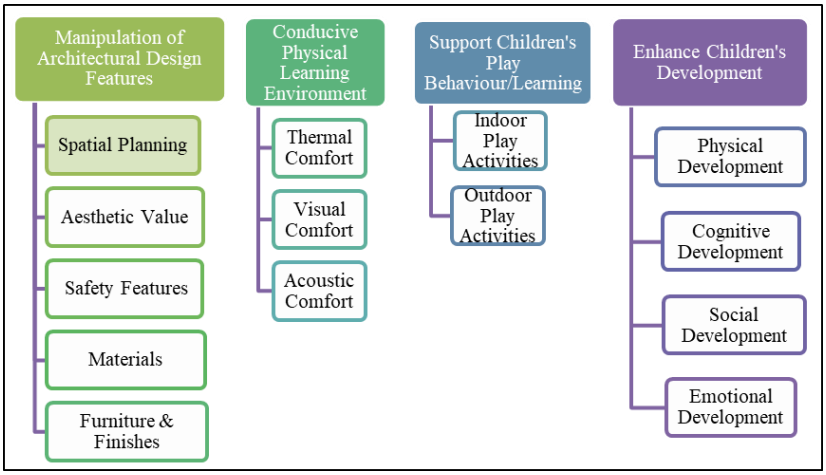


Figure 1: Kindergarten physical environment categories
Source: Shaari *et al.* (2016)

Activity based zoning is a fundamental principle in architectural design where spaces are organized based on their function, frequency of use, and intensity of activity. In understanding the intricate dynamics of a kindergarten environment, it is essential to consider spatial planning strategies proposed by Stankovic *et al.* (2015), who advocate for segmenting spaces into wet and dry regions, further subdivided into active, quiet, and outdoor zones. Additionally, Sotuku *et al*., (2016) propose categorizing the space into five distinct areas: entrance, learning area, playing area, kitchen and toilet. These divisions are based on the children's specific activities and learning practices.

Spatial Planning Guidelines for Kindergartens

Various acts and guidelines have been established to ensure the quality of kindergartens in Malaysia. The establishment of kindergartens is governed by a set of Acts and guidelines, including Guidelines on the Establishment of Kindergarten and Child Care Centre (2017), Guidelines for the Establishment, Registration and Operation of Private Kindergartens of the Ministry of Education Malaysia (2021), Uniform Building By-Laws 1984 (Amendment 2021) and Malaysian Standard MS 1525:2019 (on energy efficiency and use of natural ventilation). These regulations aim to facilitate kindergarten setup and building design.

Guidelines on the Establishment of Kindergarten and Child Care Centre (2017)

The Guideline on the Establishment of Kindergarten and Child Care Centre 2017 (*Garispanduan Perancangan dan Penubuhan Tadika dan Taska 2017*) guides local authorities, planners and those considering starting kindergartens or

childcare centres. It also serves as a useful resource for developers, architects and builders in preparing the site and building, as well as for entrepreneurs going through the process of setting up, registering and applying for business licenses for kindergartens and childcare centres (Town and Reginal Planning Department, 2017). The components and areas suggested by the guidelines comprise the minimum area for a child, kitchen area, toilet area, staff room area, store area, corridor area, open space/ play area and parking area.

Guidelines for the Establishment, Registration and Operation of Private Kindergartens of the Ministry of Education Malaysia (2021)

The Guidelines for the Establishment, Registration and Operation of Private Kindergartens of the Ministry of Education Malaysia 2021 (Ministry of Education Malaysia, 2021)(*Garis Panduan Penubuhan, Pendaftaran dan Pengoperasian Tadika Swasta Kementerian Pendidikan Malaysia 2021*) are provided to facilitate and provide guidance to Officials in the Private Education Division, State Education Department and District Education Office in matters of establishment, registration, regulation and enforcement. Among applicable sections to be highlighted are Section 4: Premises and location. Kindergarten design should consider aspects of natural lighting and ventilation, especially in new buildings, as stated in the Uniform Building By-Laws, 1984 and the requirements of the Department of Health and the Department of Fire and Rescue Malaysia. For the establishment of kindergartens in complexes or business lots, an indoor play area should be provided to replace the open space, with an approximate allocation area of 50 square meters.

Uniform Building By-Laws 1984 (Amendment 2021)

Kindergarten design must comply with UBBL 1984 (Amendment 2021) and health and fire regulations emphasizing natural lighting and ventilation. By-law 39(3) requires classrooms to have windows covering at least 20% of the floor area for light and air flow. By-law 41 allows air-conditioned spaces but mandates a permanent system with backup ventilation capable of supplying fresh air within 30 minutes of failure. Cooking is limited to electric stoves, while LPG use requires separation per By-law 139. The Seventh Schedule sets the classroom occupant load at 2 persons/m², differing from the 1.4 m² per child specified in kindergarten guidelines.

Malaysian Standard MS 1525:2019 (energy efficiency and use of renewable energy for non-residential buildings)

The Malaysian Standard MS 1525:2019 provides guidelines for energy efficiency and the use of renewable energy in non-residential buildings. In equatorial regions, the code emphasizes the importance of proper building orientation to

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maximize energy efficiency. One fundamental principle is to minimize exposure of building openings, such as windows and entrances, to intense sunlight from the east and west directions. Facades with the highest number of openings facing east or west should be avoided to achieve optimal building orientation. In the context of rooms with single windows or single-sided ventilation, the recommendation to keep the effective room depth within 6 meters is crucial for optimizing IAQ. With the limited opening, maintaining a shallow room depth ensures that fresh outdoor air introduced through the single window can effectively reach all parts of the room. Beyond this limit, the efficiency of ventilation diminishes, potentially leading to stagnant air and uneven distribution of airflow.

Indoor Air Quality in Educational Settings

IAQ is a term referring to the air quality in and around buildings, which is related to the health and comfort of building occupants. IAQ is a critical component of environmental health in early childhood facilities, where young children are particularly vulnerable to air pollutants due to their developing respiratory systems and high breathing rates. In this regard, as mentioned in the Industry Code of Practice on Indoor Air Quality (ICOP IAQ, 2010), low IAQ can result from pollutants such as carbon dioxide (CO_2), particulate matter ($PM_{2.5}$, PM_{10}), total volatile organic compounds (TVOCs), and biological contaminants such as bacteria and fungi. International guidelines from WHO and the U.S. EPA, underscore the significance of ensuring good IAQ in schools (U.S. EPA, 2025; WHO, 2011). WHO describes standardised IAQ monitoring approaches for school settings, while the U.S. EPA provides a dedicated Indoor Air Quality Design Tools for Schools framework. However, equivalent school specific IAQ guidelines are currently not available in Malaysia.

Spatial Planning and Indoor Air Quality

Although spatial planning is traditionally discussed in terms of functional layout, it significantly influences IAQ. Spatial features such as room size, window-to-wall ratio, depth of room, occupancy density, and operable windows directly affect ventilation efficiency and pollutant dispersion. For instance, single-sided ventilation in deep rooms limits airflow, while inadequate zoning between clean and wet areas can increase microbial growth. Moreover, the use of synthetic or non-breathable materials in poorly ventilated classrooms may lead to higher concentrations of VOCs. Research indicates that kindergartens with integrated spatial and environmental strategies such as cross-ventilation, shading, and operable windows demonstrate better IAQ outcomes. This highlights the importance of incorporating IAQ-sensitive design features into spatial planning from the outset.

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Adaptive Reuse of Shop Office Buildings for Kindergartens

Shop office units, originally not designed for educational use, often have deep plans, limited windows, and fixed layouts, restricting ventilation, lighting, and zoning flexibility. Studies show that such repurposed spaces frequently fail to meet spatial and IAQ standards, creating unhealthy environments for children (Chai & Mohidin, 2021). Windowless classrooms are common, leading to higher stress hormone levels, reduced focus, and poor health outcomes. The lack of daylight and ventilation also increases dependence on artificial lighting, further compromising visual comfort and air quality (Tan & Majid, 2023).

RESEARCH METHODOLOGY

This study employed a quantitative observation case study approach involving six kindergartens located within refurbished shop office buildings in Selangor, Malaysia (Table 1). The selection of case studies was based on accessibility, consent from operators, and representation of varied spatial layouts (Figure 2). Data collection focused on spatial layout assessment through on-site measurements, architectural plan reviews, and observational audits. The assessment was conducted by the researcher using structured observational checklists during site visits. Key spatial features assessed as depicted in Table 2. Each feature was evaluated using a structured scoring scale to quantify compliance with relevant regulatory and design guidelines. To calculate the compliance score, each spatial feature was assigned a score ranging from 1 to 3 based on its degree of conformity to the benchmark. For borderline conditions, the dominant spatial characteristic and overall functional suitability of the space were considered to ensure consistent interpretation across all case studies.

Table 1: Profile of the Case Studies

Kinder-garten	Storey	Area investigated	Ventilation mode	Year of occupancy
K1	1	3 classes, 1 common area, 1 kitchen	Air-conditioning only	2012
K2	1	2 classes, 1 common area, 1 kitchen	Air-conditioning only	2015
K3	2	3 classes, 1 common area, 1 kitchen	Air-conditioning only	2014
K4	1	2 classes, 1 common area, 1 kitchen	Air-conditioning only	2018
K5	1	1 class, 1 common area, 1 kitchen	Air-conditioning only	2018
K6	2	3 classes, 1 common area, 1 kitchen	Air-conditioning only	2017

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Figure 2: Six kindergartens at the shop office building
Source: Author's own work

Table 2: Spatial Planning Compliance Matrix

Spatial Feature	Source/Status	Scoring scale
1. Minimum floor area per child (1.4 m^2)	Kindergarten guidelines /Mandatory	3 = ≥1.4 m^2; 2 = 1.0–1.39; 1 = <1.0
2. Minimum 20% of floor area as window opening	UBBL 1984/Mandatory	3 = ≥20%; 2 = 10–19%; 1 = <10%
3. Open space/play area (min. 50 m^2)	Kindergarten guidelines /Mandatory	3 = ≥50 m^2; 2 = 30–49 m^2; 1 = <30 m^2 or none
4. Natural lighting and ventilation consideration	Kindergarten guidelines & UBBL/ Recommended	3 = Good daylight & cross-ventilation; 2 = One aspect present; 1 = None present
5. Air-conditioned rooms must have back-up ventilation	UBBL 1984/Mandatory	3 = Dedicated back-up ventilation system (e.g., operable windows or mechanical fans) is fully functional in all air-conditioned rooms

		2 = Partial or passive back-up available (e.g., some operable windows but not in every room) 1 = No backup ventilation system present; fully reliant on air-conditioning
6. Operable window presence and placement	Kindergarten guidelines/ Recommended	3 = All rooms have operable windows; 2 = Some operable; 1 = No operable windows
7. Proper separation of gas stove area	Kindergarten guidelines & UBBL/ Mandatory	3 = Fully separated kitchen with exhaust; 2 = Partially separated; 1 = No separation
8. Zoning between clean and wet areas	Kindergarten guidelines/ Recommended	3 = Zoning present with barriers; 2 = Partial zoning; 1 = No zoning
9. Building orientation to avoid east/west exposure	MS 1525:2019/ Recommended	3 = Not face East/West; 2 = Face East/West with shading; 1 = Face East/West
10. Room depth limit: ≤6 m for single-sided	MS 1525:2019/ Recommended	3 = ≤6 m with window 2 = ≤6 m depth without window 1 = > 6 m

The total score obtained for each kindergarten was then converted into a percentage by dividing it by the maximum possible score and multiplying by 100, as shown in Table 3. Compliance Score (%) = (Total/ Maximum Score) × 100.

Table 3: Compliance score classification

Compliance Category	Score Range (%)	Interpretation
Compliant	80 – 100%	Meets or exceeds most spatial planning guidelines
Moderately Compliant	50 – 79%	Meets some key criteria but has notable gaps
Non-Compliant	< 50%	Fails to meet minimum spatial planning standards

ANALYSIS AND DISCUSSION

The spatial layout assessment showed compliance scores from 57% to 87%. K1, K3, and K4 (>80%) were compliant, reflecting layouts that support good IAQ. K5 (73%), K6 (67%), and K2 (57%) were moderately compliant, with K5 showing minor zoning or ventilation issues, while K6 and K2 had significant weaknesses needing improvement as in Table 3.

Room Size per Child

Most kindergartens (K1, K2, K3, K5, K6) scored 2, indicating moderately acceptable space per child, while K4 scored 3, reflecting spacious classrooms that enhance air dilution and comfort. Smaller rooms with higher occupant density

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elevate CO_2 levels and limit air circulation. As 91.1% of classrooms house over 15–20 children, maintaining at least 2 m² per child (Manuel *et al.*, 2021). is essential. Moderately compliant centres should reduce class size, reconfigure layouts, or adopt space-saving, multipurpose furniture to optimize usable area.

Window Placement and Size

Many classrooms also fall below the 20% window-to-floor ratio, causing stale air and high CO_2 levels. K3 and K4 scored 3 for excellent window design, K1 and K6 scored 2 for moderate performance, while K2 and K5 scored 1, indicating critically poor fenestration (<10% window area). To improve air quality in windowless rooms, installing exhaust and supply fans on opposite ends or near the ceiling is recommended (Department of Occupational Safety and Health, Ministry of Human Resources, 2010). Limiting class size in enclosed spaces can further reduce CO_2 build-up and enhance comfort.

Zoning of Kitchen

The assessment of gas stove separation and zoning shows mixed compliance. K3 and K5 scored 3, indicating well-separated kitchens and clear zoning that minimize pollutant spread. K4 scored 1, showing poor separation and zoning, allowing cooking emissions to affect nearby classrooms (Zainudin *et al.,* 2019). To improve, physical barriers or door seals should be added between wet and clean areas, with independent exhaust systems for kitchens and toilets. Future layouts should include isolated service cores to enhance IAQ and hygiene.

Building Orientation

All kindergartens use air-conditioning, but five scored 3 for favourable orientation, minimizing east–west exposure and reducing heat gain. K6 scored 1 due to east–west orientation without shading, causing higher indoor temperatures and energy use. East–west façades increase heat and glare while north–south orientations maintain stable temperatures. Spatial constraints in refurbished units often lead to design compromises that affect IAQ and comfort.

Common Area Configuration

All kindergartens except K2 and K6 scored well in providing common areas, indicating sufficient space for shared activities. In contrast, the lack of such space in K2 and K6 likely forces multiple activities into classrooms, increasing occupancy levels and contributing to higher CO_2 concentrations, especially when classrooms double as dining or sleeping areas.

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Table 4: Comparative analysis by spatial-IAQ features

Kinder-garten	Floor area per child (≥ 1.4 m²/child)[a]	Min.20% of floor area as window opening[b]	Open space/Play area (≥50 m²)[a]	Natural lighting and ventilation consideration[a]	Air-conditioned rooms must have backup ventilation[b]	Operable window presence and placement [a]	Proper separation of gas stove area [a,b]	Zoning between clean and wet areas[a]	Building orientation to avoid east/west exposure [c]	Room depth limit: ≤6 m for single-sided[c]	Total score	% Comply	Compliance level
K1	2	2	3	2	2	2	2	3	3	3	25/30	83	Compliant
K2	2	1	2	2	1	1	2	2	3	2	17/30	57	Moderately Compliant
K3	2	2	3	3	3	3	3	3	3	1	26/30	87	Compliant
K4	3	3	3	2	3	3	1	1	3	3	25/30	83	Compliant
K5	2	1	3	2	2	1	3	3	3	2	22/30	73	Moderately Compliant
K6	2	2	2	2	2	2	2	3	1	2	20/30	67	Moderately Compliant

a Guidelines on the Establishment of Kindergarten and Child Care Centre (2017), Guidelines for the Establishment, Registration and Operation of Private Kindergartens of the Ministry of Education Malaysia (2021)
b Uniform Building By-Laws 1984 (Amendment 2021)
c Malaysian Standard MS 1525:2019 (energy efficiency and use of renewable energy for non-residential buildings)

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FUTURE RESEARCH

Future research should develop a standardized spatial layout model for kindergartens in shop offices by comparing existing plans to identify layouts that enhance IAQ, space efficiency, and safety. The model should define minimum spatial standards, integrate IAQ-sensitive design aligned with UBBL 1984, MS 1525:2019, and ICOP IAQ 2010. The model can be validated through post occupation evaluation (POE) and IAQ monitoring. The Spatial Planning Compliance Matrix introduced in this study evaluates spatial and architectural design inputs affecting IAQ, complementing the Green Building Index (GBI), which focuses on performance outcomes and certification. Furthermore, IAQ is also closely interconnected with human-related factors (Nurwidyaningrum *et al.,* 2022). Assessing elements such as knowledge, attitudes and practices of occupants significantly shape overall IAQ outcomes.

CONCLUSION

The total compliance scores across the six kindergartens range from 57% to 87%, demonstrated varying levels of compliance with spatial planning criteria associated with IAQ considerations. Common shortcomings included insufficient operable windows, overcrowded classrooms, and poor zoning of the kitchen. These findings highlight the need to strengthen the integration of IAQ-related spatial planning considerations within existing guidelines to support healthier and more effective learning environments from the planning stage.

ETHICAL APPROVAL

This study received ethical approval from Universiti Malaya Research Ethics Committee (UMREC) under the reference number UM. TNC2/UMREC_1594.

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CONDITION ASSESMENT STUDY OF ROAD DEFECTS IN MERSING DISTRICT ROAD IN JOHOR

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Abstract

This study covers road distress that is further discussed as flexible pavement distress. Road condition is crucial for safety and is also used to forecast maintenance schedules. The objectives of this study are focused on determining the road defects and identifying the conditions of the road defects in Mersing district. The method used in this study was based on observations made on the road referring to ASTM D6433 and Technical Manual, Pavement Maintenance Management which according to the Public Work Department (PWD) standard. This research concentrates on two selected roads in the Mersing district which are (i) Tanjung Resang Road and (ii) Tanjung Resang - Penyabong Road. For data collection, mixed methods such as observations (picture) and calculation of Pavement Condition Index (PCI) is used. The findings indicated that the road condition in these two Mersing roads requires more regular maintenance. The results show that the lowest priority roads require better maintenance planning and consistent implementation, as well as re-planning of maintenance structure. Overall, this study contributes novel insights into the relationship between deteriorating road conditions and the increasing demand for maintenance. The result can benefit planning of road upgrading as well as bigger scope in infrastructure of urban planning. Future research could investigate this problem successfully by expanding their data into more districts and the number of roads.

Keywords: Road, Pavement, Road Maintenance

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INTRODUCTION

Malaysia has a diverse and developed road network covering paved, unpaved, national and leading regional roads and local roads. The types of road pavement in Malaysia are flexible road pavement and rigid pavement which are constructed throughout Malaysia. Road capacity refers to the ability of a road to operate, and it largely depends on pavement surface conditions.

Roads are one of the transportation infrastructures that is classified as public goods. According to Ismail et al. (2021), in Malaysia, the road network has more than 100,000 km and is categorised into three main classes namely federal roads, state roads and toll highways. Susanna et al. (2017), emphasize that the lack of awareness regarding the state of road conditions prevents road maintenance agencies from adequately identifying the fund necessary for correct maintenance on time. Mersing District was chosen because it is a main federal road in Johor. As coastal roads, it is important to ensure the road is in good condition especially for drivers. Therefore, the objectives of this paper are to (i) determine the road defects in Mersing district and (ii) to identify the conditions of the road defects in Mersing district.

LITERATURE REVIEW

Road Conditions are Reflection of their Maintenance

Planning road maintenance activities require information on the road conditions (Setianingsih et al., 2017) . This statement is supported by Arianto *et* al. (2018), who state that to carry out road repair activities on time, a plan based on correct pavement condition data is required. Recently, Hamsan et al. (2018) reported in previous literature through road roughness measurement which looked at rutting, texture depth and crack visibility to assess the road in Petaling, Malaysia. Road condition was assessed by taking into consideration the roughness of the road, total crack area, average crack width, number of potholes, and depth of vehicle rutting (Arianto et al., 2018).

Siswanto et al. (2018) in Indonesia assessed road defects and found eighteen types of road distress. The distress or defect types include potholes, cracking, bumps, bleeding, depression and rutting. Although the primary type of road defects is similar in these studies, the differences were determined by the tools or software used to determine the road condition. Thus, Dolla and Laishram (2022) discover that concepts such as road funding and distribution of funds, road planning, design and development, maintenance services and administration, road operations, and road safety are predominantly limited to high-volume of roads in most of the research. These criteria have a lot of impacts on road flooding.

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Causal Factors of Road Damage

Road damage or defects are frequent and common problems in most countries. Many roadways are damaged or already starting to deteriorate (Angreni et al., 2018). Pavement distress is an apparent defect on the road surface, which shows that pavement structural degradation symptoms are present (Mubaraki, 2014). Sarie et al. (2015) indicates that road damage is divided into two categories which are structural damage and functional damage. Surbakti and Doan (2018) explained both damages.

Several studies have stressed that overloading vehicles are significant factors in road deterioration (Hatmoko *et* al. 2019; Ismail *et* al. 2021; Selamat *et* al. 2019). It was pointed out by Selamat et al. (2019) that the meaning of vehicle overload is the traffic load that has considerably surpassed the specified bearing capability of the proposed road structure. Many researchers also described the effects of overloading vehicles on the road, such as it could suffer from massive early pavement degradation (Hatmoko et al. 2019; Selamat et al. 2019).

Environmental conditions also play a critical factor in determining the state of health of a road and predict the road's future condition (Kulkarni & Miller, 2003). When there is an inoperative drainage channel, water can readily infiltrate through the pavement and inevitably causes road damage in the future (Hatmoko et al., 2019)..

Pavement Condition Assessment

Road pavements require non-stop repair and maintenance to prevent damage caused by repeated traffic loads and the environment. This means pavement maintenance management requires the relevant authority to carry out a pavement condition evaluation at regular intervals (Ismail et al., 2021). The data is used to regulate the functional and structural condition of the road. The data is also used to detect areas of poor condition pavements, which are then followed by pavement treatment to be applied at the most appropriate time (Hamsan et al., 2018).

Pavement Condition Index (PCI)

This rating system is referred to as Pavement Condition Index (PCI). This method is known as the Pavement Condition Index (PCI). PCI is typically determined to annually evaluate changes in the road network system (Karim et al., 2016). The pavement condition rating is calculated using six steps that follow (ASTM D6433-11 2011). First, separate pavement sections in manageable sizes or into sample units. Second, identify pavement distress, severity and extent for which they developed guidelines on how to carry out pavement distress evaluation. Third, deduct values were assigned for each distress type, severity and extent level. Fourth, the total number of deducting values are added. Fifth, the corrected deduct value is determined based on the total deduct values of the road that have

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been observed. Sixth, the pavement condition rating is determined on a scale from 0-100.

Road Maintenance Prioritization

Four classes of prioritization methods are (i) simple subjective ranking, (ii) ranking based on parameters with scoring or weighting, (iii) ranking based on parameters with economic analysis and (iv) optimization (Karim 2014)

Another factor to consider when giving priority to road maintenance is the traffic flowAnother study conducted in one Indonesian district discovered that the authorities in the district place road conditions as the priority, followed by traffic volume, economic factor, and land use (Siswanto et al., 2019).

Previous literature has shown that current road conditions are crucial to determine the safety and assessment for future maintenance management. In this study, Mersing Road was selected as a case study due to its heavy traffic.

RESEARCH METHODOLOGY

For this research, it has been decided that there will be five roads that will be assessed. The sampling used to select the study population is a convenient method of sampling for this research. The study sample then reduced to two roads as a subsample from a larger cohort of Mersing district roads. The interviewee for the fidelity of observation was also chosen based on convenient sampling. Two types of roads were assessed, and convenient sampling was chosen to select the study population. The study sample of two roads was a subsample from a larger cohort of Mersing district roads. The interviewee for the fidelity of observation was also chosen based on convenient sampling. Edgar and Manz (2017) note that convenient sampling refers to a method in which samples are obtained conveniently as they are accessible at a place or on the web.

After the road sample was determined, two road samples were divided into sample units. The number of sample units inspected was established and randomly picked. The road sample that was observed for this study has a total length of 3 km. This 3km length of the two roads sample was divided into few units. The sample unit for flexible pavement area is about 450 – 650 m2 (Karim, 2014). During a Pavement Condition Index inspection, road damage is assessed through visual observation supervised by a site engineer and is vet through based on standard evaluation rules and procedures. The inspection follows specific guidelines to ensure consistency and accuracy in identifying pavement defects. Type of road distress is based on common rules used during road damage inspection, by identifying the defects, namely longitudinal cracks, transverse cracks, alligator cracking, potholes, rutting, depression, edge cracking and patching deterioration

$$\text{Density} = \frac{\text{Distress amount in m2}}{\text{Sample unit area in m2}} \times 100$$

Figure 1: Sample Unit Formula (Source: Karim, 2014)

Where:
n = number of sample units to be inspected
N = total number of sample units (length of sample unit/length of the sample)
σ = standard deviation in PCI (10 for flexible pavement)
e = allowable error in determining the genuine PCI (allowance of 5 for error)

After recording all the defects found, each of the defects was recorded according to the severity of the defect that occurs, which is whether they are high, medium or low. The guide to determine the severity is stated in the Headquarters Department of the Army (1982) and Public Works Department (2017). Then, the roads were measured using the PCI method of calculation (ASTM D6433-11 2011; Karim et al. 2016; Mubaraki 2014; Sholichin & Utomo 2018). After recording all of these, each of the density of the road defects was documented in percentage following the formula below. Each of the density of the road defects was documented in a percentage based on the formula in figure 2, that is all the defects that are calculated in square meters (m2).

$$\text{Density} = \frac{\text{Distress amount in m}}{\text{Sample unit area in m2}} \times 100$$

Figure 2: Formula of Density in m2 (Source: Karim *et* al. 2016)

Meanwhile, the following formula for density in Figure 3 is for defects calculated in linear meters (m) such as bumps, edge cracking, joint reflection cracking, edge drop-off, longitudinal crack, and transverse cracks (Karim et al. 2016).

$$\text{Density} = \frac{\text{Number of potholes}}{\text{Sample unit area in m2}} \times 100$$

Figure 3: Formula of Density in m (Source: Karim et al. 2016)

After calculating the density (%), the deduct value will be decided. The deduct value will be decided by looking at the graphs of deducting values curve based on the Headquarters Department of the Army (1982). Each defect of the road has a different deduct value curve graph.

Then the Corrected Deduct Value (CDV) was determined. Firstly, the maximum allowable number of deducting values were established. The

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calculation is as follows: m = 1 + (9/98) (100- HDV), HDV is the highest deduct value (Mubaraki 2014). After obtaining the maximum allowable number of deducts, the deduct value was arranged in descending order. Then, the deduct value was added based on the maximum allowable number (Mubaraki 2014). The total deduct value (TDV) of each road then is adjusted to obtain the CDV. This CDV was obtained by plotting the value of TDV in Corrected Deduct Value curves stated in Appendix I (ASTM D6433-11 2011; Headquarters Department of the Army 1982). The deduct value that more than 5 (q) needed to be concluded first (Headquarters Department of the Army 1982; Mubaraki 2014; Sholichin & Utomo 2018). This *q* is the curve used to plot the Corrected Deduct Value curves. Lastly, the PCI was computed by 100 – CDV. This PCI value was categorized based on the value obtained. The road condition was based on the PCI rating shown in Figure 4.



Figure 4: PCI Rating (Source: ASTM D6433-11 2011)

The Pavement Condition Index (PCI) was used with the volume of the traffic flow to identify the pavement road maintenance priority based on the result of the PCI index. The result of the Pavement Condition Index provides a ranking on each of the roads observed. The Pavement Condition Index (PCI) is a standard method used to assess the physical condition of a road pavement. It helps engineers and local authorities determine how damaged or well-maintained a road is. A higher PCI value indicates that the road is in better condition and requires less maintenance, while a lower PCI value shows that the road is deteriorating and may need urgent repair or rehabilitation.

ANALYSIS AND DISCUSSION

Type of Road Defects in Mersing Districts

This research analysed the defects that appeared on two roads, namely (i) Tanjung Resang (TR) and (ii) Tanjung Resang-Penyabong (TRP), the two roads went through visual observation for each 1.5km of the road. The sample units are separated into the pavement feature. For flexible pavement, a sample unit of around 450 m2 - 650 m2 is used.

Type of Road Distress in Tanjung Resang (TR) Road

The sampling size for the road has been appropriately selected, considering the width of the road. Since the width of the road is 7.10 m, then it has been decided that the length of the sample size is 70.00m. Thus, making the sample size of Tanjung Resang Road to be 70.00m x 7.10m, which is 497 m2. The number of samples calculation is shown at Figure 5 below.

ROAD : Tanjung Resang Road
Length : 70 m
Width : 7.10 m

$$N = \frac{1500}{70} = 21$$

$$n = \frac{N\sigma^2}{\frac{e^2}{4}(N-1)+\sigma^2}$$

$$= \frac{21(10^2)}{\frac{5^2}{4}(21-1)+10^2}$$

$$= \frac{2100}{6.25(20)+100}$$

$$= \frac{2100}{225}$$

$$= 9$$

Figure 5: Calculation of Tanjung Resang road Sampling Unit (Mubaraki 2014)

There were three types of defects found on the TRR. The defects found are obtained from four samples which are (i)patching, (ii) alligator cracking, (iii) polished aggregate and (iv)longitudinal Cracking.

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Plate a Plate b Plate c

Figure 6: Patching on Tanjung Resang Road

Figure 6 indicates that there are patches on the Tanjung Resang Road samples of plate a, plate b and plate c, respectively. The patches on the road have the quantity of 0.40 m2, 1.15 m2 and 2.88 m2.



plate a plate b plate c

Figure 7: Polished Aggregate on Tanjung Resang Road

Figure 7 shows that polished aggregate was discovered on the Tanjung Resang road samples a, b and c. The portions on the road have the area of 1.15 m2, 1.30 m2 and 1.20m2



plate a plate b

Figure 8: Alligator Cracking on Tanjung Resang Road

Figure 8 shows that the surface area of alligator cracking is measured in meter square. Alligator cracking was identified in TRR samples. 1.15 m2 are the sizes for both road segments that encountered alligator cracking.



Plate a

Figure 9: Longitudinal Cracking on Tanjung Resang Road

Based on Figure 9, longitudinal cracking was found in Tanjung Resang Road samples 9. The length of cracking is 0.11 m.

PCI Calculation for Road Distress in Tanjung Resang (TR) Road

Table 1: Tanjung Resang Road Distress Quantity and Density (DQD)

ROAD : Tanjung Resang Road Area of sample : 497 m2

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)
1	6	L	0.40	0.08
2		M	1.15	0.23
3		H	2.88	0.58
4	1	M	1.15	0.23
5		M	1.15	0.23
6	13	-	1.15	0.23
7			1.30	0.26
8			0.40	0.08
9	14	H	0.11	0.02

(Source: Researcher's Findings)

The quantity is measured after the severity of each road defect has been determined. The density of the distress will be calculated using the measured quantity. The researcher divides the length of the defects by the area of the sample to get the density percentage.

Table 1 shows the density percentage for patching in TR roads are 0.08%, 0.23%, and 0.58% for road samples 1, 2 and 3. Furthermore, 0.23% is the density percentage for both sample 4 and 5 of alligator cracking. The third road defect is polished aggregate, which is 0.23% for sample 6, 0.26% for sample 7 and 0.08% for sample 8. The last road distress is longitudinal cracking with a density of 0.02%.

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Table 2: Tanjung Resang Road Deduct Value (DV)

ROAD : Tanjung Resang Road — Area of sample : 497 m2
Maximum Allowable Number of Deducts: 9

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)	Deduct Value	9 allowable number of deducts
1	6	L	0.40	0.08	0	14
2		M	1.15	0.23	3	10
3		H	2.88	0.58	14	10
4	1	M	1.15	0.23	10	4
5		M	1.15	0.23	10	3
6	13	-	1.15	0.23	0	0
7			1.30	0.26	0	0
8			0.40	0.08	0	0
9	14	H	0.11	0.02	4	0

The purpose of determining the severity and density percentage is to find a DV for each of the road distress. Each distress has a different distress DV curve. For patching, based on Table 2, the DV for low severity with the density of 0.08% is 0. Medium severity patching with 0.23% density has a deduct value of 3. Then, high severity patching with 0.58% density has the deduct value of 14. Next, both alligators cracking with medium severity in TR road density 0.23% have the deduct value of 14. Then, the polished aggregate deducts value curve (Appendix A) recorded the deduct value of 0 for the density of 0.23%, 0.26%, and 0.08%. Lastly, the low severity longitudinal cracking with the density of 0.02% gains the deduct value of 4.

Consequently, to obtain the PCI, the DV must first be established on the maximum allowable number of deducts, to sum up, the Total Deduct Value. The formula for the maximum number of deductions that can be taken is as follows:

[m = 1 + (9/98) (100-HDV)], where HDV is the greatest deduct value

Thus, Tanjung Resang Road, m = 1 + (9/98) (100-14) = 9 maximum allowable number of deducts. The number of deducted values should be reduced to the value of m. If the number of deducting values is less than the value of m, all of the deduct values should be used. Following the value of m, the deduct values should be listed in descending order, as shown in Table 2.

Table 3: Tanjung Resang PCI Calculation

ROAD : Tanjung Resang Road

Area of sample : 497 m2
Maximum Allowable Number of Deducts: 9

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)	Deduct Value	9 allowable number of deducts	q (deduct value greater than 5)
1	6	L	0.40	0.08	0	14	3
2		M	1.15	0.23	3	10	
3		H	2.88	0.58	14	10	
4	1	M	1.15	0.23	10	4	
5		M	1.15	0.23	10	3	
6	13	-	1.15	0.23	0	0	
7			1.30	0.26	0	0	
8			0.40	0.08	0	0	
9	14	H	0.11	0.02	4	0	
TOTAL DEDUCT VALUE (TDV)					41		
CORRECTED DEDUCT VALUE (CDV)					25		
PCI (100 - CDV)					75.00		

To obtain the PCI rating of the road condition, the corrected deduct value must be attained first. To acquire this corrected deduct value, at first, *q* needs to be determined. Q is the deduct value of which is greater than 5. For Tanjung Resang, the q is three, as seen in Table 3, and this will serve as the curve to plot to find the corrected deduct value. By looking for the proper adjustment, the researcher could ascertain the corrected deduct value from *q* and total deduct value. The total deducted value is 41 making the corrected deduct value to be 25. PCI is calculated by 100 – Corrected Deduct Value. The PCI for Tanjung Resang is 100 – 25 = 75 road condition.

Type of Road Distress in Tanjung Resang-Penyabong Road (TRP)

TRP road was the second road to be assessed. The length of the sample size has been determined to be 70.00m and the road width is 7.50 m. Hence, the TRP road sample size is 70.00m × 7.50m, with a total area of 525 m2. The number of samples in calculation is shown below:

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ROAD : Tanjung Resang - Penyabong Road
Length : 70 m
Width : 7.50 m

$N = \frac{1500}{70}$

$$n = \frac{N\sigma^2}{\frac{e^2}{4}(N-1)+\sigma^2} = 21$$

$$= \frac{21(10^2)}{\frac{5^2}{4}(21-1)+10^2}$$

$$= \frac{2100}{6.25(20)+100}$$

$$= \frac{2100}{225}$$

$$= 9$$

Figure 10: Calculation of TRP road Sampling Unit (Mubaraki 2014)

From the calculation above (Figure 10), there are 9 sections of the road that were observed for this route. TRP road had four different categories of defects namely, (i)Polished aggregate, (ii)patching, (iii)longitudinal cracking and (iv)raveling Pare were the defects discovered in TRP road in all nine samples examined.



plate a Plate b Plate c

Figure 11: Polished Aggregate on TRP Road (Source: Researcher's Observation)

The observation for the TRP road found some road defects, which are patches, as shown in Figure 11. The sizes of the road segments are both 5.25 m2 and 3.53 m2


plate a


plate b


plate c

Figure 12: Patches on TRP Road (Source: Researcher's Observation

The visual observation made from TRP road discovered that there are two patches on the road segments Figure 12. The area of the patch's defects found are 2.63 m2 and 1.50 m2 the last defect found on Tanjung Resang – Penyabong road are categorized as raveling. Figure 15 shows road segment nine which has a raveling at 1.76m2

PCI Calculation for Road Distress in Tanjung Resang – Penyabong Road

Table 4: Tanjung Resang - Penyabong Road Distress Severity

Sample	Distress Type	Distress Severity
1	13	-
2		
3		
4		
5	6	L
6		H
7		H
8	14	L
9	17	L

(Source: Researcher's Findings)

Based on Table 4, it can be found that the defects that occur are those of number 13 (polished aggregate), 6 (patching), 14 (longitudinal cracking) and 17 (ravelling) for TRP road. Next, the patching for TRP roads is low and high severity. The low severity shows that the patch in sample 5 is in good working order and delivers satisfactory results. Lastly, the TRP road has a high degree of distress severity recorded and this is when the patches must be replaced.

It has been observed that the TRP road has longitudinal cracking on the road surface.

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The last distress recorded is raveling with low severity for sample 9 on TRP road. Low severity shows the aggregate or binder has only begun to deteriorate.

Table 5: TRP Road Distress Quantity and Density (Source: Researcher's Findings)

ROAD : Tanjung Resang - Penyabong Road Area of sample : 525 m2

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)
1	13	-	5.25	1.00
2			5.25	1.00
3			3.53	0.67
4			3.53	0.67
5	6	L	2.63	0.50
6		H	1.50	0.29
7		H	1.50	0.29
8	14	L	0.47	0.09
9	17	L	1.76	0.34

From Table 5, the density percentage for polished aggregate in TRP road is 1.00%, 1.00% and 0.67% for road samples 1, 2 and 3. Furthermore, 0.50% is the density percentage for sample 4, and 0.29% is the density percentage for both sample 6 and 7 for patching. Next is the density percentage for longitudinal cracking, which is 0.09% for sample 8. The last road distress is raveling with the density of 0.34%.

Table 6: TRP Road Deduct Value (Source: Researcher's Findings)

ROAD : Tanjung Resang - Penyabong Road Area of sample : 525 m2
Maximum Allowable Number of Deducts: 9

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)	Deduct Value	9 allowable number of deducts
1	13	-	5.25	1.00	0	10
2			5.25	1.00	0	10
3			3.53	0.67	0	1
4			3.53	0.67	0	1
5	6	L	2.63	0.50	1	0
6		H	1.50	0.29	10	0
7		H	1.50	0.29	10	0
8	14	L	0.47	0.09	0	0
9	17	L	1.76	0.34	1	0

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The polished aggregate deducts value curve recorded the deduct value of 0 for the density of 1.00% and 0.67%, respectively. Table 6 found that for patching based on Appendix C, the deduct value for low severity with the density of 0.50% is 1. High severity patching with 0.29% density, as seen in Table 6, has the deduct value of 10. After that, the low severity longitudinal cracking with the density of 0.09% gains the deduct value of 0 by using Appendix D. The fourth one is raveling with low severity in TRP road density 0.34% has the deduct value of 1 using Appendix B to plot the value. TRP road maximum allowable number of deducts is m = 1 + (9/98) (100-10) = 9. Following the value of m, the deduct values were listed in descending order, as shown in Table 6.

Table 7: TRP PCI Calculation (Source: Researcher's Findings**)**

ROAD : Tanjung Resang - Penyabong Road Area of sample : 525 m2
Maximum Allowable Number of Deducts: 9

Sample	Distress Type	Distress Severity	Distress Quantity (m2 /m /nr.)	Density (%)	Deduct Value	9 allowable number of deducts	q (deduct value greater than 5)
1	13	-	5.25	1.00	0	10	2
2			5.25	1.00	0	10	
3			3.53	0.67	0	1	
4			3.53	0.67	0	1	
5	6	L	2.63	0.50	1	0	
6		H	1.50	0.29	10	0	
7		H	1.50	0.29	10	0	
8	14	L	0.47	0.09	0	0	
9	17	L	1.76	0.34	1	0	
TOTAL DEDUCT VALUE (TDV)					22		
CORRECTED DEDUCT VALUE (CDV)					17		
PCI (100 - CDV)					83.00		

Table 7 shows that TRP *q* is 2. The TDV is ascertained using the curve *q* = 2 in Appendix A. The total deducted value calculated is 22 making the corrected deduct value to be 17. PCI for TRP is 100 – 17 = 83 road conditions.

The Road Defects Identification in Mersing District

To determine the road maintenance prioritization, traffic load and PCI value are needed. The traffic flow is obtained by visual observation done for a week on each road for 6 hours. However, the traffic level may be affected since this study was conducted during COVID-19, and this contributed to fewer vehicles than the average traffic level.

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Table 8: Each Road Traffic Level

No	Name of Road	Rank	Traffic Level (vehicles/day)
1	Tanjung Resang road	1	10
2	Tanjung Resang – Penyabong road	2	48

Table 9: PCI calculation

No	Name of Road	PCI	Condition Category	Traffic Level (Vehicles)	Rank of Maintenances for traffic
1	Tanjung Resang road	75	Satisfactory	10	2
2	Tanjung Resang – Penyabong road	83	Excellent	48	1

Tables above (Table 8 and Table 9) represent the PCI calculation. For TR road is PCI 75 and for TRP road is 83 for the rank. As for the condition, TR road is satisfactory and TRP road is in excellent condition. As for Table 9, traffic level TR road is 10 and TRP road is 48. Lastly, for rank for maintenance for traffic, TR road is 2 and TRP road is 1. The roads observed in this study are two roads chosen within the Mersing district. The two roads are TR road and TRP road. Each road has its road defects that occur on the sample observed. For the first road, which is Tanjung Resang, it was discovered that the distress occurred are (i)patching, (ii) alligator cracking, (iii) polished aggregate and (iv)longitudinal cracking. For the second road, TRP road had three different categories of defects identified namely (ii)patching, (iii)longitudinal cracking and (iv)raveling.

Table 10: Road Condition categories and PCI value

No	Name of Road	PCI	Condition Category
1	Tanjung Resang road	75	Satisfactory
2	Tanjung Resang – Penyabong road	83	Excellent

From Table 10, the road condition categories and PCI value. TR road has the highest PCI value, 83, making the road categories fall into the excellent road condition category.

To conclude, the most road defects that occur in all of two roads are polished aggregate. Among other frequent defects found are patching and cracking, which are most likely due to the road having become a frequent road to travel for heavy vehicle load since all the roads above are old roads in the district.

The significance of the findings was that road maintenance management differs based on the amount of load that vehicles traveled. Early detection by evaluating the road condition and optimizing the maintenance planning schedule are necessary to ensure the efficiency of road performance. Consistency of road maintenance can minimize road damage and reduce accidents due to deteriorating roads. There is a need to identify road locations where road accidents occur frequently before proceeding to clarify underlaying issues and develop proventive measures (Bashayar Alhajri, *et.all,* (2024)

Table 11: PCI and maintenance priority

No	Name of Road	PCI	Condition Category	Traffic Level (Vehicles)	Rank of Maintenances for traffic	Priority
1	Tanjung Resang road	75	Satisfactory	10	6	3
2	Tanjung Resang – Penyabong road	83	Excellent	48	6	2

From Table 11, the road that obtains the most priority is Endau – Penyabong road because the road still maintains a satisfactory road condition even when there is a lot of traffic. This means the maintenance program for this road must be maintained and done regularly to avoid more road deterioration.

The second priority goes to Tanjung Resang – Penyabong road with excellent road condition even when the rank of maintenance for traffic flow is only 6. Tanjung Resang road is inevitably the third priority as the rank of maintenance for traffic flow is only six. The traffic level is minimal, causing the road conditions to be satisfactory. The maintenance program must be maintained for both of this road; however, maybe prioritization can be given to other roads with severe or deplorable road conditions.

Dominant pavement defects are commonly influenced by factors such as traffic loading, inadequate drainage systems, poor patching quality, pavement ageing, and environmental conditions, all of which contribute to the deterioration of road performance and service To address the inherent limitations of conventional pavement maintenance evaluation, which often struggles with fuzzy boundary values and disparate evaluation indices, advanced approaches are emerging that integrate image processing with Multi-Criteria Decision Making. (Cavalli et al., 2023)

CONCLUSION

The level of maintenance and repairing technology found in this case study were currently satisfactory, but there is still room for improvement. This research states

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that insufficient funding is the cause of ineffective road maintenance and this causes the road to continue to deteriorate. The road maintenance company should always inspect and be on the alert when it comes to monitoring the road condition. Moreover, such an approach will ensure that there is no wastage of funding allocated for road maintenance.

The findings show that the accuracy of the method used, namely Pavement Condition Index (PCI) and International Roughness Index (IRI) is reliable to determine the type of defects. Therefore, detailed data on road conditions can be used for effective maintenance planning. Future research can be more accurate and thorough if the road condition analysis is done with more advanced technology, such as using Falling Weight Deflectometer (FWD). This method can measure the structural strength of the road structure and can result in better findings for the road condition. Axle Load Test can also measure the damages done to the road surface caused by vehicles. HDM-4 also can be carried out to forecast the budget for road maintenance.

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THE CHALLENGES OF FACILITIES MANAGEMENT AND MAINTENANCE CONTRACT DOCUMENT IMPLEMENTATION FOR OFFICE BUILDINGS IN MALAYSIA

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Abstract

Facilities Management and Maintenance Contract Documents (FMMCD) play an important role in regulating facilities management and maintenance (FMM) service delivery, contract administration and maintenance responsibilities. In Malaysia, the Public Works Department (PWD) introduced the PWD FMM 2016 to standardise FMM procurement and implementation for public facilities. However, the implementation of PWD FMM 2016 in office building projects continues to face several contractual and operational challenges. This study aims to identify the implementation challenges associated with FMM 2016 in Malaysian office building projects. A qualitative approach was adopted through document analysis of the PWD FMM 2016 and semi structured interviews with six industry practitioners representing public clients and FMM service providers. The interview data were analysed using thematic analysis. The findings identified several implementation challenges related to the Instruction to Tenderers (ITT), Conditions of Contract (CoC), and Appendices sections. Key issues include unclear tender requirements, unclear technical specifications, inconsistent SLA and KPI implementation and poor CMMS and asset data management are identified. The findings demonstrate that many implementation problems originate from inconsistencies between contractual clauses, technical documentation, and operational practices. The study recommends clearer contract drafting, improved technical documentation and stronger digital asset data governance to improve implementation consistency and reduce disputes.

Keywords: Challenges, Facilities Management and Maintenance, Contract Document, Office Building

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INTRODUCTION

Facilities Management and Maintenance (FMM) has become increasingly significant in Malaysia, especially with the ongoing urban development and aging infrastructures. FMM refers to the integration of multidisciplinary activities designed to ensure the functionality, comfort and efficiency of the built environment (Ling & Husain, 2024). FMM practices are implemented across both public and private sectors, using either in-house teams or outsourcing arrangements. In Malaysia, the government oversees the maintenance of buildings and facilities by appointing the Public Works Department (Jabatan Kerja Raya or JKR) to handle FMM (Facilities Management and Maintenance) tasks for each of their departments. One of the standard forms used for government facilities management projects is the Facilities Management and Maintenance Contract Document (FMMCD) PWD FMM 2016. The contract document outlines tendering procedures, contractual obligations, technical specifications, performance requirements, and operational appendices for facilities management implementation. In the private sector, companies have the option to either manage maintenance internally or outsource the work (Zulkifly et al., 2021).

Facilities Management and Maintenance Contract Document (FMMCD) is an essential tool that regulates the legal and business rapport between the clients and service providers. It outlines the scope of work, roles and responsibilities, performance expectations and payment terms. FMMCD is generally used in the post-construction stage, especially following the handover and commissioning of the construction projects whereby the focus is on the operational maintenance (Challender & Challender, 2024). Nevertheless, some organizations have begun considering FMMCD implications at earlier phases of design and development of constructions to incorporate maintainability and lifecycle cost-efficiency into project continuation (Hassanain et al., 2025). In Malaysia, the implementation of FMMCD can be observed across several different projects. In government sector, it is primarily used for government office building, hospitals, institutional offices and residentials quarters operated by the PWD or other government agencies (Hashim et al., 2019). The contracts used for government projects are usually following standardized formats that prioritise on accountability and procedural transparency, which are in line with the public procurement policy (Saperi et al., 2025). The adoption of the FMMCD supports structured maintenance practices and promotes greater consistency in performance delivery across government facilities. Conversely, in private sectors, the FMMCD are also adopted in various types of building such as commercial buildings, corporates offices and concession-based projects such as Private Finance Initiatives (PFI) projects or Public-Private Partnerships (PPP), where FMM is often governed by performance-based contract (Hamid et al., 2023). In

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contrast to the public sector, FMMCD application in private sector are more flexible, where the content of the contract is tailored to meet the needs of the projects (Zabidi, 2023).

However, it is reported that the implementation of FMMCD in Malaysia faces several challenges such as the lack of standardized contract forms and poor understanding of the contract, which often results in inconsistencies in defining the responsibilities and expectations between parties (Tamošaitienė et al., 2021). Koc & Gurgun (2022) highlight that without uniformity, contracts become open to interpretations and ambiguity, leading to disputes and inefficiencies. Additionally, the scope of services in many FMMCD is often vague and performance indicators are not clearly defined, making it difficult to assess service quality or hold parties accountable (Demirdöğen et al., 2022). Other challenges reported including vague specifications, unclear performance indicators, inconsistent documentation and lack of expertise in contract documentation (Zabidi, 2023; Edirisinghe et al., 2020). This leads to communication breakdown and disputes (Edirisinghe et al., 2020; Zou et al., 2019). To mitigate these challenges, Haron et al. (2020) suggest that contract documents should be drafted with clarity, precision and awareness of practical realities.

This study addresses this gap by examining implementation challenges according to the three main components of the FMM 2016 contract structure, namely Instruction to Tenderers (ITT), Conditions of Contract (CoC), and Appendices. The study aims to identify the implementation challenges associated with FMM 2016 in Malaysian office building projects and to understand how contractual structure contributes to operational issues during implementation. This study contributes to the existing literature by analysing implementation challenges based on the three main components of the FMM 2016 contract document. The study links the identified challenges directly to specific components of the contract document rather than discussing FMM issues in general.

LITERATURE REVIEW

FMM and FMMCD in Malaysia

FMM in Malaysia has undergone significant evolution since its inception in the 1990s, particularly gaining momentum in the early 2010s (Kamaruzzaman et al., 2018). The importance of effective FMM was further underscored by incidents in government offices, highlighting the critical role of maintenance in ensuring safety and functionality (Awasho & Alemu, 2023). Despite transitioning from reactive to preventive maintenance strategies, Malaysia's FMM sector still faces challenges such as lack of standardized practices, insufficient awareness and limited professional development compared to countries like United States and

United Kingdom (Rahmat & Nawawi, 2017). In response to these challenges, the Malaysian government has initiated policies like the National Infrastructure Asset Management Policy, set to be implemented in 2025, aiming to cultivate efficient maintenance practices and enhance public and private sector's comfort (Bernama, 2025). Furthermore, Hamid et al. (2021) reported that the Construction Industry Development Board (CIDB) also supports the FMM through various initiatives, encouraging professionals to improve their capacity and adopt technologies. These initiatives reflect the growing institutional recognition of FMM as a key pillar of national development and long-term asset sustainability.

As FMM practices advance, the supporting documents must also be updated to align with evolving industry needs. Central to this is the FMMCD, which serves as the foundation for aligning expectations, responsibilities and service delivery standards between clients and service providers. However, studies have shown that the implementation of FMMCDs often faces challenges such as unclear scope definitions, outdated technical specifications and insufficient performance standards (Hauashdh et al., 2022). In Malaysia, the use of FMMCD remains inconsistent, particularly between the public and private sectors. While government projects may utilize standardized documentation, such as those issued by the PWD, there is currently no standardized documentation for private sector (Zabidi, 2023; Zain 2022). As a result, the private sector tends to rely on bespoke contracts that are individually modified for each project (Che Mat, personal communication, 2024). This led to the inconsistencies of the contract terms and scope definitions across different projects. These inconsistencies increase the likelihood of contractual disputes. Haron and Arazmi (2020) emphasized that ambiguities in contract clause, inaccurate interpretation and unclear risk allocation are among the most common causes of conflict. These contractual challenges can significantly affect the execution of FMM projects, especially when the obligations of each party are not clearly stated.

Structure and Components of FMMCD

In Malaysia, the PWD FMM 2016 form of contract structures the FMMCD into three key parts which are the Instruction to Tenderers (ITT), Condition of Contract (CoC) and Appendices. The ITT provides a detail on the instructions regarding how the tenderers shall prepare their tender for the submission including how the tender evaluation procedures are done. The CoC defines the obligations of the contractor throughout the contract periods and appendices act as additional information containing all specifications and information for the contractor and are used to bind the contract. Each of these components plays a crucial role in defining the contractual obligations, procedural requirements and technical details necessary for effective FMM.

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Instruction to Tenderers (ITT)

The ITT component provides guidance to tenderers regarding tender participation requirements, submission procedures and evaluation processes. This section plays an important role in supporting transparency and consistency during the procurement stage. Previous studies highlighted that inadequate tender information, unclear instructions and limited project details may contribute to misunderstanding among tenderers and reduce the quality of submitted proposals (Albtoush et al., 2022). Ambiguities in tender requirements may also create inconsistencies in interpreting contractual expectations and eligibility conditions during tender preparation.

Several studies further reported that tender preparation constraints such as limited advertisement periods and insufficient project information may affect contractors' ability to conduct comprehensive project assessments before submission (Indah Kusumarukmi & Adi, 2019). This situation may subsequently influence cost estimation accuracy and increase the likelihood of future contractual disputes. In addition, transparency and fairness during tender evaluation remain important concerns within procurement practices. According to Alwis et al. (2022), unclear tender instructions and evaluation criteria may create uncertainty among tenderers regarding compliance expectations and assessment procedures. Therefore, clear tender specifications and transparent evaluation procedures are essential to improve procurement effectiveness and reduce ambiguities during the tendering process (Khoso et al., 2021; Laryea, 2011).

Condition of Contract (CoC)

The CoC component establishes the contractual framework governing the implementation of FMM projects. It outlines the rights, responsibilities and obligations of contracting parties including matters related to payment procedures, variation orders, dispute resolution and contract administration. Existing literature indicates that contractual clarity is essential in minimizing disputes and ensuring effective contract execution. However, ambiguities and incomplete contractual provisions remain recurring issues within FMM and construction related contracts (Alghamdi et al., 2024; Haron & Arazmi, 2020).

Studies from Rao et al. (2024) and Chen et al. (2018) reported that rigid contractual structures and limited flexibility in contract modification procedures may affect project adaptability, particularly when unexpected operational requirements or technology related changes occur during implementation. Ineffective variation management procedures may further contribute to disputes, delays and cost overruns when contractual changes are not clearly regulated (Koc & Gurgun, 2021). In addition, procurement related limitations and administrative delays may affect maintenance responsiveness, especially for smaller

maintenance works that require immediate implementation (Alghamdi et al., 2024). These issues suggest that weaknesses within contractual provisions may significantly influence the efficiency and practicality of FMM implementation.

Appendices

Appendices is one of the sections in the FMMCD that serves as a supplementary component that provides detail technical and operational information to support contract execution. Among the subcomponents of appendices included in the FMMCD are forms of tender, acceptance letter, technical specification, schedule of prices and others. This section is critical for operationalizing the broader terms of the contract, offering a measurable parameter that guide day-to-day performance and compliance.

Previous studies identified several issues associated with technical documentation and information management within appendices. Lai et al. (2022) reported that incomplete information and insufficient documentation may create difficulties during project planning and implementation. Similarly, Mikulík and Hanák (2024) highlighted that vague or outdated technical specifications may affect contractors' ability to accurately assess project requirements and prepare reliable cost estimations during tendering and project execution stages.

In addition, weakly defined performance indicators and inconsistencies in technical documentation may reduce monitoring effectiveness and contribute to disputes regarding service quality and contractual expectations (Mahowa et al., 2025). The lack of standardized guidelines and reliable asset information further complicates maintenance planning and operational coordination. These issues demonstrate the importance of accurate, standardized and updated appendices in supporting effective FMM contract implementation and reducing technical ambiguities throughout the contract lifecycle.

Overall, previous studies suggest that implementation challenges in FMMCD are frequently linked to issues within tender procedures, contractual clauses and technical documentation. Table 1 summarises the key implementation issues reported in the literature according to the three main components of the FMMCD and their relevance to the present study.

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Table 1: Summary of Previous FMMCD Issues Identified

FMMCD Component	Issues Identified	Authors	Related Focus in this Study
Instruction to Tenderers (ITT)	Unclear tender instructions, inadequate project information, limited advertisement period, ambiguities in evaluation criteria and tender compliance issues	Albtoush et al. (2022); Indah Kusumarukmi & Adi (2019); Alwis et al. (2022); Khoso et al. (2021)	Tender transparency, tender compliance, tender evaluation practices and procurement related challenges
Condition of Contract (CoC)	Misinterpretation of clauses, rigid contractual provisions, ineffective variation management, procurement delays and incomplete contractual clauses	Rao et al. (2024); Chen et al. (2018); Koc & Gurgun (2021); Alghamdi et al. (2024); Haron & Arazmi (2020)	Contractual clarity, variation order management, procurement efficiency and contractual adequacy
Appendices	Incomplete technical documentation, outdated specifications, weak performance indicators, inconsistent asset information and lack of standardized guidelines	Lai et al. (2022); Mikulík & Hanák (2024); Mahowa et al. (2025)	Technical specification issues, cost assessment challenges, asset information gaps and documentation standardisation

Source: Author's Own Data

RESEARCH METHODOLOGY

This study presents findings from a preliminary qualitative survey using document analysis and semi structured interviews to identify challenges in implementing FMMCD in Malaysia. The document analysis focused on the PWD FMM 2016 contract document to examine its structure and key components and to identify relevant issues reported in the literature. The results were used to guide the interview protocol and support the analytical framework. Purposive sampling was used to select participants based on their experience in FMM projects and involvement with FMMCD implementation. The study targeted two stakeholder groups, namely public clients and FM contractors. Although ten participants were initially identified, only six agreed to participate. This number was considered sufficient as data saturation was achieved during data collection. The interview protocol was developed based on themes from the literature review and document analysis and was reviewed by two experts for clarity and relevance (Shoozan & Mohamad, 2024). Each interview lasted 45 to 60 minutes and included demographic questions and open-ended questions on FMMCD challenges. Interviews were conducted face to face or online, recorded with consent and transcribed verbatim. Data saturation occurred after the fifth interview, with the sixth confirming consistency in the findings (Guest et al., 2020). The data were analysed using thematic analysis supported by ATLAS.ti Version 24, which

assisted in coding and organising qualitative data (Herbst et al., 2024). Findings were grouped based on the FMMCD structure identified from the document analysis, namely Instruction to Tenderers (ITT), Conditions of Contract (CoC) and Appendices.

FINDINGS

Demographic Background

The demographic data gathered from the Section A were compiled from the participants which consists of their represented organisations, working experience and positions in the organisations. Table 2 presents the summary of the participant's demographic profile.

Table 2: Demographic profile (n=6)

Items	Sub-items	Frequency (n)	Percentage (%)
Stakeholders/Organisations	Public Client	1	16.7
	FM Contractor	5	83.3
Years of Experience	10-20 years	4	66.7
	20-30 years	2	33.3
Designation	Directors	3	50.0
	Quantity Surveyor	2	33.3
	Manager	1	16.7

Source: Author's Calculation

Table 2 presents the demographic background of the participants involved in the paper. The majority were FM contractors (83.3%), while only one participant represented a public client (16.7%). Four participants had between 10 to 20 years of experience (66.7%) with the remaining two having 20 to 30 years of experience (33.3%). In terms of designation, half of the participants were directors (50.0%) followed by two quantity surveyors (33.3%) and one manager (16.7%).

Challenges of FMMCD

The findings from the interviews revealed a range of issues identified from the FMMCD which are challenges of ITT, challenges of CoC and lastly challenges of Appendices. The following sub-sections will discuss the challenges identified under each main component.

Challenges related to ITT

The analysis indicates several challenges within the ITT component, including limited advertisement scope, unfair tender bond requirements, non-compliance with tender conditions and ethical concerns during tender evaluation. These issues were consistently highlighted by participants across procurement experiences.

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Ethical concerns were reported during the evaluation stage, where participants noted instances of post submission price adjustments that raise questions on fairness and transparency (P4:Q27). Similar concerns have been identified in previous studies, where lack of transparency in procurement processes may weaken trust and procedural integrity (Abul Hassan et al., 2021; Mohamad Azmi & Ismail, 2023). From a document perspective, the FMMCD evaluation structure provides general procedures but limited detailed safeguards on post submission adjustments, which may contribute to inconsistent interpretation during evaluation.

Non-compliance with tender conditions was also highlighted, where contractors without sufficient experience were allowed to participate or awarded contracts (P3:Q5). This reflects weaknesses in pre-qualification enforcement discussed in prior studies (Olanrewaju et al., 2022). The document analysis shows that eligibility criteria are stated in ITT, but enforcement mechanisms are not clearly operationalised, which may contribute to inconsistent application.

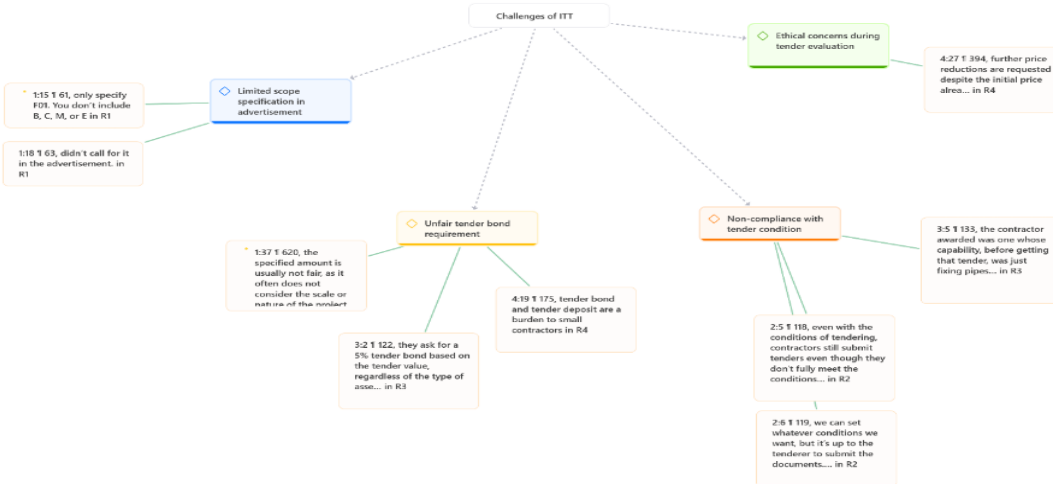


Figure 1: Network relationship for the challenges of ITT
Source: Author's Own Data (2024)

Unfair tender bond requirements were frequently mentioned as a barrier to participation, particularly for smaller contractors (P4:Q19; P1:Q37; P3:Q2). Literature suggests that high financial requirements may reduce competition and limit contractor participation (Lee et al., 2020). The document structure specifies bond requirements but does not differentiate contractor capacity, which may affect inclusivity.

Limited advertisement scope was also identified where project information is insufficient for accurate bidding decisions (P1:Q15; P1:Q18). This aligns with findings that incomplete tender information reduces bid accuracy and

increases mismatch between contractor capability and project requirements (Ayettey & Danso, 2018). The ITT section provides general scope information, but lacks detailed operational breakdown, which affects bid clarity.

Challenges related to Condition of Contract (CoC)

Figure 2 show that challenges in CoC relate to missing contractual clauses, unclear provisions, usage limitations, misinterpretation of clauses, variation order practices and procurement delays. Missing contractual clauses were frequently identified across participants, including absence of price adjustment mechanisms, extension of time provisions, variation order clauses and defect liability provisions (P4:Q17; P3:Q28; P1:Q7). Literature confirms that incomplete contract provisions may lead to ambiguity and operational inefficiency (Ahmad & Marri, 2023; Mohammad et al., 2022). The document analysis indicates that while CoC defines obligations, several operational clauses are not explicitly detailed, creating gaps during execution.

Unclear clauses and misinterpretation were reported where payment and scope provisions were interpreted differently by stakeholders (P2:Q2; P1:Q22). This aligns with studies highlighting that ambiguous wording increases dispute potential (Haron & Arazmi, 2020). The CoC document contains contractual terms but lacks operational guidance notes, which may contribute to interpretation differences. Variation order misuse was also identified, where VOs were applied beyond intended maintenance purposes (P1:Q21). Literature shows similar issues where VO mechanisms are often misapplied in practice (Koc & Gurgun, 2021). The CoC defines VO processes but does not clearly restrict application boundaries, which may lead to misuse.

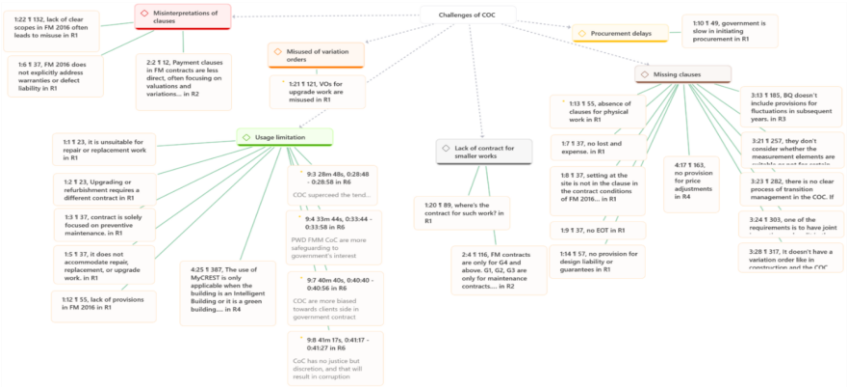


Figure 2: Network relationship on challenges of CoC
Source: Author's Own Data (2024)

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Contract limitations for smaller works were also highlighted, where maintenance contracts mainly focus on large scale works (P1:Q12). This is consistent with findings that standard contracts are not always suitable for minor works (Olanrewaju et al., 2023). The document analysis confirms limited coverage for small scale maintenance activities. Procurement delays were reported as affecting maintenance responsiveness (P1:Q10), consistent with literature on procurement inefficiency (He et al., 2023). This issue is linked more to implementation systems rather than contract wording itself.

Challenges related to Appendices

The last main component in the FMMCD is present in figure 3 which present the network relationship for challenges of appendices. The key challenges identified are the disputes over technical specification, historical data gaps, inadequate cost assessment, discrepancies in work order, lack of digital asset data at contract start and the lack of standardised guidelines.

Cost estimation difficulties were commonly reported due to insufficient asset information (P4:Q12; P7:Q1). Literature supports that incomplete data reduces cost accuracy and increases uncertainty in tender pricing (Olanrewaju et al., 2023). Document analysis shows that appendices rely heavily on provided data without ensuring completeness or verification mechanisms. Historical data gaps and lack of digital asset information were also identified (P1:Q28; P4:Q11). Studies highlight that poor data management affects maintenance planning and decision making (Razali et al., 2021). The appendices do not clearly enforce data updating standards, which contributes to inconsistency. Work order discrepancies were reported where interpretation varies between headquarters and site offices (P3:Q17; P1:Q34). This aligns with findings that lack of standard operating procedures leads to inconsistencies in execution (Ensafi et al., 2023). The document structure does not fully standardise work order procedures.

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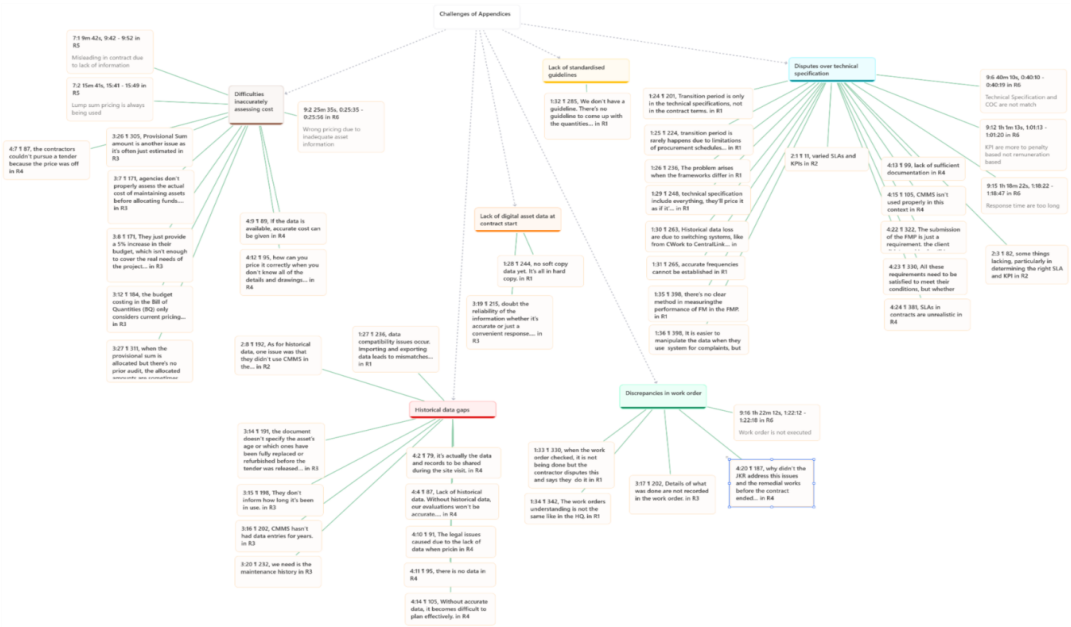


Figure 3: Network relationship on challenges of Appendices
Source: Author's Own Data (2024)

Technical specification disputes were also observed, particularly relating to SLAs and KPIs (P4:Q24; P9:Q12). Literature supports that poorly defined KPIs reduce performance clarity (Lai et al., 2022). Appendices include specifications but lack integration with operational performance systems.

DISCUSSION

The findings of this study are largely consistent with previous literature on FMM and procurement related contract management issues. Challenges related to ITT, CoC and Appendices reflect recurring problems such as unclear documentation, weak standardisation and limited operational clarity (Haron & Arazmi, 2020; Lai et al., 2022). However, this study extends the discussion by mapping these issues directly to the structural components of the PWD FMM 2016 contract document. The persistence of these challenges in Malaysia may be linked to the hybrid nature of FMM implementation, where standardized government contracts coexist with flexible operational practices. This creates variation in interpretation, particularly at the implementation level. In addition, limited integration between contract documentation and operational data systems such as CMMS may contribute to recurring inconsistencies in cost estimation, performance monitoring and maintenance execution.

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The sample of this study represents both public clients and FM contractors, which provides cross stakeholder perspectives but does not represent all sectors of FMM practice in Malaysia. Therefore, the findings should be interpreted as indicative rather than generalisable across the entire industry. The main contribution of this study is not the identification of entirely new issues, but the structured alignment of implementation challenges with specific components of the FMMCD. This provides a clearer contract-based lens for understanding where operational breakdowns occur and how contractual structure influences implementation outcomes.

CONCLUSION

This research examined the key challenges in implementing the FMMCD in Malaysia, focusing on three main components: Instruction to Tenderers (ITT), Conditions of Contract (CoC), and Appendices. Semi structured interviews with FMM stakeholders revealed recurring issues including unclear and limited tender information, inconsistent application of tender requirements, ethical concerns during tender evaluation, missing and unclear contractual clauses, rigid contract provisions, misuse of variation orders, procurement delays, incomplete technical documentation, data gaps, and inconsistencies in work order and specification details. The study shows that these challenges are interconnected across the contractual structure. Issues in ITT affect tender preparation and evaluation, gaps in CoC influence contract interpretation and implementation, while deficiencies in Appendices impact cost estimation, asset information reliability and technical execution. These findings indicate that implementation problems are not isolated but arise from structural weaknesses across the FMMCD components. The study contributes by examining the FMMCD through its three core components and linking interview findings directly to each section of the contract. This approach provides a clearer understanding of how specific contractual areas contribute to implementation challenges within Malaysian FMM practice.

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EXPECTED UTILITY AND RISK CONSIDERATIONS IN URBAN TREE MANAGEMENT: THE ROLE OF DECISION-MAKING DETERMINANTS

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Abstract

This study examined how key decision-making determinants influence urban tree retention and removal decisions in Malaysian development areas. Drawing upon the Expected Utility Theory (EUT), data were gathered through a structured survey involving 265 practicing landscape architects. The exploratory factor analysis (EFA) revealed two key dimensions of expected decision outcomes—utility maximisation and risk avoidance. Multiple regression analyses further indicated that considerations such as cost–benefit considerations, spatial and project limitations, institutional guidelines, social perception, tree characteristics, and resource availability all play significant roles in influencing these outcomes. Retention decisions were driven by long-term benefits and risk avoidance, whereas removal decisions emphasised cost efficiency, project feasibility, and institutional requirements. Overall, the findings suggest that managing urban trees effectively requires balancing practical benefits with risk considerations, supported by expert judgement and stronger policy frameworks for tree conservation.

Keywords: Decision Making, Expected Utility Theory, Urban Trees, Development Area

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INTRODUCTION

Urbanisation is advancing rapidly across the globe, intensifying the tension between the demand for new infrastructure and the preservation of urban green spaces. Trees in cities serve multiple ecological and social functions—they moderate the microclimate, support biodiversity, enhance public well-being, and contribute to cultural identity. Yet, despite these well-established benefits, many urban development projects continue to result in large-scale tree removal. The absence of a consistent and integrated decision-making framework for determining whether trees should be retained or removed remains a major challenge (Conway, 2016; Hassan et al., 2024; Hilbert et al., 2019; Jim, 2017; Kronenberg, 2014; Maidin & Mobarak Ali, 2009; Suliman et al., 2021). In Malaysia, this issue has become increasingly visible as rapid urban expansion places pressure on balancing development objectives with the conservation of existing trees. Previous studies have highlighted the ecological and social importance of urban trees, but decisions are often shaped by economic, spatial, institutional, and social constraints. Expected Utility Theory (EUT) provides a useful framework for understanding how decision-makers evaluate uncertain outcomes by weighing potential benefits against perceived risks. The theory was first formalised by von Neumann and Morgenstern (1944) and later refined by Mongin (1997) to address behavioural and contextual dimensions of rational choice. While Expected Utility Theory has been extensively used in economics and risk management, its application within urban forestry and planning remains limited.

Accordingly, this study pursued two main objectives. The first was to identify and validate the dimensions of expected decision outcomes—utility maximisation and risk avoidance through Exploratory Factor Analysis (EFA). The second was to examine how key determinants of decision-making, including cost–benefit considerations, institutional influences, social perceptions, spatial and physical environment factors, tree characteristics, survivability, project factors, and resource availability, shape retention and removal decisions using multiple regression analysis. Beyond its theoretical contribution, this study extends the application of Expected Utility Theory within the Malaysian development context and contributes to the growing literature on urban tree management. The study also sought to offer practical insights to support policy formulation, planning guidelines, and professional practice among landscape architects, local authorities, and developers. By providing empirical evidence on how benefits and risks are assessed in urban tree management, the research aimed to strengthen evidence-based decision frameworks and encourage more sustainable tree conservation practices in Malaysian cities. The following sections of this paper review the relevant literature and theoretical foundations,

describe the research methodology, present the findings, and discuss their implications for policy and professional practice.

LITERATURE REVIEW

Urban trees provide multiple ecosystem services, including shading, air purification, stormwater control, microclimate regulation, and aesthetic enhancement, and cultural identity while fostering biodiversity and public well-being (Jones & Cloke, 2002; Maleknia & Pakravan-Charvadeh, 2025; O'brien et al., 2022; Wolf et al., 2020). However, these benefits are often disregarded during urban development, where trees are perceived as physical or financial constraints (García, 2025; Willis et al., 2024). Determinants influencing urban tree decisions can be categorised into several groups. Economic factors include the costs of tree protection, maintenance, or removal, as well as the long-term benefits such as increased property value (Beuschel & Rudel, 2010; Conway, 2016; Song et al., 2018). Trees are more likely to be retained when removal costs are high or replacement planting is expensive, whereas removal can be justified when it supports efficiency, safety, or other project gains (Nik Mohamed Sukri et al., 2022). Closely related are spatial and project-related factors, which involve site suitability, underground conditions, and compatibility with development designs. Previous studies have shown that tree retention is facilitated when projects incorporate layout planning to integrate trees into design concepts, despite enhancing ecological and aesthetic values (Nik Hanita, 2012). Conversely, space constraints, narrow frontages, and infrastructure access requirements often drive tree removal (Croeser et al., 2020; Guo et al., 2018, 2019; Lavy & Hagelman, 2017; Morgenroth et al., 2017). Institutional determinants further shape decision outcomes through laws, guidelines, and compliance requirements. While tree inventories, protection lists, and enforcement mechanisms can strengthen retention, weak legislation, ineffective penalties, and limited regulation on private land often undermine protection (Clark et al., 2020; Guo et al., 2019; Ordóñez-Barona et al., 2021).

Regulatory and socio-cultural contexts further influence tree management issues in Malaysia. For example, Hamzah et al. (2017) examined urban dwellers' applications for tree removal in Kajang, revealing that cost implications, space limitations, and lack of enforcement contribute significantly to removal decisions. Local planning guidelines (PLANMalaysia, 2021) also show that weak implementation of tree protection bylaws and insufficient arboricultural expertise hinder consistent decision-making. Complementing these are social factors, which reflect the role of public perceptions, community participation, and expert involvement. Awareness of tree protection policies, socio-economic conditions, and cultural values all influence stakeholder attitudes toward tree retention, with arborists and landscape architects often serving as

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mediators, while public protests or community support may sway decisions (Conway & Bang, 2014; Danquah et al., 2023; Ordóñez-Barona, 2017). Biological and survivability factors also play a key role, including species, age, health, and structural condition. Mature, healthy, or culturally significant trees are often prioritised for retention due to their ecological and social value, whereas unsafe, diseased, or poorly adapted trees may be removed (Jim, 2005; Morgenroth et al., 2017; Roman et al., 2020). Finally, resource factors reflect the availability of funding, technical expertise, and technology. Financial constraints and insufficient training often limit local authorities' ability to manage trees effectively, leading to removal rather than retention (Brunner & Cozens, 2013; PLANMalaysia, 2021). Altogether, these determinants influence how decision-makers judge whether trees should be retained or removed when outcomes are uncertain. In this study, the Expected Utility Theory (EUT) provided the theoretical foundation for understanding this evaluation process. The theory explains decision-making as a balance between two key considerations: utility maximisation and risk avoidance. Utility maximisation reflects the pursuit of optimal benefits—such as economic gains, project efficiency, and value enhancement—when determining whether to retain or remove trees. In contrast, risk avoidance focuses on reducing potential losses and uncertainties related to safety hazards, maintenance costs, or ecological degradation. By weighing these two aspects, decision-makers aim to reach a rational, benefit–risk–based judgement under uncertain conditions.

METHODOLOGY

Study Sample and Data Collection

This study adopted a quantitative survey design to examine decision-making determinants in urban tree retention and removal in Malaysia. The study population comprised 829 landscape practitioners registered with the Institute of Landscape Architects Malaysia (ILAM) for the 2021/2022 session. Using the Krejcie and Morgan (1970) formula, a minimum of 262 samples was required, and data collection was completed after 265 valid responses were obtained, giving a 77% response rate. A simple random sampling technique was applied to ensure equal chances of selection (Gay & Airasian, 2003). Data were collected using an online questionnaire (Google Form) distributed from March to September 2022 via email, WhatsApp, Facebook, Instagram, and direct emails to registered landscape firms. The questionnaire consisted of four sections: demographics, determinants of retention, determinants of removal, and expected decision outcomes. Fourteen items were developed to measure expected decision outcomes. The determinant constructs were adapted from previous studies related to urban forestry and development planning, covering economic, institutional, social, spatial and physical environment, project-related, biological,

survivability, and resource-related considerations. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire items were reviewed by local authority officers (PBT) to ensure contextual relevance and content validity. To minimise potential common method bias, respondent anonymity was maintained and the questionnaire items were presented in a clear and neutral format.

Procedure and Data Analysis

Data analysis was conducted using SPSS Version 26. Normality tests confirmed that the dataset satisfied the assumptions required for multivariate analysis. The analysis involved two main stages. In the first stage, Exploratory Factor Analysis (EFA) with Varimax rotation was performed on 14 items to identify the latent structure of expected decision outcomes. Prior to factor extraction, the suitability of the data for Exploratory Factor Analysis (EFA) was assessed using the Kaiser–Meyer–Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO value of 0.829 indicated very good sampling adequacy, exceeding the recommended threshold of 0.60 (Hair et al., 2010). Bartlett's Test of Sphericity was statistically significant [$\chi^2(91) = 1765.335$, $p < 0.001$], confirming sufficient intercorrelations among the variables and supporting the appropriateness of factor analysis. The communalities of the retained items ranged from moderate to high, indicating acceptable representation of the variables within the extracted factor structure. Although several items showed moderate cross-loadings and lower communalities, these items were retained because they remained theoretically important within the Expected Utility Theory (EUT) framework and satisfied the factor loading retention criteria. Reliability analysis was conducted to assess the internal consistency of the extracted constructs. The Cronbach's alpha values for utility maximisation and risk avoidance were 0.829 and 0.836 respectively, indicating good internal consistency and satisfactory reliability of the measurement scales. Two distinct components emerged, representing utility maximisation and risk avoidance. Item inclusion was guided by factor loadings greater than 0.40 and cross-loadings below 0.40 (Maskey et al., 2018). Mean scores for each extracted factor were computed and subsequently used as dependent variables in the regression analyses.

In the second stage, multiple regression analyses using the stepwise method were carried out to examine how various decision-making determinants predicted these two expected outcomes across both tree retention and removal contexts. The approach was used to identify the most influential predictors for each decision outcome dimension. Prior to regression analysis, diagnostic assessments were conducted to ensure that the assumptions of multiple regression were adequately satisfied. Four regression models were tested: (i) retention and

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utility maximisation, (ii) retention and risk avoidance, (iii) removal and utility maximisation, and (iv) removal and risk avoidance. This two-phase analytical process, which combined construct validation through factor analysis with explanatory testing through regression, offered a systematic way to examine how practitioners weigh anticipated benefits against potential risks in urban tree management decisions. Figure 1 presents an overview of the methodological flow, outlining the sequence from data collection and factor validation to regression analysis and interpretation of the decision outcomes.

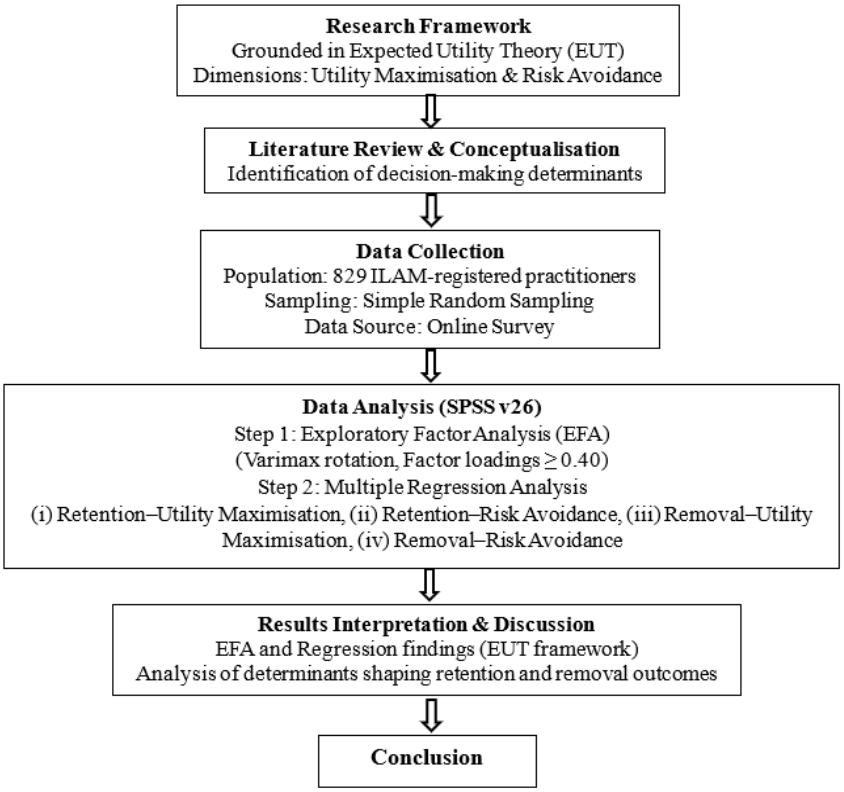


Figure 1: Summary of the research methodology

ANALYSIS AND DISCUSSION

Exploratory Factor Analysis (EFA) of Expected Decision Outcomes

Exploratory Factor Analysis (EFA) with Varimax rotation was conducted on all 14 items measuring expected decision outcomes. The analysis extracted two

components consistent with theoretical expectations, together explaining 53.81% of the total variance. Factor 1 accounted for 43.11%, while Factor 2 explained 10.70% (Table 1).

Table 1: Total Variance Explained by Factors

Component	Initial Eigenvalues	% of Variance	Cumulative %	Rotation Sums of Squared Loadings	% of Variance	Cumulative %
1	6.04	43.11	43.11	3.84	27.42	27.42
2	1.50	10.70	53.81	3.70	26.39	53.81

Inspection of the rotated component matrix (Table 2) showed that items clustered into two groups representing expected outcomes related to utility maximisation and risk avoidance. Although several items demonstrated moderate cross-loadings and lower communalities, no items were removed because they satisfied the retention criteria of factor loadings ≥0.40 and cross-loadings <0.40. The communalities of the retained items ranged from moderate to high, indicating acceptable representation of the variables within the extracted factor structure.

Table 2: Rotated Component Matrix and Communalities

Expected Decision Outcomes	Utility Maximisation	Risk Avoidance	Communality
Expected outcomes related to utility maximisation			
High costs of tree protection	**0.81**		0.656
Low financial returns from tree retention	**0.80**		0.640
Profit from timber sales due to tree removal	**0.62**		0.384
High maintenance costs of retained trees	**0.78**		0.608
Retention on high-value property is not worthwhile	**0.80**		0.640
Expected outcomes related to risk avoidance			
Retention requires additional maintenance work	0.34	**0.67**	0.564
Retention complicates construction vehicle access		**0.63**	0.397
Tree care requires expert involvement	0.39	**0.43**	0.337
Limited protective equipment for retained trees	0.38	**0.57**	0.469
Trees have difficulty adapting if retained		**0.66**	0.436
Transplanted trees often fail to survive		**0.61**	0.372
Trend of tree failure in surrounding areas		**0.62**	0.384
Retention may endanger public safety		**0.76**	0.578
Retention may disrupt construction activities		**0.66**	0.436

Regression Analysis and Interpretation

Multiple regression was used to test the influence of decision-making determinants on expected decision outcomes, separately for tree retention and tree removal. The regression analyses provide insights into how different determinants influence expected decision outcomes in urban tree management.

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Table 3: Summary of Multiple Regression Results

Decision Context	Outcome Dimension	Significant Predictors	R^2	F-value ($p < 0.05$)
Retention	Utility maximisation	Cost and benefit (β = 0.40)	0.16	50.80
Retention	Risk avoidance	Cost and benefit (β = 0.54), Spatial and physical environment (β = 0.24), Social (β = 0.17)	0.36	48.47
Removal	Utility maximisation	Cost and benefit (β = 0.54), Project (β = 0.23), Institutional (β = 0.14)	0.62	144.06
Removal	Risk avoidance	Spatial (β = 0.66), Tree characteristics (β = 0.40), Resources (β = 0.34), Project (β = 0.21), Survivability (β = 0.11)	0.69	112.76

Retention – Utility Maximisation and Risk Avoidance

For tree retention decisions, the analysis showed that cost and benefit, spatial and physical environment, and social considerations significantly influenced the expected outcomes for both utility maximisation and risk avoidance. Among these, cost and benefit were found to be the most dominant predictor of utility maximisation ($\beta = 0.40$, $R^2 = 0.16$, $F = 50.80$, $p < 0.05$), highlighting the importance of economic evaluation in shaping practical decisions. Based on the Expected Utility Theory (EUT), decision-makers tend to pursue the highest benefits while keeping potential losses to a minimum. In this study, such behaviour can be seen in the way practitioners consider financial implications, project feasibility, and social acceptance when deciding whether to retain trees within development sites.

In relation to risk avoidance, the combined influence of cost and benefit, spatial and physical environment, and social factors accounted for 36% of the variance in decision outcomes [$F (3, 261) = 48.47$, $p < 0.05$]. Proper financial planning supports adequate tree protection and maintenance, while spatial and physical environment factors, such as available planting areas and construction access help reduce possible hazards. Meanwhile, social factors like stakeholder involvement and public perception can prevent disputes and strengthen local support for retention efforts. These findings indicate that decisions to retain trees require a balanced consideration of both the expected benefits and the potential risks involved. Viewed through the EUT framework, these two dimensions are closely linked. Cost–benefit evaluations drive decisions that aim for long-term ecological, social, and economic value, whereas risk-avoidance strategies ensure that such benefits are achieved safely and sustainably. In practice, retaining high-value trees—those that contribute to air quality, energy savings, or property enhancement—is only realistic when cost, space, and safety issues are adequately managed. This suggests that tree retention is not a simple matter of cost or convenience, but rather a rational process of weighing trade-offs between

anticipated gains and possible risks, aligning well with the principles of the Expected Utility Theory (Barron et al., 2021; Fazilah et al., 2013; Kellogg et al., 2017; Pryor & Watson, 2016; Shi et al., 2023).

Removal – Utility Maximisation and Risk Avoidance

For tree removal decisions, the analysis identified two related dimensions, namely utility maximisation and risk avoidance, which reflect the complex nature of decision-making described by the Expected Utility Theory (EUT). Three determinants—cost and benefit, project-related factors, and institutional guidelines—were found to significantly predict utility maximisation, explaining 62% of the variance [$F(3, 261) = 144.06$, $p < 0.05$]. Cost–benefit analysis played a major role in determining whether tree removal would bring net advantages, particularly in cases involving diseased or hazardous trees. Project-related factors contributed to construction efficiency and better site planning, while adherence to institutional requirements ensured that removals followed legal and environmental standards. These findings are consistent with earlier studies that highlight the importance of economic reasoning and regulatory compliance in achieving optimal development outcomes (Clark et al., 2020; Lee et al., 2021; Willis et al., 2024).

At the same time, five key determinants, namely spatial constraints, tree characteristics, resources, project-related factors, and tree survivability, had a significant effect on risk avoidance decisions, accounting for 69% of the variance [$F(5, 259) = 112.76$, $p < 0.05$]. Efficient spatial planning helped reduce environmental loss and public resistance, while tree characteristics such as species, age, and health informed judgments about safety and design quality. Access to sufficient resources, including professional expertise and regulatory support, improved the quality of decisions, and consideration of survivability ensured that tree removal did not undermine long-term ecosystem services (Apfelbeck et al., 2020; Ordóñez et al., 2023). Overall, the results showed that removal decisions are shaped by a careful balance between the desire to maximise benefits and the need to minimise risks, in line with EUT's ideas. Decision-makers attempt to improve cost efficiency and project feasibility (*utility maximisation*) - while simultaneously reducing potential problems related to safety, environmental impacts, or limited resources (*risk avoidance*). In practice, choices made for economic or technical reasons are often adjusted based on risk considerations, helping to ensure that tree removal supports both short-term project success and long-term ecological resilience. This suggests that urban tree removal decisions are not purely technical or financial choices but rather deliberate assessments of benefits and risks made within the context of uncertainty.

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CONCLUSION

Multiple interconnected determinants influence decisions about urban tree retention and removal, as this study demonstrates. For retention, long-term utility and risk avoidance are primarily guided by cost–benefit considerations, spatial and physical environment constraints, and social factors, ensuring trees are maintained safely and provide maximum ecological, aesthetic, and cultural benefits. In tree removal, decisions are driven by cost efficiency, project-related factors, institutional guidelines, tree characteristics, resources, and survivability, allowing practitioners to minimise ecological and social risks while maximising development outcomes. Overall, the findings reinforce the application of Expected Utility Theory in understanding urban tree decision-making under uncertainty. They also highlight the importance of evidence-based frameworks, expert input, and comprehensive planning to ensure sustainable urban tree management, balancing environmental conservation with development needs. This study provides practical guidance for policymakers, developers, and practitioners to enhance urban tree conservation and integrate trees effectively into development projects. As this study employed a cross-sectional survey design, the findings should be interpreted as associational rather than causal relationships. Future studies may adopt longitudinal or mixed-method approaches to further examine decision-making processes in urban tree management.

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DAYLIGHT ILLUMINANCE IN A DOUBLE-LOADED CORRIDOR CLASSROOM: FIELD MEASUREMENT AND REVIT SIMULATION

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Abstract

This study evaluates daylight illuminance performance in a selected classroom located within a double-loaded corridor higher education building in Seri Iskandar, Perak, Malaysia. The case-study classroom measures 12 m × 6 m × 3.2 m and has a northwest-facing façade with one-sided tinted glazing. Field illuminance measurements were conducted using a 20-point grid at working-plane height, with representative readings reported at 8.00 a.m., 1.00 p.m. and 5.00 p.m. The results were assessed against the recommended 300–500 lux illuminance range for general teaching spaces. A Revit-based daylight simulation model was then developed to examine selected design variables, including glazing type, window height, floor reflectance and overhang provision. The field measurement results showed that the existing classroom performed below the recommended range at most measurement points, with 100% of readings below threshold at 8.00 a.m. and 1.00 p.m., and 98% below threshold at 5.00 p.m. Simulation results indicated that clear glazing, increased window height and higher floor reflectance improved daylight availability. However, several clear-glass scenarios also produced high above-threshold percentages, indicating possible over-illumination and visual comfort risks. Among the tested scenarios, the combination of larger window openings, clear glazing, higher floor reflectance and overhang provision offered a more balanced daylight improvement strategy. The findings are limited to the selected classroom and simulation assumptions but provide evidence-based guidance for improving daylight-responsive design in similar double-loaded corridor classrooms.

Keywords: Daylighting, Classroom illuminance, Revit daylight simulation, Double-loaded corridor, Glazing

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INTRODUCTION

Daylighting is an important environmental design consideration in educational buildings because it affects visual conditions, artificial lighting dependence and the quality of indoor learning spaces. In classrooms, adequate illuminance is required to support reading, writing and other visual tasks. For general teaching spaces, the recommended illuminance level is commonly placed within the range of 300–500 lux. Therefore, daylight design should not only increase the amount of natural light entering a classroom, but also provide an appropriate and relatively balanced distribution of illuminance across the working plane (Brink et al., 2021; Liu et al., 2022).

In tropical higher education buildings, achieving suitable daylight conditions can be challenging due to strong solar exposure, heat gain, glare risk and façade constraints. This challenge is particularly relevant in buildings with double-loaded corridor layouts, where classrooms are arranged on both sides of an internal corridor. Although this configuration is efficient for space planning, it can restrict daylight access and cause uneven illuminance distribution, especially where classrooms receive daylight from only one side of the façade (Alkhatatbeh et al., 2023; Kong et al., 2022).

Previous studies have examined daylighting performance in educational buildings and have highlighted the influence of window design, orientation, glazing type, shading devices and interior reflectance. However, fewer studies have focused specifically on field illuminance measurements and simulation-based daylight improvement scenarios for tropical higher education classrooms located in double-loaded corridor buildings. This creates a need for a bounded case-study investigation that links actual illuminance performance with tested design variables and a clear compliance benchmark (Syaheeza et al., 2018; Susan & Prihatmanti, 2017; Wan Abdullah et al., 2022).

This study therefore investigates the daylight illuminance performance of one selected classroom in a higher education building with a double-loaded corridor configuration. The study is guided by three research questions: (1) what are the existing daylight illuminance conditions in the selected classroom compared with the 300–500 lux recommended range; (2) to what extent does the Revit simulation reflect the daylight performance pattern of the existing classroom; and (3) how do selected design variables, namely glazing type, window height, floor reflectance and overhang provision, influence classroom illuminance distribution and the selection of a balanced daylight improvement scenario?

The contribution of this study is limited to evidence-based design guidance for classrooms with similar geometry, orientation and corridor typology. The study does not measure student learning performance, thermal comfort or glare perception directly. Instead, it focuses on illuminance

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performance and daylight distribution as measurable indicators for evaluating potential daylight-responsive classroom improvements.

LITERATURE REVIEW

Daylight Metrics and Visual Comfort in Classrooms

Classroom lighting is an important environmental factor in supporting visual tasks such as reading, writing and viewing teaching materials. In daylighting studies, illuminance is commonly used to evaluate the amount of light received on a working plane, usually expressed in lux. However, classroom daylight performance should not be assessed only by the amount of light entering the space, but also by how evenly the light is distributed across the classroom. Poor daylight distribution may create under-lit areas that require artificial lighting, while excessive daylight may increase brightness contrast and visual discomfort. Therefore, effective classroom lighting design should consider illuminance level, distribution, visual comfort and the integration of artificial lighting where daylight is insufficient (Brink et al., 2021; Liu et al., 2022; Odiyur et al., 2021).

Daylight Constraints in Double-Loaded Corridor Classrooms

Double-loaded corridors, featuring a central hallway flanked by classrooms, are common in educational buildings for efficient space use but often limit natural light penetration. As noted by Alkhatatbeh et al., (2023), this layout causes uneven daylight distribution, classrooms near the façade receive more light, while inner or lower rooms depend on artificial sources. Such imbalance affects visual comfort and learning efficiency (Kong et al., 2022). To address this, strategies like light shelves, reflective surfaces, and optimized window placement can enhance daylight access and uniformity.

Field Measurement and Daylight Simulation

Field illuminance measurement is commonly used to evaluate actual daylight conditions in classrooms because it records the amount of light received at the working plane under real building and sky conditions. In classroom daylighting studies, measurement points are usually arranged across the occupied area to capture variation in illuminance distribution, including areas near the window and deeper parts of the room. Such measurements are useful for identifying whether a classroom meets the recommended illuminance range and for detecting uneven daylight distribution that may affect visual comfort.

Daylight simulation complements field measurement by allowing different design scenarios to be tested under controlled modelling conditions. Building Information Modelling (BIM) software such as Autodesk Revit can be used to model classroom geometry, window configuration, material properties and daylight distribution. Through simulation, the effects of design variables such

as glazing type, window size, surface reflectance and shading elements can be compared before physical modification is carried out. Combining field measurement with simulation therefore provides a more comprehensive approach for assessing existing daylight performance and evaluating potential improvement strategies in educational spaces (Bakmohammadi & Noorzai, 2020; de Lima Montenegro et al., 2021; Shoshev, 2022).

Standards for Daylighting in Classroom

In classroom or general teaching space environments, daylighting strategies must achieve a balance between reducing energy consumption and ensuring adequate visual comfort for students. Malaysian standards such as MS1525:2019 and the JKR guidelines, along with the international IESNA recommendations, prescribe comparable illuminance levels for teaching spaces in the range of 300-500 lux. These benchmarks highlight the dual objective of daylighting design: minimising reliance on artificial lighting while maintaining optimal visual conditions that support effective learning. Table 1 presents a summary of the recommended values.

Table 1: Illuminance level recommendations

Learning Space	**Standards and Guidelines**		
	MS1525	JKR	IESNA
General Teaching Space	300 - 500	300 - 500	300 - 500

Source: Syaheeza et al., (2018)

RESEARCH METHODOLOGY

Research Design

This study adopts a bounded case-study approach to examine daylight illuminance conditions in a selected classroom within a higher education building designed with a double-loaded corridor. The research combines field measurement and Revit-based daylight simulation. Field measurement was used to determine the existing illuminance condition, while simulation was used to test selected improvement scenarios under controlled design assumptions. The development of the simulation scenarios was guided by daylighting design factors identified in previous work, including building form, orientation, window design, reflectance, special elements and obstructions.

For this paper, only variables that could be directly tested in the selected classroom model were modified: glazing condition, window height, floor reflectance and overhang provision. Room geometry and orientation were kept constant to maintain comparability between scenarios. Thus, the enhancements of daylighting in the classroom are based on the daylighting design factors listed in Table 2 by Wan Abdullah et al., (2022). Accordingly, the study is limited to

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daylight illuminance performance and does not directly assess occupant perception, student learning performance, glare perception or thermal comfort.

Table 2: Suggested Checklist Items for Daylighting Design Factors

Checklist	Items
Building form	Site size and shape; Building size and shape; Depth of room; Height of room
Building Orientation	Building facing
Window design	Position; Size; Shape
Reflectance	Color and material of surfaces; Arrangement of furniture
Special elements	Overhang; Light shelves; Louvres; Blind; Tinted glazing
Obstruction	Trees; Facade

Source: Wan Abdullah et al., (2022)

Each daylighting design factor listed in Table 2 directly influences the amount and quality of daylight entering the classroom. The building form and orientation determine solar exposure and penetration, while window design affects light direction, intensity, and distribution. Interior surface reflectance enhances light diffusion, and elements such as overhangs and light shelves help control glare and improve daylight uniformity. Conversely, obstructions like nearby buildings or trees reduce indoor illuminance. Understanding these relationships is crucial for evaluating overall daylight performance in classrooms.

Study Area

The selected classroom is in a higher education building at UiTM Seri Iskandar, Perak, Malaysia. The building has a double-loaded corridor configuration, with classrooms arranged on both sides of a central corridor. The selected classroom is located at the first-floor level on the northwest side of a four-storey building. The classroom was selected because it represents a common classroom layout used in Malaysian higher education buildings and because it was accessible for field measurement and modelling. The classroom measures 12 m in length, 6 m in width and 3.2 m in height, giving a gross floor area of approximately 72 m^2.

The existing classroom has one-sided tinted glazing, no external shading, white-yellowish painted walls, light grey ceramic floor tiles, a white painted concrete slab ceiling and approximately 25 desks and chairs. Therefore, the findings should be interpreted as indicative for classrooms with similar geometry, orientation and corridor typology rather than as a general representation of all higher education classrooms. Table 3 summarises the case study building and classroom conditions.

Table 3: Summary of Case Study Building

Item	Description
Location	UiTM Seri Iskandar, Perak, Malaysia
No. of storey	Four-storey higher education building with double-loaded corridor
Measurement location	First floor level
Façade/Orientation	One-sided tinted-glazed façade facing northwest
Shading	No shading
Classroom size	12 m (length) x 6 m (width) x 3.2 m (height); GFA approximately 72 m^2
Interior condition	White-yellowish painted wall, light grey ceramic tile, white painted concrete slab ceiling, whiteboard and approximately 25 desks and chairs (Figure 2 – indoor view)

Source: Wan Abdullah et al., (2022)

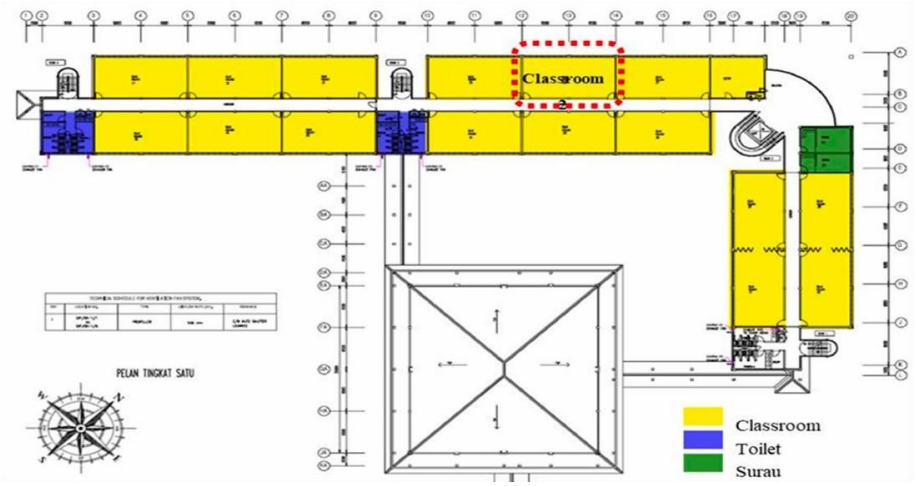


Figure 1: Location of the case study classroom at UiTM Seri Iskandar
Source: Wan Abdullah et al., (2022)



Figure 2: Classroom outdoor and indoor view
Source: Wan Abdullah et al., (2022)

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Figure 1 shows the double-loaded corridor arrangement, with the selected classroom located on the northwest side of the building. In this configuration, the internal corridor separates classrooms from direct daylight access on one side, which may limit daylight penetration and contribute to uneven illuminance distribution. As shown in Figure 2, the classroom façade faces northwest and has limited external obstruction, with small trees located approximately 3 m from the building. Therefore, external obstruction was considered minimal in this study. The façade wall is finished in white and light blue, while the classroom uses one-sided, black-tinted glazing. These existing conditions were included in the field measurement and simulation model.

Fieldwork illuminance measurement

Figure 3 shows the fieldwork measurement grid and the placement of indoor and outdoor illuminance measurement equipment. Indoor illuminance was measured at 20 grid points distributed across the classroom working plane. The measurement points were arranged approximately 1.0 m apart to capture the daylight gradient from the window zone towards the rear of the classroom. Readings were taken at a working-plane height of 0.75 m above finished floor level, corresponding to typical desk height. The classroom was unoccupied during measurement, and all electric lighting and electrical appliances were switched off to isolate the contribution of daylight.

The analysis in this paper reports three representative time points, namely 8.00 a.m., 1.00 p.m. and 5.00 p.m. These time points represent morning, midday and late-afternoon daylight conditions during typical classroom operating hours. For each time point, every grid reading was classified as below threshold, within threshold or above threshold based on the recommended illuminance range of 300–500 lux. Readings below 300 lux were classified as below threshold, readings between 300 and 500 lux were classified as within threshold, and readings above 500 lux were classified as above threshold. The percentage of points in each classification was then calculated based on the 20 measurement points.

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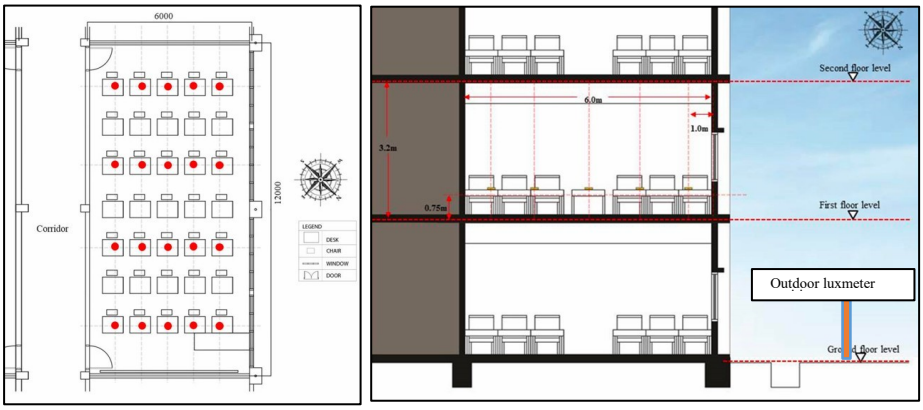


Figure 3: Fieldwork illuminance measurement grid and equipment placement
Source: Wan Abdullah et al., (2022)

Revit Daylight Simulation

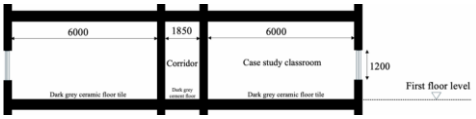
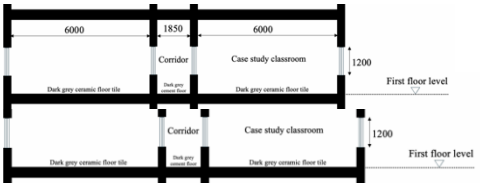
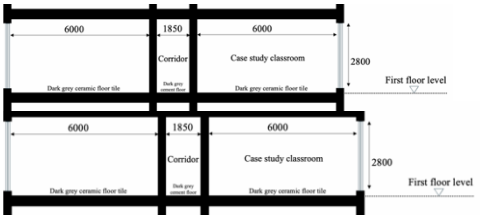
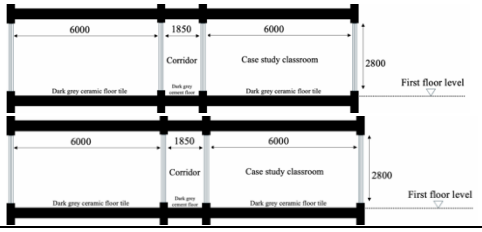
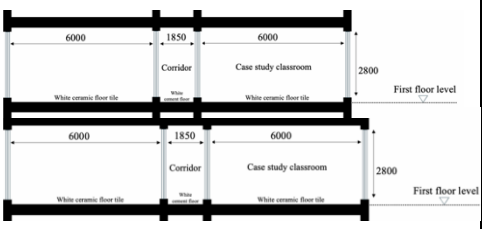
BIM software such as Autodesk Revit was utilized to develop parametric models of the selected classroom. The accuracy of the Revit model was supported by incorporating exact measurements and visual data gathered during on-site investigation. The model included the classroom walls, windows, doors and interior elements. Precise measurements and digital photographs served as references, with particular focus given to ceiling height, room orientation and obstructions that might affect natural light.

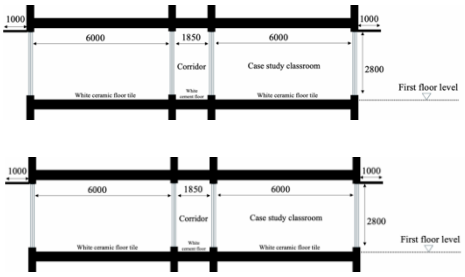
The Revit daylight simulation model was developed based on the measured classroom dimensions, orientation, window configuration and interior surface characteristics. The model represented the selected classroom as a 12 m × 6 m × 3.2 m space with a northwest-facing façade. Simulation scenarios were created by varying only the design parameters tested in this study: glazing type, window height, number/location of window openings, floor reflectance and overhang provision. Other parameters, including room geometry and classroom orientation, were kept constant to allow direct comparison between scenarios. The existing classroom simulation was first compared with field measurements to check whether the model represented the general daylight performance pattern before testing the proposed design scenarios.

Some technical details from the original measurement and simulation records were not fully available for extended reporting in this manuscript, including sensor calibration records, exact optical transmittance values of glazing materials and complete point-by-point time-series datasets. Therefore, the simulation comparison focuses on the general daylight performance pattern and percentage classification relative to the 300–500 lux benchmark. This limitation was considered when interpreting the simulated scenarios, particularly in relation to over-illumination and visual comfort risk.

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Table 4: Simulated Daylight Improvement Scenarios and Controlled Design Variables

Classrooms/Samples	Section layout	Data
Actual design • Window on one side of the wall • Tinted glass • White wall • Dark grey ceramic floor tile	Classroom height: 3.2m 	Window size: 0.6m (length) 1.2m (height) (1 panel) Total panel: 16
Sample 1 (a) Tinted glass – both side of the wall (b) Clear glass – both side of the wall		Window size: 0.6m (length) 1.2m (height) (1 panel) Total panel: 32 Floor: Dark grey ceramic floor tile
Sample 2 (a) Tinted glass – one side of the wall (window size increased) (b) Clear glass – one side of the wall (window size increased)		Window size: 0.6m (length) 2.8m (height) (1 panel) Total panel: 16 Floor: Dark grey ceramic floor tile
Sample 3 (a) Tinted glass – both side of the wall (window size increased) (b) Clear glass – both side of the wall (window size increased)		Window size: 0.6m (length) 2.8m (height) (1 panel) Total panel: 32 Floor: Dark grey ceramic floor tile
Sample 4 (a) Tinted glass – both side of the wall (floor reflectance increased) (b) Clear glass – both side of the wall (floor		Window size: 0.6m (length) 2.8m (height) (1 panel) Total panel: 32 Floor:

Classrooms/Samples	Section layout	Data
reflectance increased)		White ceramic floor tile
Sample 5 (a) Tinted glass – both side of the wall (overhang included) Clear glass – both side of the wall (overhang included)		Window size: 0.6m (length) 2.8m (height) (1 panel) Total panel: 32 Overhang: 1m from the wall Floor: White ceramic floor tile

Source: Wan Abdullah et al., (2022) & Author's analysis

Table 4 summarises the simulated daylight improvement scenarios and the controlled design variables used in the Revit model. The actual design represents the existing classroom condition with one-sided tinted glazing, white walls and dark grey ceramic floor tiles. Sample 1 tests the effect of adding window openings on both sides of the wall using tinted and clear glazing. Sample 2 examines increased window height on one side of the wall, while Sample 3 tests increased window height on both sides. Sample 4 introduces higher floor reflectance through white ceramic floor tiles, and Sample 5 adds a 1 m overhang while maintaining the larger window height and higher floor reflectance. These scenarios were developed to compare how glazing condition, window height, floor reflectance and overhang provision influence daylight penetration, illuminance distribution and possible over-illumination.

ANALYSIS AND DISCUSSION

Measured Illuminance Performance of the Existing Classroom

Table 5 summarises the field measurement results based on the 300–500 lux reference range. Readings below 300 lux were classified as below threshold, readings between 300 and 500 lux as within threshold, and readings above 500 lux as above threshold. The existing classroom performed below the recommended range at most measurement points. At 8.00 a.m. and 1.00 p.m., all 20 measurement points were below 300 lux. At 5.00 p.m., 98% of points remained below 300 lux and only 2% were within the recommended range. These results indicate that the existing one-sided tinted glazing does not provide sufficient daylight at the working plane during the selected time points.

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The dominance of below-threshold readings suggests weak daylight penetration and uneven daylight distribution across the classroom depth. In a double-loaded corridor classroom, the rear zone is expected to receive less daylight because the corridor side has limited direct contact with the exterior. This supports the need to test modifications that can improve daylight penetration and distribution.

Table 5: Field illuminance classification of the existing classroom based on 20 grid points

Time	Below threshold (<300 lux)	Within threshold (300-500 lux)	Above threshold (>500 lux)
8.00 a.m.	100%	0%	0%
1.00 p.m.	100%	0%	0%
5.00 p.m.	98%	2%	0%
n	20 grid points	20 grid points	20 grid points

Source: Adapted from Wan Abdullah et al., (2022) and author's analysis

The present analysis reports illuminance performance using percentage classification of measurement points below, within and above the 300–500 lux range. Complete point-by-point lux values were not available for additional statistical reporting in this manuscript. Therefore, mean, minimum, maximum, standard deviation, uniformity ratio and daylight penetration depth could not be calculated. This limitation was considered in interpreting the results, and the discussion therefore focuses on threshold classification, daylight distribution pattern and comparison between the field measurement and simulation outputs.

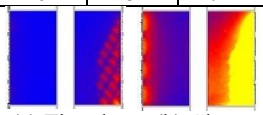
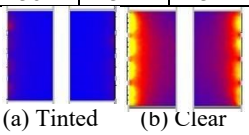
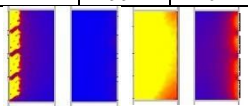
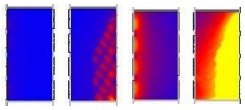
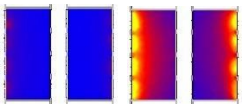
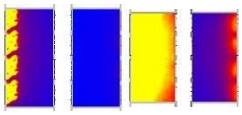
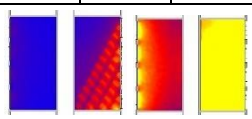
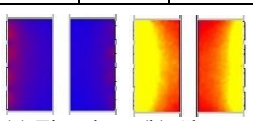
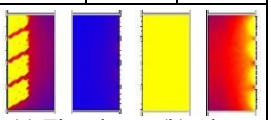
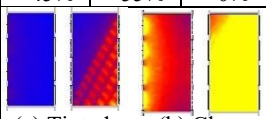
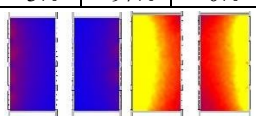
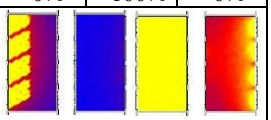
Simulation Results and Scenario Comparison

The simulation results shown in Table 6 indicate that the existing tinted-glass condition generally represented the weak daylight performance observed in the field measurement. For the actual simulated design with tinted glazing, 100% of points were below threshold at 8.00 a.m. and 1.00 p.m., while 81% remained below threshold at 5.00 p.m. The 5.00 p.m. simulated result also showed 17% above threshold, suggesting that late-afternoon daylight may create localised high illuminance near the façade even when the overall classroom remains under-lit.

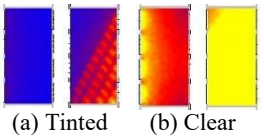
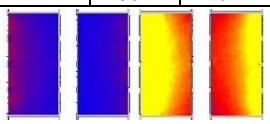
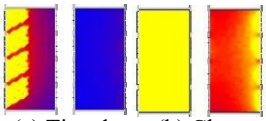
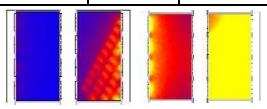
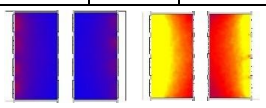
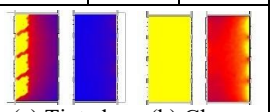
Clear glazing increased daylight availability in almost all scenarios. For example, the clear-glass version of the actual design achieved 38% within threshold and 31% above threshold at 1.00 p.m. However, the results also demonstrate that higher illuminance is not automatically beneficial. Several clear-glass scenarios produced very high above-threshold percentages, particularly at 1.00 p.m. and 5.00 p.m. Since readings above 500 lux may indicate excessive brightness, potential glare and visual comfort risk, clear glazing and larger window openings should be recommended together with appropriate daylight control strategies.

Among the tested design options, Samples 2, 3, 4 and 5 improved daylight availability compared with the existing tinted condition. Sample 3(b) achieved 45% within threshold at 8.00 a.m., while Sample 5(b) achieved 41% within threshold at 8.00 a.m. with the addition of an overhang and higher floor reflectance. Nevertheless, the high percentage of above-threshold values at midday and late afternoon suggests that the preferred daylight strategy should balance useful daylight with glare control, rather than maximise illuminance alone.

Table 6: Simulated illuminance classification for existing and improved daylight scenarios

Scenario	**8.00 a.m.**			**1.00 p.m.**			**5.00 p.m.**		
Actual (Simulation)	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	0%	0%	100%	2%	17%	81%
(b)	19%	8%	74%	38%	31%	32%	1%	99%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		
Sample 1	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	0%	0%	100%	4%	17%	79%
(b)	21%	8%	72%	35%	33%	32%	1%	99%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		
Sample 2	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	5%	0%	95%	38%	36%	26%
(b)	40%	58%	2%	3%	97%	0%	0%	100%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		
Sample 3	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	3%	0%	97%	25%	36%	39%
(b)	45%	55%	0%	3%	97%	0%	0%	100%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		

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Scenario	**8.00 a.m.**			**1.00 p.m.**			**5.00 p.m.**		
Sample 4	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	4%	0%	96%	35%	39%	26%
(b)	18%	82%	0%	1%	99%	0%	0%	100%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		
Sample 5	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
(a)	0%	0%	100%	3%	0%	97%	38%	28%	34%
(b)	41%	58%	0%	2%	98%	0%	0%	100%	0%
	 (a) Tinted (b) Clear			 (a) Tinted (b) Clear			 (a) Tinted (b) Clear		

Source: Author's calculation

Table 7: Simulated illuminance heatmap comparison between the existing tinted design and Sample 5(b)

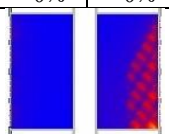
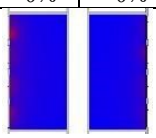
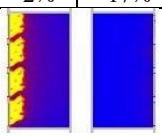
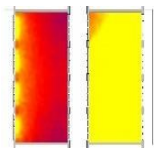
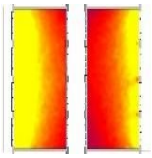
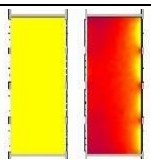
Scenario	**8.00 a.m.**			**1.00 p.m.**			**5.00 p.m.**		
	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold	Within threshold	Above threshold	Below threshold
	0%	0%	100%	0%	0%	100%	2%	17%	81%
Actual (Simulation) Tinted									
Sample 5(b) clear glazing higher floor reflectance 1 m overhang									

Table 7 compares the simulated illuminance distribution between the existing tinted design and Sample 5(b), which combines clear glazing, increased window height, higher floor reflectance and a 1 m overhang. The existing tinted design shows a larger under-lit area, particularly deeper inside the classroom, indicating limited daylight penetration from the façade. In comparison, Sample 5(b) improves daylight availability across the classroom depth. However, the brighter zones near the window also indicate the possibility of over-illumination, particularly during midday and late-afternoon conditions. This supports the interpretation that daylight improvement should balance useful daylight penetration with glare and visual comfort control.

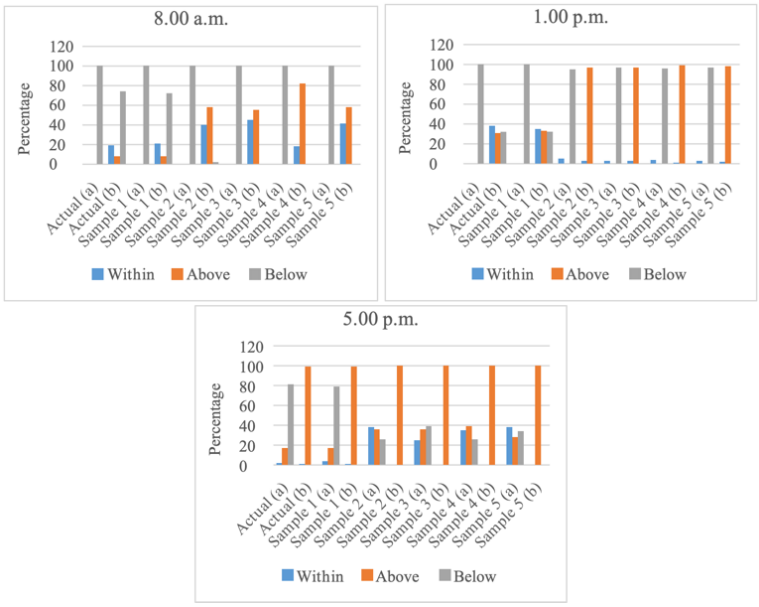


Figure 4: Illuminance level throughout the day (percentage)
Source: Author's Calculation

Figure 4 summarises the percentage distribution of simulated illuminance performance across the design scenarios at 8.00 a.m., 1.00 p.m. and 5.00 p.m. The actual tinted-glass design consistently recorded a high percentage of below-threshold points, indicating insufficient daylight availability. In contrast, the clear-glass scenarios generally increased daylight penetration, but several scenarios also produced high above-threshold percentages, particularly at 1.00 p.m. and 5.00 p.m. This pattern indicates that daylight improvement strategies should consider both daylight availability and visual comfort risk.

These findings are consistent with Syaheeza et al. (2018) and Susan and Prihatmanti (2017), who reported that classroom daylight distribution is influenced by orientation, window design and interior conditions. This alignment supports the interpretation that façade design and window-related variables play an important role in classroom illuminance performance.

CONCLUSION

This study examined daylight illuminance performance in one selected classroom within a double-loaded corridor higher education building in Seri Iskandar, Perak. The existing classroom, which uses one-sided tinted glazing, did not meet the recommended 300–500 lux range at most measurement points. Field measurements showed that all points were below the recommended range at 8.00

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a.m. and 1.00 p.m., while 98% remained below the range at 5.00 p.m. Revit-based simulation indicated that increasing window height, replacing tinted glazing with clear glazing, improving floor reflectance and adding an overhang can improve daylight availability. However, scenarios with clear glazing also produced a high proportion of above-threshold illuminance, suggesting potential over-illumination and visual comfort concerns. Therefore, daylight improvement should be evaluated not only by increased lux levels, but also by distribution, uniformity and avoidance of excessive illuminance.

The findings are limited to a single classroom, selected measurement times and the simulation assumptions used in the Revit model. Complete point-by-point lux datasets were not available for additional descriptive statistics such as mean, minimum, maximum, standard deviation, uniformity ratio and daylight penetration depth. External sky conditions, façade orientation, classroom geometry and material optical properties may influence the results. Future studies should include multi-day measurements, additional classrooms and building orientations, glare assessment, thermal performance analysis, occupant-based visual comfort evaluation and complete point-by-point illuminance data reporting.

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SUSTAINABLE ROAD TOURISM ROUTE PREDICTION: AN ANALYSIS USING KAGGLE DATA AND RANDOM FOREST

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Abstract

This paper delves into the forecasting of sustainable tourist routes using an open-access Kaggle dataset comprising 1,000 route samples and 7 predictive features, employing a Random Forest approach. The analysis includes two tasks: classification of a binary Sustainability_Target, achieving perfect accuracy (100% precision, recall, F1-score) on a held-out test set, and regression of a continuous Sustainability_Score, yielding an MAE of 0.069, RMSE of 0.081, and R^2 of 0.683. The study is situated within the ISSTERN framework to link predictions to planning actions. Findings suggest that while binary sustainability screening is highly feasible with this dataset, continuous score prediction shows moderate performance but is heavily influenced by the binary target feature, resulting in a two-cluster prediction pattern. Limitations include the use of simulated/open data, unknown generalizability to real-world Malaysia contexts, and potential data leakage due to perfect classification scores and the dominant importance of the binary target in regression. This paper contributes a reproducible data-driven workflow to sustainable tourism planning discourse.

Keywords: Sustainable Tourism, Road Tourism, Route Prediction, Machine Learning, Random Forest, Data Analysis

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INTRODUCTION

As a complex system involving the transportation of people to destinations outside their normal environment for purposes of rest and leisure, business, study, etc, tourism has great influences upon such destinations. Sustainable tourism is defined by the UNWTO as tourism that takes proper cognizance of the economic social and environmental impacts it has now and in the future and the needs of the tourist, the industry, the environment and the host community. It is not only about the conservation of the environment truth to say, but it effects an integrated and balanced way of managing resources, enabling tourism and attendant industries to generate sustainable wealth, protect and enhance the environment and social equity and cultural integrity for the foreseeable future (Purvis et al., 2019). Sustainable tourism is regarded as being one of the most important current global paradigms and is defined as a system which seeks to conserve balance between economic, environmental and socio-cultural aspects (Liu et al., 2018; Purvis et al., 2019).

Road tourism, a large chunk of this activity, is therefore one of the drivers of regional development, enabling access into remote areas and product distribution of developed areas into lesser developed ones. The beneficial aspects of road tourism, however, also come with lots of disadvantages in the form of environmental (e.g carbon rates of emissions, habitat fragmentation) and socio-cultural disruption and infrastructural weaknesses (Demirović Bajrami et al., 2020; Kanwal et al., 2020). These inherent pressures create a major dilemma for planning, on the one hand benefiting from the huge resource generating potentials of road tourism and on the other reacting to or negating any dysfunctional pressures created. The articulation and subsequent assessment of these two contradictory forces is what constitutes the major challenge for tourism planning. Therefore, the establishment of core sustainability factors, measurable factors which cover the environmental and socio-cultural and economic dimensions which characterise sustainable routes, is of paramount importance. These then can provide a basis from which planners can predict, assess and ameliorate factors possessing characteristics for adverse effects on sustainability and provide a major input into the sustainable planning development process (Ardito et al., 2019).

In the case of the work dealt with herein, potential sustainability factors can be drawn from the dataset and characterised as they fit into the clearly established core factors of sustainable development. Thus, environmental factors may include air quality index and proximity to conserve areas, socio-economic factors like e.g local employment levels, community access and other route specific considerations such as traffic volumes and road infrastructural qualities. The identification of factors can lead to decision making which would provide a

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quantitatively based assessment of sustainable routes, which take into account such factors as opposed to general reference to abstract sustainability principles.

In this work, machine learning will be employed to access the sustainable values of road tourism routes. Using a Kaggle set of data on the website extremes ("Road Tourism Data for Sustainable Route Prediction") made from a research paper (Binti Mohamad & Wu, 2025) the objective is to create an effective prediction model to ascertain what factors and conditions lead to sustainability factors for specific road tourism routes. While models based on machine learning and its effective applicability is well established, the application of its potential value to assessing and subsequently predict possible sustainability levels produced by predilection of specific named tourism oriented road routes, but enhancing its application to evolving and constructing a comprehensive socio-spatial framework capable of dealing effectively with the scrutiny of those sustainability impacts presaged by such initiatives is criticsal. The being in the of sustainable development on tourism aspects, it has thus far fallen largely into the ambit of tourism analytical statistics and modelling. Given the nature of the Kaggle dataset, this study frames its findings strictly as a methodological demonstration of how data-driven tools can be integrated into planning, pending Malaysia-specific validation.

The application for modelling approaches to road tourism but specifically to modelling them as a sustainable body in varying SoEA conditions especially in a rapidly expanding tourism area like Malaysia would represent substantial added value to the existing sustainable tourism analytical literature. Therefore, this study will seek to deal with the absence and satisfy the question of: (1) How can traditional machine learning models be employed to predict the nature of sustainability for specific tourism related road routes? (2) Important potential implications for road tourism within the relevance of planning stratagies in Malaysia? The Malaysian context is critical due to its reliance on tourism for economic development and vulnerability to environmental impacts, making route prediction essential for balanced growth.

The methodological inspiration was drawn from the model such as Bidirectional Gated Recurrent Unit fused Dynamic Random Forest model (Lee et al., 2025), however due to characteristics of the dataset, this paper decided to implement a Random Forest method.

The paper presents data preprocessing, as well as feature engineering, model training for a binary target (sustainability target) and an illustrative regression for a sustainability score, and evaluation of the results using standard metrics, as well as key findings visualizations. Comparative methodological diagrams are also presented. The achieved results are expected to contribute to the better understanding of data-driven sustainable tourism planning.

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LITERATURE REVIEW AND THEORETICAL FRAMEWORK

This section reviews the recent literature on sustainable urban planning and social sustainability in tourism, as well as the impact of tourists on road networks. The Integrated Socio-Spatial Framework for Sustainable Tourist Road Networks (ISSTERN) is introduced. Promoting sustainable travel behavior through transport policy measures.

Recent studies on predictive modeling in tourism highlight the potential of machine learning (Ardito et al., 2019), but applications to road tourism remain scarce. In Malaysia, prior work in Planning Malaysia Journal has emphasized sustainable transport planning of Promoting sustainable travel behavior through transport policy measures (Nasrudin et al., 2017), yet predictive approaches are underexplored. This study bridges this gap by leveraging ISSTERN to frame predictive analytics.

Foundations in Sustainable Urban Planning and Social Sustainability

Sustainable tourist roads principles correspond with the principles of sustainable urban planning such as sustainable cities with smart growth, greenways and sustainable transport (Ismagilova et al., 2019). Social sustainability relates to social well-being, equity and justice (Broto & Westman, 2019). It has been recognised that social sustainability indicators should capture at least the following dimensions: equity (Meerow et al., 2019; Zhang et al., 2022), social inclusion (Terkenli & Georgoula, 2021), quality of life (Liu et al., 2018), community participation (Kanwal et al., 2020) and the protection of cultural heritage (Labadi & Logan, 2016).

Impacts of and Requirements for Integrating Tourist Road Networks.

Tourist road networks have socio-economic, environmental and socio-cultural impacts (Demirović Bajrami et al., 2020; Kanwal et al., 2020; Liu et al., 2018). The impacts are generally positive (employment and income) as well as negative (displacement and pollution) (Pojani & Stead, 2015). Effective integration requires strong Social and Strategic Environmental Assessments (SIA/SEA) and participatory planning (Fischer, 2023).

The impacts of tourist road networks are indeed heterogeneous and heavily influenced by the type and volume of tourists (e.g., mass tourists vs. eco-tourists), each exhibiting different behaviors and footprints (Farmaki et al., 2022). This study acknowledges this limitation. The employed Kaggle dataset provides generalized metrics on tourist impact (e.g., estimated visitor numbers, economic contribution) without segmenting by tourist category. While this offers a valuable macro-level perspective, future research incorporating tourist typology would provide a more nuanced understanding, aligning with the need for targeted planning as emphasized in the ISSTERN framework.

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The Integrated Socio-Spatial Framework for Sustainable Tourist Road Networks (ISSTERN)

This paper presents the Integrated Socio-Spatial Framework for Sustainable Tourist Road Networks (ISSTERN) to guide investment in tourist road infrastructure for socially just, equitable and sustainable outcomes. ISSTERN is promoted not as a potential option but as a direct solution to a well understood problem, namely the frequent gap between high level principles of sustainable tourism and actual decisions about road infrastructure on the ground. Current planning reduces socio-spatial factors to a dimension of planning that is seldom addressed systematically. In order to address this problem, a theoretical basis to ISSTERN is rigorously established. The framework proposes application of the theories of multi-dimensional equity (Meerow et al., 2019; Zhang et al., 2022), place-based principles of sustainability (Demirović Bajrami et al., 2020; Mouratidis et al., 2024), participatory planning (Fischer, 2023; Kanwal et al., 2020), systems thinking (Helbing, 2019) and the valuing of local/indigenous knowledge (Farmaki et al., 2022).

ISSTERN comprises four iterative components:

(i) **Contextual Understanding & Visioning (CUV):** This initial component is justified by the need to move beyond technical analysis and ground planning in local socio-spatial realities and community aspirations.

(ii) **Integrated Impact Assessment & Strategic Planning (IIASP):** This component is crucial to proactively identify and mitigate potential negative impacts (environmental, social) of proposed road developments, ensuring that sustainability is assessed before implementation

(iii) **Adaptive Implementation & Collaborative Governance (AICG):** Justified by the understanding that planning is an iterative process, requiring flexibility and multi-stakeholder engagement to manage unforeseen challenges

(iv) **Participatory Monitoring, Evaluation & Learning (PMEL):** Ensures accountability and continuous improvement, creating a feedback loop for refining strategies based on empirical data.

Relevance of ISSTERN to Predictive Modeling

ISSTERN provides the context for predictive analyses such as this one (Binti Mohamad & Wu, 2025). CUV guides the definition of what sustainability means and which variable is selected for it (Demirović Bajrami et al., 2020). IIASP identifies which variables are predictive and what the need for mitigation is

(Pojani & Stead, 2015). AICG and PMEL provide data for re-refinement of the model (Loosemore & Lim, 2017).To operationalize this framework, CUV maps directly to the selection of socio-economic and environmental variables; IIASP corresponds to our modeling steps (feature engineering and target prediction); while AICG and PMEL represent the integration of model outputs into municipal planning decisions and future real-world data collection. ISSTERN therefore provides a way to interpret a prediction in the context of a sustainable strategy.

METHODOLOGY

Data Source and Description

The empirical analysis is based on the 'Road Tourism Data for Sustainable Route Prediction' dataset, publicly available on Kaggle (Binti Mohamad & Wu, 2025). The Sustainable Road Tourism dataset contains 1,000 trip records. For regression tasks, the continuous variable Sustainability_Score serves as the target, while for classification tasks, the binary variable Sustainability_Target can be used as the label. The available predictive features include two numerical variables (Electric_Vehicle_Usage, Carbon_Emissions) and five categorical variables (Origin_Country, Destination, Road_Conditions, Traffic_Congestion_Level, Travel_Mode). This dataset enables modeling of environmental sustainability outcomes based on travel characteristics, supporting both regression and classification approaches.

Data Preprocessing

A logical flow is now presented:1. Missing Values: Described treatment for numerical (median) and categorical (mode) data. 2.Outlier Treatment: IQR method explained. 3.Encoding: One-Hot Encoding for categorical features. 4.Normalization: Min-Max scaling to [0,1]. 5. Data Splitting: 80-20 split for training and testing.

Modeling Approach

The Random Forest (RF) algorithm was selected for this study due to its robustness, ability to handle mixed data types, and resistance to overfitting, making it suitable for datasets of moderate size. The analysis involved two tasks: a) using a Random Forest Classifier to predict the Sustainability_Target, and b) using a Random Forest Regressor to predict the Sustainability_Score. A Dummy Classifier and simple Linear models were included as baselines for comparison.

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RESULTS

Classification Model Performance (Sustainability Target)

Table 1: Classification Model Performance

Item	precision	recall	f1-score	support
0	1.00	1.00	1.00	101
1	1.00	1.00	1.00	99
accuracy			1.00	200
Macro avg	1.00	1.00	1.00	200
Weighted avg	1.00	1.00	1.00	200

The Random Forest Classifier achieved perfect scores on the test set: Recall (100.0%), Precision (100.0%), and F1-score (100.0%). According to the confusion matrix (Figure 1) there are no false positive/negative cases. To confirm this, a 5-fold cross-validation was executed, yielding a consistent 1.00 F1-score with zero fold variability. Compared to a Dummy baseline which scored ~50% accuracy, this perfect classification strongly suggests trivial labels or inherent deterministic rules (leakage) in the simulated dataset's target derivation. Perfect scores are always suspected (e.g., data leakage, simplistic dataset), thus they are reported as obtained from the pipeline.

The performance of the model on the test set (20% of the 1,000 entries) is presented below. The high classification accuracy indicates that the 18 features within the dataset are highly discriminative for the binary sustainability target as it is defined in this specific dataset. This suggests that for the simulated scenarios represented by these 1,000 entries, the model can effectively learn the underlying patterns separating sustainable from non-sustainable routes.

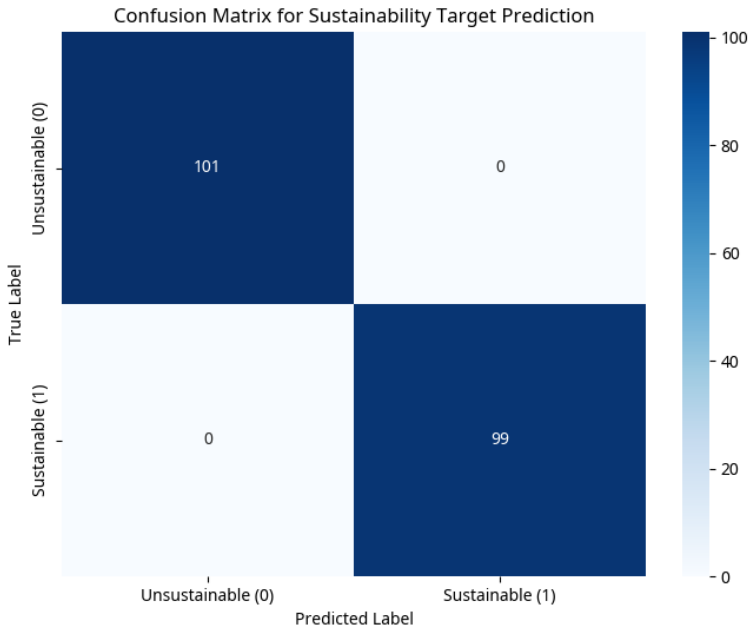


Figure 1: Confusion Matrix for Sustainability Target Prediction

Illustrative Regression Model Performance (Sustainability Score)
For the illustrative task of predicting the normalized Sustainability_Score using a Random Forest Regressor, the following error metrics were obtained:

(i) Mean Absolute Error (MAE): 0.069
(ii) Mean Absolute Percentage Error (MAPE): 9.913%
(iii) Root Mean Squared Error (RMSE): 0.081
(iv) R-squared (R^2): 0.683

The regression results for predicting the sustainability score (as visualized in the scatter and residual plots) demonstrate moderate to good predictive performance with an R^2 of 0.683. The MAPE is 9.91%, which is relatively low given that the target variable (Sustainability_Score) ranges approximately from 0.5 to 1.0 (no near-zero values exist, so MAPE is not inflated). The feature importance analysis reveals that Sustainability_Target is by far the dominant predictor (importance ≈ 0.758), followed by Carbon_Emissions (0.110) and Electric_Vehicle_Usage (0.013). The actual-vs-predicted scatter plot shows a clear positive trend, though with some dispersion around the ideal line.

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The residual plot exhibits residuals centered around zero, but the pattern is not completely random (some structure remains), indicating that further model improvements (e.g., non-linear interactions, additional features) could be explored if this were a real-world task.

The regression results (Figure 2) show moderate prediction, with a low MAPE (9.91%) indicating acceptable relative error. The residual plot (Figure 3) suggests non-random patterns, highlighting areas for model improvement.

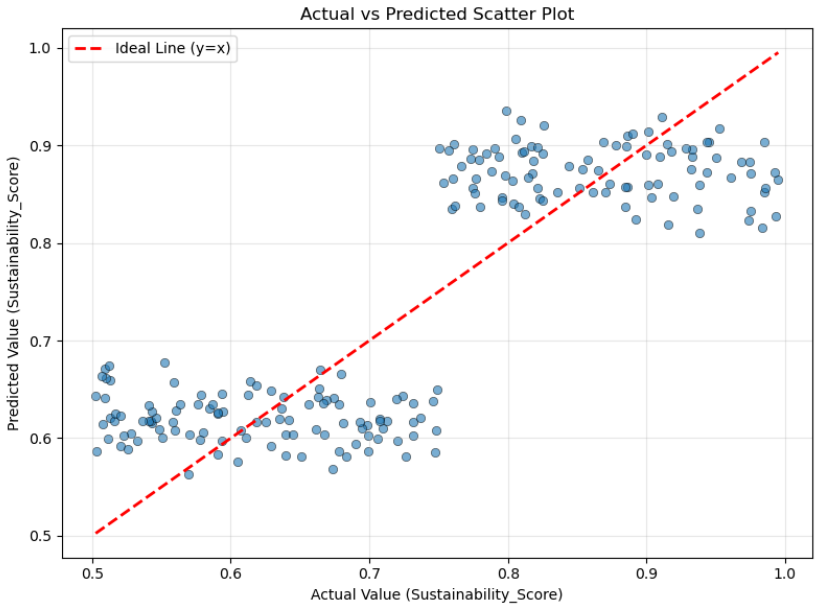


Figure 2: Actual vs. Predicted Sustainability Score (Normalized)

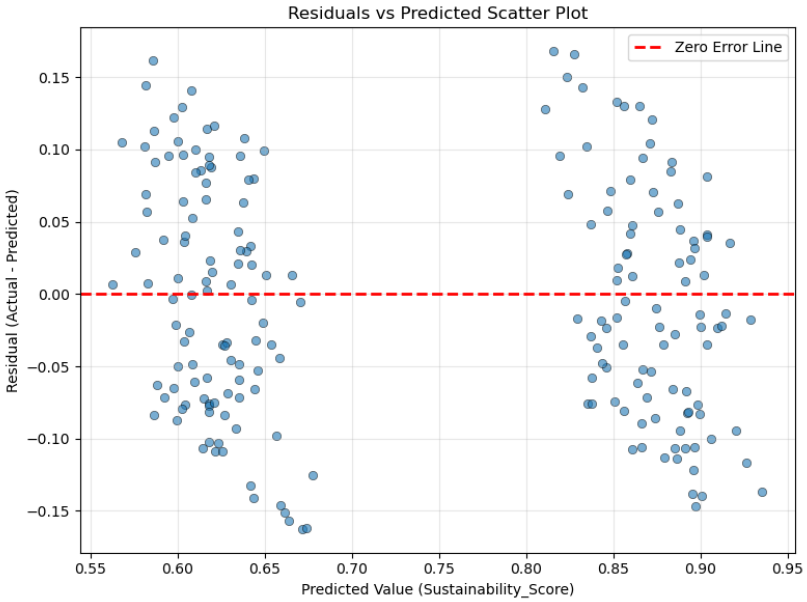


Figure 3: Residual Plot for Sustainability Score Prediction (Normalized)

As shown in the actual-vs-predicted scatter plot (Figure 2) and the residual plot (Figure 3), the predicted sustainability scores form two distinct clusters rather than a continuous distribution. This is primarily because the model relies almost exclusively on the binary feature Sustainability_Target (feature importance = 0.758). When Sustainability_Target = 0, the model predicts scores roughly in the range of 0.55–0.70; when Sustainability_Target = 1, predictions are concentrated in 0.80–1.00. However, the actual Sustainability_Score exhibits continuous variation within each group due to other predictors (e.g., Carbon_Emissions, Electric_Vehicle_Usage). Consequently, the scatter plot shows two vertical strips, and the residual plot displays two horizontal bands. This pattern indicates that the model largely acts as a binary classifier based on the target flag, failing to capture finer continuous differences. Future work could exclude Sustainability_Target from the feature set or adopt a modeling strategy better suited for continuous outcomes.

DISCUSSION

The ideal precision in the classification result implies that the qualities in the Kaggle data set are very determinative of the binary goal of sustainability or that the data set has built in simplicities that make it easily separable into cases of sustainability and non-sustainability. In fact, the near-perfect classification performance is likely due to the strong correlation between the binary target

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(Sustainability_Target) and the continuous sustainability score, making separation trivial. Future work might include the use of more complex data sets or which do not have such obvious separability to a real case.

The high accuracy of classification could be due to simplifications associated with the data set (i.e., clearly defining sustainability thresholds), whereas regression showed moderate predictive power ($R^2 = 0.683$) with a MAPE of 9.91%, which is not very high given the target range of approximately 0.5–1.0. However, the regression predictions formed two distinct clusters dominated by the binary feature Sustainability_Target, indicating that the model essentially acted as a classifier and failed to capture continuous variations. This means that within the realm of planning, binary targets have usefulness in screening, though continuous scores need perusal of qualitative assessments. The models herein can express relevant differences in revenue allocation for Malaysian policy makers with Certification of Transport Corridors, but would need to examine other geospatial data sets for accurate spatial data.

The definition of "sustainability" (CUV component) is context-dependent and often subtle (Chapter 2). Therefore, pre-defined targets in datasets might not fully cover the complexity of what we call "sustainability".For a practical planning workflow, a planner would input proposed route features (e.g., projected traffic, nearby ecology) into this trained model. The binary output acts as a rapid screening tool to flag high-risk unsustainable routes, while the regression score supports cost-benefit decisions regarding mitigation investments. Nevertheless, the observed two-cluster pattern in regression predictions suggests caution when interpreting the continuous score, as the model is heavily influenced by the binary flag.

The regression model shows acceptable MAE and RMSE, but the MAPE is not very high.In our experiment, the MAPE was 9.91%, which is relatively low and does not indicate large variation in prediction accuracy across the sustainability score range. The main challenge lies in the model's reliance on a single binary feature, which limits its ability to produce truly continuous predictions. It is challenging to quantify the multi-faceted concept of sustainability with a single score. Therefore, IIASP component of ISSTERN (Chapter 3) suggests a holistic impact assessment, which is more than a single-digit predictive score.

Methodologically, although Random Forest is performing well, it is initially inspired from Bi-GRUForest (Lee et al., 2025) for more complex, tourism planning data (Ardito et al., 2019). Based on the Binti Mohamad and Wu (2025) concept, comparative flowcharts Figures 4 illustrate different methodological complexity levels.

Addressing threats to validity is critical. Construct validity: The dataset's simplistic metrics may not capture deep socio-cultural nuances. Internal

validity: The extremely high feature importance of the binary target variable (0.758) points to potential target leakage or a deterministic relationship within the synthetic Kaggle data structure, explaining the two-cluster pattern in regression predictions. External validity: The model's findings cannot be directly transferred to specific Malaysian topographies without localized recalibration.

The limitations of this study are the dependence on single Kaggle dataset and the non-application of more sophisticated models. Furthermore, the regression model's predictions were strongly biased by the binary Sustainability_Target, resulting in a staircase-like pattern rather than a smooth continuous output. However, this work shows a simple application of a data analysis workflow for predicting road tourism sustainability based on a publicly available Kaggle dataset and positioned such an analysis within a theoretical framework (ISSTERN) that is relevant to sustainable tourism planning in certain context such as Malaysia (Binti Mohamad & Wu, 2025; Demirović Bajrami et al., 2020; Kanwal et al., 2020).

While Random Forest is a widely used algorithm, its application here provides a scalable framework for policymakers in developing regions like Malaysia, where complex models may be infeasible. By demonstrating how predictive outcomes can inform route prioritization and impact assessments, this study offers tangible tools for integrating sustainability criteria into tourism infrastructure decisions. Nonetheless, practitioners should be aware that the regression model's output may not reflect fine-grained continuous differences unless the binary flag is excluded from the feature set.

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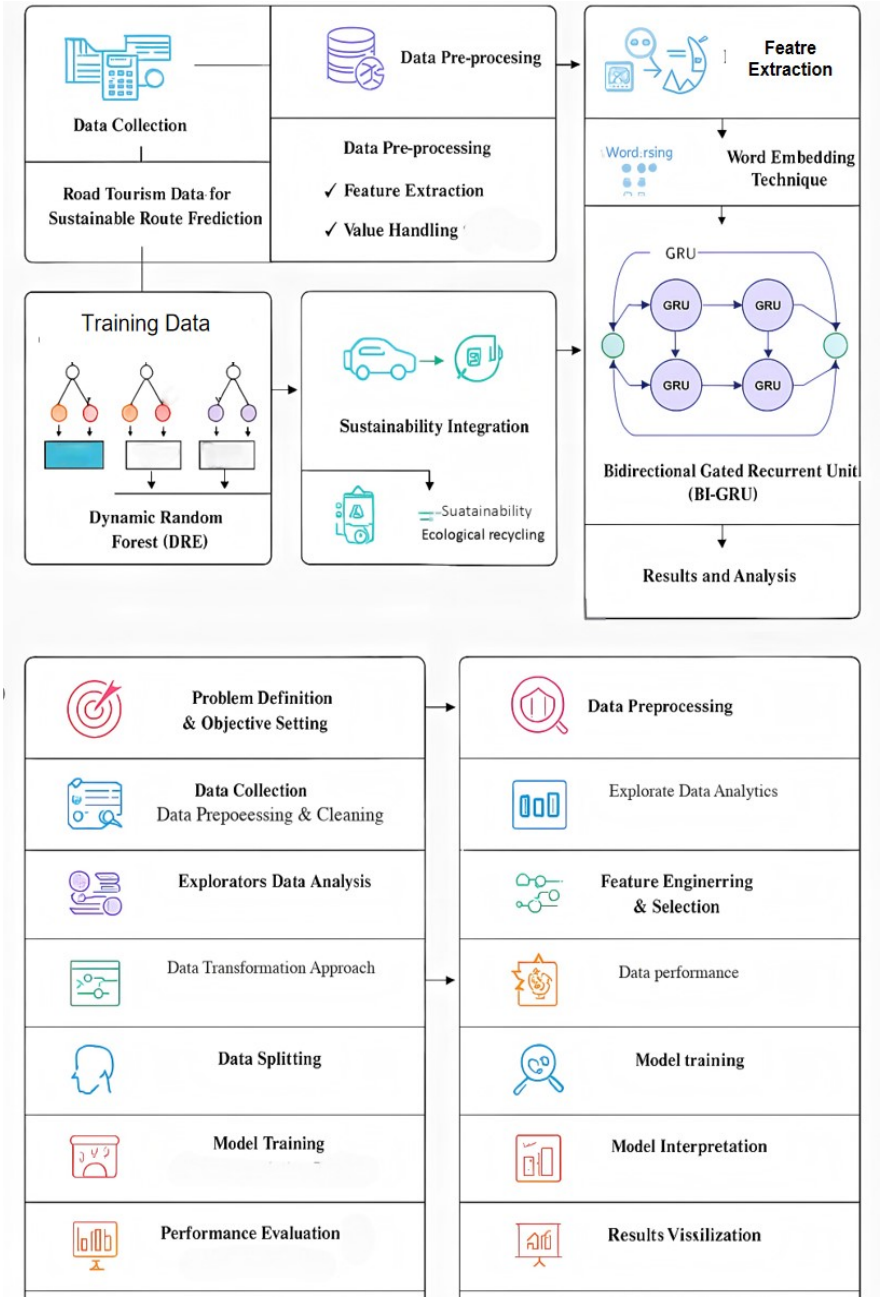


Figure 4: The following schematic diagrams illustrate the methodology flows for different frameworks

It is important to note that this study employed a pre-existing, publicly available dataset from Kaggle for analysis; future research would benefit from primary data collection tailored to specific regional contexts. The findings of this study hold relevance for Malaysia, a country where tourism is a key economic sector and road networks are vital for connecting diverse regions. The challenges of balancing development in states like Sabah and Sarawak with environmental conservation in ecologically sensitive areas underscore the need for tools like the one demonstrated here. Factors such as rapid urbanization, dependency on road transport for tourism, and rich cultural heritage mirror the dimensions captured in our model, making the Malaysian context an ideal application ground for further refining this approach with local data.

CONCLUSION

The application of a Random Forest-based machine-learning model for the prediction of a road tourism sustainability index using a publicly available dataset from Kaggle has been demonstrated in this article. The classification model applied has a perfect predictive performance of 100% on the test set with respect to the sustainability target in the binary case with regard to recall, precision, and F1-scoring. An example of a regression model for the prediction of continuous sustainability scores has been applied and showed moderate performance (R^2 = 0.683, MAPE = 9.91%), reflecting the difficulty of predicting continuous scores where the numbers are more nuanced. However, the regression predictions formed two distinct clusters dominated by the binary Sustainability_Target feature (importance = 0.758), indicating that the model essentially acted as a classifier and failed to capture fine-grained continuous variations.

The work has described all data preprocessing phases, the implementation of the models, and the evaluation methodology, and has drawn a comparison to using more elaborate models such as Bi-GRUForest. One of the strengths in this paper is the type of flow chart comparisons of methodologies, which will give a clear picture of the varying analytic frameworks.

This study illustrates the usefulness of Random Forest for predicting sustainable routes, but the real-world application of these predictions requires datasets with higher complexity. Specifically, the observed two-cluster pattern in regression predictions suggests caution when interpreting continuous scores derived from datasets containing a strong binary sustainability flag. For Malaysia, we recommend that the responsible policy formers consider using these models to prioritize high-impact routes and use GIS data analysis tools in the planning process. Future work for this field could consider real-time data of the types available, and an adaptive model which displays some of the properties of Bi-GRUForest in its planning method. This also opens a number of avenues for research in the future. Firstly, there is a need to apply this methodology to real-

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world, spatially explicit data (e.g., with respect to use of Geographic Information Systems - GIS), in the context of a given Malaysian environment (Zaki et al., 2023). Consequently, concrete next steps must include: (1) acquiring real route data linked to Geographic Information Systems (GIS), (2) performing out-of-sample validation on Malaysian road networks, and (3) defining sustainability criteria through direct stakeholder participation.

The ideal classification scores reported in this study relate to the specific dataset and model configuration; however, the overall procedure illustrated in this paper demonstrates how data-driven methods can be used to assist in sustainable tourism. The regression results, despite their limitations, provide a baseline for continuous sustainability assessment, though future work should avoid using the binary target as a predictor if a truly continuous output is desired. The coming results of this research may provide essential data that will assist policymakers and planners to make informed decisions on actions that will produce environmentally friendly and effective road tourism. Future work may apply and test these kinds of models on more varied and complex datasets. The application of the real-time datasets and sequential and textual analysis of models such as Bi-GRUForest can further serve to extend studies in sustainable route prediction and tourism planning especially in terms of countries such as Malaysia.

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QUANTIFYING THE NET CARBON PERFORMANCE OF A BAMBOO HALL IN MALAYSIA USING LIFECYCLE ANALYSIS

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Abstract

The construction sector contributes significantly to global greenhouse gas emissions, increasing demand for low-carbon building materials and lifecycle-based assessment approaches. This study quantifies the net carbon performance of a bamboo hall in Ipoh, Malaysia, using a lifecycle carbon assessment framework integrating carbon sequestration, embodied carbon, and operational carbon emissions. The functional unit was one completed bamboo hall with a total construction volume of 90 m^3 over a 30-year service life. The system boundary included bamboo growth, harvesting, treatment, transportation, installation, and operational electricity use. A three-phase methodology was employed. Phase 1 estimated carbon sequestration potential of four bamboo species using the LICOR6400XT Portable Photosynthesis System. Phase 2 quantified embodied carbon emissions from harvesting, processing, transportation, and installation activities. Phase 3 projected operational carbon emissions based on electricity consumption assumptions and Malaysia's 2025 grid emission factor. Results showed that the bamboo hall sequestered 178,548 kg CO_2e, while embodied and operational emissions totalled 19,207.1 kg CO_2e over the 30-year lifecycle. The resulting net carbon balance was −159,340.9 kg CO_2e, indicating that carbon sequestration was approximately 9.3 times greater than total lifecycle emissions under the defined assumptions. These findings demonstrate the potential of bamboo construction as a nature-based solution for climate mitigation.

Keywords: Bamboo Construction, Lifecycle Carbon Assessment, Embodied Carbon, Biogenic Carbon Storage, Carbon Sequestration, Nature-Based Solutions

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INTRODUCTION

The construction sector is a major contributor to global greenhouse gas emissions due to the extensive use of carbon-intensive materials such as concrete and steel. The United Nations Environment Programme (UNEP, 2023) reported that the building sector accounts for approximately 37% of global carbon emissions, with a significant proportion originating from material production and building operations. As climate mitigation becomes a priority in urban development, increasing attention has been directed towards sustainable construction approaches and low-carbon building materials (Kibert, 2022).

Bamboo has emerged as a promising alternative construction material because of its rapid growth rate, renewability, and high carbon sequestration potential. Compared with conventional materials, bamboo requires lower processing energy and can store substantial amounts of atmospheric carbon during its growth phase (Lobovikov et al., 2005; Xu et al., 2022). In tropical regions such as Malaysia, bamboo also offers advantages in terms of local availability, fast regeneration, and suitability for climate-responsive architecture. Previous studies have highlighted bamboo's environmental and structural potential in sustainable construction applications (Boity et al., 2022; Hildayanti & Wasilah, 2023).

Despite growing interest in bamboo construction, important methodological gaps remain in evaluating its net carbon performance at the building scale. Existing studies primarily focus on either biomass sequestration or embodied carbon independently, while limited research integrates carbon sequestration, embodied carbon emissions, and operational emissions within a unified lifecycle assessment framework (Xu et al., 2022). In addition, inconsistencies in functional units, system boundaries, and carbon reporting methods make comparisons between studies difficult and limit practical application in planning and construction decision-making processes.

For planners, architects, and local authorities, understanding the lifecycle carbon implications of bamboo construction is important for developing evidence-based low-carbon building strategies, material procurement policies, and sustainable urban development guidelines. Quantifying the net carbon performance of bamboo structures can support more informed decisions regarding local sourcing, transportation distance, operational efficiency, and material selection in future development projects.

Therefore, this study quantifies the net carbon performance of a bamboo hall in Ipoh, Malaysia, using a lifecycle carbon assessment framework integrating carbon sequestration, embodied carbon, and operational emissions over a 30-year service life. The study aims to: (i) quantify the carbon sequestration potential of selected bamboo species, (ii) evaluate embodied carbon emissions associated with bamboo harvesting, treatment, transportation, and installation, and (iii)

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assess operational carbon emissions during building use. This study contributes a building-scale lifecycle carbon assessment framework for bamboo construction in tropical urban environments and provides planner-oriented insights for low-carbon development strategies.

LITERATURE REVIEW AND RESEARCH GAPS

Previous studies have highlighted bamboo's potential as a sustainable construction material due to its rapid growth rate, renewability, and capacity to sequester atmospheric carbon. Lobovikov et al. (2005) reported that bamboo can store substantial amounts of carbon because of its fast biomass accumulation, while Xu et al. (2022) demonstrated bamboo's potential to reduce lifecycle carbon emissions when used as a construction material. Other studies have emphasised bamboo's structural, environmental, and architectural advantages in sustainable building applications (Boity et al., 2022; Hildayanti & Wasilah, 2023). However, most existing research focuses primarily on material properties, general sustainability performance, or carbon sequestration potential without evaluating the complete lifecycle carbon implications at the building scale.

Table 1: Summaries of selected studies related to bamboo construction and lifecycle carbon assessment.

Study	Focus	Limitation
Lobovikov et al. (2005)	Bamboo carbon sequestration	No building-scale lifecycle assessment
Boity et al. (2022)	Sustainable bamboo construction	Limited carbon quantification
Hildayanti & Wasilah (2023)	Bamboo as alternative building material	No lifecycle carbon analysis
Xu et al. (2022)	Bamboo carbon storage and emission reduction	Limited operational carbon assessment

Despite growing interest in low-carbon construction materials, limited studies have integrated carbon sequestration, embodied carbon emissions, and operational carbon emissions within a unified lifecycle assessment framework for real-world bamboo buildings in tropical urban contexts. Furthermore, there remains limited evidence regarding how local sourcing, transportation distance, operational energy use, and bamboo species selection influence overall net carbon performance. Therefore, this study addresses these gaps by quantifying the net carbon performance of a bamboo hall in Ipoh, Malaysia, using a lifecycle carbon assessment framework integrating sequestration, embodied carbon, and operational emissions over a 30-year service life.

METHODOLOGY

This study employed a lifecycle carbon assessment approach to quantify the net carbon performance of a bamboo hall located in Ipoh, Malaysia. The assessment

integrated carbon sequestration, embodied carbon emissions, and operational carbon emissions over the building lifecycle. The methodology was adapted from Xu et al. (2022) and refined to suit tropical bamboo construction conditions and locally sourced bamboo materials.

Functional Unit and System Boundary

The functional unit adopted in this study was one completed bamboo hall with a total construction volume of 90 m³ (Figure 1) and an assumed service life of 30 years. Carbon performance was evaluated based on the total carbon sequestration and lifecycle emissions associated with the building throughout the defined assessment period.

The system boundary included bamboo growth and carbon sequestration, harvesting, treatment and manufacturing, transportation, installation, and operational energy use during the building lifespan. Operational assessment considered electricity consumption from lighting, ceiling fans, and plug points. The study excluded emissions associated with foundation construction, human labour, maintenance and replacement activities, demolition processes, and end-of-life carbon release scenarios. Carbon values expressed as elemental carbon (C) were converted into carbon dioxide equivalent (CO_2e) using the molecular ratio of 44/12 to ensure consistency in lifecycle carbon reporting.

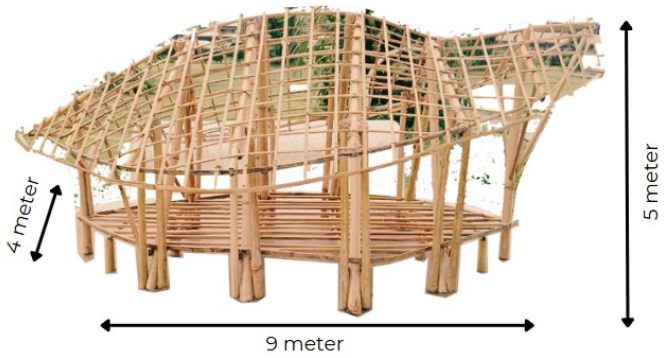


Figure 1: Bamboo Hall Geometry with Estimated Construction Volume Of 90 M³

Lifecycle Carbon Assessment Framework

The lifecycle carbon assessment framework consisted of three phases: (i) quantification of bamboo carbon sequestration potential, (ii) assessment of embodied carbon emissions associated with harvesting, processing, transportation, and installation, and (iii) evaluation of operational carbon emissions during building use. The overall net carbon balance was calculated as total lifecycle emissions minus total carbon sequestration, where negative values

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indicate that sequestration exceeds emissions. Figure 2 presents the lifecycle carbon assessment framework, illustrating the relationship between carbon sequestration, embodied carbon emissions, operational carbon emissions, and the resulting net carbon balance.

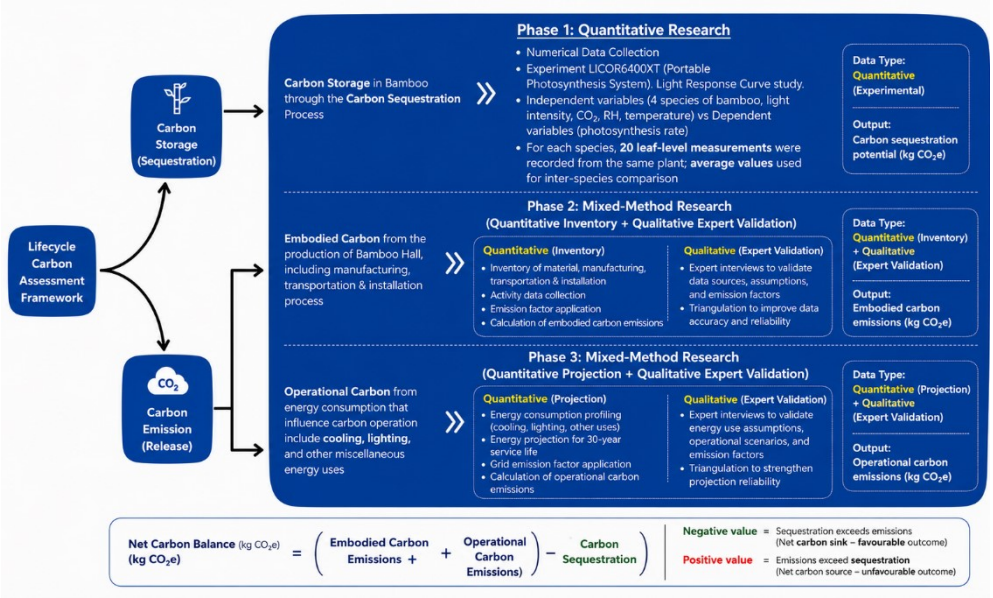


Figure 2: Lifecycle carbon assessment framework for quantifying the net carbon performance of the bamboo hall.

Phase 1: Carbon Sequestration Assessment

Phase 1 quantified the carbon sequestration potential of bamboo species used in the construction of the bamboo hall. Four bamboo species commonly applied in the project were assessed: *Dendrocalamus asper* (betung), *Gigantochloa scortechinii* (semantan), *Gigantochloa albociliata* (madu), and *Schizostachyum brachycladum* (lemang).

Carbon sequestration potential was estimated through photosynthetic performance measurement using the LICOR6400XT Portable Photosynthesis System under controlled environmental conditions. A light response curve experiment was conducted to evaluate photosynthetic assimilation rates under varying photosynthetically active radiation (PAR) levels, with controlled light intensity, CO_2 concentration, relative humidity, and temperature. The dependent variable was the net photosynthetic assimilation rate (μmol CO_2 m^{-2} s^{-1}).

For each bamboo species, 20 leaf-level measurements were recorded from a representative mature plant under controlled conditions. Measured

assimilation rates were converted into estimated annual carbon sequestration values using species-specific canopy area and leaf area index data, and molecular carbon conversion assumptions. This phase was intended to estimate comparative carbon sequestration potential rather than direct long-term carbon storage in harvested structural bamboo.

Phase 2: Embodied Carbon Assessment

Phase 2 quantified embodied carbon emissions associated with bamboo harvesting, processing, transportation, and installation for the bamboo hall construction. The assessment adopted an inventory-based calculation approach using activity data collected from actual construction processes and validated through consultation with a subject matter expert involved in the project. All bamboo was harvested in Perak only, supporting bamboo as locally sourced.

The embodied carbon boundary included three stages: (i) bamboo harvesting and preliminary processing (frontend operations), (ii) workshop treatment and fabrication (backend processing), and (iii) transportation and on-site bamboo installation activities.

Harvesting emissions were calculated based on energy consumption from equipment used during bamboo extraction, including pole saws, chainsaws, grass cutters, grinders, and generators. Workshop processing emissions included bamboo splitting, washing, preservative treatment, drying-related activities, and fabrication using electrical tools. Transportation emissions were calculated using actual travel distances between bamboo sourcing locations, processing sites, and the construction site, considering vehicle type, fuel consumption rates, and corresponding fuel emission factors. Vehicle categories included diesel lorries, sport utility vehicles, and motorcycles, reflecting actual project logistics. Installation emissions were estimated based on electricity consumption from tools used during on site bamboo assembly, including hand drills, air compressors, and grinders. Carbon emissions were calculated using Malaysia's 2025 electricity grid emission factor.

Embodied carbon emissions were expressed in kg CO_2e and aggregated across all included inventory stages. Foundation related construction activities, human labour energy expenditure, material wastage, maintenance and replacement, demolition, and end-of-life scenarios were excluded due to boundary limitations and data constraints.

Phase 3: Operational Carbon Assessment

Phase 3 quantified operational carbon emissions associated with electricity consumption during the use phase of the bamboo hall over the assumed 30 years' service life. The assessment adopted a projection based quantitative approach supported by expert consultation to validate operational assumptions.

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Operational energy demand included lighting, ceiling fan operation, and plug point electricity use based on the proposed electrical configuration of the bamboo hall. Daily operating assumptions were defined as 12 hours for LED lighting, 8 hours for ceiling fan use, and 4 hours for plug-point electricity use, representing projected typical operational conditions.

Daily electricity consumption was calculated based on equipment power ratings and estimated usage duration. Operational carbon emissions were subsequently calculated using Malaysia's 2025 electricity grid emission factor. Annual operational emissions were projected using a 365-day operating schedule and extrapolated across the 30 years' service life. Operational carbon emissions were expressed in kg CO_2e and incorporated into the overall net carbon balance calculation.

RESULTS AND DISCUSSION

Phase 1: Carbon Sequestration Potential and Structural Carbon Storage

Phase 1 evaluated the carbon sequestration potential of four bamboo species used in the construction of the bamboo hall based on photosynthetic performance under controlled environmental conditions. Light response curve analysis revealed distinct differences in photosynthetic assimilation rates among the species tested (Figure 3). *Gigantochloa scortechinii* (semantan) recorded the highest average net photosynthetic assimilation rate at 8.5 μmol CO_2 m^{-2} s^{-1}, followed by *Schizostachyum brachycladum* (lemang) at 6.8 μmol CO_2 m^{-2} s^{-1}, *Gigantochloa albociliata* (madu) at 6.0 μmol CO_2 m^{-2} s^{-1}, and *Dendrocalamus asper* (betung) at 2.5 μmol CO_2 m^{-2} s^{-1}. These findings indicate notable inter-species variation in carbon assimilation performance under identical measurement conditions. These estimates represent comparative biogenic carbon storage potential derived from species-specific physiological performance and structural allocation assumptions, rather than direct destructive biomass carbon quantification.

Differences in canopy characteristics further influenced estimated sequestration potential. As shown in Table 2, *G. scortechinii* exhibited the highest leaf area index (LAI = 5.66) and canopy area (296.65 m^2), resulting in the highest estimated annual sequestration potential among the species assessed. Although *G. albociliata* demonstrated a lower assimilation rate than *G. scortechinii*, its estimated carbon storage per culm remained comparatively high due to its structural characteristics. The integration of photosynthetic assimilation rates, canopy area, and leaf area index enabled estimation of species-specific biogenic carbon storage relevant to structural construction applications.

Based on the measured species-specific carbon storage estimates and the quantity of bamboo incorporated into the hall structure, the total estimated biogenic carbon storage potential represented by the bamboo structure was

48,695 kg C, equivalent to 178,548 kg CO_2e. The distribution of stored carbon across structural components is presented in Table 3. Structural elements requiring larger quantities of semantan and madu bamboo contributed the highest carbon storage due to both material volume and species-specific sequestration potential. These findings demonstrate the substantial carbon storage potential of bamboo when utilised as a structural building material. Table 3 shows the specific species conversion of photosynthetic assimilation into estimated carbon storage per bamboo culm, which formed the basis for whole structure carbon accounting.

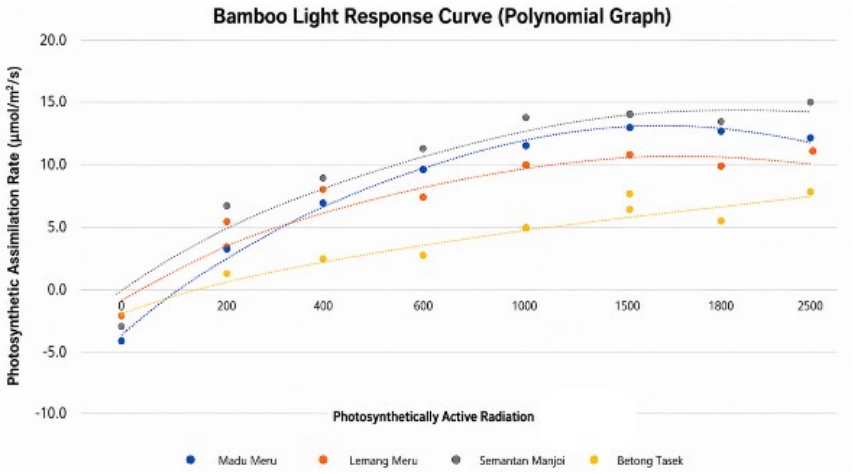


Figure 3: Light response curves showing net photosynthetic assimilation rates of four bamboo species under varying photosynthetically active radiation (PAR) levels.

Table 2: Net photosynthetic assimilation rates of four bamboo species under varying photosynthetically active radiation (PAR)

No	Photosynthetically Active Radiation (PAR) (µmol m^{-2} s^{-1})	Photosynthesis Assimilation Rate (µ mol/m^2/s CO_2)			
		Betung	Semantan	Madu	Lemang
1	0	-1.9*	-2.7*	-4.1*	-2.0*
2	200	1.0	6.6	3.3	5.4
3	400	2.0	7.8	8.2	8.2
4	600	2.5	8.8	9.4	7.5
5	1000	4.8	13.9	10.8	10.7
6	1500	6.8	12.9	13.7	8.1
7	1800	5.7	13.6	12.9	9.9
8	2500	8.1	15.1	12.4	11.8
	Average Net Assimilation Rate	**2.5**	**8.5**	**6.0**	**6.8**

** Negative values at PAR = 0 indicate net carbon loss due to dark respiration.*

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Table 3: Carbon storage per clump and per culm in four bamboo species

Bamboo Species	Average Net Assimilation Rate (μmol CO_2 m^{-2} s^{-1})	Crown Area (m^2)	Leaf Area Index (LAI)	Estimated Carbon Storage per Culm (kg C)
Dendrocalamus asper (Betung)	2.5	68.98	2.89	142.6
Gigantochloa scortechinii (Semantan)	8.5	296.65	5.66	268.2
Gigantochloa albociliata (Madu)	6.0	51.35	2.08	276.5
Schizostachyum brachycladum (Lemang)	6.8	12.11	3.88	68.6

This study estimated specific species biogenic carbon storage based on measured photosynthetic assimilation rates and structural bamboo allocation within the bamboo hall. Based on the construction inventory, the bamboo hall incorporated structural bamboo components comprising betung for columns, floor beams, and roof trusses; semantan for ceiling structures; madu for floor joists and roof beams; lemang for roof joists; and secondary flooring bamboo elements conservatively estimated using equivalent structural values. As presented in Table 4, the total estimated biogenic carbon stored in the bamboo hall was 48,695 kg C, equivalent to 178,548 kg CO_2e. These findings demonstrate the substantial carbon storage potential of bamboo construction and provide the quantitative basis for subsequent lifecycle carbon comparison against embodied and operational emissions.

Table 4: Estimated biogenic carbon storage potential by structural component in the bamboo hall

No.	Structural Component	Bamboo Type / Equivalent Material Category	Number of Bamboo Culms*	Estimated Carbon Storage per Culm (kg C)	Total Estimated Carbon Storage (kg C)
1	Columns	*Dendrocalamus asper* (Betung)	18	142.6	2,566.4
2	Flooring	*Dendrocalamus asper* (Betung) – floor beams	14	142.6	1,996.4
		Gigantochloa albociliata (Madu) – floor joists	42	276.5	11,611.7
		Secondary flooring bamboo elements**	64	68.6	4,390.4
3	Ceiling	*Gigantochloa scortechinii* (Semantan)	60	268.2	16,092.0
4	Roof	*Dendrocalamus asper* (Betung) – roof trusses	10	142.6	1,426.0
		Gigantochloa albociliata (Madu) – roof beams	24	276.5	6,636.0
		Schizostachyum brachycladum (Lemang) – roof joists	58	68.6	3,978.8
				Total Estimated Biogenic Carbon Storage	**~48,695** kgC
					178,548 kg CO_2e

* Estimation based on an average bamboo culm length of 14 feet used in the construction inventory.
** Carbon storage for secondary flooring bamboo elements was conservatively estimated using the equivalent structural carbon value of *Schizostachyum brachycladum* due to unavailable direct specific species photosynthetic measurements.

Phase 2: Embodied Carbon Emission

Phase 2 quantified embodied carbon emissions associated with bamboo harvesting, processing, transportation, and on-site installation activities within the defined lifecycle boundary. The total embodied carbon emission for the bamboo hall was estimated at 442 kg CO_2e, representing the cumulative impact of material preparation and construction-related activities prior to building operation.

As shown in Table 5, transportation contributed the highest share of embodied emissions (56.8%), accounting for most of total embodied carbon due to repeated logistics between bamboo sourcing locations, processing sites, and the construction site. This indicates that transportation distance and vehicle fuel consumption are key determinants of embodied carbon performance in bamboo construction projects. Installation activities contributed the second largest proportion (41.2%), primarily due to electricity consumption from assembly equipment such as hand drills, air compressors, and grinders. In contrast, harvesting and processing activities contributed comparatively minor emissions (2.0%).

Despite the inclusion of multiple lifecycle activities, the embodied carbon burden remained relatively low when compared with the total estimated biogenic carbon stored in the bamboo structure (178,548 kg CO_2e). This suggests that bamboo construction can maintain a favourable embodied carbon profile when locally sourced materials and relatively low energy processing methods are adopted.

Table 5: Embodied carbon emissions from bamboo hall construction activities

Lifecycle Stage	Equipment / Activity Included	Carbon Emissions (kg CO_2e)	Contribution (%)
Harvesting & Processing	Pole saw, chain saw, grass cutter, grinder, generator, bamboo splitting machine, water pressure gun, hand drill	8.9	2.0
Transportation	Material transport between bamboo source, workshop, and construction site	251.0	56.8
Installation	Hand drill, air compressor, grinder	182.2	41.2
	Total Embodied Carbon	**442.1**	**100.0**

Phase 3: Operational Carbon Emissions

Phase 3 assessed the projected operational carbon emissions associated with electricity consumption during the use phase of the bamboo hall over the assumed 30-year service life. Operational energy demand was estimated based on projected use of plug points, ceiling fans, and LED lighting under defined daily operating assumptions, with carbon emissions calculated using Malaysia's 2025 electricity grid emission factor.

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As presented in Table 6, the total estimated annual operational carbon emission was 625.5 kg CO_2e, equivalent to 18,765 kg CO_2e over the 30-year building lifespan. LED lighting contributed the largest proportion of annual operational emissions (286.8 kg CO_2e/year), followed by ceiling fan operation (239.1 kg CO_2e/year) and plug-point electricity use (99.6 kg CO_2e/year). These findings indicate that extended operational hours and cumulative electricity demand significantly influence lifecycle carbon performance, even in low-carbon construction systems.

Compared with embodied carbon emissions (442.1 kg CO_2e), operational emissions were substantially higher over the building lifespan, highlighting the importance of operational energy efficiency in long-term carbon management. Nevertheless, when compared against the estimated biogenic carbon storage of the bamboo hall (178,548 kg CO_2e), projected operational emissions remained comparatively low under the defined assumptions. This suggests that bamboo-based construction, when combined with energy-efficient operation, may serve as a nature-based solution (NbS) for climate change mitigation through reduced lifecycle emissions and long-term biogenic carbon storage.

Table 6: Projected operational carbon emissions from bamboo hall electricity use

Electrical Usage	**Number of Units**	**Power Rating (kW)**	**Daily Operating Hours**	**Daily Energy Consumption (kWh)**	**Grid Emission Factor (kg CO_2e/kWh)**	**Annual Carbon Emissions (kg CO_2e/year)**
Plug Points	2	0.05	4	0.40	0.682	99.6
Ceiling Fan	1	0.12	8	0.96	0.682	239.1
LED Lighting	4	0.024	12	1.15	0.682	286.8
					Total Annual Operational Carbon	625.5
					Projected 30 Years Operational Carbon	**18,765**

Net Carbon Balance and Integrated Lifecycle Comparison

The overall net carbon performance of the bamboo hall was determined by comparing total biogenic carbon storage against combined embodied and operational lifecycle emissions within the defined assessment boundary. As summarised in Table 7, the bamboo hall demonstrated an estimated biogenic carbon storage of 178,548 kg CO_2e, while total embodied carbon emissions amounted to 442.1 kg CO_2e, and projected operational carbon emissions over the 30 years service life totalled 18,765 kg CO_2e.

Table 7: Integrated lifecycle carbon balance of the bamboo hall

Carbon Component	Carbon Value (kg CO_2e)	Contribution to Total Lifecycle Emissions (%)
Biogenic Carbon Storage	178,548.0	—
Embodied Carbon Emissions	442.1	2.3
Operational Carbon Emissions (30 years)	18,765.0	97.7
Total Lifecycle Emissions	19,207.1	100.0
Net Carbon Balance	**−159,340.9**	—

The combined lifecycle emissions were therefore estimated at 19,207.1 kg CO_2e, substantially lower than the total biogenic carbon stored in the bamboo structure. This resulted in a net carbon balance of −159,340.9 kg CO_2e, indicating that, under the defined system boundary and operational assumptions, the bamboo hall functioned as a net carbon sink rather than a net carbon source.

Operational carbon emissions represented the largest proportion of lifecycle emissions (97.7%), while embodied carbon emissions contributed only 2.3%. These findings suggest that although bamboo construction demonstrates strong carbon storage potential, long-term operational energy use remains the dominant emission driver within the lifecycle assessment boundary.

However, this carbon-negative outcome is conditional upon the assumptions adopted in the present study, including the exclusion of foundation construction, maintenance and replacement activities, demolition processes, and end-of-life carbon release scenarios. Changes in service life, electricity grid emission factors, operational usage intensity, or material transport distances may alter the final carbon balance. Nevertheless, under the defined lifecycle boundary, the bamboo hall demonstrated a favourable net carbon performance.

Carbon Performance Interpretation

The findings demonstrate that bamboo construction can achieve a favourable lifecycle carbon profile when biogenic carbon storage is considered alongside embodied and operational emissions within a defined assessment boundary. The estimated biogenic carbon storage of the bamboo hall (178,548 kg CO_2e) substantially exceeded total lifecycle emissions (19,207.1 kg CO_2e), resulting in a net carbon balance of −159,340.9 kg CO_2e. This indicates that, under the assumptions adopted in this study, the bamboo hall functioned as a net carbon sink over its assessed lifecycle.

The results further reveal that operational carbon emissions constituted the dominant emission source (97.7% of total lifecycle emissions), while embodied carbon emissions contributed only a minor share (2.3%). This differs from conventional building carbon assessments, where embodied emissions from cement, steel, and manufactured materials frequently dominate early lifecycle stages. In the present case, the relatively low embodied carbon burden reflects the

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use of lightweight bamboo materials, low-energy processing activities, and simplified construction methods.

From a climate mitigation perspective, bamboo-based construction may also be interpreted as a potential nature-based solution (NbS), as it combines renewable biological material utilisation with measurable carbon storage in long-lived structural applications. Unlike conventional carbon intensive construction materials, bamboo enables atmospheric carbon captured during biological growth to remain stored within the built environment over the service life of the structure.

Comparison with Previous Studies

The present findings are broadly consistent with previous studies reporting the carbon mitigation potential of bamboo as a construction material. Xu et al. (2022) similarly highlighted the importance of integrating carbon sequestration and lifecycle emissions when evaluating bamboo construction performance, emphasising that biogenic carbon storage can substantially improve the environmental profile of plant-based building materials when assessed over an appropriate lifecycle boundary.

However, differences in reported carbon outcomes across studies are strongly influenced by methodological assumptions, including system boundary definition, service life assumptions, operational energy scenarios, transport distances, and treatment of end-of-life carbon release. In the present study, operational emissions emerged as the dominant lifecycle emission source, whereas studies involving more energy-intensive material processing or extended transportation logistics may report higher embodied carbon contributions. This highlights the sensitivity of lifecycle carbon outcomes to project-specific assumptions and reinforces the need for transparent boundary definition in comparative carbon accounting.

Planning Implications and Study Limitations

The findings provide several implications for planning and low-carbon built environment strategies, particularly in tropical regions where bamboo is naturally abundant and can be integrated into regional construction supply chains. Since transportation was identified as the dominant embodied carbon contributor, reducing procurement distance through decentralised processing facilities and regional material sourcing could further improve the lifecycle carbon performance of bamboo construction. Similarly, because operational emissions represented the largest proportion of lifecycle emissions, integrating passive cooling strategies, energy-efficient lighting systems, and reduced operational energy demand would strengthen long-term carbon outcomes in bamboo-based developments.

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Bamboo offers advantages over timber due to shorter maturation cycles, regenerative harvesting through rhizome retention, and increasing applicability in engineered structural systems (Dai, 2026). From a structural perspective, recent advances in engineered bamboo products, preservation treatment, and construction detailing have significantly improved the durability, dimensional stability, and long-term applicability of bamboo in permanent building systems (Dai, 2026). These innovations increase the feasibility of substituting more carbon-intensive materials such as reinforced concrete, steel, aluminium, and glass in selected structural or semi-structural applications, particularly in tropical development contexts where bamboo resources are locally available.

From a climate mitigation perspective, bamboo construction may also be interpreted as a potential nature-based solution (NbS), as it extends biological carbon sequestration into the built environment through renewable structural materials. This aligns with planning strategies that seek to integrate ecological processes, low-carbon material transitions, and climate-responsive development pathways into future urban and landscape development practice.

However, the carbon-negative outcome reported in this study should be interpreted within the defined assessment boundary and methodological assumptions. Several lifecycle stages were excluded, including foundation construction, maintenance and replacement activities, demolition processes, waste treatment, and end-of-life carbon release. The operational assessment was based on projected electricity usage assumptions over a 30-year service life using Malaysia's 2025 electricity grid emission factor, which may vary over time. In addition, secondary flooring bamboo elements were conservatively estimated using equivalent structural carbon values due to unavailable direct species-specific measurements.

These methodological considerations indicate that the reported net carbon balance represents a case-specific estimate under the defined lifecycle boundary rather than a universally generalisable benchmark. Nevertheless, the findings demonstrate the strong carbon mitigation potential of bamboo construction when lifecycle boundaries, operational assumptions, and material sourcing strategies are appropriately managed.

CONCLUSIONS

This study demonstrates the strong potential of bamboo construction as a low-carbon building strategy within tropical built environment contexts when assessed using a lifecycle carbon framework integrating carbon sequestration, embodied emissions, and operational emissions. Under the defined assessment assumptions, the bamboo hall functioned as a net carbon sink, indicating that biogenic carbon storage substantially exceeded total lifecycle emissions. These findings support bamboo's potential role as a nature-based solution (NbS) for

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climate change mitigation, particularly in regions where bamboo is locally available as a rapidly renewable material. From a planning perspective, the study highlights the importance of local material sourcing, transportation efficiency, and operational energy management in improving lifecycle carbon performance. Although the reported carbon-negative outcome remains conditional upon the defined system boundary and excluded lifecycle stages, this study provides practical evidence supporting the integration of bamboo-based construction into climate-responsive and sustainable development strategies.

ETHICS STATEMENT

Formal ethical approval was not required, as expert consultation was limited to technical verification of construction inventory data.

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ASSESSING THE CARBON SEQUESTRATION POTENTIAL OF BAMBOO IN URBAN ROAD RESERVES: A NATURE-BASED SOLUTION FOR CLIMATE MITIGATION AND URBAN PLANNING

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Abstract

Urban road reserves represent underutilized linear green spaces with significant potential to support nature-based climate mitigation strategies in rapidly urbanizing environments. Despite their availability, these spaces remain largely overlooked in urban planning as functional carbon sink corridors. This study assesses the carbon sequestration potential of *Gigantochloa albociliata* (buluh madu) cultivated within urban road reserves, using Lebuh Meru Raya, Ipoh, Perak, Malaysia, as a case study. Field measurements were conducted using a LI-6400XT Portable Photosynthesis System to determine leaf-level photosynthetic assimilation rates under controlled photosynthetically active radiation (PAR) conditions, while canopy characteristics were quantified through Leaf Area Index (LAI) measurements and crown area estimation. A light response curve analysis was applied to derive a representative net carbon assimilation rate, which was subsequently extrapolated to estimate annual carbon sequestration potential. Results indicated a mean net assimilation rate of 6.0 µmol CO_2 m^{-2} s^{-1}, with an LAI of 2.08 and a mean crown area of 51.35 m^2. Based on the modeled assumptions, a single bamboo clump was estimated to sequester approximately 121.26 kg of carbon annually, equivalent to 445.02 kg CO_2. Extrapolation across a 7 km urban road reserve corridor suggests a theoretical sequestration potential of approximately 106.1 metric tonnes of carbon per year, or 389.4 metric tonnes of CO_2 equivalent, assuming full planting occupancy. While these estimates are derived from controlled physiological measurements and annualized assumptions rather than destructive biomass validation, the findings suggest the potential of bamboo as a nature-based planning intervention for climate mitigation, green infrastructure enhancement, and low-carbon urban development.

Keywords: Bamboo, Carbon Sequestration, Urban Road Reserves, Nature-Based Solutions, Climate Mitigation, Urban Planning

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INTRODUCTION

The escalating urgency to address climate change has intensified the global pursuit of effective strategies to reduce greenhouse gas (GHG) emissions. Nature-based solutions have emerged as strategic components in climate mitigation efforts, particularly through natural carbon sequestration using fast-growing plant species. Among these, bamboo has gained prominence due to its rapid biomass accumulation, short rotation cycle, and high carbon sequestration potential. According to King, et. al (2021), certain bamboo species are capable of storing between 100 to 300 tons of carbon per hectare, depending on species and management conditions.

Gigantochloa albociliata, locally known as buluh madu, is a native Malaysian bamboo species noted for its swift growth, significant biomass yield, and strong regenerative ability (Abd. Razak, 2012). Beyond ecological applications, bamboo has also been explored in infrastructure and construction contexts due to its structural versatility and renewable material potential (Pitroda et al., 2016). It's ecological adaptability and structural characteristics make it highly suitable for incorporation into nature-based urban carbon management and sustainable land use practices (Piazza et al., 2007). Due to its minimal maintenance requirements and ability to thrive in tropical climates, it is increasingly recognised as a viable species for integration into nature-based carbon mitigation solutions (Yiping et al., 2010).

Urban and peri-urban environments especially roadside reserves represent underutilised green spaces with latent potential for biomass cultivation and carbon storage. These narrow, linear strips of land span significant areas across urban landscapes but are often overlooked in landscape and climate planning (Yasin et al., 2020). In the Malaysian context, the Low Carbon Cities Framework (LCCF) encourages sustainable urban development practices, yet the role of road reserves in national carbon offsetting and urban greening strategies remains largely unexplored.

Despite various government initiatives promoting green infrastructure, empirical research on the carbon sequestration performance of bamboo in road reserve conditions is still limited. Existing carbon offset models often exclude or underestimate the contribution of these fragmented urban lands. There is thus a pressing need to quantify the carbon sink potential of bamboo in non-forest, roadside settings, particularly using species like *Gigantochloa albociliata*.

This research examines the capacity of *Gigantochloa albociliata* to enhance carbon sequestration initiatives in underutilised areas such as road reserves. The study specifically investigates the road reserve area along Lebuh Meru in Ipoh, Perak, as a test site to evaluate the species' carbon sequestration capacity through photosynthetic assimilation analysis.

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Accordingly, this study has two objectives: (1) to assess the carbon sequestration potential of *Gigantochloa albociliata* for urban climate mitigation; and (2) to estimate a theoretical carbon sequestration contribution in the Lebuh Meru road reserve. The findings aim to offer practical insights for incorporating bamboo into sustainable land management strategies, carbon offsetting initiatives, and comprehensive climate mitigation policies.

LITERATURE REVIEW

Bamboo as a Carbon Sequestration Resource and Nature-Based Climate Solution

Nature-based solutions (NBS) have gained increasing recognition as strategic approaches for addressing climate change, biodiversity loss, and urban sustainability challenges by working with natural systems to deliver environmental and societal benefits (Cohen-Shacham et al., 2016; Seddon et al., 2020). Within climate mitigation discourse, vegetation-based interventions remain among the most accessible NBS strategies due to their ability to remove atmospheric carbon dioxide through photosynthesis while simultaneously delivering ecosystem co-benefits such as urban cooling, biodiversity enhancement, and air quality improvement.

Among plant-based carbon mitigation options, bamboo has attracted growing attention due to its rapid growth rate, high biomass productivity, regenerative growth behaviour, and adaptability across a wide range of environmental conditions (Yiping et al., 2010; Song et al., 2011, Liese & Kohl, 2015). Unlike many woody species that require long maturation periods, bamboo can establish quickly and sustain repeated biomass regeneration without replanting, making it particularly relevant for climate mitigation and sustainable land management initiatives.

Previous studies have demonstrated bamboo's significant carbon sequestration potential in forestry, agroforestry, and managed plantation systems. Nath and Das (2011) reported substantial carbon storage in bamboo-based homegarden systems, while Marchi et al. (2023) highlighted bamboo's capacity to contribute to carbon offset strategies under managed plantation conditions. King et al. (2021) further emphasized bamboo's emerging relevance within voluntary carbon markets due to its rapid carbon uptake and commercial viability. In addition to carbon mitigation, bamboo has also gained attention for its broader ecological benefits, including erosion control, habitat support, land rehabilitation, and renewable material applications within low-carbon built environment strategies (Isukuru et al., 2023).

In Malaysia, *Gigantochloa albociliata* (buluh madu) presents strong potential due to its rapid growth, structural resilience, and suitability for tropical climatic conditions (Abd. Razak et al., 2012; Salleh et al., 2014). While bamboo's

ecological and economic advantages are increasingly acknowledged, empirical studies assessing its carbon sequestration potential within urban planning applications remain limited, particularly under constrained urban land conditions.

Urban Road Reserves as Underutilized Green Infrastructure Corridors

Urban planning increasingly recognizes green infrastructure as a multifunctional strategy capable of improving ecological performance, climate resilience, and public environmental quality within built environments (Tzoulas et al., 2007). Beyond conventional parks and open spaces, underutilized urban residual spaces are increasingly being reconsidered as opportunities for ecological intervention and environmental enhancement.

Road reserves represent one such category of overlooked urban land. These linear spaces are commonly maintained for infrastructure setbacks, utility corridors, visual buffering, and transportation safety requirements, yet their ecological contribution is often minimal. Due to their extensive distribution, public accessibility, and relatively low development opportunity cost, road reserves offer practical potential for integration into urban climate mitigation strategies.

Recent planning studies have explored the adaptive transformation of residual urban spaces into functional green infrastructure systems. Mohamed Anuar and Abdullah (2022) demonstrated how underutilized spaces beneath elevated urban highways can be repurposed through green infrastructure planning to improve ecological and social outcomes. Similarly, Krishnamoorthy et al. (2024) highlighted the role of nature-based solutions in revitalizing urban voids within the Malaysian context, emphasizing the importance of strategic planning interventions for resilient city development.

From a climate perspective, roadside vegetation has also been associated with ecosystem services including air quality enhancement, thermal regulation, and carbon sequestration potential (Srour et al., 2024). However, most existing studies focus on conventional tree planting, urban forestry, or broad landscape greening strategies, with limited attention given to bamboo as a linear roadside carbon sink intervention.

Research Gap

Although bamboo's carbon sequestration potential has been widely examined in forestry and plantation contexts, limited research has investigated its application within urban roadside environments, particularly using physiological carbon assimilation measurements to estimate sequestration potential under constrained urban conditions.

Within Malaysia, studies involving bamboo have predominantly focused on cultivation, productivity, and construction applications, while

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empirical planning-oriented investigations remain scarce. Furthermore, despite increasing interest in nature-based urban interventions, road reserves remain underexplored as carbon sink corridors within local urban planning practice.

This study addresses these gaps by evaluating the carbon sequestration potential of *Gigantochloa albociliata* within an urban road reserve context using field-based physiological measurements and spatial extrapolation. By linking ecological performance with urban planning application, the study contributes empirical evidence to support the integration of bamboo planting as nature-based solutions into low carbon urban development strategies.

METHODOLOGY

Research Design

This study employed an experimental quantitative approach to assess the carbon sequestration potential of *Gigantochloa albociliata* (*buluh madu*) through field-based physiological measurements and spatial extrapolation. The study combined direct measurements of leaf-level photosynthetic carbon assimilation with canopy structural analysis to estimate theoretical annual carbon sequestration potential under modeled conditions.

Study Site

The study was conducted along the urban road reserve corridor of Lebuh Meru Raya, Ipoh, Perak, Malaysia, located between coordinates 4°40'26.5"N, 101°04'21.7"E and 4°39'51.2"N, 101°05'09.3"E. The selected site represents an underutilized linear urban green space with potential for integration into climate-responsive green infrastructure planning.

Lebuh Meru Raya was selected due to its strategic urban context, accessibility for field measurements, and availability of continuous roadside reserve areas suitable for hypothetical bamboo planting. The site is characterized by a semi-urban environment influenced by vehicular activity, open solar exposure, and fragmented vegetation, making it an appropriate setting for evaluating bamboo's applicability within urban roadside conditions. The study location and assessed road reserve corridor are illustrated in Figure 1.

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Figure 1: Study area of Lebuh Meru Raya, Ipoh, Perak, showing the assessed road reserve corridor and potential bamboo planting zones.

Sampling Procedure

A stratified canopy sampling approach was adopted to capture physiological variability across the vertical structure of *Gigantochloa albociliata*. A total of 20 healthy, mature leaves were sampled from representative canopy strata comprising the upper (n = 6), middle (n = 8), and lower canopy levels (n = 6). This approach was adopted to account for differences in light exposure and photosynthetic performance within the canopy profile, consistent with established plant ecophysiology sampling practices (Niinemets, 2010). Access to elevated canopy sections was facilitated using a skylift to ensure representative sampling across all canopy layers.

Photosynthetic Carbon Assimilation Measurement

Leaf-level photosynthetic carbon assimilation was measured using a LI-6400XT Portable Photosynthesis System (LI-COR Biosciences, USA) under standard chamber carbon dioxide conditions. Measurements were conducted using a controlled light response curve protocol to assess photosynthetic performance across varying levels of photosynthetically active radiation (PAR). PAR levels were sequentially adjusted at 0, 200, 400, 600, 1000, 1500, 1800, and 2500 µmol

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m^{-2} s^{-1} to evaluate the physiological response of *Gigantochloa albociliata* under different light intensities.

Net photosynthetic assimilation rates were recorded as μmol CO_2 m^{-2} s^{-1} for each sampled leaf. A representative mean net assimilation value derived from the light response curve analysis was subsequently used for carbon sequestration estimation.

Because the study employed controlled chamber light manipulation, measurements were standardized independently of ambient time-of-day fluctuations. Environmental parameters including temperature, relative humidity, and ambient CO_2 concentration were monitored throughout the measurement process using the integrated LI-6400XT sensors.

Canopy Structure Measurement

Canopy structural characteristics were quantified using Leaf Area Index (LAI) analysis to estimate effective photosynthetic surface area. LAI measurements were conducted using a HM-G10 Plant Canopy Analyzer, based on comparative light interception measurements above and beneath the bamboo canopy. Multiple readings were collected surrounding the representative bamboo clump to improve measurement consistency and reduce localized variability. The crown area of the bamboo clump was calculated using the measured mean crown radius according to:

$$CA = \pi r^2$$

where:
CA = crown area (m^2)
r = mean crown radius (m)

The resulting crown area and LAI values were subsequently integrated into the carbon sequestration estimation model.

Carbon Sequestration Estimation

The theoretical annual carbon sequestration potential of *Gigantochloa albociliata* was estimated by integrating measured photosynthetic assimilation rates with canopy structural parameters. This extrapolation approach is consistent with established principles for estimating carbon uptake from photosynthetic productivity measurements (Clark et al., 2001). Annual carbon uptake was estimated using:

$$Annual\ carbon\ uptake = A_n x\ CA\ x\ LAI\ x\ T$$

where:
A_n = mean net photosynthetic assimilation rate (μmol CO_2 m^{-2} s^{-1})
CA = crown area (m^2)
LAI = leaf area index
T = annual active photosynthetic duration (seconds)

A 12-hour average daily photoperiod was assumed based on typical equatorial daylight conditions and extrapolated over 365 days to estimate annual carbon sequestration potential. The resulting annual CO_2 uptake values were converted from micromoles to moles and subsequently converted into elemental carbon using the molecular conversion ratio:

$$C = CO_2 \, x \, (12/44)$$

Equivalent carbon dioxide values (CO_2e) were calculated using the standard conversion factor:

$$CO_2e = C \, x \, (44/12)$$

As destructive biomass sampling was not permitted at the study site, the analysis was based on physiological carbon assimilation measurements and modeled annual extrapolation rather than direct biomass validation.

Spatial Extrapolation
To estimate corridor-scale carbon sequestration potential, a theoretical planting model was applied to the 7 km Lebuh Meru Raya road reserve corridor. Based on the measured mature canopy diameter of approximately 8 m per bamboo clump, a full planting occupancy assumption was applied at 8-meter linear intervals, yielding an estimated 875 potential bamboo clumps.

This extrapolation represents a theoretical maximum planting scenario intended to illustrate planning-scale carbon uptake potential rather than a final implementation layout, as practical constraints such as infrastructure setbacks, access requirements, and utility corridors may reduce actual planting capacity.

RESULTS AND DISCUSSION

Photosynthetic Response of *Gigantochloa albociliata*
Photosynthetic assimilation measurements were obtained from 20 mature leaves (n = 20) sampled from a representative *Gigantochloa albociliata* clump under controlled photosynthetically active radiation (PAR) conditions using the LI6400XT portable photosynthesis system. The mean net photosynthetic assimilation rates and associated variability statistics are presented in Table 1.

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Table 1: Net photosynthetic assimilation rates of *Gigantochloa albociliata* under controlled photosynthetically active radiation (PAR) conditions (n = 20 leaves).

PAR (µmol photons m^{-2} s^{-1})	Mean Net Assimilation (µmol CO_2 m^{-2} s^{-1})	Standard Error (SE)	Standard Deviation (SD)
0	-4.1	1.72	7.7
200	3.3	1.37	6.11
400	8.2	1.3	5.81
600	9.4	2.06	9.21
1000	10.8	1.65	7.39
1500	13.7	1.50	6.69
1800	12.9	1.68	7.50
2500	12.4	1.91	8.55

Under dark conditions (PAR = 0 µmol photons m^{-2} s^{-1}), net assimilation was negative, indicating respiratory carbon loss in the absence of illumination. Once light was introduced, positive carbon assimilation was observed, with mean net assimilation increasing progressively from 3.3 µmol CO_2 m^{-2} s^{-1} at 200 µmol photons m^{-2} s^{-1} to a maximum observed mean of 13.7 µmol CO_2 m^{-2} s^{-1} at 1500 µmol photons m^{-2} s^{-1}.

Beyond this level, assimilation values remained relatively stable, with only slight reductions at higher PAR levels, suggesting saturation of photosynthetic response under the tested measurement conditions.

The light response curve (Figure 2) demonstrates a non-linear relationship between PAR and net photosynthetic assimilation. A quadratic trendline provided a strong empirical fit to the observed mean response pattern (R^2 = 0.937), supporting the suitability of the averaged response data for subsequent carbon sequestration estimation.

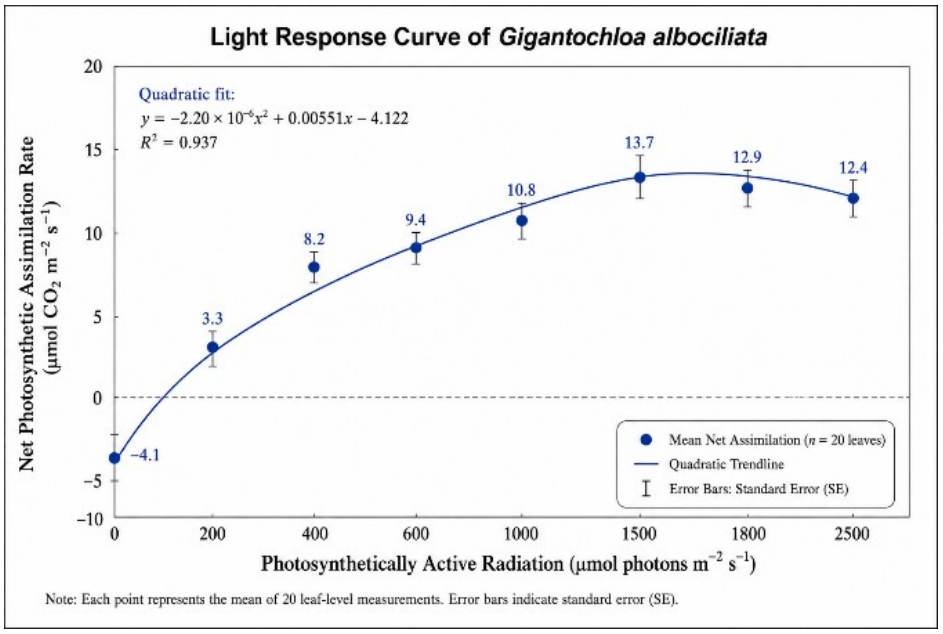


Figure 2: Light response curve of *Gigantochloa albociliata* showing mean net photosynthetic assimilation under controlled PAR conditions (n = 20; error bars represent SE).

Variability across PAR levels likely reflects physiological heterogeneity among sampled leaves from different canopy positions, together with measurement variability commonly associated with field-based physiological observations. Nevertheless, the overall response pattern remained sufficiently consistent for estimating representative carbon sequestration potential. For subsequent carbon sequestration calculations, a representative mean net assimilation value of 6.0 μmol CO_2 m^{-2} s^{-1} was adopted based on the averaged light response dataset.

Canopy Structural Characteristics

The structural characteristics of the representative *Gigantochloa albociliata* clump were assessed using crown area measurement and Leaf Area Index (LAI) analysis. The measured mean crown radius was 4.043 m, corresponding to a crown area of 51.35 m², while the recorded LAI value was 2.08. The measured canopy structural parameters are summarized in Table 2

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Table 2: Canopy structural characteristics of the representative *Gigantochloa albociliata* clump used for carbon sequestration estimation.

Parameter	Value
Mean crown radius (m)	4.043
Estimated crown area (m²)	51.35
Leaf Area Index (LAI)	2.08
Effective photosynthetic leaf area (Crown Area × LAI) (m²)	106.81

These structural characteristics indicate substantial canopy coverage and effective photosynthetically active surface area. By integrating crown area with LAI, the effective leaf surface area contributing to carbon assimilation was estimated at approximately 106.81 m².

Estimated Carbon Sequestration Potential of *Gigantochloa albociliata*

The annual carbon sequestration potential of a single clump of *Gigantochloa albociliata* was estimated by integrating the representative mean net photosynthetic assimilation rate with measured canopy structural parameters. Using a mean assimilation rate of 6.0 μmol CO_2 m^{-2} s^{-1}, crown area of 51.35 m², and LAI of 2.08, the effective photosynthetic surface area was estimated at 106.81 m². Assuming a 12-hour average daily photoperiod under tropical equatorial conditions over 365 days, the total annual uptake was estimated at approximately 10,104.68 mol CO_2 per clump.

Following molecular conversion to elemental carbon using the standard 12/44 carbon-to-CO_2 ratio, the estimated annual sequestration potential of a single bamboo clump was 121.26 kg C $year^{-1}$, equivalent to approximately 445.02 kg CO_2 $year^{-1}$. The detailed annual carbon sequestration estimation is summarized in Table 3.

Table 3: Annual carbon sequestration estimation for a representative clump of *Gigantochloa albociliata* based on physiological carbon assimilation measurements and modeled annual extrapolation.

Parameter	Value
Representative mean net photosynthetic assimilation rate (μmol CO_2 m^{-2} s^{-1})	6.0
Effective photosynthetic leaf area (m²)	106.81
Estimated carbon uptake per second (μmol CO_2 s^{-1})	640.86
Daily active photosynthetic duration (hours day^{-1})	12
Annual active photosynthetic duration (seconds $year^{-1}$)	15,768,000
Estimated annual CO_2 uptake (mol CO_2 $year^{-1}$)	10,104.68
Estimated annual carbon sequestration (kg C $year^{-1}$)	121.26
Equivalent annual CO_2 sequestration (kg CO_2 $year^{-1}$)	445.02

As destructive biomass validation was not permitted at the study site, these estimates represent theoretical carbon sequestration potential derived from

physiological carbon assimilation measurements and modeled annual extrapolation rather than direct biomass accumulation measurements.

Corridor-Scale Carbon Sequestration Potential for Urban Planning

To estimate planning-scale implications, a theoretical spatial extrapolation was applied to the 7 km Lebuh Meru Raya road reserve corridor. Based on the measured mature canopy diameter of approximately 8 m per bamboo clump, a full planting occupancy assumption yielded an estimated 875 potential bamboo clumps along the corridor.

Under this theoretical planting scenario, the total annual carbon sequestration potential was estimated at approximately 106.1 metric tonnes of carbon per year, equivalent to 389.4 metric tonnes of CO_2 annually (Table 4). This demonstrates the potential role of bamboo-integrated road reserves as supplementary urban carbon sink corridors within broader low-carbon urban planning strategies. However, actual implementation capacity may be lower due to infrastructure setbacks, access requirements, utility corridors, and maintenance considerations.

Table 4: Theoretical corridor-scale carbon sequestration potential for bamboo planting along the 7 km Lebuh Meru Raya road reserve.

Parameter	Value
Total road reserve corridor length (m)	7,000
Assumed mature canopy diameter per bamboo clump (m)	8
Estimated maximum theoretical bamboo clumps	875
Annual carbon sequestration per bamboo clump (kg C $year^{-1}$)	121.26
Total annual carbon sequestration potential (kg C $year^{-1}$)	106,102.50
Total annual carbon sequestration potential (metric tonnes C $year^{-1}$)	106.10
Equivalent annual CO_2 sequestration (metric tonnes CO_2 $year^{-1}$)	389.40

The findings indicate that *Gigantochloa albociliata* demonstrates promising physiological carbon assimilation characteristics under controlled light conditions, with photosynthetic performance increasing progressively with increasing PAR before reaching saturation at higher light intensities. This response pattern is consistent with the non-linear photosynthetic behavior commonly observed in rapidly growing plant species, where carbon assimilation increases with light availability until reaching physiological saturation (Yiping et al., 2010; Song et al., 2011). The relatively broad variability observed across sampled leaves likely reflects natural physiological heterogeneity associated with vertical canopy stratification, as measurements were intentionally obtained from lower, middle, and upper canopy positions with differing light exposure conditions.

The estimated annual sequestration potential of approximately 121.26 kg C per bamboo clump suggests that *Gigantochloa albociliata* may contribute

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meaningfully to localized carbon mitigation when strategically integrated into urban green infrastructure systems. While direct comparisons should be interpreted cautiously due to methodological differences, these findings align with broader literature identifying bamboo as a productive carbon-absorbing vegetation type due to its rapid growth, regenerative biomass dynamics, and efficient photosynthetic performance (Nath & Das, 2011; King et al., 2021). Bamboo may offer a complementary vegetation option for constrained urban corridors due to its rapid establishment and dense canopy structure.

From an urban planning perspective, the corridor-scale extrapolation demonstrates the conceptual feasibility of utilizing road reserves as supplementary carbon sink corridors within broader low-carbon urban development strategies. Urban road reserves are often maintained primarily for infrastructure clearance, visual buffering, or transport-related setbacks, yet many remain underutilized from an ecological perspective. The integration of bamboo within such spaces could potentially contribute to climate-responsive planning objectives while simultaneously supporting urban greening, microclimate improvement, and visual landscape enhancement. This is consistent with previous planning research emphasizing the multifunctional potential of underutilized urban residual spaces and roadside vegetation within nature-based urban interventions (Tzoulas et al., 2007; Srour et al., 2024; Yasin et al., 2020).

However, the findings should be interpreted within several methodological limitations. First, the physiological measurements were derived from a single representative bamboo clump, which limits broader generalizability across species populations and site conditions. Second, the annual sequestration estimates were derived from modeled extrapolation based on controlled photosynthetic measurements, assuming a constant 12-hour active photoperiod throughout the year. In reality, carbon uptake is influenced by environmental fluctuations, including cloud cover, seasonal rainfall variability, plant age, maintenance conditions, and physiological stress responses, which were not explicitly measured in this study.

Additionally, destructive biomass validation or allometric verification was not permitted at the study site, meaning the estimates represent theoretical carbon sequestration potential rather than directly measured long-term biomass carbon storage. The corridor-scale projection also assumes full planting occupancy at regular 8-meter intervals, which represents a maximum conceptual planning scenario rather than a final implementation design. Practical deployment would likely require adjustments to accommodate utility infrastructure, traffic visibility requirements, pedestrian access, drainage systems, and long-term maintenance considerations.

Despite these limitations, this study contributes localized empirical evidence to the limited Malaysian literature examining bamboo-based carbon

sequestration within urban planning applications. By linking physiological carbon assessment with spatial planning extrapolation, the study offers a practical foundation for future investigations involving multi-site validation, biomass-based carbon accounting, species comparisons, and implementation-orientated planning frameworks for bamboo-integrated urban green infrastructure.

CONCLUSION

This study assessed the carbon sequestration potential of *Gigantochloa albociliata* within an urban road reserve context using field-based physiological carbon assimilation measurements and canopy structural analysis. The findings suggest that bamboo exhibits promising photosynthetic carbon uptake characteristics under controlled PAR conditions, with an estimated theoretical annual sequestration potential of approximately 121.26 kg C per bamboo clump, equivalent to 445.02 kg CO_2 $year^{-1}$.

When extrapolated to the 7 km Lebuh Meru Raya road reserve corridor under a maximum theoretical planting scenario, the estimated sequestration potential reached approximately 106.1 metric tonnes of carbon annually, equivalent to 389.4 metric tonnes of CO_2. These findings suggest that underutilized urban road reserves may offer practical opportunities for integrating bamboo-based nature-based solutions within broader low-carbon urban planning strategies.

Beyond carbon mitigation, bamboo integration may provide additional co-benefits including urban greening enhancement, microclimate improvement, visual landscape value, and ecological enrichment within constrained urban spaces. As road reserves are widely distributed and publicly managed, their strategic ecological activation presents a potentially scalable planning intervention.

Nevertheless, the study should be interpreted within its methodological limitations, particularly the reliance on physiological extrapolation from a single representative bamboo clump and the absence of biomass-based carbon validation. Future research should therefore expand toward multi-site assessment, species comparison, long-term monitoring, and implementation-orientated planning evaluation to strengthen the practical application of bamboo within urban green infrastructure systems.

Overall, the study contributes localized empirical evidence supporting the exploration of bamboo as a nature-based climate mitigation strategy and offers a preliminary planning framework for rethinking underutilized road reserves as functional urban carbon sink corridors.

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RETHINKING URBAN SAFETY THROUGH PERCEIVED SAFETY AND COMMUNITY ENGAGEMENT IN MALAYSIA'S SAFE CITY PROGRAMME

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Abstract

This study evaluates the effectiveness of Malaysia's Safe City Programme (SCP), with a focus on perceived safety (PS) and community engagement as critical dimensions of urban crime prevention. The primary aim was to assess the social impact of the Safe City Programme (SCP) through two objectives, which are to examine variations in perceived safety across demographic and housing typologies, as well as to evaluate the role of community engagement within the Crime Prevention Through Environmental Design (CPTED) framework. A cross-sectional survey of 10,076 urban residents from 14 Malaysian states was conducted to collect quantitative data. The results indicate that Safe City Programme (SCP) infrastructure-based strategies, such as improved lighting and surveillance, enhance perceptions of safety, particularly among men and residents of low-density, high-income housing. However, fear of crime remains prevalent, particularly among women and residents of lower-income neighbourhoods. Statistical analysis revealed significant differences in perceived safety (PS) across gender and housing type. Notably, community engagement emerged as the weakest-performing CPTED component, indicating limited public participation in the Safe City Programme (SCP) initiatives. These findings highlight the disparity between the Safe City Programme (SCP) top-down approach and CPTED's participatory ethos. The paper concludes by recommending a shift towards inclusive, context-sensitive strategies that integrate community voices to foster long-term, sustainable urban safety.

Keywords: Urban Safety, Safe City Programme, CPTED, Community Engagement, Perceived Safety

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INTRODUCTION

Urban safety is widely recognised as a fundamental pillar of liveable and sustainable cities. It extends beyond the prevention of physical crime, encompassing broader dimensions such as economic resilience, mental well-being, and social cohesion (Milliken, 2016). A secure urban environment promotes mobility, community participation, and investment confidence, all of which improve the overall quality of life for residents. In response to growing concerns over urban crime and public insecurity, the Malaysian government established the Safe City Programme (SCP) in 2004 under the Ministry of Housing and Local Government. The SCP was perceived as a comprehensive strategy that integrates environmental design with policing measures to reduce crime rates and enhance public confidence in urban areas. Recognising its strategic importance, the SCP was formally incorporated into the National Key Result Areas (NKRAs) in 2009, raising urban safety to the level of a national development priority.

Since its inception, SCP has been implemented across various municipalities through tangible interventions, including the installation of closed-circuit television (CCTV), street lighting enhancements, increased police visibility, and other physical security infrastructure. Despite these extensive applications, evidence suggests that fear of crime remains prevalent among urban residents. This discrepancy raises serious concerns about the programme's effectiveness, particularly in terms of addressing the subjective dimensions of safety that influence everyday urban experiences. While previous studies have primarily focused on the physical and operational aspects of SCP, there is still a significant gap in evaluating its social impact, specifically, notably how residents perceive safety in relation to their demographic background and living environments. Moreover, the extent to which community engagement has been integrated into SCP strategies, as promoted by the Crime Prevention through Environmental Design (CPTED) framework, remains underexplored.

Accordingly, this study addresses two main dimensions of urban safety within the context of the SCP. First, it seeks to examine how demographic characteristics particularly gender and housing typology influence urban residents perceived safety (PS). Second, it aims to evaluate the effectiveness of community engagement initiatives as an integral component of CPTED-based strategies under the SCP. By addressing these objectives, the study aims to provide a nuanced understanding of urban safety that integrates infrastructure-driven approaches with socially embedded strategies for crime prevention and community resilience.

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LITERATURE REVIEW

Urban safety encompasses physical, social, and psychological dimensions that influence the liveability of cities (UN-Habitat, 2007; Cozens et al., 2005). Crime Prevention Through Environmental Design (CPTED) is the cornerstone for understanding the relationship between the built environment and human behaviour. Its five core principles, which are territoriality, surveillance, target hardening, maintenance, and community engagement, could emphasise proactive design strategies to deter crime and foster collective ownership (Cozens et al., 2005; Senna et al., 2025).

Globally, the intersection of urbanisation, safety, and community participation has been discussed extensively by UN-Habitat (2007, 2019). These reports highlight that rapid urban growth often outpaces security infrastructure, making community engagement essential for maintaining urban resilience. Comparative research in Southeast Asia shows diverse Safe City initiatives, such as Singapore's community policing model, Indonesia's neighbourhood security schemes (*Sistem Keamanan Lingkungan* - Siskamling), and the urban surveillance networks of Thailand. All of these initiatives are emphasising public–government collaboration. Table 1 demonstrates several safe city initiatives. These cases highlight the need for participatory approaches in urban safety planning.

Table 1: Comparative Overview of Global and Regional Safe City Initiatives

Country/ Region	Initiative/ Programme Name	Key Features/ Focus Areas	Approach to Community Participation	Source(s)
Global (UN-Habitat)	*Safer Cities Programme*	Promotes integrated urban safety planning, focusing on gender, youth, and community resilience.	Advocates inclusive governance and citizen-led urban management.	UN-Habitat (2007, 2019)
Singapore	*Community Policing System (COPS)*	Integrates neighbourhood police centres with local residents to co-produce safety outcomes.	Strong emphasis on community–police partnership and participatory surveillance.	Ministry of Home Affairs Singapore (2017); UN-Habitat (2019)
Japan	*Kōban (Police Box) System*	Local police stations embedded in residential areas to maintain visibility and trust.	Continuous engagement between police officers and residents	Héra (2024); UN-Habitat (2019)

Country/ Region	Initiative/ Programme Name	Key Features/ Focus Areas	Approach to Community Participation	Source(s)
			through daily interactions.	
Indonesia	*Siskamling (Sistem Keamanan Lingkungan)*	Community-based night patrols promoting neighbourhood security and social cohesion.	Residents collectively participate in routine patrols and crime reporting.	Intan Fitri (2016); Novekawati, et. al, (2023)
Thailand	*Smart Safety Zone Project*	Urban surveillance network integrating CCTV, data analytics, and community alerts.	Public–government collaboration through digital feedback channels and safety monitoring.	Royal Thai Police (2022); UNESCAP (2021)
Malaysia	*Safe City Programme (SCP)*	Combines CPTED-based environmental design, surveillance, and infrastructure improvement.	Moderate community participation; ongoing shift toward participatory CPTED and local engagement.	KPKT (2021); PLANMalaysia (2023); Lim (2020)

Source: Author (2025)

In addition to environmental approaches, the theoretical underpinnings of criminal behaviour offer further background for understanding urban safety interventions. One such approach is Rational Choice Theory. This theory, like CPTED, focuses on modifying the built environment to alter offender decision-making (Tabrizi & Madanipour, 2006; Anastasia & John, 2007). The decision to commit a crime is influenced by environmental factors. For instance, improved surveillance and territorial reinforcement might raise the perceived risk of detection, thereby deterring criminal acts. Similarly, effective target hardening can increase the effort required to commit a crime, reducing its appeal. By integrating Rational Choice Theory with CPTED (Figure 1), practitioners can gain a deeper understanding of the behavioural motivations behind crime and design urban spaces that not only reduce opportunity but also influence the offender's cost-benefit analysis.

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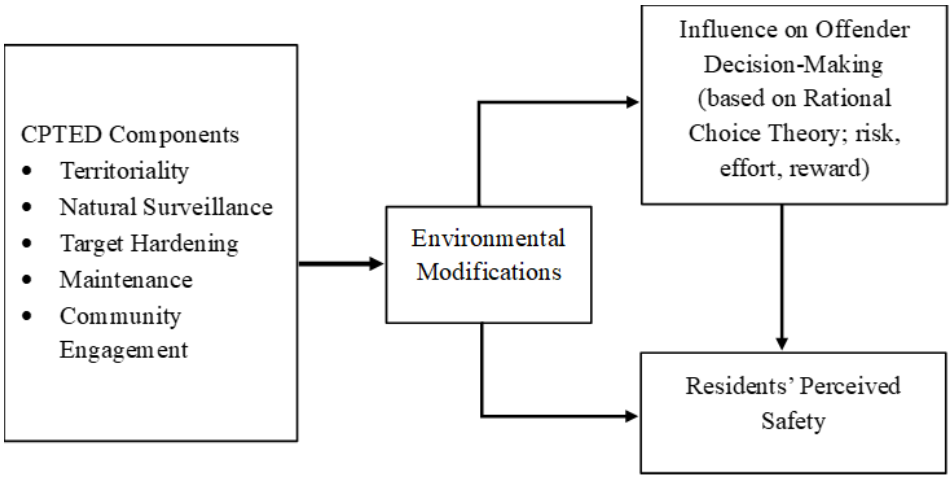


Figure 1: Conceptual Framework Integrating CPTED and Rational Choice Theory
Source: Author (2025)

In Malaysia, studies by Lim (2020) and Eizamly & Anuar (2020) have documented SCP's policy and infrastructural dimensions. However, these works often overlook residents' lived experiences, perceived safety, and CPTED's community engagement component. More recent analyses, including the Malaysia Smart City Framework (KPKT, 2021) and PLANMalaysia's Safe City Action Plan (2023), underscore the government's commitment to embedding public participation in urban safety initiatives. Nonetheless, empirical evaluation of SCP's social outcomes remains scarce. This study addresses these gaps by combining large-scale perception data with CPTED-based analysis to provide regional insights into Malaysia's evolving urban safety paradigm.

RESEARCH METHODOLOGY

This study used a structured quantitative survey design targeting urban residents across Malaysia. The data collection involved 10,076 respondents sampled from 46 local authorities across 14 states of Malaysia. These states and local authorities were chosen based on their receipt of government allocations to implement the Safe City Programme (SCP). Respondents were selected using stratified random sampling to ensure representation across gender, age, housing types, and income levels. The stratified random sampling procedure was conducted by dividing the study population according to the 46 participating local authorities across the 14 Malaysian states. Each local authority represented a primary sampling stratum to ensure geographical representation of urban areas implementing the SCP. Within each stratum, proportional allocation was applied based on population size and urban residential density. Additional sub-stratification considered demographic characteristics such as gender, age group, housing typology, and household

income to ensure balanced representation of different social groups. This proportional weighting approach minimised sampling bias and improved the generalisability of the findings across SCP-implemented municipalities in Malaysia.

It is important to note that this study only includes areas and local authorities that received government funding under the SCP within the period 2017 to 2022. As such, urban areas or municipalities not supported by this initiative were excluded from the scope of this research. This ensures that the analysis reflects the direct influence of safe city strategies and implementations as intended by national urban safety policies.

The research instrument consisted of a structured questionnaire divided into three main sections: (1) demographic profile, (2) perceived safety (PS), and (3) CPTED components, which included community engagement. All items were measured using a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. The Perceived Safety (PS) construct consisted of nine items measuring respondents' perceptions of safety within residential environments, safety during daytime and nighttime activities, and feelings of vulnerability when alone at home or outdoors. Composite PS scores were calculated by summing responses across the nine items, resulting in a possible score range of 9 to 45, where higher scores indicate stronger perceptions of safety. Similarly, CPTED dimensions were measured using multiple-item constructs covering territoriality, surveillance, target hardening, maintenance, and community engagement. The use of composite scoring enabled a broader assessment of subjective safety experiences and environmental crime prevention perceptions.

Data was collected between January and June 2023 using both online and field-distributed questionnaires. The ethical approval was acquired from Universiti Teknologi MARA, ensuring confidentiality and voluntary participation. Data reliability was validated using Cronbach's alpha, and it was greater than 0.80 across all constructs, indicating high internal consistency. Descriptive statistics summarised demographic and safety perceptions, while inferential analyses (independent t-tests and ANOVA) identified significant differences in perceived safety across demographic and housing groups. This methodological framework follows established social science research protocols (Creswell & Creswell, 2018; Hair et al., 2019).

ANALYSIS AND DISCUSSION

The demographic profile of the study's 10,076 respondents represents a diverse cross-section of Malaysian urban communities. Gender distribution was nearly equal, with 49.4% male and 50.6% female respondents, allowing for a gender-balanced analysis. Ethnically, the majority were Malay (73.9%), followed by Chinese (10.8%), Indian (6.3%), and others (9.0%), which closely matched the

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national demographic composition. In terms of religious affiliation, the majority of participants identified as Muslim (78.4%), with smaller proportions of Christians (9.4%), Buddhists (6.0%), Hindus (5.8%), and others (0.3%). A significant proportion of respondents were between the ages of 20-29 (34.1%) and 30-39 (31.6%), indicating a young population with the ability to actively engage in community safety initiatives. About 20.7% were in their 40-49 age range, with smaller numbers in the 50-59 (9.9%) age range and 60 or older (3.7%).

Education levels were relatively high, with 69.4% of respondents holding university or college degrees, 28.4% having completed secondary education, and a small minority having only primary education (1.9%) or no formal schooling (0.3%). This suggests that the study participants are generally well-educated and likely to be aware of safety-related issues.

Table 2: Demography Results

NO.	VARIABLE	DEMOGRAPHY	FREQUENCY	PERCENTAGE (%)
1	Gender	Male	4976	49.4
		Female	5100	50.6
2	Race	Malay	7451	73.9
		Chinese	1091	10.8
		Indian	632	6.3
		Others	902	9.0
3	Religion	Islam	7903	78.4
		Christian	952	9.4
		Buddha	607	6.0
		Hindu	582	5.8
		Others	32	0.3
4	Age	20 - 29	3432	34.1
		30 - 39	3186	31.6
		40 - 49	2089	20.7
		50 - 59	994	9.9
		60-an and older	375	3.7
5	Education Level	University/College	6993	69.4
		Tertiary School	2857	28.4
		Secondary School	193	1.9
		Not Applicable	33	0.3
6	Employment Sector	Non-Government Sector	2811	27.9
		Government Sector	3284	32.6
		Business / Own Business	1569	15.6
		Retired	521	5.2
		Not working	1891	18.8
7	Household Income	Less than RM2000	2740	27.2
		RM2001 – RM4000	3177	31.5
		RM4001 – RM6000	2412	23.9
		RM6001 – RM8000	1076	10.7

NO.	VARIABLE	DEMOGRAPHY	FREQUENCY	PERCENTAGE (%)
		RM9001 - RM 10,000	320	3.2
		More than RM10,000	351	3.5
8	Housing Types	Bungalow	1664	16.5
		Semi Detached (Semi-D)	985	9.8
		Cluster House	285	2.8
		Terrace House	4963	49.3
		"Zero Lot Boundary"	99	1.0
		Town House	192	1.9
		Cluster Town House	20	0.2
		Flat/Apartment House	1493	14.8
		Condominium	309	3.1
		Others	65	0.6
TOTAL RESPONDENTS			**10076**	**100**

Source: Author (2024)

In terms of employment, 32.6% of respondents worked in the public sector, 27.9% in the private sector, and 15.6% were self-employed or entrepreneurs. Meanwhile, 18.8% were unemployed, and 5.2% were retirees. Household income varied significantly: 27.2% reported monthly incomes of less than RM2,000, 31.5% earned between RM2,001 and RM4,000, and 23.9% earned between RM4,001 and RM6,000. A smaller group earned between RM6,001 and RM8,000 (10.7%), while a total of 6.7% earned more than RM9,000. Terrace houses were the most popular type of residence, accounting for nearly half (49.3%) of the respondents. Other housing types were detached houses or bungalows (16.5%), semi-detached homes (9.8%), flats or apartments (14.8%), and condominiums (3.1%). The distribution of housing types also reflects income disparities, with higher-income respondents more likely to live in detached or semi-detached houses. Overall, this diverse demographic composition provides a comprehensive foundation for analysing perceptions of urban safety and the impact of the Safe City Programme across different segments of the population.

Perception of Safety

The Perception of Safety construct was analysed to determine how safe respondents felt in their residential environments, particularly at different times of day and under various conditions. The results indicated that a significant majority of respondents reported feeling either "safe" or "very safe" at home or while walking in their neighbourhood during the day and night. For instance, 72.2% of respondents felt safe going out during the day, and 62.0% felt safe going out at night. This suggests that, overall, the Safe City Programme has been effective in fostering a sense of safety among community members.

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Table 3: Respondents' Perception of Safety Level

NO.	PERCEPTION OF SAFETY (PS)	SCALE	FREQUENCY	PERCENTAGE (%)
1	Level of safety in a residential area	Very unsafe	119	1.2
		Unsafe	212	2.1
		Less safe	1327	13.2
		Safe	**6681**	**66.3**
		Very safe	1737	17.2
2	Level of safety while inside the house	Very unsafe	58	0.6
		Unsafe	159	1.6
		Less safe	1148	11.4
		Safe	**7032**	**69.8**
		Very safe	1679	16.7
3	Level of safety while outside from house	Very unsafe	52	0.5
		Unsafe	164	1.6
		Less safe	1153	11.4
		Safe	**7276**	**72.2**
		Very safe	1431	14.2
4	Frequency of going out for night-time activities within a week	Every day	1646	16.3
		Once or twice a week	**3487**	**34.6**
		3 to 4 times a week	2526	25.1
		5 to 6 times a week	1859	18.4
		Never go out during night-time	558	5.5
5	Level of safety when outside at night-time	Very unsafe	274	2.7
		Unsafe	448	4.4
		Less safe	2161	21.4
		Safe	**6265**	**62.0**
		Very safe	941	9.3
6	Level of safety when home alone at night-time	Very unsafe	201	2.0
		Unsafe	365	3.6
		Less safe	2314	23.0
		Safe	**6397**	**63.5**
		Very safe	799	7.9
7	Frequency of going out for day-time activities within a week	**Every day**	**5037**	**50.0**
		Once or twice a week	555	5.5
		3 to 4 times a week	1166	11.6

		5 to 6 times a week	3228	32
		Never go out during day-time	90	0.9
8	Level of safety when outside during the day-time	Very unsafe	29	0.3
		Unsafe	73	0.7
		Less safe	821	8.1
		Safe	**7579**	**75.2**
		Very safe	1574	15.6
9	Level of safety when home alone the day-time	Very unsafe	29	0.3
		Unsafe	182	1.8
		Less safe	900	8.9
		Safe	**7383**	**73.3**
		Very safe	1582	15.7

Majority of respondents were satisfied with their safety in residential areas. Approximately 83.5% of respondents reported feeling either "safe" (66.3%) or "very safe" (17.2%) in their neighbourhoods. Only a small proportion (3.3%) felt "unsafe" or "very unsafe." This indicates a high level of confidence in local safety infrastructure and community vigilance. Respondents felt even more secure while they were inside their houses. A total of 86.5% reported feeling "safe" and "very safe" in their own residences. This reflects the success of home-level safety measures, as well as neighbourhood dynamics such as familiarity with neighbours and effective territorial reinforcement.

In terms of behaviour, 34.6% of respondents reported they went out at night once or twice a week, while 43.5% said they went out more frequently (three or more times per week). This behavioural data supports the perception results: a large portion of the population not only feels safe but is also active in their neighbourhoods at night. Even though there is a lot of activity at night, some people are still worried about their safety. While 71.3% of respondents felt "safe" (62.0%) or "very safe" (9.3%) at night, about 28.5% expressed reduced confidence, with 2.7% feeling "very unsafe," 4.4% "unsafe," and 21.4% "less safe." This indicates an opportunity for improvement, especially in lighting and patrol visibility.

In contrast, daylight behaviours reflected high levels of mobility and confidence. A full 50% of respondents left their homes every day, and another 32% did so 5–6 times per week. Less than 1% reported that they never left their home during the day. An overwhelming 90.8% of respondents felt "safe" (75.2%) or "very safe" (15.6%) when going out during daylight hours. Only 1% reported feeling "unsafe" or "very unsafe." These findings indicate that daytime safety is strongly perceived, which confirms the Safe City Programme's effectiveness in improving public space security. Lastly, 89% of respondents said they felt "safe" (73.3%) or "very safe" (15.7%) while they were by themselves at home during

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the day. The minimal percentage reporting feelings of unsafety (2.1%) reflects confidence in both community safety and home-level security during off-peak crime hours.

All of these findings point to a community that generally feels safe in its daily environment. The highest levels of perceived safety were recorded at home and during the day, particularly reflecting the success of built environment factors and potentially the Safe City Programme's influence in strengthening community infrastructure. Although still positive, nighttime safety perceptions were more variable, From the perspective of Rational Choice Theory, these findings suggest that environmental safety measures influence offender decision-making by increasing the perceived risks associated with criminal behaviour. Improved street lighting, visible surveillance, and active neighbourhood presence may elevate the likelihood of detection, thereby reducing the attractiveness of criminal opportunities. This supports the CPTED proposition that environmental design can shape behavioural choices by altering the cost-benefit calculations of potential offenders. Areas with weaker visibility or reduced nighttime activity may conversely provide opportunities perceived as lower risk, contributing to residents' lower feelings of safety after dark. Suggesting that future Safe City Programme interventions might focus on improving evening community policing, lighting, and visibility. A key area of interest was the relationship between PS and demographic variables. Inferential analysis revealed statistically significant differences in perceived safety based on gender and type of housing.

Table 4: Mean Value for Perceived Safety Based on Gender

	Gender	N	Mean	Std. Deviation (SD)
PERCEPTION OF SAFETY (PS)	Male	4976	**27.66**	3.59
	Female	5100	**27.23**	3.43

Table 4 shows that men reported a higher composite Perceived Safety (PS) score (M = 27.66, SD = 3.59) than women (M = 27.23, SD = 3.43). The PS score represents the summed responses across nine perceived safety items measured on a five-point Likert scale, with higher scores indicating stronger perceptions of safety. The gender difference was statistically significant ($p < 0.001$), suggesting that women continue to experience higher levels of insecurity and vulnerability within urban environments. This finding is consistent with existing literature, which indicates that women often perceive greater exposure to crime risk due to social and environmental factors.

Table 5: Mean Value for Perceived Safety Based on Housing Types

Housing Types	N	Mean Value	Std. Deviation
Bungalow	**1664**	**28.5132**	**3.84890**
Semi Detached (Semi-D)	985	28.1401	3.56910
Cluster House	285	26.3684	3.76619
Terrace House	4963	27.2688	3.14270
"Zero Lot Boundary"	99	27.4949	3.62073
Town House	192	27.6354	2.85466
Flat/Apartment House	1493	26.4903	3.89327
Condominium	309	28.2330	3.46467
Others	65	25.6769	4.05859

Similarly, the type of housing had a considerable impact on perceived safety. Bungalows have the highest mean PS (M = 28.51), while those living in cluster houses and flats reported lower levels of perceived safety. This variation may be attributed to disparities in environmental control, private space, and security infrastructure, which are generally more prevalent in high-income, low-density housing. Wealthier individuals feel safer living in homes with greater security features (e.g., alarm systems, gated entry, surveillance cameras). These findings underline the importance of environmental and socioeconomic contexts in shaping individual experiences of safety. The Safe City Programme interventions may therefore need to be tailored according to neighbourhood typologies to maximize impact.

Fear of Crime (FOC)

Fear of crime was examined through three dimensions: physical deterioration, social disorder, and indirect victimization. Across all 13 items used to assess FOC, a substantial proportion of respondents expressed worry or anxiety. The most common triggers included seeing vandalism, walking near overgrown vegetation or abandoned housing, and hearing stories of crime from the media or acquaintances. Gender differences were once again prominent. Women had considerably higher fear of crime (M = 53.92, SD = 6.40) than men (M = 51.90, SD = 7.27), which was both statistically and practically significant ($p < 0.001$). This is consistent with other studies (e.g., Callanan & Teasdale, 2009; Gilchrist et al., 1998), which explain women's increased anxiety as a result of their perceived vulnerability and socially constructed gender roles regarding personal safety.

Interestingly, residents of bungalows reported a stronger sense of safety and a greater fear of crime (M = 55.67) than those in other housing types, including condominiums (M = 48.58). This contradiction can be explained by the concept of asset-based anxiety: higher-income individuals with more goods may feel more vulnerable to targeted theft or burglary. Moreover, their homes are often more isolated, increasing the perception of exposure to criminal activity.

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The fact that some residents simultaneously feel "safe" yet remain "fearful" highlights the complex psychological nature of urban security. It underscores the necessity of Safe City Programme interventions that address both objective safety (e.g., crime rates, infrastructure) and subjective perceptions (e.g., fear, vulnerability).

Table 6: Mean Value for Fear of Crime (FOC) Based on Housing Types

Housing Types	N	Mean Value	Std. Deviation
Bungalow	**1664**	**55.6689**	**7.53826**
Semi Detached (Semi-D)	985	54.4721	6.54980
Cluster House	285	51.3930	5.96763
Terrace House	4963	52.6278	6.47772
"Zero Lot Boundary"	99	51.8586	6.75823
Town House	192	53.5521	5.63064
Cluster Town House	20	50.5000	6.24500
Flat/Apartment House	1493	51.0261	6.68789
Condominium	309	48.5825	7.30130
Others	65	53.4308	9.02076

Effectiveness of CPTED Strategies

The Safe City Programme adopts the CPTED (Crime Prevention Through Environmental Design) framework, which consists of five core principles: territoriality, natural surveillance, target hardening, maintenance, and community engagement. The study examined how successfully these principles were perceived and practiced within residential areas.

Table 7: Comparison of CPTED Elements in Residential Areas

No.	CPTED Elements in Residential Areas	Score	Mean Value	Std. Deviation	Rank
1	Territoriality	358310	35.56	4.826	**1**
2	Maintenance	327389	32.49	4.240	**2**
3	Surveillance (Natural Surveillance)	314172	31.18	4.614	**3**
4	Target Hardening	279936	27.78	7.189	**4**
5	Community Management	152633	15.15	3.289	**5**

The territoriality recorded the highest composite CPTED score (M = 35.56), followed by maintenance (M = 32.49) and natural surveillance (M = 31.18), suggesting that residents were more actively engaged in environmental ownership and upkeep practices than in collective community management initiatives. These behaviours align with territorial reinforcement strategies that discourage criminal activity by signalling active occupancy and informal control.

This finding also reinforces the assumptions of Rational Choice Theory, which posits that offenders make calculated decisions based on perceived risks and rewards. Strong territoriality cues such as maintained front yards, resident monitoring, and visible occupancy increase the perceived effort and likelihood of apprehension for offenders. Consequently, criminal behaviour becomes less attractive because the environmental conditions reduce opportunities for anonymous or low-risk offending. The integration of CPTED principles with Rational Choice Theory therefore provides a stronger behavioural explanation for how environmental design contributes to crime deterrence within residential communities.

Maintenance practices were also robust. Most respondents regularly repaired damaged windows and doors, ensured outdoor lighting was functional, and maintained their gardens. These actions contribute to a well-kept environment, which, according to CPTED principles, deters crime by projecting order and reducing opportunities for misconduct.

Natural surveillance was another key element. Residents expressed awareness of unfamiliar individuals in their area and were likely to monitor street activity. However, some limitations were noted, especially in multi-level dwellings where visual surveillance is less effective. In such cases, infrastructural enhancements such as strategic lighting, open fencing, and window placements could improve visibility and deter criminal behaviour.

The lowest-scoring component was community engagement and awareness, indicating a gap in collaborative crime prevention efforts. This point to an opportunity for the Safe City Programme to strengthen community-based initiatives, such as neighbourhood watch programs, community policing forums, and awareness campaigns that foster collective responsibility.

This finding demonstrates the Safe City Programme's general effectiveness, with high resident satisfaction regarding safety, especially in higher-income and well-maintained housing environments. Demographic factors and housing typologies significantly influence safety perception and fear of crime. Implementing CPTED principles, such as clear territorial boundaries and proper maintenance, proves vital in fostering safer urban communities.

CONCLUSION

This study demonstrates the general effectiveness of the Safe City Programme in enhancing urban safety, as reflected in the high levels of resident satisfaction and positive perceptions of safety across various residential environments. Notably, individuals living in higher-income neighbourhoods and well-maintained housing areas reported greater feelings of safety, underscoring the role of socioeconomic status and environmental quality in shaping security experiences. These findings align with broader urban safety literature, which suggests that

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investment in infrastructure and residential upkeep contributes directly to perceived and actual crime reduction. The data also reveal that demographic factors such as gender, age, and household income as well as housing typologies like bungalows, flats, condominiums, and others, have a significant influence on both perception of safety and fear of crime. For instance, while women expressed a higher fear of crime, residents of detached houses, despite feeling safer overall, exhibited elevated concern due to greater asset exposure. These nuanced patterns suggest that safety is not a uniform experience but rather contextual and shaped by personal circumstances and living environments.

Crucially, the study highlights the value of incorporating Crime Prevention Through Environmental Design (CPTED) principles into residential planning. Territoriality, natural surveillance, and routine maintenance were all substantially linked to higher levels of safety perceptions. High scores in territoriality reflect a sense of ownership and stewardship among residents, which deters criminal activity by creating environments that are clearly defended and monitored. Likewise, regular maintenance of public and private spaces projects order and discourages vandalism and neglect, which are commonly associated with criminal behaviour. However, the lower ratings for community engagement and collective management indicate a need for further development. While physical and infrastructural interventions are essential, fostering social cohesion and resident participation in safety initiatives such as neighbourhood watch groups or community patrols could enhance the Safe City Programme's impact. Such efforts would empower residents not only as observers but as active stakeholders in the collaborator of safety.

The findings further validate the integration of Rational Choice Theory within the SCP and CPTED framework. Environmental interventions such as surveillance, territorial reinforcement, and maintenance not only improve residents' perceptions of safety but also influence offender behaviour by increasing perceived risks and reducing criminal opportunities. This demonstrates that urban safety strategies are most effective when physical design interventions are understood not merely as infrastructural improvements, but as mechanisms capable of shaping behavioural decision-making within urban environments.

In conclusion, the Safe City Programme has made significant progress in addressing urban safety concerns in Malaysia, particularly through environmental and structural strategies. Moving forward, a holistic approach that integrates physical design, social participation, and targeted policy interventions will be essential for building resilient and secure communities. Urban authorities may improve the Safe City Programme's long-term viability and sustainability by customising safety strategies to population demands and housing situations, as well as strengthening the social fabric through community-driven initiatives.

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INTEGRATING ISLAMIC REASONING INTO CONTEMPORARY ECONOMIC DEVELOPMENT AND PLANNING

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Abstract

While there is growing research focusing on the higher objectives (Maqasid) and ethical underpinnings of Islamic economics, the methodological significance of reasoning within the field remains underexplored. This study examines the assimilation of classical Islamic reasoning methods into contemporary planning development within the framework of Islamic economic research methodology. It explores the classification and epistemological basis to emphasize the importance of classical Islamic reasoning methods in bridging Shariah-based ethical principles with contemporary Islamic economic research framework. The qualitative review uses exploratory methods, juristic opinions (fatwas), and conceptual models through thematic approach and hermeneutic analysis in an integrated study framework. Drawing upon existing empirical studies on Zakat reforms and regulation of digital Islamic finance and cryptocurrencies, this study illustrates the practical usage of Islamic-based reasoning methods, revealing how various reasoning approaches, including Maqasid-based reasoning, collectively ensure Shariah compliance and ethical orientation in contemporary scenarios. Findings reveal a fragmented yet evolving reasoning landscape, where researchers inconsistently utilize deductive reasoning (from Islamic texts), empirical induction, jurisprudential comparison, and reasoning based on higher purposes, lacking clarity in methodological justifications. Outlining the importance of methodological reflexivity and the Maqasidi approach in contemporary planning framework, this study concludes that structured, transparent, and ethically anchored integrated reasoning approach, is essential for advancing Islamic economic research. This integrated approach advances ethics based, applied, and context-relevant development planning ensuring equitable resource distribution and financial inclusion initiatives for social welfare.

Keywords: Mantiq, Reasoning, Research Methodology, Planning and Development, Islamic Economics, Maqasid

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INTRODUCTION

In Islamic sciences, reasoning (*mantiq*) as articulated by scholars such as Ahmad Damanhuri (2006), Al-Shanqiti (2007), Murtadha Mutahhari (2011), and H. Syukriadi Sambas (2003), comprises three main components: *tasawwur* (conception), *tasdiq* (affirmation), and *al-istidlal* (inference). These methods form a complete cycle: *Tasawwur* (conception) characterizes the objects and concepts; *Tasdiq* (affirmation) provides methods for determining the truth or falsity of the notions; and *al-istidlal* (inference) encompasses verification and the derivation of evidence (*dalil*) through direct means (e.g., through *taqabal* (Opposition) and '*akas* (Exchange)) or indirect postulation, such as *qiyas* (deductive), *istiqra'* (inductive), and *tamthil* (analogy) (Ahmad Damanhuri, 2006; Al-Shanqiti, 2007; Murtadha Mutahhari, 2011). These methods indicate human mind's ability to think beyond the five senses. According to Islamic *tasawwur* and epistemology, Muslims must believe in both apparent and unseen phenomena. Not everything can be explained by mathematical calculation. However, economics relies on mathematical calculation as proof. The question is, in researching Islamic economics, which reasoning methods are more holistic that can understand both apparent and unseen aspects?

In addition, the types of argumentations are also discussed in the science of *mantiq*. According to the science of *mantiq*, arguments can be divided to two; *Naqli* and *Aqli*. *Naqli* arguments are based on al-Qur'an and al-Sunnah (Ahmad Damanhuri, 2006). While *Aqli* arguments are based on human thought. This is a clear division. It distinguishes between arguments based on revelation and arguments based on human mind and senses. According to Al-Quwasini, n.d.), under *aqli* arguments there are five sources which are *burhan* (Truth), *jadal* (Debate), *khitabah* (Lecture), *sha'r* (Feeling) and *sufastah* (Imaginative) arguments (al-Shanqiti, 2007). From these discussions, the science of *mantiq* can be seen in the context of Islamic economics research methodology to identify *mantiq* reasoning method for application in Islamic economics research methodology.

Although there is increasing literature discussing the higher objectives (Maqasid) of Islamic law and ethical underpinnings of Islamic economics, amid this discussion, there is a critical absence of literature analysing the forms of reasoning used by researchers in Islamic economics (Furqani & Haneef, 2012). In current scholarship, the methodological role of reasoning, whether deductive (from texts), inductive (from observation), analogical (*qiyas*), or purposive (Maqasid-based), has yet to be fully articulated (Latif et al., 2024; Rafikov & Akhmetova, 2020). This methodological gap is troubling because Islamic economics requires interplay between revealed knowledge and rational inquiry, a situation we would not wish to obfuscate. Therefore, understanding the reasoning types used in Islamic economic research, their foundations, methods,

and implications is crucial for advancing the discipline's maturity, consistency, and practical application. This study addresses the identified research gap through these objectives:

Firstly, to discern reasoning employed in Islamic economic research. It aims to classify and analyze reasoning types in the underpinnings of such research, both theoretical and empirical.

Secondly, to investigate how scholars use reasoning to integrate Islamic principles with economic theory. The paper uncovers how reasoning links Islamic normative values with analytical frameworks, producing practical and ethical hybrid models.

Thirdly, to explore methodological implications for Islamic economics. This evaluates reasoning approaches' strengths, weaknesses, and their impact on rigor, validity, and innovation potential in Islamic economics research.

LITERATURE REVIEW

In recent times, Islamic economics has shown a considerable growth in the theoretical foundations, institutional framework, and ethics of Islamic economics (Furqani & Haneef, 2012). However, the methodological significance of reasoning in this field remains understudied.

The Foundations of Islamic Economic Methodology

The methodology used in Islamic economic research are based on the epistemology of Islam which recognizes the dual-source model of *naqli* (revealed) and *aqli* (rational) knowledge (Ibrahim et al., 2017). This epistemology is essential for understanding economic concepts from an Islamic Perspective. Revealed sources like the Qur'an and Sunnah serve as highest reference points in Islamic sciences, including Islamic economics. This reference provides ethical standards on justice (*adl*), trust (*amanah*), interest prohibition (*riba*), uncertainty (*gharar*) and economics behaviour. They mainly declare normative principles rather than detailed economic specifications, such as those governing Zakat distribution and other Islamic finance regulations. The intellect (*aql*) complements revelation by enabling contextual understanding for changing socio-economic conditions (Malik, 2025). In classical Islamic scholarship, *naql* and *aql* were mutually reinforcing. Ibn Rushd (d. 1198) asserted that *aql* is crucial for understanding divine revelation (Ahmad Damanhuri, 2006; Habti, 2011). The economic implications of this dual approach are numerous. When we extract norms from *naqli* sources, we are using *aqli* tools to create economic theory and analysis. **Figure 1** depicts this interplay, showing revealed knowledge as the foundational source providing ethical principles, which are then contextualized and applied through reason (*'aql*), which is central to Islamic economic

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methodology, illustrating how reasoning integrates Islamic values with scientific inquiry to attain the higher objectives.

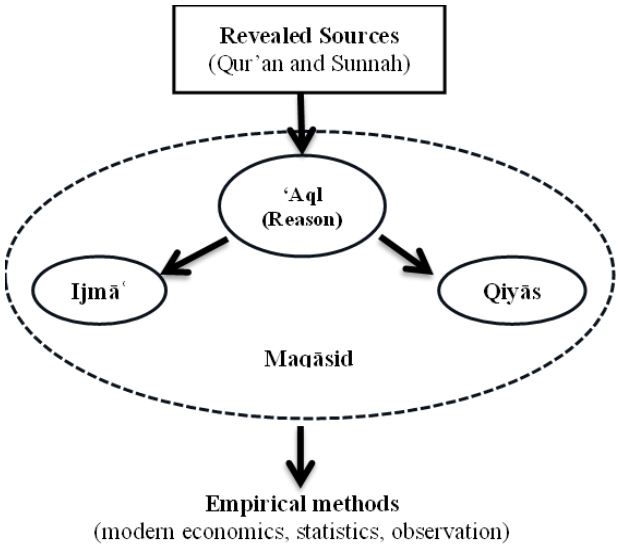


Figure 1: Interplay of Revelation (*naql*) and Reasoning (*aql*) in Islamic Economic Methodology

The Shariah aims at the welfare of human beings. Islamic economics shares this with other disciplines in the Islamic tradition. It aims at constructing a just economic order based on the Shariah moral-legal framework. To understand the methodology of Islamic economics requires knowledge of *fiqh* (jurisprudence) and its basic principles. Fiqh offers practical legal guidance, particularly concerning transactions and property rights (*muamlat*), a concept widely recognized by modern scholars. To implement Islamic law in economic matters, qiyas (analogical reasoning), ijma (scholarly consensus), *isihtsan* (juristic preference), and Maqasid (higher objectives of Islamic law) must be employed (Quraishi-Landes & Kamali, 2000; Ghazali et al., 2021). These tools act as sophisticated legal devices that have epistemological potential in complex modern contexts. The classical legacy of Islamic legal theory is an important part of the resource base, which is an existential base for Islamic rationality that is a necessary part of an integrated Islamic worldview.

Reasoning in Contemporary Islamic Economic Literature

Modern Islamic economic scholarship has incorporated classical reasoning in differing forms in which contributors approach reasoning from normative to

positive styles. Notable contributors to the literature such as Chapra (2000), Siddiqi (2011), and Asutay (2012) show achievements and gaps in methodological reasoning. Muhammad Umer Chapra gives a moral framework of Islam for economics. He integrates ethical objectives with policy recommendations and emphasizes Maqasid, though his work often presumes rather than explains cognitive processes linking values with models (Chapra, 2000). M. N. Siddiqi advocates for value-oriented social science rooted in Islamic ethics, noting Islamic principles align with Western empirical economics while critiquing mechanical replication of western methodologies. His methodological approach remains vague (Siddiqi, 2011). Mehmet Asutay (2012) presents an Islamic moral economy perspective as an alternative to neoliberal capitalism, using Maqasid-based reasoning to critique Islamic finance's commercialization. While these scholars have enriched Islamic economic thought, their use of different reasoning forms lacks clarity, with insufficient analysis of how reasoning forms are systematically used in research (Hantrais, 2014).

RESEARCH METHODOLOGY

This study uses a qualitative-exploratory approach based on an integrated reasoning framework which systematically relates its classical Islamic reasoning methods with its practical applications in the field of contemporary Islamic economic research and policy applications. As Islamic economics is of a normative nature relying on divine revelation and rational reasoning, qualitative methods can effectively unpack the epistemological orientations informing the preference for divine and human sources in this field (Addas, 2008; Choudhury, 2011). The data sources selected for this study were aimed to ensure a wider coverage of both classic and contemporary scholarly works. These were retrieved from referred Islamic jurisprudential texts including classical and contemporary fiqh manuals, juristic opinions (fatwas) from specific fatwa councils or bodies, reliable databases such as Scopus, Web of Sciences, and conceptual models from leading Islamic institutions. The inclusion criteria focused on sources explicitly discussing reasoning methods or their application in Islamic economic development and planning, while exclusion criteria removed purely descriptive works without methodological reflection. The corpus comprised of diverse selection ensured a profound understanding of reasoning patterns across various sources. The analytical process involved several phases including initial reading and identification of explicit statements or implicit arguments related to reasoning methods, their justifications, and applications. For theme generation and checking whether the themes generated are accurately reflected, the data examined initially was classified into potential thematic categories such as deductive, inductive, analogical, and Maqasid-based reasonings. For developing clear definitions and

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names for each theme, often drawing from the Islamic intellectual tradition such as *qiyas* for analogical reasoning, a hermeneutic interpretation involving a deeper and iterative analysis of the identified themes and their interrelationships was performed. Considering the gaps in the literature that studies the methodology of reasoning in the realm of Islamic economics (Hassan, 2018), this study rather finds the patterns, not reiterating the established theories. The hermeneutic interpretation helped to explore how different reasoning methods interact and to know their epistemological underpinnings and their implications for Islamic economic methodology, especially concerning the intersections between revealed texts and empirical sources.

The integrated framework involved in this study is operationalized through illustrative case studies, selected for their contemporary relevance, methodological complexity, and their ability to demonstrate the application of diverse Islamic reasoning methods. The first illustrative case on Zakat distribution reforms in Bangladesh was selected because it represents a specific area where traditional Islamic injunctions intersect with modern institutional challenges, requiring a blend of inductive analysis of institutional inefficiency, deductive relationship with Qur'anic principles, analogical adaption to modern systems, and Maqasid to attain social wellbeing. This case presents the empirical assimilation of various reasoning types in addressing socio-economic issues. The second case on the regulation of digital Islamic finance and cryptocurrencies was selected because of its emergent nature and the methodological dilemmas it poses. This field needs a robust analogical reasoning to new instruments. It demands a rigorous deductive Shariah compliance, inductive market evaluation, and Maqasid-based risk mitigation and inclusion to develop an ideal context and to emphasize the intricacy and necessity of using an integrated reasoning method while addressing financial innovations. This method ensures that Islamic economic models and policies are Shariah-compliant, empirically verifiable, contextually relevant and ethically oriented, with an iterative refining process that responds to contemporary socio-economic challenges.

FINDINGS

This section of the paper summarizes our findings based on a textual analysis of the literature on Islamic economics. It emphasizes the reasoning approaches used, their impact on theory and model construction, their epistemological foundations, and the broader implications for methodology. The findings show an advanced and multi-layered use of various reasoning modes that combine divine guidance with logical evaluation to create ethical and sustainable economic alternatives.

Classification of Reasoning in Islamic Economic Research

The research identifies and classifies four main types of reasoning used in Islamic economic studies. Each with specific epistemic and methodological importance are summarized in **Table 1**. This classification does not occur solely in Islamic economic studies. Also, it appears in Islamic sciences and in a more general sense in other modern practices. Each type helps to align Islamic principles with the changing dynamics of contemporary economic scenarios.

Table 1: Typology of Reasoning in Islamic Finance Research Methodology

Reasoning Type	Narrative	Example
Deductive Reasoning	From general Islamic principles to specific rulings (Chapra, 1992; Rafique, 2025)	Deriving prohibition of *riba* from Qur'an and Sunnah
Inductive Reasoning	From empirical patterns to general ethical-economic principles (Khan, 2017).	Inferring Maqasid-based outcomes from Zakat distribution(Obaidullah & Khan, 2008).
Analogical Reasoning (*qiyas*)	Applying known rulings to new issues based on effective cause (*illah*) (El-Gamal, 2006).	Applying Zakat rules to digital assets
Maqasid-Based Reasoning	Reasoning guided by overarching objectives of Shariah (Auda, 2008).	Promoting financial inclusion under the *maqṣad* of *ḥifẓ al-maal* (Asutay, 2012).

In Islamic economics, deductive reasoning infers economic norms from primary Islamic sources i.e. Qur'an and Sunnah through logical and theocentric argumentations. This approach was frequently utilized by the early Muslim economists. It is deemed to be the most reliable approach by most scholars (Chapra, 1992; Rafique, 2025). Based on the Islamic injunctions, detailed principles are derived such as prohibition of *riba* (usury), justice (*adl*) in trading, Zakat (almsgiving) and many more. Inductive reasoning is the development of a useful analytical and empirical description of economic phenomena. Islamic economists use experiences from Muslim communities to develop theories and models, addressing issues like poverty and inequality (Obaidullah & Khan, 2008). Reasoning by analogy (*qiyas*) is a jurisprudential process whereby an established ruling from a clear case (*aṣl*) applies to a new case (*far'*) that shares similar attributes. Islamic economists apply this methodology for modern financial instruments such as *murabaḥah* (cost-plus financing), *ijarah* (leasing), or *sukuk* (Islamic bonds), and reason by analogy to classical contracts like *bai'* (sale) or *ijarah* (leasing) (El-Gamal, 2006). While comparing these types,

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reasoning based on Maqasid from the Islamic law perspective is holistically more superior and teleological, focusing on achieving higher objectives of Islamic law (Auda, 2008). This rationale underpins conversations on welfare, justice, and financial inclusion.

Illustrations from Literature and Practice

A thematic evaluation reveals that there are differing approaches for reasoning in Islamic economics. M. Umer Chapra (2000) employs deductive reasoning to build an alternative paradigm based on the foundational texts of Islam and to reach ethical decisions. Monzer Kahf (2004) uses inductive reasoning to analyse the poverty data and suggests Zakat reform based on observed need. Islamic scholars apply analogical reasoning in classical juristic ideas to evaluate contemporary economic trends like derivatives or cryptocurrencies. The Islamic moral economy model constructed by Mehmet Asutay (2012) employs Maqasid-based reasoning to build an objective-based framework that centres on justice, well-being, and spirituality. These illustrations reflect how Islamic economics has transformed methodologically away from jurisprudential imitation.

Case Studies: Operationalization of Reasoning Methods

The case studies below demonstrate how different types of reasoning methods are applied in real-life or specific cases. Examining these examples show that reasoning frameworks can be operationalized and examined in the modern context. Adopting reasoning techniques in varied contexts highlights the strategies required, as seen by these examples.

Illustrative Case Study 1: Analysis of Reasoning-based Empirical Data on* Zakat *Collection and Distribution in Bangladesh

The survey data on the efficiency of Zakat collection and distribution in Bangladesh by Rahman (2024) reveals institutional trust, payer engagement, and oversight mechanisms. As detailed in **Table 2**, the trustworthiness of Zakat institutions as the strongest reason for choosing these institutions, accounting for 43.48% of responses. Other reasons include familiarity (26.09%), transparency (14.49%), and hassle-free payment system (10.14%). As evident in the **Table 2**, this distribution underscores that the driving forces behind the mobilization of Zakat through private organizations, which occupy a primary institutional position, are relational and credibility factors. When it came to verification behaviour from Zakat payer on the distribution of fund accuracy, we see a mixed behaviour, whereby 43.1% inquire about the accuracy of fund disbursement and 56.9% don't. This shows a major oversight gap that can threaten transparency and accountability, which is essential to ensure Zakat reaches the right people.

Table 2: Motivation for Paying Zakat to the Institution

Criteria	Frequency	Percent
Trust	60	43.48
Nearness	6	4.35
Familiarity	36	26.09
Transparency	20	14.49
Easy system	14	10.14
Other	2	1.45
Total	138	100.00

Data Source: (Rahman, 2024)

Through inductive logic, following observations are made by assimilating empirical survey data on payer behaviour and institutional practices for a better understanding of the current operational dynamics. This also helps in identifying the areas of improvement. The principles of classical jurisprudential jurisprudence can be adapted to institutional contexts through analogical reasoning. It specifically focuses on the mechanisms of accountability and digital payment gateways. While as Maqasid-based reasoning makes it possible to evaluate the normative status of such practices and their coordination to achieve higher objectives of Islamic law, like justice, welfare, and protection of wealth. The integrated reasoning framework, especially the Maqasid-based reasoning approach applied to inductive findings on limited payer verification, indicates that the institutional arrangements should be strengthened with better transparency and participatory oversight to make practices more Maqasid-oriented.

This data indicates that adaptive Zakat management policies should be developed, which can balance community trust and convenience with accountability and ethics. Using a modern planning framework of integrated reasoning to combine empirical insights with normative principles can enhance the efficiency and social outcome of institutional Zakat in such cases.

Case Study 2: Regulatory Perspectives on Digital Islamic Finance (Cryptocurrencies)

To demonstrate the operationalization of reasoning methods, this case provides an illustrative analysis of survey data on regulatory perspectives on cryptocurrencies in Islamic finance by Naz and Nazir (2024) indicates diverse views of Shariah scholars. **Table 3** presents divers views among Shariah scholars regarding cryptocurrencies. Notably, 50% advocate for centralization as a necessity for Shariah compliance, believing a central authority is important for

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public good and fraud prevention. They believe that having a central authority is necessary to serve the public good and avoid fraud. In contrast, 42% suggest that public acceptability is more important and cryptocurrencies should function without being controlled or regulated by any authority in the event of legal problems. This division demonstrates the application of analogy as a reasoning tool while adapting classical monetary principles to decentralized digital currency.

Table 3: Regulatory Perspectives on Cryptocurrencies

S.No	Important issue of cryptocurrency	Shariah Scholars' Response	
		Response Type	%
1	Centralization is necessary for a currency in Shariah	Yes	50
		No	42
		NR	8
3	A money must be good "store of value"	Yes	38
		No	29
		NR	33
5	Cryptocurrency involves *maysir*	Yes	37
		No	50
		NR	13
6	Cryptocurrency jeopardizes Maqasid *al*-Shariah	Yes	17
		No	47
		NR	37
7	"Vulnerability to hacking attacks" disqualifies cryptocurrency in Shariah	Yes	17
		No	58
		NR	25
8	Identity of currency's creator is important in Shariah	Yes	17
		No	83
		NR	0
9	Cryptocurrency is impermissible because of promoting "illegal activities"	Yes	0
		No	83
		NR	17

Data Source: (Naz and Nazir, 2024)

Regarding the acceptability of currency, as depicted in **Table 3**, 38% accept limited-use currencies if agreed mutually while 29% consider its universal acceptability. 38% support money as a store of value to deter oppression compared to just 29% who think exchange functions suffice. These exemplify the inductive reasoning from observation. Approximately half of the respondents permit investment in cryptocurrencies for speculative purposes under the rules of *bai al-sarf*. One-third oppose permission because they argue that a cryptocurrency does not fully align with attributes of money as highlighted in Shariah perspective. On inherent *maysir*, 37% see volatility as problematic, while 50% attribute *maysir* to usage rather than the currency. This shows that Maqasid-based reasoning counterbalances to ethical demands and market realities. A mere 17% percent respondents asserted that cryptocurrencies endanger Maqasid al-Shariah but 47% opted for lesser volatile currencies. When it comes to hacking risks, 17% of investors view them as disqualifying. However, 58% make an analogy with traditional asset risks. It demonstrates deductive and inductive reasoning. According to most scholars (83%), the identity of the creator is not significant for Shariah compliance. On the other hand, approximately 17% of scholars opined that trustworthiness and accountability are important in this context. No one thinks a cryptocurrency is impermissible just because they promote illegal activity; 83% state that it should be neutral as to currency. Moreover, 71% accepting regulated digital currencies as Sharia-compliant and 21% concerned about the preservation of wealth. This reveals the Maqasid-based openness to innovation with ethical safeguards.

The findings show that the regulatory stance is pluralistic. In other words, it is formed from inductive expertise from the market, deductive adherence from sharia law, analogical adaptations from technology and Maqasid-based normative reasoning for justice, welfare and risk mitigation. The difference of opinions calls for a relevant Shariah-compliant regulatory framework that is contextual, adaptive, and strikes a balance between the ethical imperative and innovation. This framework is crucial for effective development governance, particularly in areas of risk management, transparency and public trust. This case illustrates an example of the methodological dilemma in Islamic finance regulation. The need for integrated reasoning involving observation, text, analogy, and purposive Maqasid considerations, is essential for a coherent policy response to issues in digital finance.

DISCUSSION

This research examines the varied and dynamic nature of reasoning in Islamic economics research. It draws relevant insights and engages with larger conversations relating to research methodologies and current socio-economic

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situation. For methodological reflexivity and the application of a Maqasid-based reasoning framework are important in this context.

Reasoning in Theory and Model Making

The paper outlines a framework on how a reasoning types can create models of Islamic economics. In Islamic banking, principles are established through deductive and analogical reasoning from the Qur'an. The prohibition of interest (*riba*) resulted in the emergence of profit-loss sharing agreements such as *muḍarabah* and *musharakah*. The variant of financing *murabaḥah* is criticized for imitating the debt structure of the conventional system. Inductive and Maqasid reasoning that influences Zakat groups are analysed by scholars to understand economic disparities and propose reforms for social justice. Maqasid rationalizes structural shifts like centralizing Zakat collection. In profit-loss sharing schemes, deductive reasoning affirms that the risk is shared in an ethical manner. Inductive reasoning explains implementation difficulties via legal and institutional blockades.

Despite these developments, challenges remain to consistency, coherence, and contextualisation. It is due to inconsistency in the application of reasoning frameworks. Despite the ethical emphasis on equity and risk-sharing, debt-based instruments are preferred in Islamic banking. This reflects an inconsistency between expected and real. Additionally, the use of different types of reasoning is sometimes made without methodological coherence. Advancements in economic arguments are made with deductive Shariah reasoning. Policy proposals, however, rely on inductive logic from social sciences. These two elements are not blended. Reasoning allows for flexibility, but some models remain too uncontextualized for today's realities. Thus, there is a necessity to strengthen Maqasid-orientated reasoning, so that the model is not only compliant but also responsive to contemporary issues such as digital transformation, climate adaptation and economic inequality.

Epistemological Commentators

The reasoning of Islamic economics has both *naqli* and *aqli* foundations which is the second aspect. Normative scriptural sources offer prohibitions and ethics but rarely directly solve complex economic issues. Islamic economists must bridge scripture for contemporary needs. The Fiqh-based reasoning retains the authority of Scriptures through jurisprudence while the philosophical reasoning runs on economic modelling and empirical analysis with revealed knowledge. This makes Islamic economics adaptable and prevents blind adoption of Western models. Scholars now either advocate for the use of the traditional textual interpretation for divine guidance or the use of ijtihad which involves ethical and empirical considerations. This indicates the debate about the improvement of economic

science within ethics. There's literature that provides strong evidence using Maqasid al-Shariah for the combination of revelational ethics with rational policy development.

Planning Development and Socio-Economic Justice

Islamic economics widely supports policy formulation through reasoning approach. Through Maqasid based reasoning, the welfare policy can tackle inequality, social protection and environmental sustainability. Scholars use inductive reasoning to synthesize data to create Islamic economic models with real-time scenarios. Policymakers can use analogical reasoning to tackle new issues in climate finance and digital currencies based on established policies. In development governance, the integrated reasoning framework acts as a mechanism for conduct, regulating decision-making processes to ensure policies and actions consistently uphold justices, promote wellbeing, and preserve dignity across all development initiatives.

Diverse Reasoning Approaches and Contemporary Challenges

There is no single type of reasoning, be it deductive, inductive, analogical, or Maqasidi reasoning, that can suffice the demands alone. The demands of contemporary Islamic economics necessitate an integrated application of different reasoning methods, rather than relying on any single method in isolation. The perceived incoherence is using diverse methods is a wrong interpretation of their complementary. Different reasoning methods serve different purposes in advancing knowledge. Inductive reasoning allows us to adapt in different circumstances, while deductive reasoning establishes a moral framework consistent with Islamic values. Analogical reasoning reinterprets legal concepts in novel contexts while Maqasid-based reasoning drives to justice and welfare. These methods create an integrated approach which fuses tradition and modernity. In digital finance, analogy is crucial for relationship-based businesses. Planetary stewardship demands Maqasidi reasoning behind climate financing and sustainable development. Lack of a unified application of reasoning across Islamic banks, economists and jurists will lead to fragmentation of solutions. Consequently, an integrated reasoning is essential to building accurate models that reflect reality.

Methodological Reflexivity and Transparency

Addressing the identified gaps, a significant challenge in existing Islamic economics literature endures from a relative lack of methodological reflexivity and transparency. Scholars often employ various types of reasoning without putting them under epistemological scrutiny or evaluating their methodology. In Islamic epistemology, it encompasses explaining the balance between *naqli* and

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aqli sources, justifying reasoning methods for research contexts, and acknowledging limitations of specific reasoning approach. The absence of reflexivity leads to methodological shortcomings for example, treating complex moral-economic issues as merely legal issues or technical matters without accounting for socio-historical context. Without clarification, the use of different analytical tools complicates scholars' ability to assess or develop previous research. The absence of insight for using Western economic models can lead to a tendency to adopt and apply without criticism. On the other hand, approaches that are too conventional do not address contemporary issues. To overcome these limitations, Islamic economic research should provide an explicit methodology section in any published Islamic economic scholarly work that indicates the kind of reasoning used, the justification of the reasoning, and its compatibility with Islamic epistemology. Increased academic dialogue, knowledge accountability, and academic discipline will enhance global recognition of the discipline. Moreover, lessons on philosophy of science, epistemology and methodology must be enshrined in a training programme in Islamic economics for budding scholars to build reflexivity and transparency.

Contemporary Planning Framework of Integrated Reasoning

This research proposes a Maqasid oriented contemporary planning framework of integrated reasoning to overcome the fragmentation and opacity discussed above. This framework integrates various types of reasoning into Shariah objectives so that Islamic economic reasoning is effective and normatively grounded. The higher objectives of Islamic law, refer to the normative framework that is designed to guide people. It transcends technical legalistic literalism and is expressive of the divine intention. These objectives are meant to serve as guiding principles for ethical concerns. The guideline to protect and promote: 1. *Dīn* (faith); 2. *Nafs* (life); 3. *Aql* (intellect); 4. *Nasl* (progeny); 5. *Maal* (wealth); and 6. *ʿIrḍ* (honor or dignity). Using Maqasid as a leading paradigm ensures congruence between different reasoning approaches on a common end, namely human well-being, justice and balance. Additionally, it is a moral yardstick for evaluating the impacts of economic choices and policies. The Maqasid-based contemporary planning framework of integrated reasoning also includes some essential constituent elements such as epistemological dualism of *naqli* and *Aqli* sources of knowledge, cross-disciplinary research, adoption of purpose-oriented reasoning, outcome orientation and context sensitivity.

CONCLUSION

This study has illuminated the crucial role of multidimensional reasoning within the studies of Islamic economy and identifies reasoning types including

deductive, inductive, analogical and Maqasid-based reasoning. Our findings reveal that these methodologies are important to Islamic economic studies, however, due to inconsistency in applying these methods and lack of methodological comprehension hinders their coherence and impact of the subject. This interplay between revealed texts and human reasoning offer epistemological depth and methodological challenges. This necessitates researchers to balance traditional elements with modern demands. The study revealed a pervasive lack of methodological transparency in prior studies, underscoring the urgent need for clearer reasoning processes to elevate academic discourse in the field. The need for improvement in academic discussions through clearer reasoning processes is the main emphasis. By examining the existing field studies on Zakat reform and regulation of digital Islamic finance, the study demonstrated that the integrated research approach especially Maqasid-based method is necessary to overcome socio-economic issues and secure practical application of Shariah compliance.

To address these challenges, this study advocates for a Maqasid-based framework based on integrated reasoning approach to deal with the issues. The proposed framework offers a comprehensive model of reasoning for the improvement of human wellbeing, justice, and strengthening a clear, ethical and operational Islamic economic methodology. This study demonstrates that embracing methodological reflexivity and an integrated reasoning framework is essential for developing an Islamic economic methodology capable of addressing contemporary challenges in structured, transparent, and resilient way. Future studies should leverage this integrated reasoning approach in other areas of Islamic economics and development planning. This approach would need comparative studies with conventional economic systems, spanning various disciplines including philosophy, sociology, data science, economics, Islamic jurisprudence, and so on. Integrating diverse reasoning strategies within a Maqasid-based framework promises a more context-sensitive, ethically transformative, and robust Islamic economics capable of addressing contemporary global economic challenges.

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AI CONTENT FABRICATION AND DECEPTION: AN ISLAMIC ETHICAL AND SOCIETAL ANALYSIS

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Abstract

The pervasive increase of AI-generated content, such as deepfakes and forged religious texts has raised serious concerns about deception, disinformation, trust breaches, ethical accountability, and more. These issues concern both secular and religious spheres. Although research on the ethics of AI is growing, the Islamic scholarly works that deal specifically with ethical frameworks of AI-generated misinformation and deception are inadequate. This study employs a qualitative interpretive approach rooted in ethical reasoning and normative analysis, involving hermeneutical engagement with primary Islamic texts, classical legal opinions, along with contemporary fatwas, literature, and illustrative real-life case studies. This study formulates an Islamic ethical framework rooted in principles such as *ṣidq* (truthfulness), *amānah* (trust), and *maṣlaḥah* (public interest), which serve as foundation for a profound digital trust infrastructure. This framework tackles the epistemic and ontological dilemmas of AI, while maintaining human ethical accountability of AI content. The findings reveal that the concoction of content is forbidden (*ḥarām*) in the Shariah due to its capacity to cause societal harm and division in the society. Effective public-information governance necessitates Interdisciplinary collaboration of scholars and institutions, technologists, educators and policy makers to create effective verification and digital literacy protocols. This framework provides a structured approach that combines Islamic principles along with technology development to enhance ethical AI oversight and awareness.

Keywords: Islamic Ethics, Artificial Intelligence, Content Fabrication, Deepfakes, Techno-Ethical Governance

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INTRODUCTION

The global expansion of AI technologies can be seen as the beginning of an era full of innovation (Islami et al., 2025; Yakub et al., 2021) and ethical and socio-cultural uncertainty (Momeni, 2024). AI generating false content is an increasingly contentious matters, posing significant dangers as anyone can create hyper-realistic and false digital content (Popa et al., 2025). At present, anyone can create a hyper-realistic but false digital object for any purpose, using deep-fake or voice-impersonating technologies (Popa et al., 2025). It affects politics, spreads disinformation, religion, personal attacks, and other far-reaching implications (Kharvi, 2024). Pira (2023) argues that this constitutes a technology revolution that impacts how societies establish truth and trust institutions. Although secular ethical frameworks highlight the importance of transparency and accountability, their impact, particularly on fake information, fatwas, fabricated hadiths, and impersonation of scholars, is limited (Abdulrahman & Walusimbi, 2024; Bhojani & Schwarting, 2023). In Muslim societies where religious knowledge is generally disseminated by scholars (*'ulamā'*), religious institutions and authoritative texts, the impact of AI-generated fake content shows its own repercussions. A case of this is the jeopardy of AI content fabrication in Muslim societies. The proliferation of AI-driven deepfakes on religion-related matters creates more confusion among the digitally engaged population, a phenomenon increasingly explored in academic discourse (Al-Arja, 2025; Metz & Blumenthal, 2019). Such deceptive content, capable of inciting extremism and falsely justifying illegal acts, poses a big threat to community resilience and social cohesion. In the era of digitalization, the misinformation created by AI led to epistemic moral anarchy, which is forbidden in Islam (Hate, 2024; Zhang et al., 2025). The revealed text of Islam promotes truthfulness (*ṣidq*) and the preservation of peace (*sulḥ*). The Prophet Muhammad (peace be upon him) said, "whoever deceives us is not one of us" (Sahih Muslim, 102). So, any sort of AI-generated deception can be construed as a moral violation with serious spiritual consequences.

The study examines the use of AI-generated content specifically in religious texts and to explore it from an Islamic ethical and social understanding. The study adopts basic principles of Islam and applies them to real-life case studies of deepfake fatwas, fabricated hadiths, and politically motivated deepfake videos to formulate an ethical framework. This study is guided by the following key research questions.

1. How do Islamic ethical and juristic values assess deceitful content generated by AI, particularly in the fabrication and dissemination of religious or political content?

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2. What are the implications of AI-generated misinformation on social and religious life of people in Muslim societies? And how it impacts on the community's admiration for religious authority, public trust, and harmony?
3. How Islamic values including *maqāṣid al-shariah*, *amānah* and *ṣidq* can support the ethical governance of AI technology while enhancing public awareness and institutional regulations?

The proposed Islamic ethical framework for AI governance aims to inform robust policy responses. This includes drawing up institutional regulations for AI development and deployment, alongside mandates for public awareness and digital literacy programs to prevent digital harm.

LITERATURE REVIEW

This section reviews the key themes arising from AI ethics and Islamic moral philosophy, delineates their areas of convergence and differences, and emphasizes the pressing necessity for contextually linked Islamic ethical responses.

Recent Empirical Studies on AI-generated Misinformation, Deepfakes, and Synthetic Media

The recent statistical data of OECD (2026) that reports a tenfold increase in AI content incidents (Gaudiaut, 2026; OECD, 2026), reveals a remarkable increase in AI-generated misinformation and its societal repercussions. A global survey conducted by Gillespie et al. (2025) reveals that 70% of the respondents find it difficult to trust information on the internet due to the uncertainty regarding AI-generated content. 64% are concerned about the ability of the AI content to meddle with the electoral process and the issue of democracy losing its integrity. Only 47% of people are confident in spotting AI-generated misinformation. There is strong public support for regulation of AI. 88% advocate for laws to curb AI misinformation, while 86% support enhanced fact checking by news and social media organizations, alongside mechanisms to identify AI-generated content across text, images, audio, and video (See Table 1).

Table 1: Impact, and Responses to AI-Generated Misinformation

Impact Description	**% Agree***	**Number of Incidents**	**Source**
Media-reported incidents of AI-generated content and deepfakes (Jan 2026)	—	~500 monthly cases	(Gaudiaut, 2026; OECD, 2026)
Media-reported incidents baseline (early 2020)	—	~50 monthly cases	
Escalation Factor	—	10x increase	

Impact Description	% Agree*	Number of Incidents	Source
Difficulty trusting online information due to AI-generated content uncertainty	70%	—	(Slotta, 2025)
Difficulty discerning AI-generated content (A Global Survey Report, 2025)	70%	—	(Gillespie et al., 2025)
Concern about AI-generated content manipulating electoral processes	64%	—	
US adults concerned about deepfake videos and audio	60%	—	(Statista, 2026)
Global online users regarding deepfakes and AI-assisted scams as threats	69%	—	(Zandt, 2024)
Confidence in ability to detect AI-generated misinformation	47%	—	(Gillespie et al., 2025)
Support for enhanced fact-checking protocols	86%	—	
Support for laws to curb dissemination of AI-generated misinformation	88%	—	

*% Agree = 'Somewhat agree', Agree', and 'Strongly agree'
Source: Compiled by the authors based on empirical studies and data extracted from: (Gaudiaut, 2026), (Gillespie et al., 2025), (Slotta, 2025), (Statista, 2026), and (Zandt, 2024).

In the United States, 60% of adults express concern about AI-produced deepfake videos and audio, while 69% of global online users consider deepfakes and AI-assisted scams significant threats (Statista, 2026; Zandt, 2024). The European Union's Artificial Intelligence Act, implemented in August 2024, addresses AI-driven misinformation risks (Gillespie et al., 2025; Stoll, 2025). Nonetheless, data on AI-generated religious misinformation remains limited, with statistics primarily focusing on political and social impacts. The evidence shows we need comprehensive strategies to counter this, which combines legal frameworks to impose accountability on AI developers, technological safeguards to detect and prevent misinformation, and public education.

Major AI Ethical Concerns in Secular Perspective

Within the secular AI ethics space, we can find the Asilomar AI Principles (Future of Life Institute, 2025), OECD Principles on AI (OECD, 2025), and Ethics Guidelines from the EU's High-Level Expert Group on AI (Lemonne, 2021), based on norms of transparency, accountability, fairness, explainability, and non-maleficence. Nonetheless, these elements do not encompass certain fundamental components present in the social and theocentric framework of Islamic ethics (Huang et al., 2022). Mainstream AI ethics lacks religious perspectives, which is problematic for Muslim societies and globally significant,

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emphasizing the need for inclusive ethical governance in AI development (Chaudhary, 2020; Roche et al., 2022; Elmahjub, 2023). With religion influencing global morals, any AI ethics excluding religious traditions like Islam is incomplete. Islam's legal reasoning and ethical governance apply to digital issues. The lack of Islamic values in AI ethics seems to assert a foreign hegemony over Muslim societies. Legal maxims (*qawāʿid fiqhiyyah*) must be employed to engage Islamic ethical values. According to Al-Zuḥailī (2006), the maxim *ḍarar yuzāl* (harm must be avoided) concerns AI safety, while *al-umūr bi-maqāṣidihā* (actions are judged by intentions) relates to AI accountability.

Islamic Moral Values on *Ṣidq* (Truth), *Amānah* (Trust), and *Ḍarar* (Harm)

Islamic ethics, rooted in the Qur'an and Prophetic traditions, provide moral terms for addressing deception. Key ethical values include truthfulness (*ṣidq*), trust (*amānah*), and preventing *ḍarar* (harm). The Qur'an commands believers to uphold truth and avoid falsehood. In the Qur'an (49:6), it states "*O you who have believed, if there comes to you a disobedient one with information, investigate, lest you harm a people out of ignorance and become, over what you have done, regretful.*" This principle is emphasized in Prophetic traditions, including the hadith narrated by Muslim that whoever deceives us is not one of us. The principles of *amānah* require honesty in speech, trustworthiness in knowledge dissemination, and integrity in responsibilities. These principles are violated when AI technologies deceive people through impersonating scholars or spreading false religious content. The legal maxim *'al-ḍarar yuzāl*' (harm must be avoided) forbids spreading synthetic news in Islam. These principles are embedded in Islamic legal objectives (*maqāṣid*), including protection of religion (*ḥifẓ al-dīn*), life (*ḥifẓ al-nafs*), intellect (*ḥifẓ al-ʿaql*), lineage (*ḥifẓ al-nasl*), and wealth (*ḥifẓ al-māl*). AI-generated content can undermine these objectives, making this issue significant for Islamic legal deliberations.

Contemporary Islamic Scholarship and Institutional Responses to AI Technologies

Recent advancements in Islamic scholarship show increasing recognition of ethical dilemmas posed by AI. Scholars and institutions actively discuss AI ethics issues. Scholars like Shaykh Abdallah bin Bayyah and Dr. Jasser Auda advocate reinterpreting *maqāṣid al-sharī'ah* for digital ethics, emphasizing Islamic legal theory's adaptation to AI. Discussions focus on moral accountability (*taklīf)* of AI developers and users, exploring principles like *amānah* (trust) and *ṣidq* (truthfulness) in AI content. Scholars examine *ijtihād* in the digital era to authenticate AI-produced religious content. Islamic institutions like Dar al-Ifta', Majlis Ulama Indonesia, and the International Islamic Fiqh Academy have issued fatwas on AI ethics, denouncing deepfakes and false claims. They emphasize verification and labelling to counter AI misinformation. Collaborative

frameworks uniting scholars, technologists, and ethicists are needed for AI guidelines based in Islamic jurisprudence. Universities in Muslim-majority countries are establishing AI ethics research units integrating Islamic principles with governance models. Islamic digital literacy curricula evaluate AI content through principles like *ḥifẓ al-dīn* and *ḍarar yuzāl*.

Although the literature on AI ethics is growing, but scholarship highlighting the gaps from an Islamic perspective is scant. Lack of comprehensive Islamic frameworks to evaluate the misinformation generated by AI, especially disinformation affecting spiritual authority. There are not enough case studies demonstrating how AI manipulates data to fool Muslims using deepfake fatwas and AI-generated impersonations. Most fatwa bodies and Islamic leaders ignore procedures for assessing AI technology risks. The promotion of Islamic digital literacy is insufficient, particularly among the youth who are susceptible to misinformation through mobile applications and social media. The global discourse on AI governance is largely dominated by secular frameworks and lacks Islamic perspectives. The holes necessitate an integrated approach that considers the ethical issues of AI disinformation and provides solutions based on Islamic philosophy. This research aims to contribute towards offering a framework for assessing AI-generated content, resolving strategy issues including real-life case studies, and ideas in an Islamic perspective.

METHODOLOGY

This research employs a qualitative interpretive method based on Islamic ethical reasoning and normative analysis to critique the AI content fabrication and disinformation, particularly among Muslim societies. Using hermeneutical engagement with primary Islamic texts and classical works of jurisprudence, it develops normative ethical principles while normative legal reasoning with approaches such as *qiyās, maqāṣid al-shariah*, and *qawāʿid fiqhiyyah*. This framework allows for a principled evaluation of AI-based misinformation using ethical concepts such as preventing harm, intention-based judgement, and safeguarding the public interest. The present study uses a variety of primary and secondary data that are relevant to the research questions.

A triangular data source model (as shown in **Figure 1**) is applied to the present study. The data sources are based on a range of normative, jurisprudential and social responses to the research questions. The approach involves case studies of incidents involving AI misinformation, triangulation of secondary sources, including fatwas and academic literature, and socio-technical contextualization from digital media and AI governance. Quantifying the impact of AI-generated religious misinformation with empirical and statistical data, A dynamic approach would adjust the ethical framework to change in context and assists in creating policy recommendations to alleviate the issues of AI deception in Muslim societies.

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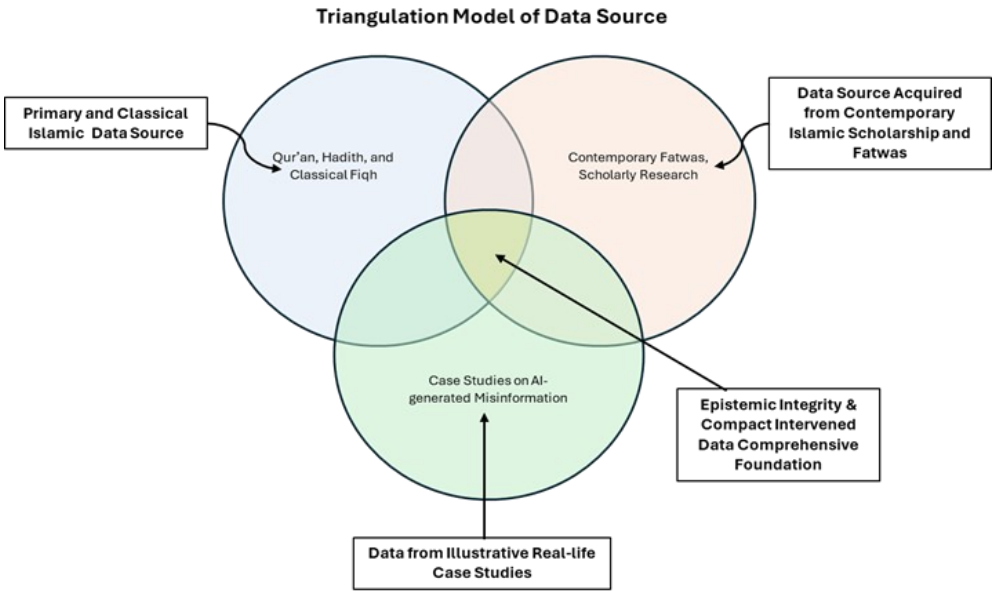


Figure 1: Triangulation Data Source Model
***Source**: Created by the Author*

CASE STUDIES

This section investigates three different illustrative case studies that have raised ethical, epistemic and social issues regarding AI-generated content from within the Muslim majority regions. These case studies were chosen for their widespread impact and high social-religious stakes. These cases serve as critical real-life illustrations, providing empirical justification for the urgent development of robust planning and governance policies to avoid AI-driven harms. To achieve these objectives, the study aims to showcase how *maqāṣid al-shariah*, *qawāʿid fiqhiyyah*, and epistemic integrity can help provide diagnoses and measures to tackle the cases of AI disinformation by applying Islamic ethics principles and juristic reasoning to these cases.

Case 1: Deepfake Fatwa by a Prominent Scholar

In June 2024, the Media Center of the Egyptian Dar al-Iftaa affirmed that Minister of Endowments Dr. Mohamed Mokhtar Gomaa did not endorse dubious individuals or disseminate spurious hadiths. Dar al-Iftaa exonerates the Minister of Endowments in the AI-generated deepfake video. The center stated that the video of the Minister of Endowments circulating online was fabricated and deceptive, generated by artificial intelligence, and emphasized that it served as a promotional campaign for an electronic gaming application. The center further clarified that Dr. Mokhtar Gomaa does not endorse dubious individuals. The

Media Center highlighted the peril of employing AI to distort facts and create deceptive videos that endorse dubious products or applications aimed at defrauding individuals, asserting that all legal actions would be pursued in this matter (Ahl Masr News, 2024; OECD.AI, 2024).

Impact and Analysis

The public's response was outrage and confusion, with calls for investigation. Religious authorities were thrown into disarray and had to issue clarifications and takedown demands. However, this episode made it such that authorities would have to discuss the issue. With a sermon penned, local muftis and preachers addressed Friday prayer service, warning against unauthenticated religious content.

From a jurisprudential standpoint, the incident is concerned with the relationship between the *ʿāmmī* (layperson) and the *ʿālim* (scholar). The Islamic legal tradition allows *taqlīd* (the following of a scholar's opinion) when one does not have skills for *ijtihād* (the independent reasoning). *Taqlīd* demands an understanding of the scholar's identity, background, and credibility. A fatwa made by a digital device that imitates the appearance of a scholar is termed as false attribution (*iftirā'*) and is a violation of the maxim *'al-umūr bi-maqāṣidihā'* (actions are judged by intentions). Reforming trust infrastructure requires a well-defined accountability, as AI-generated content without *niyyah* (pure intention) and human oversight loses legal status. Second, it is the responsibility (*amānah*) of institutions to implement authentication protocols, thereby restoring epistemic integrity and public trust.

Case 2: AI-Generated Hadiths in Islamic Apps

In June 2025, observations of numerous Islamic mobile applications using generative AI have revealed instances where some apps produced weak and forged Islamic content (Patel, 2025). This case illustrates a prevalent issue rather than a single or isolated event. An unbiased appraisal undertaken by Islamic scholars showed that some of the apps produced weak (*ḍaʿīf*) and completely fabricated (*mawḍūʿ*) hadiths and false information. There were no citations or grading of authenticity for most of the content. Many users, including youth and people learning about Islam, allegedly widely circulated the content on social media thinking it was true (Patel 2025).

Repercussions and Ethical Judgment from Hadith Sciences and Epistemology

This scenario shows the incident of epistemological crisis in digital propagation (*daʿwah*) of religious content. Though these apps may have been developed with the intent of democratizing access to religious knowledge, they inevitably become misinformation platforms by their very design. Using such apps, the

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youth are making themselves more vulnerable by relying on mobile apps instead of conventional sources such as scholars and textbooks.

The propagation of unauthenticated narrations wrongly portrays the sacred assets of the knowledge of Prophetic traditions, and it misleads the people to false beliefs and practices. Some fake content presented as Prophetic traditions may incite superstitions or extremist behaviours which have absolutely nothing to do with the very essence and balanced teachings of Islam.

The hadith sciences, from its classical development, has always had principles and rigorous criteria for assessing narrations to consider their authenticity. This includes a consideration of the transmitters (*rijāl al-ḥadīth*) and the chains of narration (*isnād*). Generative AI cannot produce works that are religiously authoritative because it is not produced by any of these filters. The use of fabricated hadith is a direct violation of the Qur'anic command, "*And do not say about what your tongues assert of untruth…*" (Qur'an 16:116). It also transgresses the moral principle *ṣidq* and the epistemic duty of verifying information before transmitting it. This breach is also mentioned in another verse of the Qur'an where Allah states: "*O you who have believed, if there comes to you a disobedient one with information, investigate, lest you harm a people out of ignorance and become, over what you have done, regretful*." (Qur'an 49:6).

Religious texts written by AI cannot be accepted unless validated by qualified scholars. Applications that are created for such purpose must have an authorizing system. Those who fail to do so align with the promoters of disinformation that warns that causing an error is like committing it.

Case 3: Deepfake Incitement in Conflict Zones

In April 2024, a picture of burning a building went viral on Facebook in Sudan. According to the captions that circulated widely with the image stated, this building had belonged to Al-Jazeera University in Wad Madani and had been bombed by the Sundanese army. Many politicians and influential personalities became its victims and promulgated it. But that was not an isolated incident. As fighting continues between the national army and rebel paramilitary Rapid Support Forces, the social media arena has turned into another battleground. Both sides are using AI-driven deepfakes to spread disinformation and gain support. Such incidents pose considerable challenges to the Northeast African nation that desperately needs a sturdy information ecology, a concern widely discussed in studies on disinformation in conflict zones (Jareh, 2025; Suliman, 2024).

Impact and the relevance of Islamic legal perspective

This case demonstrates how AI can be deployed as a tool for factional provocation in conflict zones. Although forensic experts later proved that the footage was fake, the damage was already done. People became increasingly

estranged and there was no more dialogue between the two groups. What's worse, political leaders and other important people fell victim to it and shared it.

In an Islamic juristic perspective, such cases are governed by multi-layer *qawa'id fiqhiyyah* (legal maxims):

Firstly, for policy making, the Islamic legal maxim *Ḍarar yuzāl* (harm must be removed) mandates immediate removal of false content and the adoption of preventive strategies, while holding platforms accountable.

Secondly, *Darʾ al-mafāsid muqaddam ʿalā jalb al-maṣāliḥ* (preventing harm takes precedence over acquiring benefit) implies that AI technologies, despite potential benefits, require rigorous scrutiny and regulation in volatile contexts to prevent digital harm. Thirdly, the legal maxim *Al-maṣlaḥa al-ʿāmma muqaddama ʿalā al-maṣlaḥa al-khāṣṣa* focuses on public interest by taking precedence over private interest. To maintain harmony (*sulh*) and avoid discord (*fitnah*), public policies are introduced even if it curtails the right to freedom of expression to a certain extent of the content creator.

Beyond condemning digital incitement, Islamic ethics advocates for strong institutional coordination among scholars, government, and technical platforms, as essential strategies for improving community resilience against the harmful impact of AI deception. The Qur'an states: *"Indeed, those who like that immorality should be spread [or publicized] among those who have believed will have a painful punishment in this world and the Hereafter..."* (Qur'an 24:19).

DISCUSSION AND RECOMMENDATIONS

The rapid increase of fake AI content, especially content that impersonates religious authority, fabricates hadiths, or instigates religious sectarianism, raises critical legal and ethical questions for Islamic jurisprudence as to who bears the liability. Technology may be advanced, but the rulings given in the past have ample precedent on false religious literature, false testimonies, and misrepresentation of Islam.

Legal Maxims (*Qawāʿid Fiqhiyyah*) as Ethical Anchors

Islamic Legal maxims apply Shariah to new areas. These principles provide ethical clarity and legal guidance beyond the classical texts. Two maxims about the ethics of AI-generated content are significant: *Al-Ḍarar Yuzāl* (Harm Must Be Removed) and *Al-Umūr Bi-Maqāṣidihā* (Actions Are Judged by Intentions). The first maxim ranks amongst the highest in Islam jurisprudence. It holds that AI content causing misinformation, deviation from true religion, or social discord is harmful. Through disinformation, it can cause epistemic harm, mislead believers, and incite sectarianism. According to this advice, designers and users of AI should foresee and warn against dangers, which will ensure human intervention when needed. The second maxim relates to the ethical status and the intention (*niyyah*). Machines themselves have no intent, but the designers, users

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and distributors do. Policy design for digital harm prevention must establish clear responsibility frameworks, ensuring liability falls on human designers and platform providers when AI undertakes tasks without supervision. This necessitates regulatory assessment of both the *maqāṣid* (objectives) and *niyyah* (intention) of the human actors involved in the AI content lifecycle.

Developers and Users: *Taklīf* and *Dhimmah*

The ethical and legal aspects of Islamic thought focus on the notion of moral agency and accountability. The term *mukallafūn* refers to the human condition. It is an Arabic word that relates to people who are bound by obligations. These are obligations that will make them responsible according to Shariah. In the context of AI, we may accentuate *mukallafūn*, which refers both to the developer and user.

Developers of generative AI systems producing religious content bear considerable responsibility. In the absence of any verification mechanisms or disclaimers in the system, where the data sources are not curated, and the AI is imitating known scholars without any consent, they will have to take more responsibility. The acts in question entail either an intentional misrepresentation (*tadlīs*) or negligent causation (*tasabbub*), resulting in binding the action and the agent with a *dhimmah*. They take part in epistemic harm with potential. According to *Surah Al-Ḥujrāt*, verse 6, the Qur'an instructs to verify information. Those who disseminate AI-generated content without checking will be liable. The duty to spread verified religious content lies with the users. This is because the Prophet (peace be upon him) said: "It is enough falsehood for a man to speak of everything that he hears" (Sahih Muslim, 31:6). Islamic ethics requires Muslims to practice good digital discernment, especially with matters of faith.

***Tazwīr* and Fabricated Fatwas in Fiqh Tradition**

Although there are new challenges with AI, Islamic law has been used in the past to address forgery and false knowledge of religion. Classical texts examine forgery, fake hadith and false fatwas. *Tazwir* involves forging documents and faking signatures and seals. Jurists object to forgers since they threaten textual truth. The scholarship on false hadiths, as presented by the scholars like Ibn al-Jawzī (d. 1201) and al-Dhahabī (d.1348), explains the spiritual and legal consequences of following false narrations. People without proper knowledge who contested law were incorrect because of religious opinion faced very strong opposition. These judgments apply to AI systems that cause such issues in the digital environment. A false fatwa generated by AI impersonating a scholar is same as a fabricated fatwa in history. Like how Hadith scholars create chains of transmission (*isnād*) for verification, digital authentication must be made to preserve epistemic sanctity.

Recommendations for Framework on Integrating Islamic Ethics with Contemporary AI Technologies

The ethical challenges caused by AI-generated content in Muslim communities require a revised framework relating traditional Islamic ethics with modern AI technology. Although Islamic Law has principles such as truthfulness, trust, and avoidance of harm, applying these principles to the scale, autonomy, and complexity of AI poses various challenges.

An expansion of traditional Islamic legal maxims and their connection to ethical theories of AI, algorithmic decision-making and data bias is required. The principle of *maqāṣid al-sharī'ah* can be used anew for digital justice and accountability and ensure, at a minimum, the compatibility of AI systems with the public interest while safeguarding values.

The AI generating religious content raises several pertinent questions. The impact of machine-generated knowledge on information trustworthiness must be addressed by Islamic ethics. There is a need for such a criterion to evaluate the AI Output. There should be an Integration of the Islamic principles of *ijtihād* and *taqlīd* in the digital setting. Also, there should be human oversight of the religious content.

The framework must define ethical accountability in creating and sharing AI content. Islamic principles concerning *taklīf* (moral responsibility) apply to AI developers, platforms, and users in AI ecosystems. Although AI systems do not have intent, it is the humans designing and deploying the systems who are ethically responsible, which aligns with "actions are judged by intentions."

To address the socio-cultural implications of AI, an Islamic framework for technology ethics must integrate insights from AI ethics, digital media studies, and social sciences. In Muslim communities, how AI will impact community harmony, religious leadership and identity, it is necessary for scholars, technologists and policymakers to create a framework for the development of AI that coordinates with Islamic framework through digital literacy programs and governance.

As AI develops, Islamic ethical governance must evolve from legal maxims to contemporary *ijtihād* and through the establishment of institutional capacity which is equipped to assess AI. Not only that, but ethical discussions must also be promoted along with the advancement of technological foresight into legal processes.

Implications

This framework recognizes the common ethical challenges that people experience such as preserving the integrity of religious knowledge, promoting communal harmony (*sulḥ*), and managing digital epistemic trust in the wake of AI-driven misinformation. It suggests:

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- Formation of technology-oriented Islamic ethical rulings for AI that incorporate ethical plurality.
- Advancing digital literacy among people to protect them from the harmful aspects of AI.
- Fostering collaboration to create AI governance frameworks that cater to specific cultural contexts.
- Assistance for an international conversation on AI ethics that respects Islamic values and people's sentiments.

CONCLUSION

This study concludes with the fact that any promulgation of AI-generated disinformation such as fabricated fatwas, forged hadiths, and deepfake impersonations is categorically prohibited in Islamic law. This judgment proceeds from its direction violation of *ṣidq* and *amānah*, and its potential to inflict societal harm. The study used a qualitative interpretive method that brings together Islamic jurisprudence with real-life examples. This approach has helped to produce a clear ethical framework for addressing various issues on AI. It emphasizes the ethical accountability of AI developers, service providers, and users. It argues that while AI itself lack intent, human actors bear ethical and legal responsibility consistent with the legal maxims of Islam. The study recommends development of AI-specific ethics, propagation of digital awareness programs which are conducted by interdisciplinary and transdisciplinary scholars. The study highlights the essentiality of conducting such programs to safeguard epistemic integrity, harmony, and uphold the higher objectives of *maqāṣid* in rapidly changing digital world.

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FROM HERITAGE TO SUSTAINABILITY: INTERPRETING *DARURIYYAT* IN THE GREEN DESIGN OF THE SÜLEYMANIYE COMPLEX

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Abstract

According to the history of Ottoman Turkey, the Süleymaniye Complex is the best example of a green building. The Süleymaniye Complex is also a well-known socio-religious and nature-friendly complex that is established and managed according to the teachings of Islam. While *maslahat* comprises three levels, this study focuses specifically on the *daruriyyat* (necessities) aspect to analyze how basic human needs are integrated into Islamic green design. Sustaining public interest is important because it functions to assist society's continuity in life. Practicing sustainable public interest would place the Süleymaniye Complex in the category of an Islamic-based green building. Hence, what is sustainable public interest? What are the characteristics of sustainable public interest found in the Süleymaniye Complex? Generally, this study intended to answer these questions and the fieldwork method through observation was used to analyse the characteristics of sustainable public interest. The findings revealed the characteristics of an Islamic-based green building, based on sustaining the public interest has been featured in the Süleymaniye Complex and how to connect it to the modern green building practices.

Keywords: Green building, sustaining public interest, Süleymaniye Complex, *daruriyyat, heritage*

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INTRODUCTION

The green building concept has been developed and applied in various types of buildings, including homes as well as commercial and industrial buildings. Lately, buildings of worship have been earmarked for development by adopting the green building concept. In the context of this study, the green building concept is driven by the green movement that strongly advocates the well-being of humans and nature in the course of development (Abdul-Matin, 2010), which is reflected in the sustainability concept (Folke, 2016). Well-being is also aligned to values, materials as well as economic, social, spiritual and physical elements (Koburtay et al., 2022). According to Islam, public interest (*maslahat*) shapes the lifestyle of individuals, society, and even the universe, with the ultimate aim of achieving human well-being grounded in fundamental human needs. Within the Islamic worldview, *maslahat* refers to the prioritisation of benefit and the avoidance of harm in the fulfilment of those needs. This study further presumes that well-being encompasses both worldly and afterlife dimensions, as human life is intrinsically connected to blessings and sins, as well as the ultimate reward and punishment as described in the Quran (Faizin, 2019; Syamsuddini, 2022). Hence, only then can it be called sustainability in the perspective of Islam.

As outlined by Faizin (2019) for the case of *maslahat al-mursalat*, that is human needs that is not stated explicitly in the religious text (as opposed to *maslahat mu'tabarat* and *maslahat mulgat*), are devided into three levels, *daruriyyat* (necessities - primary level); *hajiyyat* (complements - secondary level); and *tahsiniyyat* (embellishments - tertiary level).

This study intended to examine the meaning of sustainable public interest or as mentioned earlier *maslahat* specifically on the *daruriyyat* (necessities) aspect to analyze how basic human needs are integrated into Islamic green design as observed in the Süleymaniye Complex. It also intended to determine the characteristics of sustainable public interest that are in the level of *daruriyyat* as were found in the Süleymaniye Mosque, Rabi Madrasah and the people's kitchen (community kitchen), which represents the whole of the Süleymaniye Complex.

LITERATURE REVIEW

History of the Süleymaniye Complex

The Süleymaniye Complex began construction on 20 July 1550 and was completed on 20 October 1557 (Necipoglu-Kafadar, 1985). The cost of constructing the complex, which is 85,000m2, was 55 million akçe (Necipoglu-Kafadar, 1985), or it is estimated to be at the value of $147 million USD during that time. It is the second largest complex after the Fatih Complex, which is 100,000m^2.

The Süleymaniye Complex is a chain of buildings consisting of 18 buildings with each having a specific social role. The 18 buildings comprise the Süleymaniye Mosque, primary school (*sibyan mektepi*), al-Qur'an madrasah (*dar al-qurra*), Hadith madrasah (*dar al-hadith*), Evvel madrasah (Evvel *medrese*), Sani *madrasah* (Sani *medrese*), Salis *madrasah* (Salis *medrese*), Rabi *madrasah* (Rabi *mederese*), Medical *madrasah* (Tib *medrese*), hospital (*dar al-shifa*), guest house (*caravanserai*), people's kitchen (*imaret*), sauna house (*hammam*), water tower (*çeşme*), toilet, Sultan Suleiman's mausoleum, the Sultana's mausoleum and Sinan the architect's mausoleum (Necipoglu-Kafadar, 1985).

15 out of 18 buildings in the Süleymaniye Complex provide social services to the community. It is the largest network of Ottoman buildings that reflect the power and social control of the Ottoman empire (Aydüz & Yıldırım, 2002; Necipoglu-Kafadar, 1985). The main aim of building this complex was to provide social facilities for the people as well as enhance Islamic Shariah.

Sustainable Public Interest (*Maslahat*) and *Daruriyyat* Aspect

Sustainable public interest refers to human well-being that is derived based on elements that are given preference in the Syariah. The term 'sustainable public interest' is made up of two words, namely 'sustainable' and 'public interest'. Sustainable refers to preservation and the mutual reaction between nature, humans and life (Al-Mumar & Albaghdadi, 2023), while public interest (*maslahat*) refers to safeguarding the aims of Syariah by providing benefits or goodwill to the public and avoiding negative or non-Syariah compliant elements in every aspect of life.

In other words, Syariah advocates the well-being of humans, which is obtained by adhering to the priorities mentioned in the Syariah (Zul Anwar Ajim Harahap, 2014). Syariah was delivered solely for ensuring the well-being of humans, such as organising matters pertaining to human life. Therefore, Syariah outlines the rules of life for individuals, society and the universe to achieve human well-being.

In the context of this study, well-being involves both, worldly and afterlife matters, because human life takes into consideration the blessings and sins as well as the rewards of heaven and the punishment of hell. Hence, it is called the ultimate sustainability. To achieve well-being in Islam, there are three prerequisites, namely *daruriyyat*, *hajiyyat* and *tahsiniyyat* (Faizin, 2019; Official Website Mufti of Federal Territory, 2019). These three elements are related to the

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level of necessities, complements and embellishments of a human being (Rosidi et al., 2022).

The three prerequisites are fulfilled based on the public interest's order of importance. Public interest should be sustainable so that human life can continue without harming the spiritual and physical aspects of human life.

In this context, the *daruriyyat* element is the most important (Faizin, 2019). *Daruriyat* means the most fundamental and mandatory necessities that individuals must fulfil (Amir & Rahman, 2017) concerning with the preservation of religion, life, intellect, lineage, and property. In accordance to that, Amir and Rahman (2017) opined that *daruriyyat* is something that is greatly needed and reflected in its level of urgency, compulsion and inevitability. According to (Faizin, 2019), the need for food and drinks, clothing, a home or living quarters, school and hospital are all elements of *daruriyyat*. Hence, *daruriyyat* is an important and mandatory need that leads to the prevention of deleterious effects on society and the occupants of buildings for the continuity of human life.

As for *hajiyyat*, it is something that is not related to basic needs (Zakaria & Mohamad, 2019). It does not lead to deleterious effects but can lead to difficulties and discomfort to humans (Zainur, 2020). Thus, *hajiyyat* is a general need that affords comfort to society and occupants of a building, while its absence can hinder any social activity, including activities by occupants of buildings (Hajar Opir et al., 2017).

Tahsiniyyat can be defined as something complimentary to life and obtaining it leads to perfect and enriched humans (Syamsuddini, 2022). *Tahsiniyyat* also fulfils needs that are enriching and surpasses the level of basic needs (Mu'alim, 2022). *Tahsiniyyat* can be more than a basic need that complements the lives of members of society and occupants of buildings so that life can be perfect and enriched.

In the context of public interest, according to 'Abd al-Wahhab Khalaf, *tahsiniyyat* is not a priority if there is *hajiyyat*, whereas both *hajiyyat* and *tahsiniyyat* are not a priority if there is *daruriyyat* (Deski, 2022). Besides that, humans not only have the responsibility for forging well-being amongst humans but they also have the responsibility to preserve the sustainability of nature. Thus, this study focuses specifically on the *daruriyyat* (necessities) aspect.

Therefore, in the context of this study, sustainable public interest refers to human well-being that includes values, materials as well as economic, social, spiritual and physical elements for the continuity of human life and not to harm any aspects of human beings. Hence, with the presence of sustainable public interest, humans can continue living in this world and at the same time obtain rewards in the afterlife. However, as for this paper sustainable public interest concept in the study only touches on the *daruriyyat* element, which mainly

focuses on the role played by buildings mentioned earlier towards the sustainability of public interest in the aspects of basic necessities.

RESEARCH METHODOLOGY

Qualitative descriptive method and tabulation analysis approaches were used in this study. All of the information and data regarding the research object were obtained from observation through field study which involved direct and indirect observation of the Süleymaniye Mosque, Rabi Madrasah, and the Community Kitchen from October 2016 to February 2017, semi-structured interviews with at six informants, including staff and researchers at the site and related documents analysis. The information and data were depicted and interpreted in accordance with the basis set for sustainable public interest. This qualitative descriptive method was selected due to the research objective that is to understand the characteristics of green building and the sustainable public interest of the Suleymaniye Complex. It also applied the case study method to ensure complete and in-depth information was gathered. Within the scope of the study, Suleymaniye Complex was examined through direct and indirect observation. From the observation done, all significant information from the observation and related documents were documented and analysed. Data analysis for this study was done after the field study was conducted to complete the analysis of the entire study. Open and axial coding were used to categorize architectural features into the *daruriyyat* level of *maslahat*. Analysis at this stage was done using tabulation analysis methods (open and axial coding, cross tabulation) to achieve the objectives. This tabulation analysis method lists all the characteristics obtained at the study site in the form of a table to detect the characteristics of the building being studied in an organized and clear manner to ensure the validity of the data.

ANALYSIS AND DISCUSSION

Generally, this study found that the Süleymaniye Complex fulfils the criteria for a building that supports sustainable public interest according to its importance, which is the *daruriyyat* need (providing essentials). It is a human need for living a comfortable or complete life and not otherwise. Findings indicate that the Süleymaniye Complex shows preference for the *daruriyyat* needs. The *daruriyyat* needs is reflected in the Süleymaniye Mosque as a place of worship, the Rabi Madrasah as a place that imparts knowledge (education) and the people's kitchen (community kitchen) as a place that provides food. These characteristics are related to the sustainability of public interest, namely fulfilling the *daruriyyat* needs. Before presenting the reason behind the fulfilment of *daruriyyat*, this analysis and discussion section will present main role of the of Süleymaniye Complex.

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The Role of the Suleymaniye Mosque as a Kulliye Center

The most prominent role played by the Suleymaniye Mosque within the Suleymaniye Complex is as the centre of the *kulliye*. In Arabic, the term *kulliyyat* (كلية) means "all," derived from the root word *kul* (كل), which also means all. In Turkish, *kulliyyat* (كلية) evolved into *kulliye* (küllî), retaining the same meaning. Thus, based on its original Arabic meaning, the terms *kulliyyat*, and *kulliye* refer to a gathering or integration of all elements, both physical and functional, toward a unified purpose (Avcıoğlu, 2024).

According to "Dictionary of Islamic Architecture" (1996), a *kulliye* refers to a large complex surrounding a mosque, consisting of madrasahs, libraries, public baths, and soup kitchens. (Freely, 2011) defines it as a complex of educational, religious, and other institutions typically integrated with a mosque. (Hakky, 1992) describes a *kulliye* as comprising three or more facilities that is religious, educational, social, and commercial - built by a patron as a *waqf* (endowment) for the benefit of the community. Therefore, based on these definitions, a *kulliye* is a socio-religious *waqf* centre anchored by a mosque and designed for public service. The characteristics of a *kulliye* can be considered part of the features of an Islamic green building.

In this context, the Suleymaniye Complex functions as a socio-religious centre, with the Suleymaniye Mosque at its core. The complex provides public amenities across four domains: worship, economy, education, and food provision (Kolay & Çelik, 2019; Necipoglu-Kafadar, 1985). These four domains represent essential aspects of societal life. The religious aspect is fulfilled through worship at the mosque. Economic services are provided through lodging facilities, education through the madrasahs, and food provision through the soup kitchen, which serves the poor and travellers. This socio-religious centre reflects the characteristics of an Islamic green building, emphasizing the integration of worship, economy, education, and food provision. However, this study focuses on three of these aspects: worship, education, and food provision.

Historically, the concept of *kulliye* originated during the Seljuk era. The idea was later extended into the Suleymaniye Complex from its Seljuk foundations (Aslanapa, 2011). During the Seljuk period, socio-religious centers typically consisted only of a mosque and a madrasah. The development of the kulliye as a comprehensive socio-religious centre took considerable time to mature. Under the Ottoman Empire, these centres were expanded and perfected, eventually becoming fully developed socio-religious hubs. They also incorporated extraordinary artistic elements inherited from pre-Islamic Turkish traditions and refined during the Islamic period (Aslanapa, 2011). The *kulliye* concept was implemented throughout the Ottoman Empire, becoming a hallmark of Ottoman architecture (Freely, 2011). In other words, the *kulliye* became a symbol of Turkish architectural identity.

These distinctive features were inherited by the Suleymaniye Complex and other complexes established during the Ottoman Caliphate. As a result, the Suleymaniye Complex emerged as the largest socio-religious center of the Ottoman era (Bier, 2017). Consequently, the Suleymaniye Mosque became a focal point for the community. There are several worship activities carried out based on the information provided by the informant as follows:

"*The mosque has its usual activities, which are teaching quran recitation after prayers, congregational prayers and Friday prayers, and tourist visits*"
(Informant 1)

The Role of Madrasah Rabi in the Suleymaniye Madrasah System

Madrasah Rabi is one of the eight madrasahs that surround the Suleymaniye Mosque. These eight madrasahs form a large educational institution that became a focal point for the community. All eight madrasahs are centred around the Suleymaniye Mosque, which is located within the Suleymaniye Complex. This makes the mosque an integral part of the educational institution. Collectively, the eight madrasahs are known as *Sahn-ı Seman Medrese* or *Semâniyye*, meaning "eight courtyard madrasahs." The educational system of these madrasahs was structured into four levels, ranging from elementary to advanced education (Bayindir, 2011). This system is also known as the Suleymaniye Madrasah System. It was established, developed, and strengthened by Sultan Suleiman the Magnificent himself.

Madrasah Rabi is one of the madrasahs that completes the Suleymaniye Madrasah System. It is a higher-level madrasah, equipped with various specializations such as theology, law, medicine, astronomy, physics, mathematics, Quranic exegesis (*tafsir*), hadith studies, and literature (Somel, 2010). In addition, all four major Islamic schools of thought (*mazhab*) were also taught in this madrasah (Bayindir, 2011). Madrasah Rabi is used as a training academy, training center and a venue for organizing events related to the academy's research work (Informant 6).

Previously, madrasah education systems did not include faculties for medicine or mathematics. However, due to the needs and circumstances of the time, courses such as medicine, mathematics, and hadith were added to the Suleymaniye Madrasah System (Ilhan, 2007). As a result, subjects like physics, mathematics, astronomy, and law were taught at Madrasah Rabi. These additions transformed the Suleymaniye Madrasah System into a holistic institution that encompassed both worldly and spiritual knowledge, as well as religious and social sciences.

Graduates of this madrasah system went on to hold high-ranking positions within the Ottoman Empire, such as sharia judges, military judges, and

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chief religious officers in cities like Istanbul, Mecca, Medina, Jerusalem, Damascus, Aleppo, Egypt, Edirne, and Bursa (Bayindir, 2011). Consequently, the Suleymaniye Mosque became a center of attention for people from various regions, due to its role as a renowned educational complex in 15th-century Istanbul, Turkey (Somel, 2010).

In summary, Madrasah Rabi was one of the key institutions within the Suleymaniye Madrasah System, with the Suleymaniye Mosque serving as its central hub. All fields of knowledge - from elementary to advanced - were integrated and systematically organized within this system. This made the Suleymaniye Mosque a center for intellectual development and a major attraction for the public.

The Role of Food Provision by the Public Kitchen

The public kitchen played a vital role in food provision as part of the socio-religious function of the Suleymaniye Complex. It was established to distribute free meals to the public, particularly the poor and travellers (Necipoglu-Kafadar, 1985). Like Madrasah Rabi, the public kitchen was located around the Suleymaniye Mosque, making both institutions centred on the mosque. This spatial arrangement reflects characteristics of an Islamic green building.

During the field study, the public kitchen was found to serve traditional Turkish cuisine. It was frequented by people from various backgrounds, including ordinary citizens and leaders, as noted by informants. The kitchen was funded by a royal endowment known as the Suleymaniye Waqf (Orbay, 2019), which was sponsored and maintained by the Sultan and the royal family. This royal waqf functioned as a redistributive institution. The act of distributing food through the public kitchen carried strong implications of generosity. Sultan Suleiman himself exemplified this virtue by giving alms to those in need after Friday prayers (Necipoglu-Kafadar, 1985). Such practices reflect a deep concern for meeting societal needs and sharing blessings and are considered noble acts in Islam - especially the care shown toward the poor.

In this regard, the public kitchen also provided free meals to mosque staff, teachers and students of the Suleymaniye madrasahs, Sufis, government officials traveling for duty, travellers, and the poor (Singer, 2002). The kitchen was systematically managed, with meals distributed according to established rules and categories, typically served in the morning and evening. Morning meals in Ottoman public kitchens usually consisted of *çorba* (soup) and bread, while evening meals included *bulgur* soup and bread. Additionally, bread and honey were served to travellers to provide the energy needed for their journey (Singer, 2002). According to informant 2, the public kitchen became a dining hall until the last era of the Ottoman Caliphate. Then, it was transformed into the Museum of Islamic and Turkish Art. Then, in 1987-1990, it was made into the Turkish

Research Institute (Turk Arastirmalari Vakfi). Finally, in 1992, this public kitchen became a restaurant that served Turkish dishes. After field research was conducted, it was found that the public kitchen became a restaurant that served traditional Turkish food and was privately managed.

However, the meals served at the Suleymaniye Complex's public kitchen differed from those in other Ottoman kitchens (Singer, 2002). This distinction may be due to its funding by the royal waqf and its status as an administrative center of the Ottoman Empire. Dishes such as spinach, carrots, and rice soup blended with coriander leaves were available at the Suleymaniye kitchen. Moreover, travelers were honored with special meals including lamb (*dane*) and rice prepared with honey and saffron (*zerde*). On festive occasions such as the nights of Ramadan, Eid al-Fitr, Eid al-Adha, the Prophet's birthday (Maulid), Nisfu Sha'ban, Ashura, Friday nights, and Regaib, these special evening meals were distributed to all attendees.

Nevertheless, the portion sizes varied among individuals. According to (Singer, 2002), food distribution was prioritized for distinguished guests, teachers and students of the Suleymaniye madrasahs, public kitchen staff, mosque workers, travelers, the poor, and women. These activities clearly demonstrate that the Suleymaniye Complex served people from all levels of society. Consequently, the Suleymaniye Mosque also became a focal point for the community.

Overall, the roles played by the Suleymaniye Mosque, Madrasah Rabi, and the public kitchen illustrate the Suleymaniye Complex as a socio-religious centre designed to address social needs at the individual, communal, and universal levels. The Suleymaniye Mosque functioned as the core of this centre. Madrasah Rabi served as an educational institution for society, offering instruction from basic levels to the professional training of individuals who would serve the Ottoman Empire. The public kitchen, meanwhile, provided food to various segments of society, including the poor and travelers. Therefore, the socio-religious role of the Suleymaniye Complex reflects one of the key functions of Islamic green building principles, namely, the promotion of sustainable public interest from an Islamic perspective. The following section presents a detailed discussion of this issue.

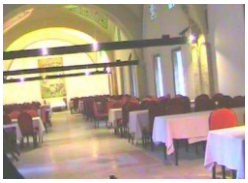
From the above discussion, it is evident that all three buildings within the Süleymaniye Complex continues to function effectively to this day. Moreover, the architectural integrity of these buildings has been preserved, maintaining their original design and structural character.

Collectively, the three buildings contribute directly to the creation of an ideal environment that consistently fulfils the essential needs (*daruriyyat*) of both the public interest and building occupants. They sustain and support human life through spaces dedicated to worship, the pursuit of knowledge, and the provision of food. Consequently, the complex fosters holistic well-being among community

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members and its occupants. This observation is based on the functional roles performed by each building within the Süleymaniye Complex, as summarised in Table 1.

Table 1: Sustainability of Public Interest (*Maslahat*) at the level of *Daruriyyat*

Building of Süleymaniye Complex	**Mosque**	**Madrasah Rabi**	**People's Kitchen**
Specific features and original functions	• Place of worship – hall for congregational prayer, Friday prayer • Information delivery through minaret and *mahya* – include royal messages to the public and *zikr* reminder	• Education – consists of 8 madrasas, a lecture hall and students' rooms	• Provision of meals, especially for the poor – food counters and dining halls
	 Ablution area of Suleymaniye Mosque	 Main Entrance Madrasa Rabi	 Food counter
	 Mahya	 Lecture Hall	 Community Kitchen – Dining Hall
Daruriyyat	✓ Has the stated feature	✓ Has the stated feature	✓ Has the stated feature
Original function	Worship	Education	Food provision
Current function	Worship	Training centre	Restaurant
Sustainability of Function	✓	✓	✓

Note:
✓ Function retained
✗ Function not retained

Table 1 shows that all three buildings help sustain public interest, mainly by fulfilling the *daruriyyat* aspect. According to Table 1, the role of worship, education and providing food (public kitchen) fulfils the need for humans to continue living in this world and in the afterlife. At the same time, it strengthens two relationships, which are the relationship amongst humans and between humans and Allah SWT through the mosque, which plays the role of an institution of worship. This is because the mosque helps to gather people to carry out their acts of worship, such as carrying out their congregational and Friday prayers, which helps to build a relationship with Allah SWT. Congregational prayers help to strengthen relationships among Muslims and narrow the relationship gap in society. It is also here that all types of information and assistance can be delivered to all levels of society. At the same time, the use of manpower and water at home or the workplace can be optimised since congregations meet in the mosque.

Second, the relationship amongst humans is strengthened. This is evident when the Rabi Madrasah and people's kitchen (community kitchen) manage to sustain public interest, namely the *daruriyyat* need. The Rabi Madrasah fulfils the education need, whereas the people's kitchen (community kitchen) fulfils the need for food. The need for education is important for the progress of human live and building a civilisation. Education helps to enhance an individual's life as well as obtain and manage an ideal environment for the progress of society (Shaardan et al., 2025). Similarly, the need for food is important for continuity of human life (Yuancheng & Roosli, 2026). When the need for food is fulfilled, it helps alleviate the burdens in life as well as enable humans to focus on the tasks at hand. Indirectly, the people's kitchen (community kitchen) helps the needy and the poor by providing food for them.

Therefore, the role of worship, education and providing food directly fulfils two human functions. First, the human function of being a subject of Allah SWT by strengthening the relationship between humans and Allah SWT. Second, the human function of being a Caliph by strengthening the relationship amongst humans and the relationship between humans and creatures.

Characteristics of sustainable public interest in buildings are found in all three buildings examined in this study, which indirectly show that the Süleymaniye Complex plays several social roles from the worship, education and provision of food aspects. In a similar vein, al-Faruqi also stated that all the buildings in the Islamic world play various roles (Alashari, 2021).

Heritage vs. Modern Standards: A Critical Comparison of the Süleymaniye Complex and LEED / BREEAM

The Süleymaniye Complex demonstrates a paradigm where sustainability is intrinsically woven into the socio-spatial fabric. This heritage model suggests that

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environmental performance is not an adjunct to design, but a fundamental byproduct of it. For instance, while a LEED (Leadership in Energy and Environmental Design) - certified building might earn points for "Acoustic Performance," Sinan achieved world-class acoustics using hollow clay jugs embedded in the dome - a low-tech, high-wisdom solution (Kayili, 2005). Similarly, where BREEAM (Building Research Establishment Environmental Assessment Method) looks at "Land Use," the Kulliye (complex) was a masterpiece of integrated living(Ediz & Ostwald, 2012). It wasn't just a religious site; it was a hospital, a school, and a kitchen, functioning as a decentralized hub for social equity (Kayili, 2005). This shows that in modern architecture, we often treat "green" features as add-ons such as solar panels on a roof or high-tech sensors in a room. However, looking at the Süleymaniye Complex through a human lens, we see that sustainability was woven into the social fabric.

Practical Implications for Contemporary Mosque Planning

This study on the sustainability of heritage building, the Süleymaniye Complex offers a historical blueprint for addressing contemporary urban challenges through the lens of Islamic-based development and functional sustainability. For modern urban planners and architects, this research highlights several critical applications. First, Shift to Multi-functional Hubs: Modern mosque design should move away from being isolated prayer halls and return to the Kulliye model which is an integrated socio-religious center that provides essential services like education and welfare within a single walkable footprint. Second, Prioritizing Daruriyyat in Design: In alignment with sustainable public interest (*maslahat*), public facility planning should prioritize *daruriyyat* (basic necessities) such as food security and accessible education, ensuring that infrastructure serves the most vulnerable members of society, including the poor and travelers. Third, Adaptive Reuse and Longevity: The fact that the Rabi Madrasah and the Community Kitchen have transitioned into a training center and restaurant while maintaining their structural integrity demonstrates that "green" design is fundamentally about functional longevity and the ability of a building to evolve without losing its social value. Fourth, Social Equity as Sustainability: True sustainability in an Islamic context goes beyond environmental metrics to include social well-being. Thus, planners can use the Süleymaniye model to foster community cohesion by designing spaces that strengthen relationships between individuals and the collective society. Fifth, Resource Optimization: By centralizing social functions around the mosque, planners can optimize the use of manpower and water, as gathering the community in a shared space reduces the resource burden of individual households.

CONCLUSION

Overall, it can be concluded that characteristics of sustaining public interest found in the Süleymaniye Complex fulfil the *daruriyyat* needs. These characteristics still play their fundamental role until today and can be used to refer to characteristics of a green building. All three buildings play an important role in community development including institutions of worship, education and society propagate important principles of development consistent with the implementation of Islamic-based development. In this study, providing food services is one aspect of societal life. Hence, *daruriyyat*, which is one of the characteristics of sustaining public interest, is also one of the characteristics of Islamic-based green buildings.

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DEVELOPING A SIRAH INSTRUCTIONAL PLANNING FRAMEWORK: INTEGRATING THE COMPOSITION OF HIGHER-ORDER THINKING SKILLS (HOTS)

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Abstract

This study adopts a mixed-contribution design comprising two integrated scholarly objectives: (1) a quantitative descriptive survey to evaluate the implementation level of Higher-Order Thinking Skills (HOTs)-integrated instructional composition among Islamic Education Teachers (IETs) in Sirah Education at the secondary school level, and (2) a framework development component that proposes a HOTs Composition-Based Sirah Instructional Planning Framework grounded in the empirical findings. Although HOTs has been institutionalised within the national curriculum, its execution in Sirah instruction necessitates structured planning to ensure the continuity of cognitive development among students. This research aims to identify the level of instructional composition implementation, covering the induction, developmental, and closure phases that integrate HOTs elements. Adopting a quantitative survey design, the study involved 406 IETs from national secondary schools across five major zones in Malaysia. Data were collected via a structured questionnaire adapted from the Curriculum and Assessment Standard Document (DSKP) and relevant literature. Descriptive statistical analysis, performed using IBM SPSS 29.0, was employed to determine mean scores and implementation levels. Findings indicate that the implementation of HOTS-integrated instructional composition is at a moderately high level (mean = 3.90). The induction phase recorded the highest mean score (4.03), followed by the developmental (3.87) and closure (3.83) phases. Although HOTs elements are present in each phase, the progression of cognitive levels throughout the teaching and learning (T&L) process requires further strengthening. This study proposes the development of a HOTs Composition-Based Sirah Instructional Planning Framework to ensure more systematic alignment between objectives, pedagogical strategies, and assessment. This framework offers significant potential to enhance pedagogical planning and elevate the quality of Sirah instruction, as well as other fact-based disciplines.

Keywords: Instructional Framework, Sirah Education, Instructional Composition, Higher-Order Thinking Skills (HOTs)

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INTRODUCTION

The study of Sirah constitutes a core component of Islamic Education, serving to elucidate and operationalise the teachings of the Quran and Sunnah within contemporary contexts. Its importance has been widely highlighted in global Islamic education reform, particularly during the First World Conference on Muslim Education in Mecca (1977), which called for a holistic transformation of the curriculum (Farid et al., 2012). In Malaysia, this aspiration was institutionalised through the National Education Philosophy (FPN) and the Islamic Education Philosophy (FPI) in 1987, both of which emphasise holistic human development grounded in religious values and aligned with national principles (KPM, 2012). Within this framework, Sirah is not merely a historical account of the Prophet Muhammad (SAW), but a practical model demonstrating the application of Quranic principles in real-life contexts (Abdul Karim, 2015).

However, existing studies indicate that Sirah instructional practices remain in need of substantial improvement, particularly in developing pedagogical approaches that meaningfully connect content with students' cognitive development and lived experiences (Jahidih et al., 2025). This limitation calls for a shift in instructional planning, where Sirah is no longer treated as a collection of facts, but as a discipline that fosters critical understanding, internalisation, and transformation. Accordingly, Islamic Education and Sirah must evolve towards cultivating complex competencies, especially leadership and higher-order thinking skills (Khairul Aiman et al., 2025). This transformation aligns with the national emphasis on Higher-Order Thinking Skills (HOTs), which has become a central agenda in Malaysia's education system (KPM, 2014), grounded in Bloom's Taxonomy (Bloom, 1956) and its revision by Anderson and Krathwohl (2001).

Nevertheless, effective HOTs integration in Sirah Education requires systematic instructional planning that balances cognitive, affective, and psychomotor domains (Jahidih et al., 2025). Without structured pedagogical design, HOTs risks remaining theoretical rather than meaningfully translated into classroom practice. Consequently, there is an urgent need to develop a HOTs Composition-Based Sirah Instructional Planning Framework that systematically organises content elements, pedagogical strategies, and learning outcomes to support students' higher-order cognitive development (Nurhayati et al., 2024), aligning with the national agenda to cultivate critical, reflective, and morally upright individuals capable of navigating 21st-century challenges.

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LITERATURE REVIEW

Sirah Instruction and the Imperative for Pedagogical Transformation

The instruction of Sirah within Islamic Education serves as a critical conduit for students to comprehend the teachings of the Quran and Sunnah through their practical applications. Sirah transcends the mere narration of historical events; it encapsulates how the actions, ethics (akhlak), and cognitive paradigms of the Prophet Muhammad (SAW) were manifested within the societal realities of his time (Abdul Karim, 2018), necessitating strategic pedagogical planning capable of fostering profound understanding and internalising core values among learners. Nevertheless, empirical evidence suggests that current practices remain anchored in rote-memorisation and exam-centric approaches (Rosnani et al., 2022), with conventional evaluations prioritising memorisation at the expense of spiritual formation and critical thinking (Ahmad Termizi, 2025), thereby restricting students' ability to synthesise Sirah content with contemporary challenges. Sirah instruction therefore demands a more structured design to holistically engage the cognitive, affective, and psychomotor domains within the framework of 21st-century education (KPM, 2014).

Integration of Higher-Order Thinking Skills (HOTs) in Education

The implementation of Higher-Order Thinking Skills (HOTs) remains a pivotal agenda in the national curriculum transformation. Anchored in Bloom's Taxonomy (1956) and the revised framework by Anderson and Krathwohl (2001), HOTS pertains to a student's capacity to analyse, evaluate, and create through complex cognitive processes. Within the ambit of Islamic Education, HOTS should not be perceived solely as a cognitive faculty. Rather, it serves as a pedagogical approach that facilitates deeper comprehension and fortifies students' convictions regarding the knowledge they acquire and the faith they embrace (Talhah Ajmain & Ahmad Marzuki, 2020; Farid et al., 2025).

Despite its importance, empirical findings indicate that the integration of HOTs within Islamic Education Teaching and Learning (T&L) remains inconsistent. Research by Saidatul et al. (2024) suggests that the instructional practices of Islamic Education Teachers (IETs) are still largely traditional. A related study by Talhah Ajmain et al. (2024) further confirms that HOTS integration in Sirah lessons operates only at a moderate level, particularly at the closure stage, underscoring the need for more structured pedagogical frameworks. Similarly, Ab. Halim and Nik Mohd. Rahimi (2011) observe that teaching remains predominantly anchored in didactic methods, such as lectures, rote explanations, and conventional inquiry, which often fail to stimulate critical and reflective thinking.

Furthermore, studies by Mazlan (2018) highlight that students are insufficiently engaged in higher-level cognitive activities, with fragmented

instructional planning, limited use of instructional media, and failure to contextualise content with contemporary issues resulting in passive knowledge assimilation (Cathrine & Sabariah, 2019).

Instructional Planning and the Concept of Composition

Within the pedagogical realm, instructional planning serves as the fundamental cornerstone that determines classroom efficacy. Systematic planning ensures rigorous alignment between learning objectives, content selection, pedagogical strategies, and assessment modalities. The concept of instructional composition pertains to the strategic arrangement of these elements to form a cohesive, interconnected, and meaningful structural whole (Syaubari, 2018; Talhah Ajmain, 2021).

Operationally, instructional composition refers to the synergistic sequencing of the induction, developmental, and closure phases, meticulously designed to ensure a progressive and lucid learning trajectory (KPM, 2014; Slavin, 2015). This composition transcends a mere chronological sequence of steps; it is a deliberate architecture that dictates how ideas are introduced, scaffolded, and synthesised within a single instructional session. While existing literature has explored composition within the context of Islamic Education Teachers (IETs) (Hanani, 2017), these studies have predominantly focused on the nexus between instructional practice and student achievement, often without explicitly integrating the HOTs dimension. Conversely, research linking composition with HOTs has been concentrated in other domains, such as Aqidah (Syaubari, 2018), leaving a notable research lacuna within the field of Sirah.

In summary, the literature highlights three major challenges in Sirah instruction: reliance on rote-learning approaches, inconsistent implementation of HOTs, and the absence of a systematic instructional planning structure. While HOTs integration has proven effective across disciplines such as history (Mazlan, 2018), and science (Norshuhada & Kamisah, 2019), its application within Sirah Education remains underexplored. Therefore, there is a critical need to develop a HOTs Composition-Based Sirah Instructional Planning Framework that systematically embeds HOTs across all instructional phases, providing a structured guide for Islamic Education Teachers (IETs) to design impactful Sirah lessons.

RESEARCH METHODOLOGY

This research adopts a purely quantitative methodology employing a cross-sectional survey research design to evaluate the implementation level of instructional composition among Islamic Education Teachers (IETs) in Sirah Education, specifically focusing on the integration of Higher-Order Thinking Skills (HOTs). The quantitative approach was selected to facilitate a systematic

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measurement of research variables and to analyse implementation patterns across a substantial population. According to Othman Lebar (2007), quantitative research is inherently deductive, aiming to elucidate phenomena through empirical measurements that allow for statistical generalisation.

The assessment of HOTs elements in this study is grounded in the policies and rubrics established by the Curriculum Development Division (BPK) of the Ministry of Education Malaysia (MOE), encompassing the cognitive levels of applying, analysing, evaluating, and creating. This framework is aligned with Bloom's Taxonomy (1956) and its subsequent revision by Anderson et al. (2001), while being conceptually enriched by Ibn Khaldun's hierarchy of intellect (1958). Consequently, this study focuses exclusively on the cognitive dimension of HOTS; while the affective and psychomotor dimensions are not directly measured, they are acknowledged as vital supportive elements in reinforcing the cognitive aspects of instruction.

The research population comprises all IETs serving in National Secondary Schools (SMK) across Malaysia, totalling 38,502 individuals based on data from the Daily School Management Division, MOE. Utilizing the sample size determination guidelines by Krejie and Morgan (1970) and supported by Pallant (2010) as per shown in table 1 below, a total of 406 IETs were selected as respondents. A multistage cluster sampling technique was employed across five major geographical zones (Northern, Central, Southern, Eastern, and East Malaysia) to ensure balanced representation. The scope is delimited to IETs teaching lower secondary levels (Forms 1 and 2) in public national schools; private, international, and vocational religious schools were excluded to maintain curricular uniformity.

Table 1: Population and Study Sample Size.

No.	Zone	Population size	Sample
1	Northern	3,554	80
2	Central	3.424	89
3	Southern	3,123	77
4	Eastern	3,240	77
5	East Malaysia	3,872	83
Total numbers in Malaysia		**38,502**	**406**

The research instrument consists of a structured questionnaire adapted and validated from previous scholarly works (Syaubari, 2018; Zarkhuan Zainol, 2019) to ensure its suitability within the Sirah instructional context. The questionnaire comprises three main dimensions corresponding to the three instructional phases under investigation: (1) the Induction Phase (3 items), (2) the Developmental Phase (5 items), and (3) the Closure Phase (3 items), yielding a total of 11 items. All items were measured using a five-point Likert scale ranging

from 1 (Strongly Disagree) to 5 (Strongly Agree). Item development was strictly guided by the Standard Curriculum and Assessment Document (DSKP) for lower secondary Islamic Education (Forms 1 and 2). The instrument encompasses key thematic units, including Pre-Islamic (Jahiliyyah) society, the biographical narrative of Prophet Muhammad (SAW), the Hijrah, the establishment of the Islamic state, the era of the Rightly Guided Caliphs (Khulafa' al-Rasyidin), as well as themes of fraternity (ukhuwwah), the construction of mosques, and the contributions of the Companions (Sahabah).

This delimited scope ensures rigorous alignment between the national curriculum and the instructional composition constructs under investigation. Content validity of the instrument was established through expert review involving a panel of Islamic Education specialists and curriculum experts prior to data collection. Reliability analysis was subsequently conducted on pilot data (n=30), yielding Cronbach's Alpha coefficients of 0.928 for the Induction Phase, 0.954 for the Developmental Phase, and 0.927 for the Closure Phase, with an overall reliability index of 0.974. All values exceed the minimum acceptable threshold of 0.70 (Pallant, 2010; Uma Sekaran, 1992), thereby confirming the high internal consistency of the instrument. A total of 450 questionnaires were distributed to account for non-returns, of which 406 were returned fully completed, representing a response rate of 90.2%. All participants were informed of the voluntary and confidential nature of their involvement, and data were collected in accordance with the ethical guidelines of the Ministry of Education Malaysia, with formal research approval obtained from the Educational Planning and Research Division (EPRD), KPM, and the respective State Education Departments (JPN) across all thirteen states involved.

This study examines the implementation of instructional composition across three primary phases: induction, developmental, and closure, anchored in the pedagogical frameworks of Al-Qabisi (1955) and Le Francois (1997). The primary analytical focus is to ascertain the extent to which each phase integrates HOTs elements within the Teaching and Learning (T&L) process. Data were analysed using descriptive statistics to compute mean scores and determine implementation levels. The interpretation of these mean scores was based on the weighted ranges proposed by Pallant (2010) and Field (2012) as shown in table 2. This comprehensive analysis aims to provide an overarching profile of HOTs-based instructional composition within the context of secondary school Sirah Education in Malaysia.

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Table 2: Min Score and Interpretation.

Min Score	Interpretation
1.00 - 2.33	Low
2.34 - 3.49	Medium
3.50 - 4.00	Medium High
4.01 - 4.49	High
4.50 - 5.00	Very High

ANALYSIS AND DISCUSSION

Implementation of the Induction Phase Composition in Sirah Instruction

The descriptive analysis of the induction phase, encompassing lesson planning, the formulation of learning objectives, and the implementation of induction sets, yielded an overall high mean score of 4.03 (Table 3), indicating that Islamic Education Teachers (IETs) have relatively institutionalised these preparatory elements. However, an elemental analysis reveals a moderately high implementation pattern across its sub-components. This nuance suggests that while the foundational structure exists, the integration of HOTs within the induction phase has yet to achieve total consistency and comprehensiveness across all teaching practices.

Table 3: Summary of Variance and Mean Scores for the Implementation of the Induction Phase among Islamic Education Teachers in Secondary School Sirah Education

Item	Statement	Variance	Mean	Int.
B1	Instructional planning integrating HOTS	0.489	4.15	H
B2	Formulation of learning objectives integrating HOTS	0.465	4.10	H
B3	Implementation of induction sets integrating HOTS	0.627	3.80	MH
	Overall Induction Phase Integrating HOTS	**0.521**	**4.03**	**H**

The instructional planning dimension recorded the highest mean (M=4.15), indicating that Islamic Education Teachers (IETs) prioritise systematic preparation aligned with the DSKP. However, this planning remains predominantly content-centric and compliance-driven, risking a pedagogical paradigm that prioritises syllabus coverage over profound contextual adaptation and higher-order cognitive development. This challenge extends to the formulation of learning objectives (M=4.10), which, despite being measurable, often lack clear operationalisation across distinct cognitive levels. As posited by Ibn Khaldun (1958), learning must progress through structured stages; thus, failing to explicitly orient objectives toward HOTs restricts students to passive information reception rather than active meaning construction.

Conversely, the implementation of induction sets yielded the lowest score within this phase (M=3.80), suggesting that while teachers consistently initiate lessons, these activities are frequently leveraged for motivation rather

than as intellectually provocative catalysts for cognitive activation. Theoretically, these results corroborate the frameworks of Al-Qabisi (1955) and Le Francois (1997), which anchor instructional efficacy in clear, strategic initiation. Consequently, the induction phase must be reconfigured from a routine classroom procedure into a strategic mechanism that establishes cognitive continuity through critical inquiry and analytical focus.

Implementation of the Developmental Phase Composition in Sirah Instruction

The instructional developmental component evaluates HOTs integration during the core phase of the T&L process, yielding an aggregate mean score of 3.87 (moderately high). This suggests that while implementation is relatively effective, it has yet to reach an optimal and consistent threshold. A multifaceted analysis across five dimensions, content delivery, questioning techniques, enrichment, remedial interventions, and resource utilization, reveals a consistent moderately high implementation pattern (Table 4), indicating that HOTs has not been fully mainstreamed within the broader Sirah pedagogical architecture.

Table 4: Summary of Variance and Mean Scores for the Implementation of the Developmental Phase in Secondary School Sirah Education

Item	Statement	Variance	Mean	Int.
C1	Instructional content delivery integrating HOTS	0.464	4.15	H
C2	Implementation of questioning techniques integrating HOTS	0.55	3.9	MH
C3	Implementation of enrichment strategies integrating HOTS	0.678	3.82	MH
C4	Implementation of remedial interventions integrating HOTS	0.595	3.78	MH
C5	Utilization of educational resources integrating HOTS	0.679	3.67	MH
	Overall Developmental Phase Integrating HOTS	**0.598**	**3.87**	**MH**

Instructional content delivery achieved the highest mean score (M=4.15), reflecting structured and interactive execution aligned with both classical and contemporary pedagogical tenets (Al-Qabisi, 1955; Le Francois, 1997). However, a critical tension persists between teacher-led delivery and the profound activation of student cognition, as higher-order thinking requires a shift from exposition to student-centred inquiry . This is further highlighted in questioning techniques (M=3.90), where successful HOTS integration is fundamentally determined by the cognitive quality and depth of inquiries, specifically "why" and "how" prompts, rather than lower-level factual recall (Wan Ahmad Ismail et al., 2016)

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Furthermore, enrichment and remedial strategies often function as supplementary tasks rather than progressive cognitive challenges (Ibn Khaldun, 1958), while instructional resource utilisation recorded the lowest mean (M=3.67), indicating insufficient technological integration to scaffold HOTs in the PAK 21 era (Mohd Isa, 2013). The developmental phase must therefore be systematically structured around a cognitive hierarchy to transition Sirah education from procedural compliance toward profound internalisation.

Implementation of the Closure Phase Composition in Sirah Instruction

The instructional closure component evaluates HOTs integration during the final T&L stage, yielding a moderately high aggregate mean of 3.83 (Table 5). While closure elements are consistently implemented, the integration of HOTs at reflective and evaluative levels has yet to reach an optimal threshold. Within this component, the evaluation of student comprehension emerged as the highest-scoring dimension (M=3.99), followed by the synthesis of instructional content (M=3.82) and the reflective assessment of objectives (M=3.68).

Table 5: Summary of Variance and Mean Scores for the Implementation of the Closure Phase in Secondary School Sirah Education

Item	Statement	Variance	Mean	Int.
D1	Implementation of reflective assessment of objectives integrating HOTS	0.733	3.68	MH
D2	Synthesis of instructional content integrating HOTS	0.578	3.82	MH
D3	Evaluation of student comprehension integrating HOTS	0.496	3.99	MH
	Overall Closure Phase integrating HOTS	**0.601**	**3.83**	**MH**

Evaluative assessment of student comprehension yielded the highest score in this phase (M=3.99), indicating that IETs prioritize monitoring student progress through conventional, content-centric modalities. However, effective evaluation must transcend rote-learning to measure analytical and creative capacities, ensuring rigorous alignment with high-level objectives (Muhd Zulhilmi Haron et al., 2019). This limitation is mirrored in the synthesis of instructional content (M=3.82), which, while providing structural clarity, often lacks student agency and fails to stimulate contemporary contextualisation as advocated by Le Francois (1997).

The reflective assessment of objectives recorded the lowest mean score (M=3.68), suggesting that reflection remains a superficial restatement of facts rather than a metacognitive mechanism for deep self-evaluation (Glaser, 1983; Aimi Hafizah, 2017). Consequently, the closure phase must be reconfigured from a routine conclusion into a sophisticated arena for high-level synthesis and internalisation. By orienting this phase toward metacognition and contextual

application, Sirah education can effectively bridge the gap between theoretical understanding and practical, real-world application.

Overall Summary of Descriptive Analysis Results

Comprehensive descriptive analysis (Table 6) indicates a moderately high implementation of HOTS-integrated instructional composition (M=3.90). While the induction phase exhibits high implementation (M=4.03), a marginal decline in the developmental (M=3.87) and closure (M=3.83) phases suggests that HOTS integration is more explicitly manifested during preparatory stages. This demonstrates that IETs prioritise planning, aligning with Le Francois (1997), yet struggle to maintain the continuity of cognitive progression throughout the Teaching and Learning (T&L) process.

Table 6: Overall Summary of Mean Scores and Variances for the Implementation of HOTS-Integrated Instructional Composition among Islamic Education Teachers (IETs) in Secondary School Sirah Education

Item	Statement	Variance	Mean	Int.
B	Induction phase integrating HOTS	0.521	4.03	H
C	Developmental phase integrating HOTS	0.598	3.87	MH
D	Closure phase integrating HOTS	0.601	3.83	MH
	Overall findings of HOTS-integrated instructional composition	**0.578**	**3.9**	**MH**

These findings corroborate research asserting that effective thinking-based instruction is contingent upon the rigorous alignment of objectives, strategies, and assessment (Ghazali & Abd Rachman, 2012). Without systematic planning across all T&L phases, as emphasised by the Ministry of Education Malaysia (2014), HOTs integration risks becoming a procedural routine with negligible impact on profound cognitive development. This reinforces Ibn Khaldun's (1958) theory of pedagogical progression, which necessitates a gradual and staged execution to cultivate complex thinking skills. Ultimately, as articulated by Al-Qabisi (1955), a structured instructional architecture is essential for guiding students toward deep-seated understanding. The synergy between induction, development, and closure must be viewed as an interconnected framework (Figure 1) rather than a mere sequence of steps. This justifies the need for the HOTs Composition-Based Sirah Instructional Planning Framework to ensure the holistic formation of higher-order cognitive faculties in secondary school Sirah Education.

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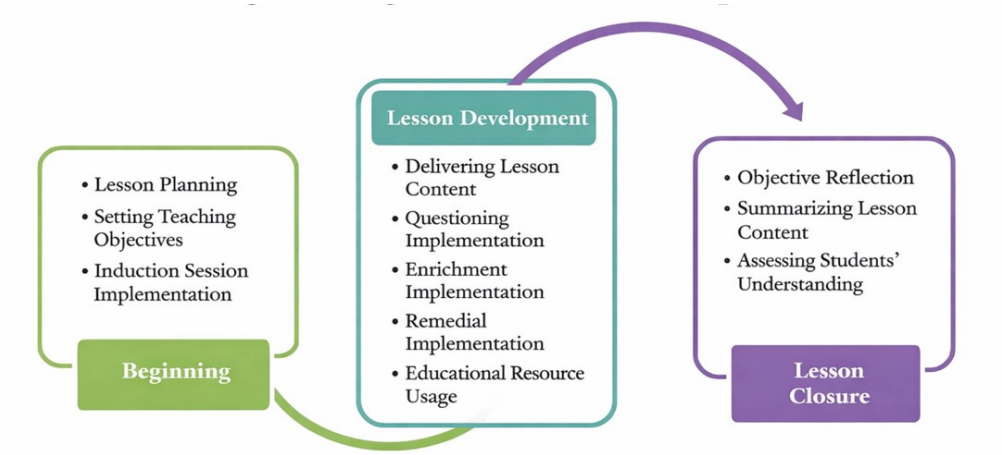


Figure 1: Development framework of Islamic History Teaching Planning Based on HOTS Composition

The HOTs Composition-Based Sirah Instructional Planning Framework

Grounded in the empirical findings of this study, the HOTs Composition-Based Sirah Instructional Planning Framework is proposed as a structured pedagogical model to systematically embed HOTS across all three phases of instructional composition. As illustrated in Figure 1, the framework comprises three interconnected components: (1) the Beginning Phase (Induction), (2) the Lesson Development Phase (Developmental), and (3) the Lesson Closure Phase, each operationalised through specific instructional elements aligned with HOTS cognitive levels per Bloom's Taxonomy (1956) and Anderson and Krathwohl (2001).

The Beginning Phase encompasses three elements: Lesson Planning, Setting Teaching Objectives, and Induction Session Implementation. Teachers are guided to formulate HOTS-oriented objectives targeting the higher cognitive levels of applying, analysing, evaluating, and creating, while the induction session functions as a deliberate cognitive activation mechanism employing provocative questioning and Sirah-based case studies rather than a mere motivational opener (Al-Qabisi, 1955; Ibn Khaldun, 1958).

The Lesson Development Phase comprises five elements: Delivering Lesson Content, Questioning Implementation, Enrichment Implementation, Remedial Implementation, and Educational Resource Usage. Teachers are guided to shift from content-centric exposition toward student-centred inquiry using Socratic "why" and "how" prompts, with enrichment and remedial activities structured as progressive cognitive challenges ensuring differentiated HOTS engagement. Strategic integration of digital tools and authentic Sirah-based

materials scaffolds complex thinking within the PAK 21 paradigm (Le Francois, 1997; Mohd Isa, 2013).

The Lesson Closure Phase encompasses three elements: Objective Reflection, Summarising Lesson Content, and Assessing Students' Understanding. This phase is reconceptualised as a metacognitive arena wherein teachers facilitate structured reflection requiring students to synthesise learning and evaluate the contemporary relevance of Sirah narratives. Assessment modalities are aligned with HOTS cognitive levels, measuring analytical and evaluative capacities rather than rote recall (Glaser, 1983; Le Francois, 1997).

Critically, the framework operates as an interconnected, cyclical architecture wherein each phase informs and reinforces the next, reflecting Ibn Khaldun's (1958) theory of graduated cognitive challenge as a prerequisite for cultivating complex thinking faculties. This evidence-based framework provides IETs a structured guide for designing pedagogically coherent Sirah lessons aligned with the national HOTS agenda. Expert validation and pilot implementation are recommended as essential next steps.

CONCLUSION

This research concludes that HOTs-integrated instructional composition among IETs in Sirah Education is at a moderately high level overall. While the induction phase exhibits more robust implementation, the developmental and closure phases require further reinforcement to sustain higher-order cognitive development throughout the T&L process. These findings underscore that HOTs efficacy is not solely dependent on initial planning but requires sustained alignment between learning objectives, pedagogical strategies, and assessment modalities across all instructional phases. Consequently, this study proposes the HOTs Composition-Based Sirah Instructional Planning Framework as a systematic, evidence-based guide for IETs, strengthening synergy across all instructional phases to ensure HOTS cultivation occurs in a gradual and structured manner. The framework carries significant potential to elevate Sirah Education quality while supporting national aspirations to develop critical, analytical, and contextually aware students.

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DEVELOPING URBAN PLANNING POLICIES BASED ON A MAQĀṢID-ORIENTED HUMAN-FRIENDLY FRAMEWORK

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Abstract

Cities are increasingly assessed through indicator-based frameworks measuring livability, sustainability, and governance performance. However, urban planning still lacks a clear normative integrator to manage trade-offs between competing objectives such as efficiency and equity, growth and sustainability, and technological optimization versus human-scale design. This paper addresses this gap by proposing a maqāṣid-based human-friendly city framework that operationalizes the principle of balance (mīzān) within urban planning indicators. Using a qualitative normative–analytical approach, the study integrates human-centered urbanism with maqāṣid al-sharīʿah as a higher-order evaluative core. Mīzān is conceptualized as a proportional trade-off logic rather than a theological abstraction. Six urban domains—urban form, mobility, public space, housing, environmental systems, and governance—are aligned with five objectives: protection of life, intellect, wealth, dignity, and ecological balance. The resulting indicator architecture ensures traceability from ethical intent to measurable criteria. Unlike conventional indices, it embeds balance through paired indicators (e.g., equity–efficiency gaps), shifting evaluation toward proportional governance and offering both theoretical and policy contributions.

Keywords: Human-Friendly City, Maqāṣid al-Sharīʿah, Urban Planning Indicators, Ethical Urbanism, Urban Governance, Sustainable Cities, Trade-Off Management.

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INTRODUCTION

Background and Problem Statement

Cities are increasingly evaluated not only by economic productivity and infrastructure efficiency, but also by their ability to sustain human well-being, social cohesion, and ecological integrity. The concept of the "human-friendly city" captures concerns of livability, inclusivity, safety, accessibility, and quality of life, which have been widely emphasized in contemporary urban planning literature (Mouratidis, 2021). Despite extensive measurement tools, planning frameworks remain fragmented in reconciling competing objectives such as efficiency and equity, growth and sustainability, or density and comfort. These tensions are often treated as technical issues, while their ethical dimensions remain underdeveloped.

Recent scholarship shows that development-driven land use may undermine social values when guided primarily by economic incentives. Empirical evidence indicates that unbalanced land use disrupts tenure systems and marginalizes communities. Evidence from Canggu, Bali illustrates how such imbalances weaken social cohesion and restrict equitable access (Suhirman et al., 2026). This highlights the need for planning approaches that balance economic growth with community rights and spatial justice.

In Muslim-majority contexts such as Malaysia, planning must also align with culturally embedded values like justice and dignity. However, literature on the "Islamic city" remains largely descriptive, with limited operational translation, creating a gap between normative discourse and indicator-based governance.

The Need for an Ethical Integrator in Urban Planning

Urban planning indicators—such as those embedded in SDG 11, livability indices, and smart city dashboards—play a critical role in benchmarking and performance assessment; however, they often embed implicit assumptions about prioritization and trade-off management, as noted in urban sustainability and governance literature (Sharifi, 2016). Efforts to optimize single objectives—such as carbon reduction, traffic efficiency, or digitalization—may unintentionally exacerbate affordability, accessibility, or exclusion challenges, leading to fragmented and incoherent planning outcomes in the absence of a clear normative logic. Policy-oriented research further highlights the importance of localizing global development frameworks, as illustrated by the transition from Local Agenda 21 to SDG localization in Miri, where context-sensitive and people-centered strategies proved more effective than uniform indicator applications (Zanudin et al., 2026). In response, this study advances the principle of balance (mīzān) as a normative–analytical framework for managing urban trade-offs, conceptualizing it not as a religious prescription but as a proportional logic that

structures how multiple planning objectives are weighted, aligned, and integrated within human-centered urban development.

Maqāṣid al-Sharīʿah and the Human-Friendly City

Maqāṣid al-Sharīʿah provides a well-established normative framework for evaluating societal outcomes through higher-order objectives such as the protection of life, intellect, wealth, and dignity (Auda, 2008; Dusuki & Abdullah, 2007). While maqāṣid-based approaches have been applied in governance, finance, and sustainability, their integration into indicator-driven urban planning remains limited, particularly in translating ethical principles into measurable planning criteria related to zoning, mobility, public space, and infrastructure. Existing literature indicates that, although concepts such as social balance and participatory governance are increasingly recognized, few frameworks offer a clear normative structure for managing trade-offs among competing urban objectives. Addressing this gap, the present study proposes a maqāṣid-oriented human-friendly framework in which maqāṣid serves as the ethical core and mīzān operates as the balancing logic, thereby linking human well-being, social justice, and sustainability within a coherent, indicator-based evaluative architecture.

Research Gap

Three interrelated gaps are evident. First, human-friendly and livability frameworks often lack an explicit ethical integrator to guide prioritization, a limitation widely noted in contemporary urban planning literature (Sharifi & Yamagata, 2016). Second, Islamic urban scholarship remains largely non-operational in contemporary planning contexts. Third, despite the growing body of maqāṣid-based sustainability research, its translation into urban indicators and governance tools is still limited. These gaps collectively highlight the need for a framework that is both normatively grounded and operationally implementable.

Aim and Objectives

The aim of this study is to develop a maqāṣid-based human-friendly city framework by translating the principle of balance (mīzān) into a structured set of urban planning indicators.

The objectives are to:

1. Conceptualize the human-friendly city as an integrated planning outcome.
2. Theorize mīzān as a trade-off management principle in urban planning.
3. Construct a maqāṣid-informed indicator architecture for human-friendly cities.
4. Propose an implementable framework that complements global benchmarks such as SDG 11.

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Contribution and Significance

This study contributes to urban planning scholarship by introducing a structured normative lens that links human-centered urbanism with explicit trade-off logic, addressing a key gap in integrating ethical reasoning within planning frameworks (Sharifi & Yamagata, 2016). Methodologically, it advances the operationalization of ethical principles through indicator development, while practically offering policymakers a tool for aligning indicator-driven planning with sustainability benchmarks without losing an integrated ethical orientation.

METHODOLOGY

Research Design

This study adopts a qualitative normative–analytical design with a structured indicator development approach, aiming to develop a theoretically grounded and operationally coherent framework for urban planning rather than empirically testing a specific city. It integrates three layers: a normative layer (Maqāṣid al-sharīʿah and mīzān), an urban planning layer (human-centered and sustainability frameworks), and a translational layer that converts these principles into measurable indicators. This multi-layered approach responds to recent calls for integrating normative reasoning into indicator-based planning systems (Sharifi & Yamagata, 2016).

Conceptual Clarification of Mīzān (Balance)

In this study, the principle of mīzān is conceptualized as a structured analytical logic rather than a purely theological proposition. Operationally, balance is defined as a proportional ordering mechanism that manages trade-offs among competing urban objectives while preserving overall human well-being and systemic coherence. This definition enables mīzān to function as a practical trade-off management principle across key planning tensions, including efficiency versus equity, growth versus sustainability, density versus comfort, technological optimization versus human scale, and centralization versus community empowerment. By framing mīzān in this way, the study aligns it with contemporary planning approaches that emphasize balancing competing priorities within complex urban systems, thereby positioning it within mainstream planning theory rather than outside it (Campbell, 1996).

A critical distinction in this study lies in differentiating the concept of mīzān from the generic notion of "balance" commonly employed in planning discourse. In much of contemporary planning literature, balance is typically invoked descriptively to denote moderation or compromise among competing urban objectives; however, it often lacks a structured analytical mechanism for prioritization and proportional evaluation. In contrast, mīzān is conceptualized in

this study as a formalized trade-off logic that functions as a proportional ordering mechanism across interconnected urban indicators. Rather than serving as a rhetorical ideal, mīzān establishes measurable relationships that determine how competing objectives—such as efficiency and equity, growth and sustainability, or density and comfort—should be aligned within a coherent evaluative structure. This interpretation aligns with foundational planning theory emphasizing the need for systematic approaches capable of managing the inherent contradictions of sustainable urban development (Campbell, 1996), while also resonating with contemporary scholarship calling for integrated and coherence-oriented sustainability frameworks (Sharifi & Yamagata, 2016). By embedding mīzān within indicator architecture, the framework transforms balance from an implicit normative aspiration into an operational governance tool that enables transparent prioritization, traceability, and consistency in complex urban decision-making systems.

Analytical Framework for Maqāṣid Translation

The study conceptualizes maqāṣid al-sharīʿah as higher-order societal objectives that can inform planning evaluation. For the purposes of operationalization, five primary objectives are considered:

1. Protection of Life (Health, Safety, Environmental Security)
2. Protection of Intellect (Knowledge, Cultural Infrastructure, Public Space Quality)
3. Protection of Wealth (Economic Access, Mobility, Affordability)
4. Protection of Dignity (Inclusion, Spatial Justice, Non-Discrimination)
5. Ecological Balance (Extended contemporary articulation linked to environmental sustainability)

Each objective is translated into urban domains through a structured mapping procedure.

Literature Synthesis Procedure

To ensure alignment with contemporary planning discourse, this study conducted a structured review of key literature, including human-friendly and livability frameworks, urban sustainability indicators, SDG 11 targets and UN-Habitat metrics, smart city and governance evaluation systems, as well as spatial justice and public space research. The reviewed literature was analyzed using a thematic coding approach to identify recurring indicator domains such as accessibility, health and safety, environmental quality, governance transparency, social cohesion, housing adequacy, and mobility and connectivity. These domains were subsequently cross-referenced with maqāṣid objectives to identify areas of

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conceptual convergence and potential gaps, enabling the integration of ethical principles within indicator-based planning systems. This approach is consistent with established methodologies in urban planning research that employ systematic literature synthesis and thematic analysis to structure complex planning indicators (Sharifi & Yamagata, 2016).

Indicator Development Process

The development of urban planning indicators followed a five-step procedure:
The indicator development process began with domain identification, where urban planning components were consolidated into six macro-categories: urban form and density, mobility and accessibility, public space and social infrastructure, housing and neighborhood quality, environmental systems, and governance and participation. This classification provided a structured foundation for organizing planning indicators.

In the second step, each domain was systematically mapped against the five maqāṣid objectives to establish normative alignment. For instance, mobility and accessibility were linked to the protection of wealth and dignity, public space to intellect and dignity, and environmental systems to life and ecological balance, ensuring that each domain reflected higher-order ethical purposes.

The third step involved balance integration, where potential trade-offs within each domain were identified. Key tensions—such as density versus comfort, surveillance versus privacy, and economic growth versus environmental preservation—were explicitly incorporated, enabling indicators to capture not only performance but also proportional balance.

In the fourth step, indicators were specified through a structured format that included clear definitions, measurement units, data sources (e.g., census, GIS, municipal data), and interpretation logic. This ensured compatibility with existing urban data systems and enhanced practical feasibility.

Finally, a coherence check was conducted to ensure that no single domain disproportionately dominated the framework. The objective was to maintain systemic balance across all domains, thereby shifting the focus from sectoral optimization toward an integrated and proportionally aligned planning approach.

Table 1: The Five-Step Procedural Framework for Developing Maqāṣid-Based Urban Planning Indicators.

Step	Phase	Key Activities & Description	Objective/Outcome
1	**Domain Identification**	Categorizing urban planning components into six macro-categories:	Establishing a structured foundation for organizing indicators.

Step	Phase	Key Activities & Description	Objective/Outcome
		Urban form & density, Mobility, Public space, Housing, Environmental systems, and Governance.	
2	**Normative Alignment**	Mapping each domain against the five *Maqāṣid* objectives (e.g., linking mobility to wealth/dignity, and environmental systems to life).	Ensuring domains reflect higher-order ethical and sharīʿah purposes.
3	**Balance Integration**	Identifying and incorporating potential trade-offs (e.g., density vs. comfort, surveillance vs. privacy, growth vs. preservation).	Capturing proportional balance and performance simultaneously.
4	**Indicator Specification**	Defining clear measurement units, data sources (GIS, Census), and interpretation logic for each indicator.	Enhancing practical feasibility and compatibility with urban data systems.
5	**Coherence Check**	Reviewing the framework to prevent any single domain from dominating the system.	Achieving systemic balance and an integrated planning approach.

Structure of the Indicator Architecture

The resulting architecture is organized as a hierarchical model consisting of four interconnected levels: normative objectives (maqāṣid) at the highest level, followed by urban domains, specific indicators, and measurement metrics. This structured arrangement ensures clear traceability from overarching ethical principles to concrete and measurable planning outcomes, thereby linking normative intent with practical implementation in urban governance.

Validation Strategy

Although this paper does not undertake empirical validation, it proposes three pathways for future research to strengthen the framework's operational credibility: the use of the Delphi method through expert consultation with planners, urban designers, and governance specialists; comparative benchmarking to assess alignment with SDG 11 and established global livability indices; and illustrative case applications involving pilot implementation in mid-

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sized metropolitan areas. Together, these approaches provide a structured basis for testing, refining, and enhancing the practical applicability of the proposed model.

Methodological Limitations

This study is conceptual and indicator-development oriented. It does not include statistical modeling or field-based empirical testing. The indicator list is proposed as a structured framework rather than a finalized index. Empirical calibration and weighting procedures require further applied research.

Delphi Validation Approach

To enhance the methodological robustness and preliminary validity of the proposed indicator framework, a modified Delphi approach was employed. A purposively selected panel of experts in urban planning, sustainability, and shariah participated in the evaluation process, consistent with the use of expert-based consensus methods in planning and indicator development research (Okoli & Pawlowski, 2004). Given the conceptual nature of the framework, the Delphi process was conducted in a single iterative round focusing on three principal evaluation criteria: relevance, clarity, and applicability of the proposed indicators. Experts assessed each indicator using a five-point Likert scale and provided qualitative feedback regarding wording precision, contextual adaptability, and data feasibility. The evaluation results demonstrated a high degree of agreement across the assessed dimensions, with only minor recommendations for refinement. These suggestions were subsequently incorporated into the final indicator architecture. Although preliminary in scope, the Delphi exercise provides an important initial validation layer that strengthens the conceptual credibility, coherence, and practical applicability of the framework, aligning with established practices of expert-informed model refinement in planning and policy research (Hsu & Sandford, 2007).

RESULTS

Indicator Architecture and the Maqāṣid–Mīzān Translation

The results of this study present a structured indicator architecture that translates the principle of balance (mīzān) into measurable urban planning criteria. Rather than introducing a standalone index detached from existing global frameworks, the model operates as a normative overlay that organizes and aligns current urban indicators within a coherent ethical logic. The architecture is hierarchically structured across four interconnected levels—normative objectives (maqāṣid), urban domains, operational indicators, and trade-off logic (mīzān)—ensuring clear traceability between higher-order human objectives and specific planning

metrics. This layered configuration responds to ongoing efforts in urban planning scholarship to enhance coherence and integration within indicator-based governance systems (Meijer et al., 2019), thereby reducing fragmentation and strengthening the interpretability of planning outcomes.

Domain Consolidation: Six Pillars of the Human-Friendly City

Based on a thematic synthesis of contemporary urban planning literature, six macro-domains were identified as the structural pillars of a human-friendly city: urban form and density, mobility and accessibility, public space and social infrastructure, housing and neighborhood quality, environmental systems and resilience, and governance, participation, and digital ethics. These domains reflect widely recognized components of livability and sustainability frameworks in urban studies (Wang et al., 2023). However, the present model distinguishes itself by anchoring these domains normatively through maqāṣid mapping, thereby linking empirical planning dimensions with higher-order ethical objectives.

Translating Maqāṣid into Urban Domains

Each maqāṣid objective informs specific urban domains, creating a matrix-based relationship rather than a linear hierarchy.

The protection of life is operationalized through indicators related to road safety, air quality exposure, access to green spaces, housing adequacy, and heat resilience. These dimensions reflect the well-established relationship between urban environmental conditions and human health outcomes (Wang et al., 2023).

The protection of intellect is translated into access to cultural and learning infrastructure, high-quality public spaces, digital inclusion, and participatory governance. This dimension extends beyond formal education to encompass cognitive well-being, social interaction, and the enabling environments that support knowledge development, as emphasized in studies on public space and social cohesion (Qi et al., 2024).

The protection of wealth is operationalized through indicators such as transport affordability, job proximity, mixed land-use efficiency, and housing affordability. In this framework, economic access is not viewed as mere growth maximization but as the equitable distribution of opportunities across urban populations, aligning with research on accessibility and inclusive economic development (Wey & Huang, 2018).

The protection of dignity is reflected in universal accessibility, mobility equity, anti-discrimination planning practices, and transparency and accountability in governance. Here, dignity is embedded within spatial justice, ensuring inclusive and fair urban environments for all groups, consistent with contemporary governance frameworks (Meijer et al., 2019).

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Finally, ecological balance is expressed through indicators such as urban canopy coverage, stormwater resilience, emissions exposure, and waste management performance. Environmental integrity is thus positioned as a structural condition necessary for sustaining human well-being and long-term urban resilience (Sharifi & Yamagata, 2016).

Table 2: Mapping Maqāṣid Objectives to Urban Planning Domains and Performance Indicators.

Maqāṣid Objective	Urban Planning Domains	Key Performance Indicators (KPIs)
Protection of Life	Health & Safety	Road safety, air quality, green space access, housing adequacy, heat resilience.
Protection of Intellect	Learning & Social Environment	Cultural infrastructure, public space quality, digital inclusion, participatory governance.
Protection of Wealth	Economic Accessibility	Transport/housing affordability, job proximity, mixed land-use efficiency.
Protection of Dignity	Social Justice & Equity	Universal accessibility, mobility equity, anti-discrimination, governance transparency.
Ecological Balance	Environmental Resilience	Canopy coverage, stormwater resilience, emissions, waste management.

Operationalizing Mīzān: Trade-Off Management Logic

The most significant analytical contribution of this study lies in the operationalization of mīzān as a structured trade-off logic within urban planning. Rather than treating indicators as isolated measures, the framework introduces balance categories that guide interpretation and ensure proportional alignment across competing objectives, consistent with broader calls for integrated sustainability frameworks (Sharifi & Yamagata, 2016).

The equity–efficiency dimension emphasizes the need to evaluate indicators such as mixed land-use efficiency and mobility equity gaps together, ensuring that improvements in efficiency do not reinforce spatial or socio-economic inequalities, as highlighted in research on equitable urban accessibility (Wey & Huang, 2018).

The growth–sustainability dimension addresses the tension between economic expansion and environmental resilience by jointly assessing indicators such as housing affordability and energy efficiency, thereby promoting development that remains environmentally responsible and aligned with sustainable urban transitions (Sharifi, 2016).

The density–comfort dimension balances compact urban development with human well-being by linking density measures with overcrowding and perception-based comfort indicators, preventing high-density strategies from

diminishing quality of life, as supported by studies on livable dense urban environments (Lang et al., 2019).

The technology–human scale and centralization–community empowerment dimensions ensure that digital innovation remains people-centered by balancing digital inclusion with privacy safeguards, while aligning participatory planning with governance structures to avoid marginalizing community agency, in line with open governance frameworks (Meijer et al., 2019).

Within this framework, balance is not merely a normative ideal but a measurable cross-check mechanism that systematically ensures proportionality, transforming urban evaluation from isolated performance metrics into an integrated and coherent governance approach that enhances overall urban well-being (Wang et al., 2023).

Table 3: Operationalizing Mīzān: Trade-off Dimensions and Integrated Evaluation Logic in Urban Planning.

Balance Dimension	Competing Objectives (Trade-offs)	Integrated Indicators/Metrics	Purpose of Alignment (Mīzān Logic)
Equity–Efficiency	Resource optimization vs. Spatial justice.	Mixed land-use efficiency & Mobility equity gaps.	Preventing efficiency gains from reinforcing socio-economic inequalities.
Growth–Sustainability	Economic expansion vs. Environmental limits.	Housing affordability & Energy efficiency.	Ensuring development remains environmentally responsible and resilient.
Density–Comfort	Compact urban form vs. Individual well-being.	Density measures & Overcrowding/Perception-based comfort.	Preventing high-density strategies from diminishing quality of life.
Tech–Human Scale	Digital innovation vs. People-centered design.	Digital inclusion & Privacy/Agency safeguards.	Ensuring technology supports rather than marginalizes human needs.
Centralization–Empowerment	Governance structures vs. Community agency.	Participatory planning & Open governance metrics.	Balancing top-down management with bottom-up community empowerment.

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Indicator Distribution and Structural Coherence

The final catalogue comprises 41 indicators distributed across six domains, with each maqāṣid objective linked to multiple domains to avoid reductionism, ensuring that no single domain monopolizes an objective and no objective remains confined to a single sector. This distribution achieves systemic coherence in three key ways: horizontal coherence, where indicators across domains reinforce one another (e.g., transport safety simultaneously supports health and dignity); vertical traceability, whereby each indicator is clearly linked to a higher-order normative objective; and balance integrity, as trade-off pairs prevent unilateral optimization. Consequently, the framework shifts urban evaluation from isolated, single-metric benchmarking toward a model of proportional and integrated governance.

Complementarity with Existing Global Frameworks

The proposed architecture does not compete with SDG 11 or established livability indices; rather, it introduces an explicit normative integrator that clarifies prioritization logic within complex planning contexts. While SDG 11 promotes inclusive, safe, resilient, and sustainable cities, the maqāṣid–mīzān framework specifies how these objectives should be proportionally aligned when tensions arise. This approach is consistent with contemporary urban planning research that emphasizes the need for integrated frameworks capable of managing multidimensional complexity in sustainability governance (Sharifi & Yamagata, 2016). In doing so, it addresses a central challenge of modern urban planning—managing complexity without resulting in ethical fragmentation.

Illustrative Application Potential

Although empirical testing lies beyond the scope of this study, the proposed framework is designed with high adaptability for practical use. Municipal authorities can employ the indicator matrix as a diagnostic tool, integrate it into planning evaluation checklists, apply it in district-level audits, and incorporate it within performance dashboards. Given that the indicators are aligned with existing municipal data systems—such as census data, GIS platforms, utility records, and transport databases—the framework offers strong implementation feasibility and ease of integration into current planning practices. This aligns with contemporary urban governance research emphasizing the importance of data-integrated and interoperable planning systems for effective decision-making (Meijer et al., 2019).

Synthesis of Results

The results demonstrate that maqāṣid can function as a structured normative core for urban evaluation, while mīzān can be operationalized as a practical trade-off

management mechanism within planning systems. Furthermore, the findings show that human-friendly city planning can be translated into measurable indicators without departing from established global standards. This approach aligns with contemporary research emphasizing the integration of human-centered principles within indicator-based urban planning frameworks (Sheikh & van Ameijde, 2022). Accordingly, the framework bridges ethical theory and planning practice, offering a coherent and structured approach to human-centered urban governance.

DISCUSSION

Theoretical Contribution: From Ethical Abstraction to Indicator Architecture

This study advances urban planning theory by introducing a structured normative integrator that bridges ethical principles with measurable planning instruments. While human-centered urbanism, livability indices, and sustainability frameworks offer robust empirical tools, they often lack a clear logic for prioritizing and reconciling competing objectives. The maqāṣid–mīzān framework addresses this gap by positioning maqāṣid as a higher-order normative core that defines human-centered objectives, and mīzān as a trade-off logic that structures proportional alignment among indicators. Rather than embedding religious doctrine, the framework translates ethical balance into a functional governance mechanism, transforming maqāṣid from a moral narrative into a structured evaluative architecture that ensures traceability between planning metrics and broader human outcomes. This approach aligns with contemporary efforts in planning theory to reintegrate normative reasoning into technically driven systems and sustainability frameworks (Campbell, 1996).

Reframing the Human-Friendly City

Contemporary planning discourse frequently employs terms such as “livable,” “inclusive,” “healthy,” or “smart,” yet these concepts are often translated into fragmented indicator sets that lack integrative coherence. The proposed framework reconceptualizes the human-friendly city as a proportionally ordered system rather than a checklist of independent metrics, recognizing that cities may achieve high density, rapid economic growth, and digital innovation while simultaneously undermining housing affordability or social cohesion. In the absence of a balance principle, indicator-driven governance risks optimizing isolated dimensions at the expense of overall well-being, a limitation highlighted in studies on the fragmentation of livability frameworks (Sochacka et al., 2021). By embedding trade-off pairs—such as equity–efficiency and growth–sustainability—the maqāṣid–mīzān model shifts evaluation from performance maximization toward proportional governance, thereby advancing planning

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theory through enhancing systemic coherence, integrating ethical proportionality into quantitative assessment, and offering a structured response to multidimensional urban complexity.

Complementarity with SDG 11 and Global Urban Frameworks

The framework does not compete with existing global sustainability agendas; rather, it clarifies their normative alignment. While SDG 11 promotes inclusive, safe, resilient, and sustainable cities, it often lacks explicit mechanisms for prioritizing among competing objectives when tensions arise, such as between rapid development and environmental conservation. This limitation has been noted in urban sustainability research, which highlights the need for integrative approaches capable of reconciling competing goals (Sharifi, 2016). The mīzān logic introduces an interpretive layer that guides when efficiency gains should be balanced by equity considerations, when growth should be moderated by ecological thresholds, and when technological innovation should be evaluated against human-scale impacts. In this way, the framework functions as a normative overlay rather than an alternative system, enhancing the coherence and interpretability of existing planning metrics.

The proposed maqāṣid–mīzān framework does not replicate existing sustainability agendas such as SDG 11 or established livability indices; rather, it complements them by introducing an explicit normative integrator that clarifies prioritization and trade-off management. While SDG 11 provides a comprehensive set of targets for inclusive, safe, resilient, and sustainable cities, it largely operates through indicator aggregation without specifying how competing objectives should be proportionally aligned in practice. Similarly, livability frameworks offer valuable benchmarking tools but often lack a coherent ethical logic linking indicators to higher-order human outcomes. In contrast, the maqāṣid–mīzān model functions as a normative overlay that structures the relationships among indicators through a proportional governance logic, enabling policymakers to interpret when and how objectives such as efficiency, equity, sustainability, and well-being should be balanced. This approach aligns with contemporary research emphasizing the need to move beyond fragmented indicator systems toward integrated and value-informed urban evaluation frameworks (Sharifi & Yamagata, 2016; Stanislav & Chin, 2019). By embedding ethical proportionality within measurable indicators, the framework enhances the interpretive coherence of SDG-aligned planning and shifts urban evaluation from metric accumulation toward balanced and context-sensitive development assessment.

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Implications for Muslim-Majority Urban Contexts

In cities where planning decisions intersect with culturally embedded normative expectations, the absence of structured ethical translation often results in symbolic rather than operational alignment with values. The maqāṣid-based indicator architecture addresses this gap by integrating widely recognized planning standards with context-sensitive ethical reasoning, while avoiding two extremes: purely technocratic planning detached from normative grounding, and value-based discourse lacking measurable criteria. This challenge has been highlighted in recent research on culturally grounded sustainability frameworks, which emphasizes the need to embed ethical worldviews within operational planning systems (Al-Jayyousi et al., 2022). By operationalizing the principle of balance into concrete indicators, municipalities can align with international benchmarks while articulating a coherent, human-centered planning rationale rooted in culturally resonant principles.

Governance and Policy Relevance

The governance implications of this framework are significant, as it provides local authorities with a diagnostic tool that identifies imbalance rather than merely underperformance—for instance, high economic productivity alongside rising mobility inequity indicates disproportionate efficiency, smart city expansion without privacy safeguards reflects technological overextension, and compact urbanization combined with overcrowding signals density imbalance. Furthermore, the framework promotes cross-departmental coordination by recognizing that each maqāṣid objective spans multiple domains, making siloed planning inadequate and requiring integrated evaluation across urban form, mobility, housing, environment, and governance. This aligns with contemporary research emphasizing integrated and cross-sectoral approaches in urban governance systems (Meijer et al., 2019). Additionally, it supports policy sequencing by using balance logic to guide targeted interventions where disproportions emerge.

Comparison with Existing Livability Indices

Existing livability indices, such as global city rankings, typically aggregate indicators into composite scores without transparent weighting logic; while useful for benchmarking, they rarely clarify the ethical rationale behind indicator selection and prioritization. This limitation has been highlighted in urban planning literature, which notes the interpretive ambiguity and fragmentation within livability assessments (Stanislav & Chin, 2019). In contrast, the maqāṣid–mīzān framework introduces normative explicitness through clearly defined and traceable objectives, enhances trade-off visibility by pairing indicators to reveal underlying tensions, and adopts a balance-oriented evaluation approach in which

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success is assessed based on proportional alignment rather than mere performance magnitude, thereby reframing urban evaluation from competitive ranking toward balanced development assessment.

Conceptual Strengths and Limitations

The framework offers several strengths, notably its integration of normative reasoning into indicator-driven planning and its ability to bridge ethical philosophy with measurable urban metrics, an approach increasingly emphasized in contemporary human-centered planning literature (Sheikh & van Ameijde, 2022). It preserves conceptual integrity without relying on doctrinal language and remains adaptable across diverse urban contexts. However, it is primarily conceptual and requires empirical validation and statistical weighting, reflecting a common limitation in emerging planning frameworks that lack applied testing and methodological calibration (Sochacka et al., 2021). Additionally, applying maqāṣid principles in non-Muslim contexts may require contextual adaptation. Future research should therefore focus on expert validation, pilot testing, and the development of a weighted Urban Maqāṣid Index.

Advancing Ethical Urbanism

At a broader theoretical level, this study contributes to ongoing debates on ethical urbanism by highlighting the limitations of purely technocratic approaches in addressing contemporary urban challenges such as climate crises, social fragmentation, and technological disruption. This critique aligns with contemporary planning scholarship that calls for reintegrating normative reasoning into sustainability frameworks (Campbell, 1996). It argues that planning increasingly requires explicit ethical frameworks capable of navigating complexity while maintaining coherence. In this context, the maqāṣid–mīzān model offers a structured approach that translates the principle of balance into measurable governance logic, demonstrating how ethical principles can function as practical analytical tools rather than merely rhetorical claims.

Synthesis

The discussion highlights that human-friendly city planning requires proportional governance rather than isolated optimization, emphasizing the need to balance competing urban objectives in a coherent manner. This perspective aligns with contemporary planning research that underscores the importance of integrated and human-centered approaches in livability frameworks (Sheikh & van Ameijde, 2022). It demonstrates that mīzān can be operationalized as a structured trade-off management principle, while maqāṣid provides a stable normative anchor that remains compatible with contemporary planning discourse. Furthermore, the proposed indicator architecture serves as a bridge between

culturally grounded values and global urban benchmarks, thereby advancing both the theoretical and practical dimensions of human-centered urban planning.

CONCLUSION

This study develops a structured framework for a maqāṣid-based human-friendly city by translating the principle of balance (mīzān) into operational urban planning indicators. It addresses a key gap in contemporary planning, where existing frameworks often lack a clear normative integrator for managing trade-offs. Using a qualitative normative–analytical approach, the study positions maqāṣid as an evaluative core and mīzān as a trade-off logic, resulting in an indicator architecture that links ethical objectives to measurable planning criteria across six urban domains. The study contributes by integrating normative reasoning into planning theory, operationalizing mīzān as a measurable principle, and aligning the framework with global benchmarks such as SDG 11, thereby shifting evaluation from performance maximization to proportional governance. From a policy perspective, it offers a practical diagnostic tool adaptable to diverse contexts. However, the framework remains conceptual and requires empirical validation and further development, while highlighting the growing importance of ethical urbanism in contemporary planning.

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ALIGNING CULTURAL HERITAGE INNOVATION WITH THE SUSTAINABLE DEVELOPMENT GOALS: PLANNING PERSPECTIVES FROM THE INSPIRE INITIATIVE

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Abstract

Contemporary planning is increasingly recognising that sustainable development is not limited to physical infrastructure and economic growth, but also has a cultural and knowledge dimension. Cultural heritage, when mobilised through innovation and digital transformation has the potential to become a strategic planning resource in line with the Sustainable Development Goals (SDGs). However, its integration into planning frameworks is fragmented and under-theorised. This article discusses how the cultural heritage innovation can be aligned with the SDG agenda from a planning perspective, based on the qualitative case study of the INSPIRE Initiative at the Universiti Sultan Zainal Abidin. Using document analysis and theory-informed thematic analysis, SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 16 (Peace, Justice and Strong Institutions) and SDG 17 (Partnerships for the Goals) are the SDGs that will be focused on. The findings suggest that INSPIRE is a knowledge-based planning model mobilising heritage as a development capital through education, cultural sustainability, institutions and multi-stakeholder partnerships. The article is proposing the Cultural Heritage-SDG Planning Framework and providing policy-relevant insights for those planners aiming to incorporate the cultural knowledge systems into sustainable development strategies in Malaysia.

Keywords: Cultural heritage innovation; Sustainable Development Goals (SDGs); Planning and development; Knowledge based planning; Institutional capacity.

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INTRODUCTION

Contemporary planning and development discourse is increasingly aware that sustainable development can not be achieved through economic growth and physical infrastructure only. The social, cultural and knowledge dimension of development has become an important part of developing resilient communities, inclusive institutions and sustainable cities. Within this context, cultural heritage, which for many years has been seen mainly as an object of preservation, has been progressively redefined as a strategic resource that can contribute to the development planning, social cohesion and long-term sustainability (UNESCO, 2016; Pendlebury, 2013). This shift is especially important in countries that have a rich intangible and documentary heritage where historical knowledge systems, local wisdom and cultural memory are not as widely used in formal planning processes.

The adoption in 2015 of Sustainable Development Goals (SDGs) by the United Nations has helped fuel this paradigm shift even more. Although culture is not formulated as a goal in itself in the SDG framework, it is increasingly recognised as a cross-cutting enabler, supporting several of the goals, notably those concerning education, sustainable cities, institutional strength and partnerships (UNESCO, 2016; United Nations, 2015). In planning practice, this has stimulated new focus on the inclusion of cultural assets, knowledge systems and heritage innovation in development strategies. However, in spite of increasing policy recognition, the process of translating cultural heritage into operational planning instruments is uneven, fragmented and often symbolic rather than operational.

One constant difficulty is the conceptualisation of cultural heritage in planning institutions. Heritage is often seen as a static thing, often limited to conservation areas, museums or archival repositories, rather than as a dynamic source of knowledge that can provide input to current development agendas (Smith, 2006). This narrow understanding of heritage affects the ability of heritage to contribute meaningfully to spatial planning, community development and to policy innovation. As a result, planning frameworks are often seen to fail to exploit indigenous knowledge systems, historical manuscripts and cultural narratives that could otherwise enhance local identity, social legitimacy and community commitment to development processes.

In the Malaysian situation, this challenge is especially pertinent. Malaysia has a huge amount of cultural heritage, such as Malay manuscripts, indigenous knowledge traditions and historical intellectual networks evidence of hundreds of years of interaction with science, governance, medicine and ethics. Yet, these knowledge resources appear to be largely disconnected from mainstream planning and development discourse which still takes a lead in terms of technocratic, sectoral and infrastructure based approaches. While such

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approaches have provided tangible economic consequences, it has also led to a social fragmentation, cultural marginalisation and increasing disconnection between development policies and community values (Yusoff & Ngah, 2019). Recent scholarship in planning studies has therefore argued for more knowledge based and culturally informed planning models especially in the Global South where development paths have to balance modernising processes with cultural continuity (Healey, 2010; Watson, 2014). Within this emerging discourse, innovation has a critical role with more than the technological meaning of the word but also as a process of reconfiguring existing knowledge systems in order to address contemporary challenges. Digital technologies, in particular, have opened new possibilities for transforming cultural heritage from passive archives into an active platform for learning, engagement and policy relevant knowledge production (Giaccardi, 2012).

It is in this larger context of planning and development that the INSPIRE (Research Institute of Islamic Product and Malay Civilisation) Initiative, Universiti Sultan Zainal Abidin (UniSZA) is located as a relevant case study. Mandated by the Malaysian Ministry of Education (Kementerian Pendidikan Malaysia, 2020), INSPIRE operationalises the concept of heritage as development capital in a progressive three-tier model of: it functions as (1) a digital archive for Islamic and Malay world manuscripts (Research Institute of Islamic Product and Malay Civilization, n.d., "Research" section); (2) a collaborative network (SDG 17) with local and international institutions (e.g., Universiti Sultan Zainal Abidin, 2023); and most critically, (3) a wisdom hub that actively interprets This evolution from preservation to knowledge generation makes INSPIRE a prime empirical model to analyse how heritage innovation is translated into actionable planning resources.

Although a great number of heritage related initiatives have been developed across the region, there is a gap in the literature regarding empirical and conceptual studies that explore such initiatives explicitly from a planning perspective. Much of the available literature on cultural heritage innovation is concerned with tourism, conservation or cultural industries, with little attention given to the role of heritage-based knowledge platforms in informing planning institutions, policy formulation and development strategies (Ashworth, Graham & Tunbridge, 2007). As a result, there are often no clear frameworks that planners and policymakers can use to understand the relevance, scale and policy implications of heritage-driven initiatives.

This article aims to remedy this lack by looking at the case study of the INSPIRE Initiative as an example of cultural heritage innovation in line with the SDG agenda analysed using the tool of planning and development studies. Rather than assessing the cultural or historical content of heritage materials as such, the research aims to address the question of how heritage innovation can be

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operationalised with respect to planning frameworks, and contribute to development objectives and the enhancement of institutional capacity. By doing so, the article answers calls for greater incorporation of more integrated and interdisciplinary approaches to planning that recognise culture and knowledge as a central component of sustainable development (UNESCO, 2016; Healey, 2010).

The central research problem guiding this research can be stated as follows: How can cultural heritage innovation be aligned with the Sustainable Development Goals in ways that are meaningful, practical and relevant to planning institutions? To address this question, it is necessary to go beyond normative advocacy and to analyse the role of heritage initiatives as planning resources, how they relate to policy frameworks and what forms of institutional support are needed to sustain these initiatives.

Accordingly, the article aims at three key objectives. First, it seeks to analyse the conceptual background of cultural heritage innovation in the context of the present-day planning and the SDG framework. Second, it considers INSPIRE Initiative as an applied model, in relation to its mechanisms of knowledge mobilisation, institution collaboration and community engagement. Third, it identifies some of the important planning and policy implications emanating from this case, especially in terms of how such initiatives can be integrated into regional and urban development strategies in Malaysia and others that share similar circumstances.

The significance of this study is that it adds to planning scholarship and practice. By making cultural heritage innovation a planning-relevant phenomenon, rather than a marginal cultural activity, the article proposes an alternative lens through which planners and policymakers may approach heritage, in search of sustainable development. In doing so, it strengthens the case that the achievement of the SDGs does not only require technical solutions and economic instruments, but also the strategic mobilisation of cultural knowledge, institutional trust and collective memory as basic elements of the development planning.

METHODS

This study adopts the qualitative case study research method to examine the possibilities of cultural heritage innovation, which can be aligned with the Sustainable Development Goals (SDGs) in the context of planning and development. The qualitative case study method is particularly appropriate for exploring complex, context dependent phenomena where institutional processes, policy interactions and knowledge practices are central to analysis (Yin, 2018; Creswell, 2014). In planning research, case studies are broadly employed to

produce in-depth information on practices, models and frameworks that may not be readily captured through quantitative indicators alone (Healey, 2010).

This study adopts the qualitative case study research method to examine the possibilities of cultural heritage innovation, which can be aligned with the Sustainable Development Goals (SDGs) in the context of planning and development. The qualitative case study method is particularly appropriate for exploring complex, context dependent phenomena where institutional processes, policy interactions and knowledge practices are central to analysis (Yin, 2018; Creswell, 2014). In planning research, case studies are broadly employed to produce in-depth information on practices, models and frameworks that may not be readily captured through quantitative indicators alone (Healey, 2010).

Research Design

The research is designed as an exploratory and analytical case study, with the INSPIRE Initiative as a bounded system of activities, institutional arrangements and development-oriented programmes as its object. Rather than aiming for statistical generalisation, the research looks to aim for analytical generalisation whereby findings from the case are used to inform discussions about planning frameworks, policy integration and sustainable development strategies at a broader level (Yin, 2018). This approach is in line with the goal of the study, which aim to understand how and to what extent cultural heritage innovation is an innovation that is relevant as a planning resource.

A qualitative design is also justified by the nature of cultural heritage innovation itself which involves interpretive processes, knowledge mobilisation and institutional collaboration that are best examined through document analysis and thematic interpretation (Giaccardi, 2012). By placing the analysis in the context of established planning and SDGs discourses, the study results in the gap between empirical observation and conceptual reflection.

Case Selection: The INSPIRE Initiative

The INSPiRE Initiative was chosen as the case study on three major criteria. First, it symbolizes a structured and ongoing attempt to incorporate cultural heritage, especially manuscript based and indigenous knowledge, into the contemporary development agendas using digital innovation. Second, the initiative is part of an institutional framework involving universities, public agencies and community stakeholders, which makes it relevant for planning and policy analysis. Third, INSPIRE explicitly ties its activities to the goals of sustainability, education, community empowerment and institutional collaboration which fit closely with key targets in the SDGs.

In planning research, such information-rich cases are of special value regarding understanding emerging models and practices, which may inform

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policy learning and institutional adaptation (Flyvbjerg, 2006). The selection of INSPIRE is therefore not so much to view it as an exceptional or an isolated initiative as it is to see it as relevant as a representative example of heritage-based innovation, which has planning implications.

Data Sources

Data for the study was obtained from a range of qualitative sources to ensure the robustness of the analysis through data triangulation. The primary sources include:

i. Document analysis, including institutional reports, programme descriptions, strategic plans and project documentation and public communications relating to the INSPIRE Initiative. These documents give insight into the objectives, operational mechanisms and development orientation of the initiative.
ii. Policy and planning documents, such as national development plans, cultural policy statements and frameworks relating to SDGs, placing the initiative in a broader context of planning and governance; and;
iii. Secondary literature such as academic studies on cultural heritage, planning theory, sustainable development and knowledge based development models.

Document analysis is an established method in planning and policy research, especially in the analysis of institutional intent, governance arrangements and strategic alignment with policy objectives (Bowen, 2009). The combination of several document types enables a more complete visitation of cultural heritage innovation (how it is framed, justified and operationalised).

Analytical Framework

The analysis is guided by a thematic analytical framework on mapping the activities and characteristics of the INSPIRE Initiative against selected SDGs that are most relevant to planning and development. Based on the literature and the stated objectives of the initiative four SDGs were identified as the main analytical lenses: SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 16 (Peace, Justice and Strong Institutions) and SDG 17 (Partnerships for the Goals).

The analytical process had three major stages. First, relevant data sections were identified and coded based on thematic categories such as knowledge mobilisation, digital innovation, engagement in the community, institutional collaboration and relevance to planning. Second, these themes have been discussed regarding the targets and principles linked to the selected SDGs.

Third, interpretations of the findings were informed by planning theory specifically concepts concerning knowledge-based planning, institutional capacity and culturally informed development (Healey, 2010; Watson, 2014).

This kind of theory-driven thematic analysis allows the study to go beyond descriptive accounts to an interpretive understanding of the contribution of cultural heritage innovation in the framework of underlying planning objectives. It also enables to identify enabling factors and constraints affecting the integration of heritage initiatives in formal planning and policy framework.

Reliability, Validity and Weaknesses

In order to increase the credibility and reliability of the study, several strategies were used. Data triangulation across multiple sources helps to mitigate the risk of single source bias and enhances consistency of interpretations. The application of tried and tested frameworks in planning and SDGs further justifies analytical validity as this anchors the findings in recognised theoretical and policy discourses (Creswell, 2014).

Nevertheless, there are some limitations to the study. As a single case study, the findings are context-specific, and may not be directly transferable to all planning environments. In addition, since document-based data is relied upon, informal practices and tacit knowledge may not be fully captured. These limitations are recognized as inherent to exploratory qualitative research and these are managed by focusing the results as analytical insights rather than prescriptive solutions.

Table 1: Mapping of Data Sources, Analytical Themes and Sustainable Development Goals (SDGs)

Data Source	**Key Data Focus**	**Analytical Theme**	**Relevant SDG**	**Planning Relevance**
INSPIRE institutional reports and programme documents	Objectives, programme design, implementation strategies	Knowledge mobilisation and heritage innovation	SDG 4 (Quality Education)	Supports lifelong learning, knowledge-based development and educational planning
Digital manuscript platforms and heritage	Digitalisation processes, content accessibility,	Digital innovation and cultural sustainability	SDG 11 (Sustainable Cities and Communities)	Enhances cultural identity, place-making and

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Data Source	Key Data Focus	Analytical Theme	Relevant SDG	Planning Relevance
innovation outputs	user engagement			community resilience
Strategic plans and collaboration records	Institutional partnerships, governance structures	Institutional capacity and collaboration	SDG 16 (Peace, Justice and Strong Institutions)	Strengthens institutional legitimacy, governance and trust
Inter-agency and community engagement documentation	Multi-stakeholder participation, network formation	Partnership and stakeholder integration	SDG 17 (Partnerships for the Goals)	Facilitates integrated planning and cross-sectoral coordination
National development plans and SDG policy frameworks	Alignment with national and global sustainability agendas	Policy alignment and development integration	SDG 11, SDG 16	Ensures coherence between heritage initiatives and planning policies
Academic and policy literature	Conceptual framing, comparative insights	Knowledge-based and culturally informed planning	SDG 4, SDG 11	Provides theoretical grounding for planning innovation

Table 1 illustrates the analytical mapping between data sources, thematic categories and selected Sustainable Development Goals. This mapping provides a structured framework for examining how cultural heritage innovation within the INSPIRE Initiative aligns with planning-relevant sustainability objectives. By explicitly linking empirical data to SDG themes, the analysis ensures conceptual clarity and policy relevance within a planning and development

RESULTS AND DISCUSSION

Cultural Heritage Innovation and the SDG 4: Quality Education

One of the most obvious points of correspondence between the INSPIRE Initiative and the Sustainable Development Goals lies in its contribution to SDG 4 (Quality Education). Within planning and development discourse, education is increasingly being seen as not merely referring to formal schooling, but as an ecosystem of lifelong learning and access to knowledge and intellectual power (UNESCO, 2016). From this perspective, the digitalisation and activation of

manuscript heritage carried out by INSPIRE is a kind of educational innovation that is going beyond the conventional curricular frameworks.

Rather than addressing manuscripts and heritage materials as specialist or elite knowledge that is restricted to archives, INSPIRE redefines them as resources for learning for students, educators and the wider public. This approach is consistent with the emerging planning literature that emphasises on the role of knowledge infrastructure in supporting inclusive development (Healey, 2010). By making heritage accessible as digital platforms and interpretive content, the initiative plays a role in lowering barriers to access knowledge, especially to those communities that may be marginalised by geographic or institutional location.

From a planning perspective, this educational dimension has more general implications. Knowledge-based development models state that learning environments, both formal and informal, play a crucial role in the formation of human capital and social resilience (Watson, 2014). INSPIRE's activities therefore address SDG 4 not only through preserving cultural knowledge but also though putting that knowledge in a development-oriented learning ecosystem. This is a challenge for planners to reconsider education-related indicators, going beyond school infrastructure and including cultural knowledge platforms as part of planning strategies for human development.

Cultural Heritage Innovation and the Achievement of SDG 11 - Sustainable cities and Communities

The aligning with SDG 11 (Sustainable Cities and Communities) can be seen in the way that INSPIRE contributes to the cultural sustainability, place identity and community cohesion. Sustainable urban and regional development is increasingly recognising that physical infrastructure is not enough to build communities that are liveable and resilient; cultural meaning, historical continuity and social attachment play equally important roles (Pendlebury, 2013).

Through its focus on heritage innovation, INSPIRE assists in the preservation and reinterpretation of cultural memory as a living part of the present-day development. Digital heritage platforms in this sense serve as tools of place-making, both in the re-enforcement of common narratives and collective identity. Planning theory has proposed that such narratives are a must if it is to facilitate community participation and long-term stewardship of urban and regional environments (Smith, 2006).

In the Malaysian context where rapid urbanisation has often seen returns in the homogenisation of space, initiatives such as INSPIRE provide alternative pathways in the sustainable development of a community. This is relevant to local studies, for example those from Ismail and Ahmad (2021), showing how the integration of cultural heritage in urban planning can help develop place identity and community resilience in historic cities, such as George Town. By bringing

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manuscript heritage and local knowledge into public discourse, the initiative plays a role in developing cultural distinctiveness without detaching from modernisation. This balance between continuity and change is one of the key principles of SDG 11 and a constant challenge for planners working in fast developing regions.

Importantly, and in contrast to the notion that the relevance of INSPIRE to SDG 11 is in the physical conservation results, it is in its capacity to integrate cultural sustainability into development thinking. This increases the scope of planning activities beyond zoning and land use, so that planners tend to focus on integrating intangible cultural dimensions in urban and regional strategies.

Cultural Heritage Innovation and SDG 16: Peace, Justice and Effective Institutions

The link between cultural heritage innovation and SDG 16 (Peace, Justice and Strong Institutions) is less obvious at first, but is also as important from a planning and governance point of view. Strong institutions may be characterized not only through administrative efficiency, but also through legitimacy, trust and social embeddedness (United Nations, 2015).

Cultural knowledge is a part of what INSPIRE contributes to these dimensions as a public resource that strengthens institutional credibility. Through the involvement of communities, academics and public agencies in heritage-based knowledge-related programmes, a sense of community ownership, and openness is created. Planning research emphasizes that institutions seen to be culturally disconnected tend to find it difficult to win people's trust, which undermines policy implementation (Healey, 2010).

Furthermore, heritage innovation is also supportive of SDG 16 on promoting inclusive narratives and historical awareness as an essential part for social cohesion in plural societies. This is echoed in the work of Omar and Mohd Noor (2020) and the emphasis that they lay down on the role of community participation in heritage conservation as a means of strengthening institutional legitimacy and public trust in Melaka. Rather than giving precedence to one authoritative discourse over the other, digital heritage platforms do not dismiss the possibility of interpretive plurality, including the possibility for institutions to play a facilitative role rather than as mere regulator. This participatory orientation is familiar to the current generation of governance models which focus on collaborative planning and deliberative processes (Watson, 2014).

From a policy perspective, the INSPIRE Initiative is a clear example of how cultural heritage can serve as an institutional asset, providing solid social ground on which planning decisions are made. This reframing presents a challenge for planners in that it requires them to think about governance capacity

in such a way that they not only think about the technical capacity, but also the cultural legitimacy, and the continuity with the past.

Cultural Heritage Innovation and the SDG 17: Partnerships for the Goals

The best match between INSPIRE and the SDG is arguably SDG 17 (Partnerships for the Goals). Contemporary planning is increasingly relying on cross-sectoral collaboration because complex development challenges go beyond the capacity of single institutions (United Nations, 2015). INSPIRE is a good example of this approach with the multi-stakeholder model that brings together academic institutions, government agencies, cultural organisations and local communities.

Such partnerships are not just operational arrangements, but act as knowledge networks to facilitate the circulation of expertise, resources and legitimacy. Planning literature emphasises on the importance of relational capacity, which is the ability of the institutions to work across the boundaries in achieving the sustainable development outcomes (Healey, 2010). INSPIRE's collaborative structure therefore contributes to its relevance as a planning-oriented project, as opposed to a cultural project per se.

The partnership dimension is also an aspect of policy scalability. Heritage initiatives tend to get stuck at the pilot stage because of fragmentation and lack of coordination of institutions. By having collaboration as part of the core structure, INSPIRE has shown the value of heritage innovation in relation to enduring and scaling it across wider development ecosystems. This has direct implications for planners who are looking to operationalise SDG 17 in the national and regional development frameworks.

INSPIRE as a Knowledge Based Planning Model

Taken together, then, the alignments with SDG 4, 11, 16 and 17 place the INSPIRE Initiative in the position of a knowledge-based planning model as opposed to a conventional heritage programme. Its significance cannot be attributed to the amount of the digitised materials and the amount of activities that have been conducted, but rather in the way that it reconfigures the notion of cultural heritage as a form of development capital.

This model connects with emerging planning paradigms that focus on learning, collaboration and cultural intelligence as building blocks of sustainable development (Watson, 2014). By integrating heritage innovation into education, community development, institutional governance and partnerships, INSPIRE shows a holistic approach that is close to that of the integrated nature of the SDG agenda.

However, there are also several challenges presented in the discussion. The process of integrating heritage innovation into the formal planning systems is still limited by regulatory frameworks which ascend physical development

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indicators. In addition, maintaining cross-sectoral partnerships requires the support of institutions and policies over the long term. These challenges make the need for planners to come up with new evaluative tools and policy mechanisms that recognise the legitimacy of cultural knowledge as a component of development planning.

POLICY IMPLICATIONS AND PLANNING RECOMMENDATIONS

The analysis of the INSPIRE Initiative proves that cultural heritage innovation can be used as a strategic planning resource, if it is institutionally supported, digitally enabled and linked to the Sustainable Development Goals. This section presents some of the important policy implications and planning recommendations based on the case study with relevance to planning institutions, local authorities and development agencies in Malaysia.

Changing the Policy of Cultural Heritage as Development Capital

A key policy implication of this study is the importance of reorienting cultural heritage in terms of planning as a form of development capital, as opposed to a sectoral or ancillary issue. Existing planning instruments and plans, such as structure plans and local plans, tend to focus on physical infrastructure, economic indicators and land use efficiency. While these dimensions are critical, the results show that the cultural knowledge systems cannot be ignored if sustainable development strategies are to be long-term and socially legitimate.

Therefore, planning policies should explicitly recognise the contribution of cultural heritage innovation; in particular of knowledge-based and digital heritage initiatives to human development, community resilience and institutional strength. This may be operationalised including cultural knowledge indicators in planning assessments, e.g. accessing heritage-based learning resources, community participation in cultural programmes and institutional collaboration around heritage innovation (UNESCO, 2016). Such indicators would enable planners to assess the outcomes of development in ways beyond physical and economic indicators.

Incorporating Cultural Heritage Innovation in Planning Instruments

A second implication is that of heritage innovation in formal planning instruments. While heritage has been addressed in many cases by conservation guidelines or special zones, the INSPIRE case demonstrates the potential of non-spatial knowledge-based heritage initiatives to support planning objectives.

Local authorities and planning agencies might want to consider including heritage innovation strategies as part of structure plans, local plans and sectoral development policies. For example, digital heritage platforms may be aligned with education planning, programmes for developing communities and

smart cities. This approach involves bringing heritage out of policy policy silos and into mainstream development planning.

From the point of view of governance this integration needs inter-departmental coordination, especially to the planning units, cultural agencies and educational institutions. The INSPIRE Initiative is a great example of how such coordination can improve policy coherence and limit fragmentation, a long-term challenge in development planning (Healey, 2010).

Strengthening Institutional Capacity and Governance using Heritage Innovation

The convergence of the innovation of cultural heritage and the SDG 16 (Peace, Justice and Strong Institutions) appear to indicate that heritage-based initiatives can build institutional capacity if they are placed in a governance framework. Cultural knowledge in which institutions are engaged are more likely to be perceived as legitimate, inclusive and responsive to community values.

Policy frameworks should therefore support planning institutions to take a participatory and cultural approach. This may involve supporting heritage knowledge platforms as tools for public engagement, consultation and policy communication. By using stories and knowledge from culture and history, the planners can increase the public's understanding of development policies and create trust between institutions and communities (United Nations, 2015).

In addition, capacity-building programmes of planners and public officials with exposure to cultural heritage innovation and knowledge-based development models. This would provide planning professionals with the conceptual and practical tools they need to bring cultural dimensions into policy formulation and implementation.

Institutionalising Multi-Stakeholder Partnership for Sustainable Development

The importance of multi-stakeholder partnerships in operationalising planning on a SDG-aligned process is underlined under the INSPIRE Initiative. Effective partnerships go beyond ad hoc collaboration and require institutional mechanisms to support a long-term engagement, sharing of resources and decision-making.

Planning policies should, therefore, give formal recognition and support for partnerships between academic institutions, cultural organisations, community groups and public agencies. This may include the setting up of joint planning committees, joint funding schemes or knowledge-sharing platforms that will enable continued interaction. Such arrangements are in line with modern planning paradigms that emphasise collaborative governance and networked planning (e.g. Healey, 2010).

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Moreover, partnerships grounded in cultural heritage innovation provide planners with a way of bridging the gap between technical planning processes and community knowledge and lived experiences. This integration increases the relevancy and acceptability of development strategies, especially in cultural diverse situations.

Cultural Heritage-SDGs Planning Framework Development

Based on the findings, this study proposes the development of a Cultural Heritage-SDG Planning Framework as a planning guide for planners and policy makers. Such a framework would explain the role of heritage innovation in the context of achieving more than one SDG at once, offering a way of structuring how to integrate policies.

Some of the key components of the framework may include:

i. Knowledge mobilisation - using heritage resource for education, learning and innovation (SDG 4).
ii. Cultural sustainability - heritage narratives in the urban and regional development strategies (SDG 11).
iii. Institutional legitimacy - drawing upon cultural knowledge to support governance and the public trust (SDG 16)
iv. Partnership mechanisms - supporting cross-sectoral cooperation and policy coherence (SDG 17).

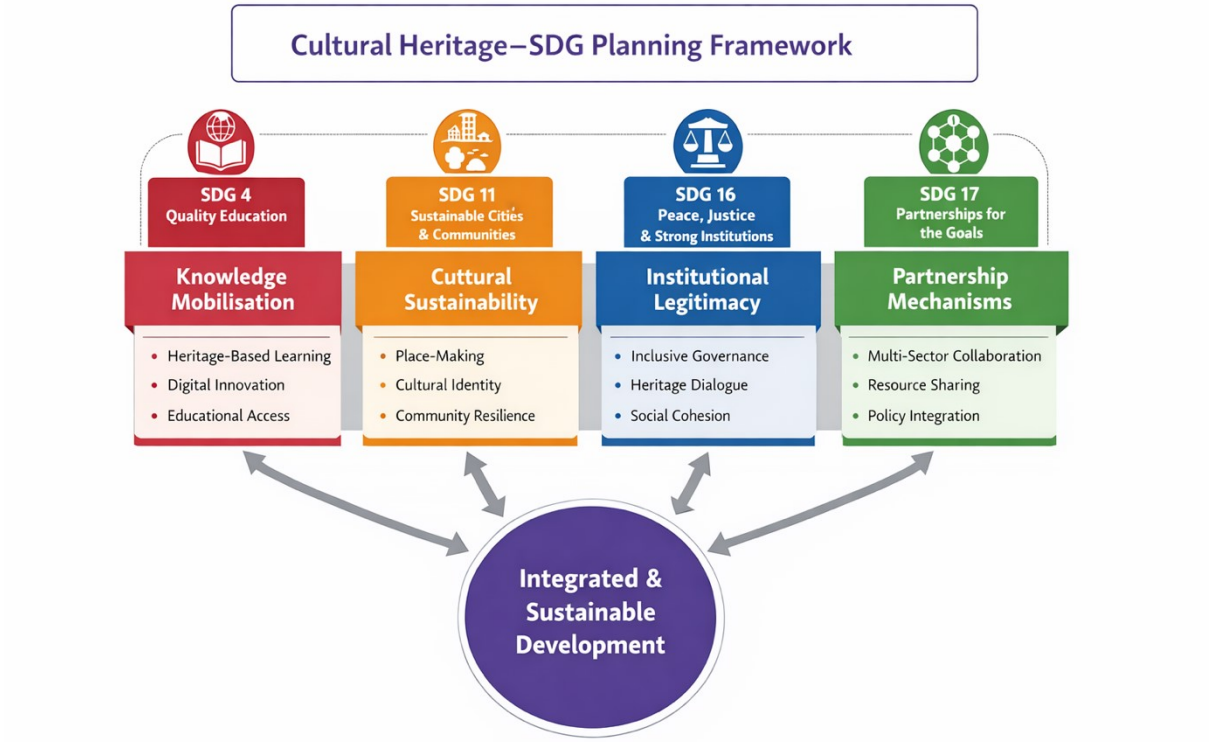
By adopting such a framework it is possible for planning institutions to move to more integrated, culturally informed and sustainable development models. This approach is not alien to Abdullah and Hassan (2019) who suggest a knowledge-based development framework that makes cultural sustainability a key element of urban planning in Malaysia.

Implications for Malaysian Planning Practice and More

For Malaysia where development planning is carried out in a culturally rich and plural social setting, the implication of this study is particularly pertinent. Integrating cultural heritage innovation into planning practice provides a way of achieving the SDGs in a way that is locally based and socially sustainable. At the same time, the insights gained from the INSPIRE Initiative are transferable to other contexts in the Global South where similar problems of cultural marginalisation and institutional fragmentation continue to exist.

Ultimately, the policy implications outlined in this section support the argument that the planning for sustainable development must involve not only a spatial dimension and an economic dimension, but also a cultural dimension and a knowledge foundation of society. Cultural heritage innovation, if well

integrated within planning and policy frameworks, is a valuable yet under-used resource for the further implementation of the SDG agenda.



CONCLUSION

This manuscript has contributed to a conceptual and strategic re-thinking of cultural heritage as a crucial driving force in the Sustainable Development Goals (SDGs) and not a side or symbolic concern. By proposing the Cultural Heritage-SDG Planning Framework the study shows that heritage - by mobilising knowledge systems, institutional legitimacy, cultural sustainability and strategic partnerships - can serve as an integrative axis for inclusive and sustainable development.

The framework puts knowledge mobilisation in the foreground as a fundamental pillar, and brings cultural heritage to the intersection of SDG 4 by rethinking of heritage as a living epistemic resource. Through teaching, digital innovation and public involvement, heritage goes far beyond the preservation of archives, to become a means of inter-generational learning and capacity building

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for society. This shift is of particular relevance in the context where the deployment of indigenous knowledge, traditional wisdom and historical memory, has been marginalised for a long time within formal development paradigms.

Equally important, the pillar of cultural sustainability enhances the role of heritage in the construction of resilient communities, sustainable urban and rural environments in relation to SDG 11. By taking the concepts of place-making, cultural identity and community participation into account in the development planning, heritage comes out as a stabilising force that can contribute to strengthening the sense of social belonging, while counteracting the homogenising pressures of globalisation. This perspective criticises models of sustainability that focus on the technocratic dimensions of human well-being at the expense of the cultural dimensions of human well-being.

The framework further highlighted institutional legitimacy to be a key condition for sustainable development which speaks volumes in connection with SDG 16. Heritage-based governance if based on inclusiveness, dialogue and social cohesion helps to strengthen public trust and credibility on policy. In this regard, cultural heritage is not only an object of protection, but also normative resource that supports the work of ethical governance, conflict mediation and participatory decision-making.

Finally, the focus on partnership mechanisms is reflective of the need for multi-sectoral partnership that is called for by SDG 17. There are synergies needed between academic institutions, government agencies, civil society, cultural practitioners and international partners in order to have effective heritage-led development. The framework shows that such partnerships are not add-ons, but structural enablers which ensure heritage initiatives are able to scale along with being financially viable and achieving long-term policy integration.

Taken together, the Cultural Heritage-SDG Planning Framework is meant to be the conceptual as well as the practical planning tool. It offers a coherent framework for policy makers, researchers as well as development practitioners to integrate cultural heritage initiatives in the global agendas for sustainability without being too prescriptive or abstracted from local contexts and epistemologies. More broadly, according to the paper, the concept of sustainable development without a cultural grounding is at risk of becoming socially fragile and ethically hollow.

Future research may consider testing this framework empirical in different socio-cultural contexts, evaluate the applicability of this framework in digital and post-pandemic development contexts, and refine its indicators to evaluate policy contexts. Nonetheless, this manuscript proves that cultural heritage, if well planned and institutionally supported, has a transformative potential in changing an integrated, inclusive and truly sustainable development agenda.

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HARMONIZING SDG 16 'PEACE, JUSTICE, AND STRONG INSTITUTIONS' WITH *MAQĀṢID AL-SHARĪ'AH*: A COMPARATIVE ANALYSIS

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Abstract

In contemporary society, various factors threaten global peace and security, making issues of justice, peace, and institutional strengthening pivotal in global discourse. These elements are central to the Sustainable Development Goals (SDGs), particularly in promoting inclusive and resilient institutions. This paper explores the role of institutional strengthening in achieving peace and justice through the lenses of both the SDGs and the principles of Maqāṣid al-Sharīʿah. The study adopts a qualitative approach, employing content analysis of relevant literature related to the SDGs and Maqāṣid al-Sharīʿah. Data analysis is conducted using descriptive and comparative methods to fulfill the study's objectives. The findings reveal a significant alignment between the goals of sustainable development and the objectives of Islamic law (Maqāṣid al-Sharīʿah). The strengthening of political, social, and economic institutions, in accordance with the principles of Maqāṣid al-Sharīʿah, typically involves two key mechanisms: the promotion of public welfare (jalb al-manāfiʿ) and the prevention of harm (darʾ al-mafāsid). Given the pressing global challenges, the latter mechanism is particularly vital. Furthermore, the concept of Islamic governance, or Siyāsah Sharʿiyyah, empowers leaders to address these threats effectively within their jurisdictions. Therefore, in addition to considering the principles of Maqāṣid al-Sharīʿah, efforts to realize and promote sustainable development should also be reinforced by insights derived from Siyāsah Sharʿiyyah, to forge resilient institutions capable of fostering long-term peace, justice, and societal harmony in an increasingly complex global landscape. Ultimately, this paper proposes a strategic policy framework that synthesizes Maqāṣidic principles with SDG 16 targets, offering actionable governance implications for contemporary institution-building.

Keywords: *Maqāṣid Sharīʿah*, Peace, Justice, SDG 16, *Siyāsah Sharʿiyyah.*

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INTRODUCTION

The Sustainable Development Goals (SDGs) represent a global consensus to address systemic governance and development challenges, aiming for a sustainable future by 2030 (Long et al., 2023). Central to the United Nations (UN) 2030 Agenda is a mission to eradicate poverty, safeguard the environment, and promote universal peace (Shahyrar, 2024; Ghosh & Chakravarty, 2024). Building upon the Brundtland Commission's definition, sustainable development necessitates fulfilling present needs without compromising the ability of future generations to meet theirs (Gram-Hanssen, 2012; Haliza, 2013b). This multidimensional balance requires an intricate integration of environmental, social, and economic pillars to ensure holistic human well-being (Zanudin et al., 2026).

Among the 17 goals, SDG 16 serves as a foundational pillar by addressing the critical necessity for peace, justice, and strong institutions. It seeks to curb corruption, violence, and organized crime while fostering participatory governance (Karl et al., 2022; Fallah & Shayyan, 2022). By upholding the rule of law through transparent public institutions, SDG 16 envisions a framework where individuals live free from fear (Md. Dali et al., 2016; UN, 2022). However, global progress remains stymied by climate emergencies, economic stagnation, and the lingering effects of the COVID-19 pandemic, leading to warnings that the 2030 Agenda faces significant risks of failure without immediate intervention (UN, 2023).

The structural integrity of SDG 16 is currently threatened by two major crises: violence and corruption. Human trafficking remains a persistent threat to global stability (Rashila & Nor Azzizan, 2013; UN, 2023b), while rampant corruption in the judiciary and law enforcement costs an estimated USD 1.26 trillion annually (World Economic Forum, 2019; Commissioner for Human Rights, 2021). These governance failures extend to public procurement, where collusive practices add billions to global costs (Bosio, 2021; Kawai & Nakabayashi, 2022; Decarolis & Giorgiantonio, 2022a). Beyond economic loss, the human cost is devastating; conflict-affected regions have seen millions of children drop out of school, leaving them vulnerable to exploitation and hindering long-term societal development (Elin et al., 2013; UNICEF, 2017).

To overcome these global failures, there is an emerging need to ground institutional frameworks in robust ethical paradigms. From an Islamic perspective, social justice is not merely a policy goal but the cornerstone of a prosperous society (Usman & Adeel, 2014). Islamic governance, rooted in the *Maqāṣid al-Sharīʿah* paradigm, emphasizes justice and moral responsibility as essential pathways to *al-falāḥ* (true success) (Fakhri, 2014; Uula & Darwis, 2023). By safeguarding the five essential values: *dīn* (religion), *nafs* (life), *ʿaql* (intellect), *nasl* (lineage), and *māl* (wealth or property), this paradigm aligns naturally with the core tenets of

sustainable development (Ahmad Sarkawi et al., 2008; Mahaiyadin, 2017; Harahap et al., 2023)

Therefore, this study aims to synthesize a strategic governance framework that harmonizes SDG 16 with the *Maqāṣid al-Sharī'ah*. By examining the tiers of *ḍarūriyyāt* (necessities), *hājiyyāt* (complementary needs), and *taḥsīniyyāt* (embellishments), it explores how this classical Islamic framework can bolster institutional resilience and global security (al-Shalabi, 2002; Abdul Rasool, 2020). Furthermore, the research positions Islamic ethical governance as a constructive, complementary model for realizing the UN's vision of international peace and justice, leveraging selected institutional applications to offer high-level policy guidance.

METHODS

This research utilizes a qualitative, library-based methodology, integrating primary and secondary data to fulfill the study's objectives. Authoritative documents from UNESCO, UNICEF, and the UN, alongside academic studies on SDG 16, were selected for their relevance and significance. Complementary sources on *Uṣūl al-Fiqh* and *Maqāṣid al-Sharī'ah* were further employed to facilitate a comparative analysis from an Islamic perspective. The data were analyzed using content analysis to identify key themes, while descriptive and comparative approaches were applied to highlight conceptual parallels and distinctions. This rigorous approach ensures that the findings are impactful, contributing to academic discourse and the development of inclusive, justice-oriented policies. While fundamentally a conceptual analysis, the study contextualizes its findings through the lens of specific institutional mechanisms to demonstrate practical policy implications.

RESULTS AND DISCUSSION

Maqāṣid Sharī'ah and the SDGs

The *Maqāṣid Sharī'ah* framework offers a complementary perspective on the SDGs' aspirations for peace, justice, and institutional development. Its core objectives (namely safeguarding religion, life, intellect, lineage, and property) serve as a comprehensive guide for achieving holistic human development (Kamali, 2008; Fares & Younes, 2021). In the context of institutional development, these objectives align with SDG 16 by promoting justice and good governance. Just as SDGs advocate for the eradication of violence, inequality, and corruption, *Maqāṣid Sharī'ah* emphasizes the need for institutions that safeguard public welfare and justice.

From the Islamic perspective, justice (*'adl*) is a fundamental principle for ensuring societal harmony and development. The *maqāṣid* approach ensures that

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the *ḍarūriyyāt* (necessities) are protected while facilitating *hājiyyāt* (complementary needs) and *taḥsīniyyāt* (luxuries) that contribute to human flourishing (al-Ghazali, 2007). For example, in striving for economic justice, Islamic teachings promote wealth redistribution mechanisms like *zakat*, which ensures that wealth circulates within society to avoid concentration in a few hands, thus contributing to social equity, a goal echoed by the SDGs.

The SDG indicators emphasize reducing violence, ensuring accountability, and building transparent institutions by 2030 (UN, 2022). Likewise, *Maqāṣid Sharīʿah* underscores the need to establish justice systems that are responsive, inclusive, and grounded in fairness. The intersection of these frameworks reveals a shared commitment to institutional integrity, social justice, and the protection of human dignity.

The Prophetic Foundations of Institutional Governance: Aligning SDG 16 with the Maqāṣid Paradigm

Strengthening institutions and ensuring security are crucial pillars for societal development. Historically, these elements are deeply ingrained in Islamic governance, as demonstrated by the actions of the Prophet Muhammad when establishing social and governmental institutions upon his arrival in Medina. These foundational institutions such as mosques, markets, and military structures, served as critical components for sustainable civilization growth, in line with the core purposes of Islamic law (*Maqāṣid Sharīʿah*) demonstrated by the actions of the Prophet Muhammad when establishing social and governmental institutions upon his arrival in Medina (Fadzli et al., 2026).

In Qur'anic discourse, the notion of peace (referred to as *al-amn*) is mentioned 45 times, while the term faith (*īmān*) appears over 800 times (Burhanuddin et al., 2017). This frequent emphasis on peace, trust, and security underscores their significance in Islamic governance. In the context of *Maqāṣid Sharīʿah*, peace and security are classified as *maṣlaḥah ḍarūriyyāt*: the indispensable necessities for human life, society, and state stability.

The Prophet Muhammad used the analogy of passengers on a ship (*al-Rukkab al-Safīnah*) to describe the necessity of safeguarding communal welfare and preventing societal collapse. If passengers on the lower deck were to pierce the ship's hull to access water, the entire vessel would be at risk of sinking (al-Bukhari, 2001; Hesham, 2003). This allegory underlines the critical need for proactive institutional policies that prioritize collective security over individual liberties when public welfare is threatened.

Maqāṣid al-Sharīʿah, referring to the higher objectives of Islamic law, constitute a normative framework that seeks to uphold human welfare (*maṣlaḥah*) and avert harm (*mafsadah*). Scholars such as 'Izzu-l-dīn 'Abd al-Salām (2002) and al-Shāṭibī (1992) have categorized these objectives into three tiers:

1. *Al-Ḍarūriyyāt* (necessities), which is crucial for survival and without which societal collapse occurs;
2. *Al-Ḥājiyyāt* (complementary needs), which facilitates comfort and ease of life, though their absence does not lead to destruction; and
3. *Al-Taḥsīniyyāt* (embellishments or luxuries), which enhance the beauty and quality of life but are not essential to its continuation.

These categorizations reflect a comprehensive understanding of societal well-being, aligning with the aims of both *Maqāṣid Sharī'ah* and the SDGs.

From an Islamic perspective, the promotion of peace and security aligns with the very etymology of Islam, derived from the root word silm, which signifies peace and submission. The Qur'anic verse al-Baqarah (2:126) illustrates this through Prophet Ibrahim's supplication for a secure and peaceful land, emphasizing that submission as a servant of God is the foundation for attaining societal peace. Likewise in verse al-Nūr (24:55), the Qur'an articulates a divine pledge wherein God assures believers who perform righteous deeds and worship Him without association (*shirk*) that they shall be granted security and protection from threats. This underscores that the promised stability in human life and peace (*amn*) are not merely social ideals, but divine bestowals contingent upon moral and spiritual integrity.

It is also worth noting that hadith literature reinforces this emphasis. For example, from Anas R.A, the Prophet is reported to have said, "*Feed the hungry, spread peace, speak kind words, and pray at night when people are sleeping. You will enter Paradise in peace*" (al-Bazzar, 1988). Similarly in another hadith, the Prophet assured divine reward for those who promote peace and give food to others (Ibn Hibban, 1988). These traditions collectively illustrate that peace is not only a societal responsibility but also a means to attain divine rewards.

Maqāṣid al-Sharī'ah, therefore, serves as a comprehensive framework for strategic policy formulation in the institutionalization of peace and justice by advancing the safeguarding of five essential objectives, namely: religion, life, intellect, dignity, and property. From a governance and planning perspective, institutions (especially those entrusted with the administration of justice and the maintenance of security) serve as the operational mechanisms to ensure these objectives are translated into measurable policy outcomes, safeguarding both societal harmony and individual rights.

Harmonizing SDG 16 with Maqāṣid Sharī'ah

The aims of SDG 16, which encourage 'peace, justice, and strong institutions,' align closely with the tenets of *Maqāṣid Sharī'ah*. Both frameworks stress the importance of robust institutions for achieving sustainable societal welfare. In

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Islamic tradition, institutional management and integrity are rooted in the principles of *Siyāsah Sharʿiyyah* (Islamic Governance), which prioritize the welfare of society through the establishment of just, transparent, and accountable institutions (Atwah, 1993; Luqman & Saim, 2013; Ahmad Shukri & Rosli, 2021).

The concept of *maṣlaḥah* (public welfare), a cornerstone of *Maqāṣid Sharīʿah*, extends to the regulation of institutions for both development and protection. Islamic legal tradition recognizes the authority of governing bodies to regulate societal affairs in line with public welfare, even in cases where explicit Sharia texts may not mandate specific actions (Wan Mohd Yusof et al., 2024). This flexibility allows Islamic governance to align with modern standards of institutional management, as seen in the SDGs, while remaining rooted in traditional ethical values.

Briefly, fostering peace, justice, and strong institutions is a shared goal between *Maqāṣid Sharīʿah* and the SDGs. Both frameworks advocate for the development of robust institutions that safeguard societal welfare, security, and justice. For the successful realization of these goals, it is imperative that governments, civil society organizations, and relevant stakeholders forge collaborative partnerships aimed at reinforcing institutional integrity, transparency, and accountability across all tiers of governance. As Ibn ʿĀshūr (1998) emphasizes, justice is a foundational principle in both governance and religion, guiding the ethical management of societal affairs.

Institutional Frameworks for Realizing Public Welfare (Maṣlaḥah)

Institutional frameworks are paramount in ensuring the administration, execution, and regulation of a country's governance, leading to just and sustainable societies. The judiciary and legislative bodies, particularly the courts, are essential in upholding justice. In line with *Maqāṣid Sharīʿah*, justice (*ʿadl*) is a critical value that transcends race, religion, and social status (Mohamad et al., 2014; Wan Chik et al., 2018). As emphasized in the Qur'anic verse of al-Nisā' (4): 58: "*Indeed, Allah commands you to render trusts to whom they are due and when you judge between people to judge with justice. Excellent is that which Allah instructs you. Indeed, Allah is ever Hearing and Seeing*".

Hence, institutions that safeguard their citizens such as military and police forces are indispensable for the preservation of life (*ḥifẓ al-Nafs*), one of the essential objectives (*ḍarūriyyāt*) in *Maqāṣid Sharīʿah*. These institutions are critical in ensuring defense, security, and safety, as these are essentials for a functioning society, enabling the fulfillment of both individual and collective responsibilities.

Islamic law (s*harīʿah*) emphasizes not only the advancement of human well-being (Mohamad et al., 2018; Shuid et al., 2018; Md. Ali et al., 2022) but also the prevention of harm. The institutionalization of military and police organizations, when aligned with *Maqāṣid Sharīʿah*, is required to uphold human

dignity and rights as bestowed by Allah. Grounded in justice, truth, loyalty, and trust – these institutions form the basis of peace (*salām*) in both wartime and peacetime (Burhanuddin et al., 2017; Surwadono et al., 2018; Safiyanu, 2021). Thus, justice and institutional stability are crucial components for promoting *maṣlaḥah* and preventing corruption, which is antithetical to these objectives.

Institutional Mechanisms for Harm Mitigation (Dar' al-Mafāsid)

In order to build a sustainable society, economic development must be pursued through a holistic lens, encompassing both material and spiritual dimensions, which ultimately leads to the realization of social justice (*al-'adl al-ijtimā'ī*). This vision resonates with the higher objectives of *Maqāṣid al-Sharī'ah*, notably the preservation of wealth (*ḥifẓ al-māl*). Islamic financial institutions such as the Islamic Development Bank (IDB) operating under the auspices of the Organization of Islamic Cooperation (OIC), endeavour to enhance socio-economic well-being through *Sharī'ah*-compliant financial instruments that uphold principles of equity, distributive justice, and ethical stewardship (Fakhri & Hammad, 2015; ISDB, 2022).

Similarly, the role of *Maqāṣid Sharī'ah* in combating corruption cannot be understated. Corruption (*fasād*) directly undermines the ethical governance of resources and wealth distribution, which is essential for societal well-being. As a practical application of this conceptual framework, the Malaysian Anti-Corruption Commission (MACC) serve as a critical apparatus for promoting institutional integrity and preventing corrupt practices (Manan et al., 2022; Junus et al., 2024). This demonstrates how Islamic governance elements of *dar' al-mafāsid* are operationalized in modern national planning.

Even more so, corruption, explicitly condemned in the Qur'anic verse al-Baqarah (2:188) undermines societal trust and obstructs the realization of *maṣlaḥah*. From a governance and strategic planning perspective, this necessitates the integration of rigorous ethical audits and transparent oversight mechanisms within national development blueprints. Failure to operationalize these preventive measures (*dar' al-mafāsid*) at the policy-making stage not only jeopardizes the foundational aims of *Maqāṣid al-Sharī'ah* but also structurally limits the achievement of SDG targets.

Synergizing Maqāṣid al-Sharī'ah with Universal Human Rights Frameworks

A strong institutional framework is necessary to safeguard justice and human rights on a global scale, especially in today's interconnected world. International institutions like the UN and the OIC were created to preserve human rights, justice, and peace globally (Turan, 2022). The safeguarding of human life and dignity as enshrined in the principles of *Maqāṣid al-Sharī'ah* finds profound resonance with

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the foundational aims of the Universal Declaration of Human Rights (UDHR) which was established in 1948.

Islam highlights the importance of upholding justice and human rights as part of the preservation of life and dignity. The OIC specifically remains resolutely committed to the safeguarding of Muslim rights across the globe, guided by Qur'ānic imperatives that call for the establishment of peace and the prevention of injustice. By grounding international efforts in the *Maqāṣid Sharīʿah* framework, Muslim-majority nations can work towards sustainable development while upholding ethical and 'just' governance.

To sum up whole discussions, the table below illustrates the thematic harmony between SDG 16 and *Maqāṣid Sharīʿah*, also highlighting how the implementation of *Siyāsah Sharʿiyyah* elements are essential for transforming these shared principles into robust institutions and ethical frameworks that safeguard global peace, justice, and societal welfare.

Table 1: Comparative Matrix of SDG 16 Targets and *Maqāṣidic* Principle / *Siyāsah Sharʿiyyah* Elements

Theme	UN Framework (SDG 16 Targets)	*Maqāṣidic* Principles (MP) / *Siyāsah Sharʿiyyah* Elements (SSE)	Policy Guidance and Institutional Implications
Governance and Accountability	*Target 16.6*: Develop effective, accountable and transparent institutions at all levels.	*MP*: *Jalb al-Maṣāliḥ* (Attaining benefits / welfare) *SSE*: *Al-Ḥisbah* (institutional accountability and ombudsman mechanisms).	Establish independent oversight bodies to audit public administration, ensuring transparency aligns with both SDG indicators and Islamic ethical stewardship.
Justice and Rule of Law	*Target 16.3*: Promote the rule of law at the national and international levels and ensure equal access to justice.	*MP*: *Al-ʿAdl* (Justice) SSE: *Wilāyat al-Qaḍā'* (Independent and impartial judiciary).	Strengthening legislative and judicial courts to uphold justice impartially across race or religion, bridging systemic legal gaps.
Integrity and Anti-Corruption	*Target 16.5*: Substantially reduce corruption and bribery in all their forms.	*MP*: Preservation of wealth (*māl*) & harm mitigation (*dar' al-mafāsid*). SSE: *Sadd al-dharā'iʿ* (blocking the means to evil / preventive policies).	Operationalize proactive integrity frameworks (e.g., the MACC in Malaysia) to prevent *fasād* (corruption) rather than merely punitive measures.
Peace and Security	*Target 16.1:* Significantly reduce all forms of violence and related death rates everywhere.	*MP*: Preservation of life (*al-nafs*) SSE: *Siyāsah dākhiliyyah wa-khārijiyyah* (internal security and foreign diplomacy policies).	Formulate national defense and security policies that empower police and military forces to safeguard citizens' right to life and societal stability.
Socio-Economic Equity	*Target 16.4:* Significantly reduce illicit financial and arms	*MP*: *Al-ʿAdl al-Ijtimāʿī* (social justice)	Deploy Shariah-compliant financial instruments (e.g., IDB frameworks) to ensure equitable

Theme	UN Framework (SDG 16 Targets)	*Maqāṣidic* Principles (MP) / *Siyāsah Shar'iyyah* Elements (SSE)	Policy Guidance and Institutional Implications
	flows, strengthen the recovery and return of stolen assets.	*SSE: Siyāsah māliyyah* (Islamic economic policies and fiscal regulation).	wealth distribution and combat illicit financial practices.
Global Human Rights	*Target 16.c:* Promote and enforce non-discriminatory laws and policies for sustainable development.	*MP*: Preservation of Dignity (*al-'irḍ*) SSE: *Mu'āhadāt dawliyyah* (compliance with 'just' international treaties / covenants).	Align national human rights policies with international frameworks (UN, OIC, UDHR) to globally safeguard human dignity without discrimination.

CONCLUSION

The realization of *Maqāṣid Sharī'ah* is inherently connected to the strategic goals of sustainable development. The elements of *Siyāsah Shar'iyyah* provide the state with the essential governance framework to enact actionable policies that promote *maṣlaḥah* and prevent *mafsadah*. In this light, strong institutions are not just a means of governance but a religious imperative and a planning necessity, contributing to the broader aims of human flourishing, peace, and justice. As the Qur'ān reminds us in al-Anfāl (8:60): *"And prepare against them whatever you are able of power…"* a command that extends beyond military preparedness to include robust legal, political, and economic institutions that safeguard the well-being of humanity.

Hence, the preservation of institutional integrity (rooted in the principle of *Maqāṣid al-Sharī'ah*) emerges as indispensable in realizing the SDGs pertaining to peace, justice, and strong institutions. By offering a synthesized *Maqāṣidic*-governance framework, this paper provides explicit policy guidance for contemporary statecraft. The convergence between the *Maqāṣid al-Sharī'ah* and the SDGs signifies a profound and enduring commitment to human flourishing, the mitigation of harm, and the cultivation of a just and secure societal order. Ultimately, this alignment transcends theoretical discourse, equipping policymakers with the structural and ethical imperatives needed to build resilient institutions for generations to come.

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FROM TECHNOCRATIC CITIES TO TRUST-BASED URBANISM: RE-CONCEPTUALISING URBAN PLANNING THROUGH ISLAMIC ETHICAL EPISTEMOLOGY IN THE DIGITAL AGE

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Abstract

The modern rhetoric of smart cities is largely technocratic in its rationale in the sense that it privileges algorithmic efficiency and data mining over human wellbeing. This paradigm is commonly referred to as algorithmic governance, which has occasioned a crisis in trust, which comes in form of surveillance anxiety and social alienation into the urban space. The paper is a critique of the sterile determinism of the modern digital urbanism and suggests the re-conceptualisation of the planning structures by referring to the Islamic ethical epistemology. Using a qualitative conceptual approach, the paper integrates classical Islamic ideas, namely, *Amanah* (ttrustworthiness), *Khilafah* (stewardship), and *Hisbah* (public accountability), with contemporary theory of the city in order to create a model of Trust-Based Urbanism. These results indicate that the Islamic concept of *Khilafah* radically changes the planner into a bottom-up controller but Amanah re-categories data not as an object of extractibility (surveillance capitalism) but as a religious trust to be defended by ethical considerations. In addition the principle of *Hisbah* provides an algorithmic transparency mechanism so that digital systems are not unaccountable to the society. The paper finds that the incorporation of these metaphysical aspects of ethics do not rejection of technological progress but rather humanises the urban pathway by transforming the urban city into a technocratic city of sensors into a city of souls based on trust. It is a non-Western conceptual framework that contributes to the discussion of ethics and city governance in the digital world in a new way.

Keywords: Sustainable, Islamic Ethical, Smart Cities, Trust-Based Urbanism, Khilafah.

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INTRODUCTION

Historically, the technological trends have significantly influenced the development of urban planning that has introduced what we currently call the technocratic cities or urban settings that heavily depend on Information and Communication Technologies (ICT) and more information-based decision-making systems (Gavade, 2024). The self-proclaimed smart cities strive to make their cities more efficient, sustainable and the overall quality of their life through the use of the latest technologies, including the Internet of Things (IoT), artificial intelligence (AI) and big data analytics (Esashika et al., 2021; Garg & Sharma, 2023; Gavade, 2024).

However, this technocentric paradigm has also not been devoid of its critics with insevere issues of concern about surveillance capitalism coming out. The unification of human behavior into commodities and the widespread harvesting of information by monopolistic enterprises like Google, Amazon, and Microsoft have caused an immense amount of discussion regarding the problems of privacy and moral control (Mahmoudi et al., 2024; Zuboff, 2022).

Whereas the technocratic model emphasizes on social trust, community participation, and ethical values to a lesser extent, the trust-based urbanism model lays an immense insistence on social trust, community involvement, and ethical issues in urban planning. This paradigm will seek to achieve an inclusive, participatory urban environment where the expectations and expectations of the immediate populace are preempted rather than being tied to technological remedies only (Åström, 2020; Bosso et al., 2025). The concepts of trust-based urbanism are in line with the values of the Islamic ethical epistemology that fosters justice and equity and communal wellbeing as the main principles of urban development (Kannike & Fahm, 2025; Raimi, 2024).

The digital era presents unique prospects and obstacles regarding re-imagining the city planning with the explicit reference to the Islamic ethical epistemology. Transparency, accountability, and involvement of people can be enhanced through the inclusion of digital technologies in the urban governance system, thus making people trust authorities and authorities trust citizens (Duenas-Cid et al., 2022; Ulivieri, 2005). However, it also requires a careful evaluation of the ethical standards in order to make sure that the technological advancement does not undermine the basic postulates of justice, privacy, and human dignity (Kannike & Fahm, 2025; Misra et al., 2025).

Incorporating Islamic ethical principles into urban planning can enhance urban resilience of the city especially in disaster management. The investigative studies based on the outcomes of empirical research in the location of Banda Aceh, Indonesia help to shed the light on the central place of the influence which religious and cultural determinants occupy in space planning paradigms. These determinants have been purposely grouped into spatial

patterns, infrastructural structures, cultural dimensions, non-physical and religious constituents, all of which are invaluable foundations of the engineering of a sound urban milieu. By integrating indigenous wisdom that emerges through religious and cultural systems of values to the realities of city planning, the practitioners are enabled to incorporate a more context-specific approach to urban planning so as to enhance resiliency in cities (Senjana et al., 2025; Zuraidi et al., 2023).

The Islamic epistemology, which highlights the complementary nature of Islamic revelation and human reason, provides invaluable information to modern urban planning. Classical Islamic philosophers like Al-Farabi and Al-Ghazali have contributed to this intellectual tradition and have entangled the philosophical inquiry and political administration. Modern examples, especially Masdar City can show how injunctions of the Quran on co-operation and justice and ecological trusteeship can be used to model sustainable and ethically sound urban development. Overall, this view testifies to the visionary nature of Islamic thinking on addressing the contemporary issues of the world and promoting social welfare (Elouazzani, 2024).

Islamic urbanism, which is based on ethical requirements and community-based orientation, is a potentially useful alternative to the current technocratic paradigm. The doctrine of *Ḥuqūq* a rights based praxis, which creates self-regulation and equity, is central in this discourse and is consistent with the epistemological schema of Lakatos. This position is quite different to the traditional Western model which often simplifies the Islamic city situation into superficial morphological observation. Islamic urbanism has the potential to alleviate such pressing issues of environmental degradation and social economic inequity by prioritising the rights mechanism together with decentralised decision-making process that will further develop a model of sustainable and participatory urban development (Akbar, 2025).

Although there is a bright future in adopting Islamic ethical practices in the city planning systems, empirical confirmation and comparative studies are conspicuously low. Although there is theoretical exposition on the salutary gains of an Islamic orientated paradigm, there is a need to conduct more research to examine modern ḥuqūq-based advancements and their concrete implications (Soud et al., 2010). Further, in most cases, the encroachment of contemporary Western urbanization has resulted in culturally discordant and ecologically unsustainable metropolis. The requirement is to face these challenges through a methodological synthesis between conventional Islamic principles and the latest technological advances, hence allowing the creation of a more just and inherently resilient urbanscape (Kamal et al., 2025).

To explore the topics of transition to trust-based urbanism and the change in technocratic cities, this article will question the relevance of Islamic

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epistemological principles as navigations in the modern planning praxis in the digital era. Combining the moral requirements of the Islamic teaching with the possibilities of contemporary digital technologies, the research introduces a model of the sustainable and morally responsible city building, putting the interests of the city in the background of the well-being of the whole society and the balance between the ecological environment.

LITERATURE REVIEW

The concept of smart cities has been extensively studied over the past two decades, with a focus on their primary characteristics such as advanced ICT technology, sustainability, innovative governance, and citizen participation (Esashika et al., 2021; Garg & Sharma, 2023). These cities leverage technology to optimize urban functions, enhance economic growth, and improve the quality of life for their residents. However, the implementation of smart city initiatives often faces challenges related to inadequate public participation, transparency, and the alignment of urban developments with local needs (Angelidou, 2017; Bosso et al., 2025).

Surveillance capitalism, a term coined to describe the commodification of human behavior through data extraction, has become a significant concern in the context of smart cities (Mahmoudi et al., 2024; Zuboff, 2022). The pervasive use of surveillance technologies, such as AI-powered cameras and facial recognition, has raised alarms about the erosion of personal freedoms and the potential misuse of data (Misra et al., 2025; van ‘t Wout & Molina, 2024).

Islamic ethical epistemology offers a valuable framework for addressing these challenges by emphasizing principles such as justice, equity, and the well-being of the community. Islamic ethics, derived from the Qur'an and Hadith, advocate for sustainable development through ethical behavior, environmental stewardship, and social responsibility (Kannike & Fahm, 2025; Raimi, 2024). These principles can guide the integration of digital technologies in urban planning to ensure that they align with the values of justice, transparency, and human dignity.

The role of trust in urban planning is crucial for fostering a sense of community and ensuring the success of participatory governance initiatives. Trust-based urbanism emphasizes the importance of building trust between citizens and authorities through transparent and inclusive decision-making processes (Åström, 2020; Ulivieri, 2005). This approach aligns with the Islamic concept of trust (amanah), which underscores the responsibility of leaders to act in the best interests of their communities (Kannike & Fahm, 2025; Raimi, 2024).

Digital technologies can play a significant role in enhancing trust in urban governance by improving transparency, accountability, and public participation. E-participation platforms, for example, can facilitate citizen

engagement in urban planning processes, thereby fostering a sense of ownership and trust in the outcomes (Duenas-Cid et al., 2022; Ulivieri, 2005). However, it is essential to address the ethical challenges associated with digital surveillance and data privacy to ensure that these technologies do not undermine the fundamental values of trust-based urbanism.

In conclusion, the transition from technocratic cities to trust-based urbanism requires a re-conceptualization of urban planning practices through the lens of Islamic ethical epistemology. By integrating the principles of justice, equity, and community well-being with contemporary digital innovations, it is possible to develop sustainable and ethically grounded urban environments that prioritize the needs and aspirations of their inhabitants. This approach not only addresses the ethical concerns associated with surveillance capitalism but also fosters a more inclusive and participatory urban governance model.

Conceptual Framework

This conceptual framework illustrates the transition from a technocratic, efficiency-driven urban model toward a trust-based urbanism. The model identifies 'Technocratic Urbanism' and 'Traditional Islamic Urbanism' as the primary drivers and foundational paradigms. The core of the framework is the 'Islamic Ethical Epistemology,' which acts as a mediator by synthesizing divine revelation and human reason. This epistemology manifests through three specific mechanisms: *Ḥuqūq* (rights-based self-regulation), Care Ethics (reclaiming socio-spatial dynamics), and Local Wisdom (enhancing resilience). These mechanisms collectively mitigate the negative impacts of datafication and instrumental rationality, resulting in a synthesized 'Trust-Based Urbanism' that yields resilient, equitable, and sustainable societal outcomes.

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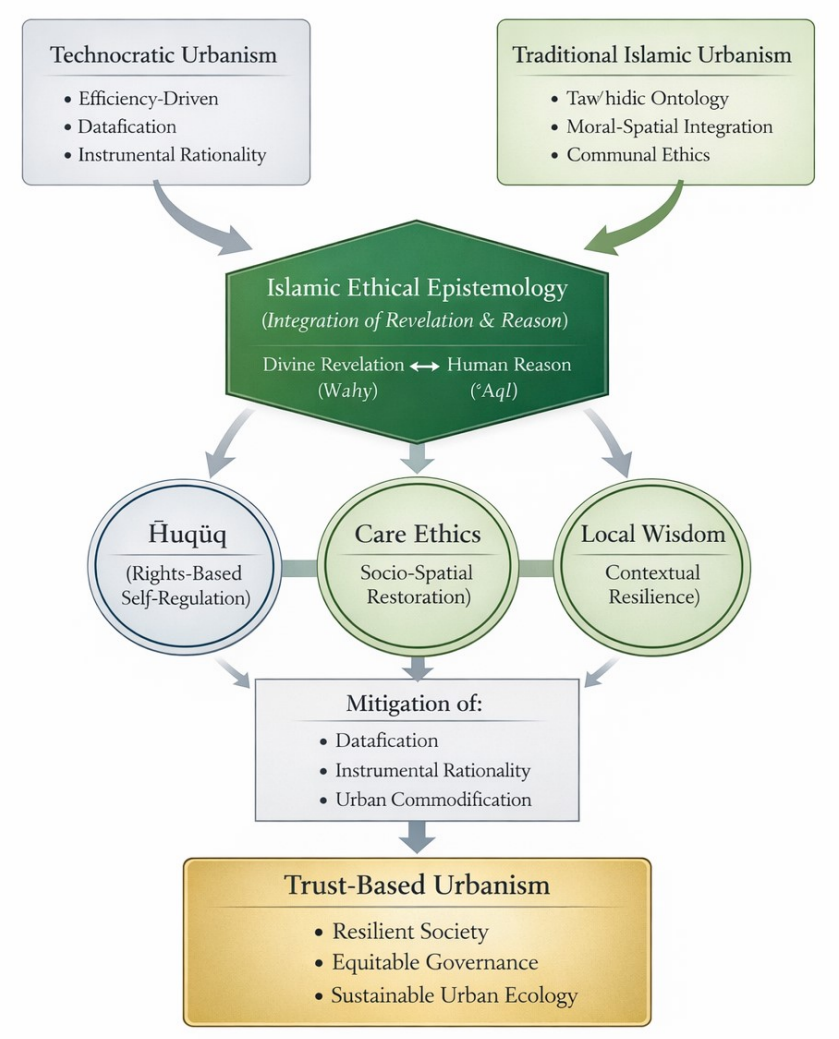


Figure 1: Conceptual Framework

METHODOLOGY

This study takes the form of a conceptually informed qualitative research design that is based on the critical urban theory and the epistemology of Islamic moral imagination. Instead of basing on empirical measurement, the methodological position tries to focus on systematic theoretical synthesis (Richardson et al., 2019) to also challenge the epistemological substratum of technocratic smart-city governance but also builds an ethical urban paradigm which presents an opposing view.

The analysis path is organized into three phases which are connected to each other. The first stage involves a critical synthesis of the existing literature and algorithmic governance on smart-city issues in a bid to explain how efficiency-based rationality reframes urban power structures, data practices, and subjectivities of citizens. The second stage challenges classical and modern sources of Islamic ethics with a view to reducing fundamental principles of governance, to the state of normative epistemological constructs and not theological abstractions. This step materialises the Islamic ethics in the logics of governance that is able to interact with the contemporary digital systems. The third step arrives at a conceptually synthesizing model integrating Islamic moral processes with technocratic urbanism failures in an identified manner, resulting in the Trust-Based Urbanism model as an alternative model of smart-city governance.

The study relies on thematic conceptual mapping and comparative paradigm analysis to protect the rigor of the analysis (Kumar, 2024; Ridley & Jeffrey, 2017). The essential aspects of governance, such as rationality, data governance, accountability, role of citizens, and technological control are comprehensively compared in terms of technocratics smart-city models and the suggested model of Islamic ethical governance. This is a systematic opposition that helps in theory-building with the abstraction, synthesis and normative reconstructions. Although the study does not use empirical approaches, it adds explanatory layers by reinventing ethics as a structuring factor in the governance of the digital cities, and not as a regulatory supplement. Thus, the methodology advances urban research by providing a conceptual framework of the sustainability of urban development ethically and smartly, that is, at the foundational philosophical basis of operational conceptual models.

RESULT AND FINDING

Technocratic Governance and the Ethical Crisis of Smart Cities

Modern models of smart cities are becoming more technocratic in epistemology and understand urban life in terms of optimisation, prediction, and control. It is within this paradigm that the algorithmic systems are not just considered as the administrative tools, but as the governing rationality that dictates what is considered to be knowledge, efficiency, and success in managing urban areas. The pre-eminence of indicators of performance that are measurable reconfigures the city into an enumerable system, in which the complex social matter is fragmented into datasets and modes of behaviour. This means that normative aspects like social justice, dignity, and collective wellbeing become subcontracted to instrumental goals to yield a type of governance that is operationally effective but ethically thin. This change represents a further change

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in city planning in the context of deliberate reasoning of the masses into managerialism by technologic structures.

Algorithms governance is tightly connected with the political economy of surveillance capitalism, where urban data is derived as a strategic commodity by means of omnipresent digital infrastructures. Continuous monitoring is incorporated into the daily city through the integration of sensors, facial recognition and predictive analytics, and the data mining becomes a matter of course to provide security and service. This is a process of concentration of power on technological platforms and the privatized vendors of digital architectures that pose novel dependencies to governments. Opacity in governance represents the situation in which algorithmic systems start to mediate the decisions on mobility, policing, allocation of resources, and urban services without a clear accountability mechanism. Citizens are thereby rearranged as rights-bearing subjects to data generating subjects whose behaviour is being continually profiled and monitored.

These kinds of structural changes have far-reaching implications on social trust and civic livelihood. The understanding of being under constant surveillance combined with the little knowledge that the general public has on the nature of processing and implementation of this data creates the atmosphere of uncertainty and psychological discomfort in the urban realm. Algorithms urbanism is likely to promote isolation, obedience and fragmentation of society instead of creating involvement and shared ownership over city governance. It is not that trust is destroyed by the mere existence of surveillance but this is because power is concentrated asymmetrically within the invisible technological systems that can no longer be subject to democratic control. The smart city thus becomes a regime of political-economic control, which is concerned with power and performance rather than ethical legitimacy and substructs such relational principles as inclusive and strong urban communities rely on.

Islamic Ethical Epistemology as a Normative Reorientation of Urban Governance

The ontological and normative background of the digital era of the city governance is presented as radically different by the Islamic ethical epistemology. Instead of defining technology as a means of neutral optimisation, it places governance in a moral universe, which is organised around responsibility, accountability and communal wellbeing. The moral principles of Amanah, *Khilafah* and *Hisbah* are not abstract moral ideals but they comprise governance logics that can reorganise institutional behaviour and technological design. This paradigm shift puts smart city development in a new frammation as a moral undertaking that is interested in the fair exploitation of power, security of human dignity, and management of social and environmental resources.

The principle of *Khilafah* transforms the concept of urban authorities and planners as the custodians of people and place and not as technocratic operators of infrastructures. Governance is made to be geared towards protection of common interests, inclusiveness and social harmony instead of maximizing performance measures. The logic of stewardship per se requires participatory involvement since only the responsiveness to community needs can constitute ethical legitimacy, not just algorithmic results. The city is therefore perceived as collective ethical zone where making decisions has social and spiritual responsibility other than bureaucratic effectiveness.

The notion of data as a trust instead of a commodity, which Amanah changes digital governance ethics even further, also occurs. Unlike the extractive logic of surveillance capitalism, Amanah data stewardship must involve consent, proportionality, transparency, and guard against misuse. Information infrastructures are consequently morally obliged to be used as communal good and not corporate hoarding or governmental oversight. In addition to this, Hisba comes in with a structure of societal responsibility, which requires that power is checked, even an algorithmic system that is increasingly defined of the city. It offers the standard upon which transparency, ethical audit, and social questioning of the processes of digital governance are founded. Collectively, these ethical constructs instantiate moral responsibility into technological systems, which provides a holistic governance architecture that can accommodate the ethical shortcomings of the current smart cities.

Emergence of Trust-Based Urbanism as an Alternative Smart City Paradigm

Trust-Based Urbanism is an alternative governance paradigm based on the integration of Islamic ethical epistemology with the critical urban theory of digitally mediated cities. This framework does not contradict technological progress but essentially reinvigorates its role not in control and extraction but in social trust, moral responsibility and human flourishing. Digital technologies are re-evaluated as a means of enhancing relational governance and making transparent decisions, involving all participants and managing ethical data. City smartness turns into the tool of community empowerment, but not into behaviour surveillance.

In this paradigm trust is a governance goal and organising principle of urban systems. Trust is nurtured by openness, accountability and mutual moral responsibility as opposed to being built by behavioural surveillance. Citizens can actively participate in urban planning and make decisions fairly with the help of participatory digital platforms, transparent algorithmic processes, and ethically regulated data ecosystems. Governance therefore becomes more about relationships based on mutual responsibility between communities and institutions as opposed to command structures that are hierarchical.

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Trust-Based Urbanism eventually turns the smart city into an ethical ecosystem of sensors as embedded in society. The city is made a place of moral interaction instead of algorithmic control by integrating metaphysical principles of stewardship, trust and accountability in digital governance. The idea of this non-Western computing philosophy brings a fresh dimension to the concept of the smart city around the world because it shows that ethical epistemologies can also be used as a working form of government instead of a symbolic mark of value. It provides a way forward to humanising digital urban futures whilst keeping technological progress and innovation, controlling the excesses of surveillance, rebuilding civic trust, and placing human dignity back at the centre of the modern city development.

DISCUSSION

The analysis mentioned that technocratic smart city governance is not simply a model of functional administration but rather an epistemological configuration of the urban order in terms of calculability, optimisation and predictability of behaviour. In such an arrangement, algorithmic systems play a role as a lawmaking institution that reconfigures power by giving preference to technical knowledge and proprietary digital infrastructures over democratic decision-making. This transformation creates a governance environment whereby the ethical legitimacy is supplanted by the functioning efficacy and the citizens are being increasingly turned to data objects in the surveillance-based urban ecosystems. The ensuing crisis of trust is thus not accidental, but inherent in the logic of algorithmic urbanism itself.

The Islamic ethical epistemology is based on an ontology of governance which is radically different, which is based on moral responsibility, relational accountability and stewardship of communal life. The main idea of this re-orientation is the notion of Khilafah, which makes human authority a trust and not a sovereignty. When applied to city government, Khilafah redefines planners, policymakers and technological institutions as custodians responsible to society and superior moral standards with the consequences of their choices. This logic of stewardship is a direct response to technocratic determinism which makes the maximisation of technology subordinate to the morality and the common good. Urban planning as practiced under Khilafah can therefore be an ethically-driven practice that is geared towards social justice, environmental sustainability and participatory legitimacy as opposed to a managerial practice that is aimed at maximising performance.

To supplement this governance reorientation, there is what is known as the principle of Amanah that reestablishes the ethical position of digital data in smart city systems. Amanah views information as a moral trust and vested in institutions to benefit the community where algorithmic governance views data

as a resource to be extracted and operationalised to generate profits. This would mean that there is a high ethical responsibility with regard to the consent, restriction on use, safeguarding against harm, and data flow transparency. Regarding real-life governing practices, Amanah requires the development of digital infrastructures which focus on data minimisation, accountability to the people, and anti-commodification. The principle in this way squarely challenges the extractive logics of surveillance capitalism by instituting moral limits within technological systems per se.

The Hisba concept also further terms the ethics mode of governance through the establishment of continuous public accountability to authority and power. As a social supervisory mechanism in the past, Hisba offers normative basis to current algorithms transparency and ethical audit. In smart city governance, Hisba can be translated into institutionalised systems whereby digital systems become subject to the scrutiny of the public, the explanation requirement, and remedial intervention. Instead of making algorithmic decision-making opaque and technocratically insulated, Hisba requires technological power to be socially responsible. This becomes a moral obligation and not a procedural compliance exercise, but an obligation to accountability based on the common good and fairness.

The synthesis of Khilafah, Amanah, and Hisba creates the structure of Trust-Based Urbanism that recreates the smart city government as a socio-technical system of ethics. Trust is not a behavioural product that is a result of predictive analytics but as a relational state that arises as a result of stewardship, ethical data governance and public accountability. The digital technologies are available to be repurposed in accordance with the common good, in the process of participative decision-making and moral accountability. Here, technological advancement is not dismissed but humanised thus making it possible to replace the cities that are controlled by surveillance systems with the cities that are organised in terms of ethical relation and social legitimacy.

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Table 1: Comparative Paradigms of Smart City Governance

Dimension	Technocratic Smart City	Trust-Based Urbanism (Islamic Ethical Framework)
Governance Rationality	Governance driven by quantification, algorithmic optimisation and efficiency	Normative-ethical rationality grounded in stewardship (*Khilafah*), moral responsibility, and communal wellbeing
View of Citizens	Data subjects	Moral stakeholders
Role of Technology	Governing authority	Ethically regulated tool
Data Governance	Extractive commodification	*Amanah* (ethical trust)
Accountability	Opaque algorithmic control	*Hisbah* (public oversight)
Planning Orientation	Top-down technocracy	*Khilafah* (Participatory stewardship)
Social Outcome	Surveillance-driven alienation	Trust-based cohesion

Theoretical Contributions

This study advances smart city scholarship by demonstrating that the ethical crisis of algorithmic governance is fundamentally epistemological rather than merely regulatory. It contributes a novel non-Western normative framework that positions Islamic ethical principles as operational governance architectures capable of structuring digital systems and institutional practices. By translating Khilafah into stewardship governance, Amanah into ethical data regimes, and Hisba into algorithmic accountability mechanisms, the study moves Islamic ethics from moral discourse into applied urban governance theory. The concept of Trust-Based Urbanism further provides an integrative paradigm that bridges technology, ethics, and participatory governance within a coherent theoretical model.

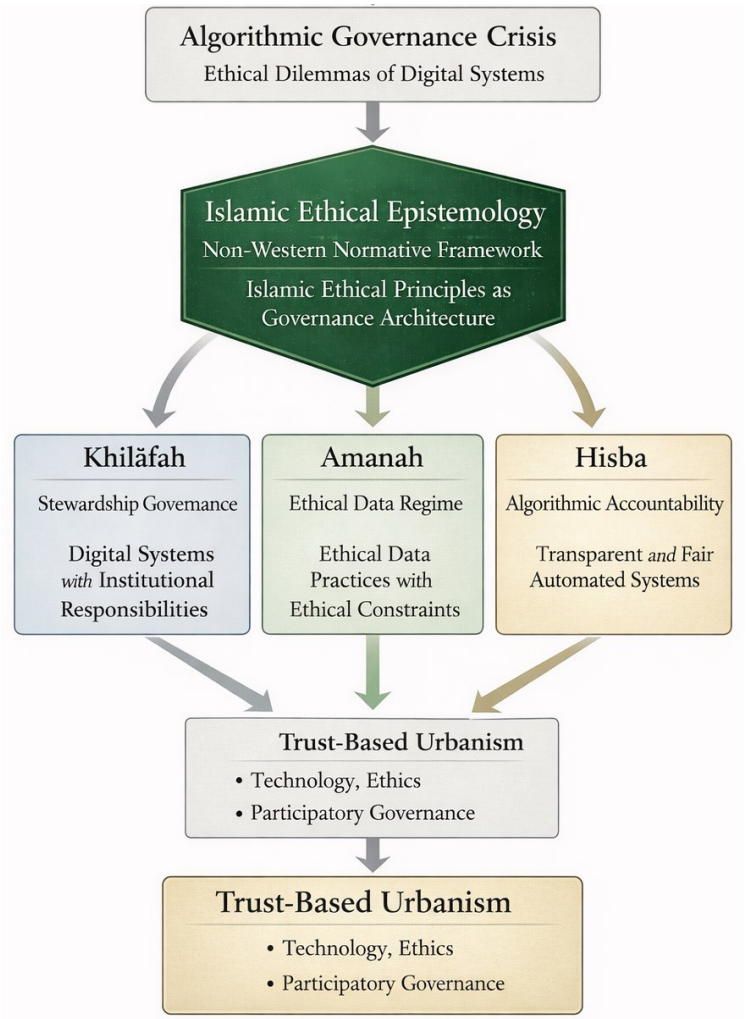


Figure 2. Epistemological Reconfiguration of Smart City Governance through Islamic Ethical Frameworks

CONCLUSION

This study demonstrates that the ethical challenges of contemporary smart cities are not primarily technological or regulatory but epistemological, rooted in the technocratic rationality of algorithmic governance that prioritises optimisation and data extraction over human-centred values. By revealing how digital urban systems restructure power relations, commodify urban life, and erode social trust, the paper reframes smart cities as socio-political regimes rather than neutral technological solutions. This reconceptualisation shifts scholarly attention from

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implementation failures to the underlying governance logic that shapes urban digitalisation.

By integrating Islamic ethical epistemology, the study advances a novel normative framework in which Khilafah, Amanah, and Hisba operate as governance architectures that restructure institutional authority, ethical data practices, and public accountability. The resulting paradigm of Trust-Based Urbanism demonstrates that technological innovation can be humanised through moral stewardship, ethical data governance, and participatory oversight, offering an alternative smart city model that restores civic trust while maintaining digital advancement. This non-Western theoretical contribution expands urban governance scholarship by positioning ethics as a structural driver of digital city design rather than a supplementary regulatory concern.

Urban policymakers should move beyond technocratic optimisation frameworks and institutionalise ethical governance mechanisms within smart city strategies. This includes embedding data stewardship principles that prioritise consent, transparency, and public benefit; establishing independent oversight bodies to audit algorithmic systems; and adopting stewardship-oriented planning approaches that centre community participation in digital urban development. Recognising trust as a form of critical urban infrastructure is essential for ensuring the long-term legitimacy, resilience, and social sustainability of smart city initiatives.

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TOWARDS A TAWHIDIC EPISTEMOLOGY OF PLANNING: REFRAMING AL-'ILM FOR SUSTAINABLE DEVELOPMENT GOVERNANCE IN MALAYSIA

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Abstract

Planning theory has evolved from technocratic rationalism to communicative and sustainability-oriented paradigms, yet its epistemological foundations remain largely secular and immanent. This article reconstructs planning rationality through a Tawhidic Epistemology of Planning grounded in the Islamic concept of *al-'ilm*. Using qualitative conceptual and comparative epistemological analysis, the study examines Western planning theory and Islamic epistemology across ontological, epistemic, and teleological dimensions. The analysis reveals structural fragmentation within secular planning rationality and identifies the integrative potential of Tawhid as an ontological core. Building upon these findings, the article develops a layered framework consisting of ontological unity, integrated epistemic foundations, ethical–normative orientation, and governance translation. The framework preserves empirical inquiry and participatory governance while re-situating them within moral accountability and metaphysical coherence. The study contributes to planning theory by re-centering epistemology as a foundational concern and offers preliminary implications for sustainable development governance in Malaysia, particularly for sustainability assessment practices, statutory spatial planning interpretation, and professional planning ethics.

***Keywords*:** Tawhidic Epistemology, Islamic Planning Ethics, Sustainable Development Governance, Spatial Planning Theory, Malaysia

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INTRODUCTION

Planning theory has undergone significant intellectual evolution over the past century. Emerging from the rational–comprehensive paradigm, the discipline initially framed planning as applied scientific reasoning grounded in technical analysis and optimization (Faludi, 1973; Hall, P., & Tewdwr-Jones, M., 2011). Subsequent critiques, however, highlighted the political and communicative dimensions of planning practice. Forester (1989) demonstrated how planning decisions are shaped by power relations and institutional constraints, while Healey (1997) reframed planning as a deliberative process grounded in stakeholder dialogue. Planning rationality thus evolved from instrumental analysis toward communicative legitimacy (MacCallum, D., 2008).

More recently, sustainability and resilience paradigms have expanded the normative scope of planning theory. Concerns over climate change, ecological degradation, and social inequality have repositioned planning as a key arena for negotiating long-term futures (Campbell, 2016; Meerow et al., 2016). Despite these developments, the epistemological foundations of planning theory remain largely implicit. Dominant paradigms continue to operate within secular assumptions in which knowledge is validated through empirical evidence, procedural legitimacy, or discursive agreement, leaving questions of metaphysical coherence and moral accountability largely unaddressed (Davidoff, P., 1965)

The issue becomes particularly significant in plural societies where civilizational worldviews shape governance discourse. Malaysia provides a relevant context for examining such epistemological questions (Shamsul, A. B., 2001; Ooi, K., 2003). Recent governance discourse, including the Malaysia MADANI framework, similarly emphasizes ethical governance and sustainable development. As a multi-ethnic nation whose constitutional framework recognizes Islam as the religion of the Federation, Malaysian planning operates at the intersection of Western administrative rationality and Islamic ethical traditions (Lateh, N. H. M. et al., 2024; Balaraman, R. A. et al., 2024). While Islamic concepts such as Maqasid al-Shariah have been incorporated into planning discourse, their role remains largely normative rather than epistemological.

This raises a key theoretical question: can Islamic civilizational concepts contribute not only normative guidance but also epistemological foundations for planning rationality? Although this question is increasingly relevant within the Malaysian context, systematic attempts to reconstruct planning theory at the epistemological level remain limited.

This article argues that meaningful epistemic coherence requires reconstruction at the level of epistemology. It proposes a Tawhidic Epistemology of Planning grounded in the concept of al-ʻilm, which re-situates empirical

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inquiry, ethical reasoning, and governance practice within an ontological framework defined by Tawhid. The study is guided by the following research question:

How can planning rationality be reconstructed through a Tawhidic epistemological framework that integrates empirical science, ethical accountability, and ontological unity in a manner relevant to Malaysian development governance?

To address this question, the article adopts a qualitative conceptual design based on comparative epistemological analysis across ontology, epistemology, and teleology. Through conceptual synthesis, it develops a layered framework translating ontological unity into planning governance.

This article contributes to planning scholarship in three ways. First, it re-centers epistemology as a foundational concern. Second, it develops a structured Tawhidic framework integrating empirical inquiry with ethical accountability. Third, it advances theoretical pluralism by demonstrating the relevance of civilizational epistemologies to contemporary planning theory.

LITERATURE REVIEW

Secular Epistemology in Planning Theory

Planning theory emerged within Enlightenment rationalism, privileging empirical verification and instrumental reasoning. The rational–comprehensive model framed planning as systematic analysis aimed at optimizing decision-making through technical expertise and empirical evidence (Faludi, 1973).

Late twentieth-century critiques challenged this technocratic orientation. Forester (1989), Wolff, A. (2020) and Levin-Keitel, M., et al., (2017) highlighted the communicative and political dimensions of planning, emphasizing how decisions are shaped by power relations and institutional constraints. Healey (1997) subsequently articulated the communicative turn, reframing planning as collaborative deliberation among stakeholders rather than purely technical optimization. In this perspective, planning rationality becomes dialogical and socially embedded. Despite these paradigm shifts, planning theory continues to rely primarily on empiricism and procedural legitimacy, leaving deeper ontological questions outside its analytical framework (Innes, J. E., 1995; Rittel, H. W., 1973).

Recent scholarship has examined competing rationalities within strategic planning processes (Mattila, 2024), highlighting tensions between instrumental efficiency and deliberative legitimacy. Similarly, evidence-informed policy discourse reinforces empirical authority by emphasizing data analytics and evidence synthesis in decision-making (Head, 2016). While these

developments strengthen methodological sophistication, they do not fundamentally challenge the secular epistemological premises underlying planning rationality.

Overall, planning theory has diversified methodologically from technocratic to communicative and strategic paradigms yet continues to operate within largely secular epistemological assumptions.

Sustainability, Resilience, and Governance Debates

The sustainability paradigm represents a major normative expansion within planning theory. Campbell's (2016) "planner's triangle" highlights the enduring tension between economic growth, environmental protection, and social equity, while resilience scholarship further broadens planning's conceptual scope. Urban resilience is commonly defined as the capacity of cities to absorb, adapt, and transform in response to shocks and stresses (Meerow et al., 2016), with adaptive governance playing a key role in managing complex socio-ecological systems (Folke, 2016). Together, these perspectives position planning as an integrative framework for addressing long-term environmental and societal challenges.

However, several scholars caution that resilience discourse may become managerialized. Pizzo (2015) argues that resilience risks conceptual vagueness when translated into policy frameworks, while Datola (2023) demonstrates how resilience is often operationalized through regulatory indicators and performance metrics. Although such tools enhance measurability, they may also dilute normative depth.

Debates surrounding the concept of public interest reveal similar tensions. Recent scholarship has further examined competing schools of thought surrounding the concept of public interest in planning, particularly in relation to procedural legitimacy, distributive justice, and normative interpretation (Sheydayi & Dadashpoor, 2022). Dadashpoor and Sheydayi (2021) demonstrate that public interest is interpreted differently across planning contexts, oscillating between procedural legitimacy and distributive justice. Planning ethics scholarship further highlights the challenges planners face when balancing professional responsibility with institutional constraints (Sturzaker & Hickman, 2024).

These developments illustrate the expanding normative scope of planning theory. Sustainability, resilience, and justice are increasingly central to planning discourse (Jepson Jr, E. J., 2009). Nevertheless, these commitments are frequently framed through procedural and managerial instruments rather than grounded in coherent ontological foundations.

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Islamic Epistemology and the Concept of Al-'Ilm

Islamic epistemology presents an alternative orientation grounded in ontological unity. The concept of al-'ilm understands knowledge as both a cognitive and ethical phenomenon. Unlike secular epistemologies that separate fact from value, Islamic thought integrates epistemology with ontology and teleology.

Tawhid (the affirmation of divine unity) constitutes the ontological core of Islamic epistemology. Reality is understood as unified within a coherent moral order. Knowledge derives legitimacy not solely from empirical verification but from alignment with this ontological unity. Islamic scholarship recognizes multiple sources of knowledge: revelation (wahy), intellect ('aql), empirical observation, and reflective reasoning. These sources are complementary rather than antagonistic. Empirical inquiry is encouraged, yet it operates within moral accountability.

Teleology is central. Knowledge is purposive, oriented toward justice ('adl), balance (mizan), and public good (maslahah). Governance is conceptualized as trusteeship (amanah), implying accountability beyond institutional compliance. Contemporary scholarship has applied Islamic ethical principles to development policy, finance, and governance. However, these applications often function at the level of normative guidance rather than epistemological reconstruction. The deeper question of how ontological unity might reshape planning rationality remains underexplored.

Malaysian Planning Scholarship and Normative Integration

Within Malaysian planning discourse, issues of sustainable urban growth, housing governance, and environmental management have received considerable scholarly attention. Existing PMJ studies have examined liveability within the Islamic framework of Maqasid al-Shariah, low-middle income housing challenges, and compact city elements for sustainable urban development (Dali et al., 2016; Kamal et al., 2020; Nor'Azmi & Sahrir, 2024).

Although these studies demonstrate growing engagement with sustainability and governance challenges, they generally operate within institutional and policy-based rationalities. Islamic ethical constructs particularly Maqasid al-Shariah are occasionally referenced in discussions of wellbeing and development, yet their application often remains normative rather than epistemological. Recent Malaysian planning scholarship has also begun engaging with Malaysia MADANI-oriented governance discourse, particularly in relation to ethical planning, community well-being, and sustainable governance in emerging technological contexts (Embong et al., 2026).

Consequently, Islamic principles tend to function as evaluative supplements within existing planning frameworks rather than informing the foundational rationality of planning itself. Thus, Malaysian planning scholarship

demonstrates growing normative engagement with sustainability and governance challenges, yet systematic epistemological reconstruction remains limited.

Identifying the Epistemological Gap

The preceding discussion reveals a structured gap across both global and Malaysian planning scholarship. Planning theory has developed sophisticated procedural tools and expanded its normative commitments to sustainability, justice, and public interest. Malaysian planning research has likewise engaged actively with housing, urban development, and environmental governance.

However, across these domains, epistemological assumptions remain largely implicit and secular. Normative values are frequently acknowledged, yet they are typically operationalized through procedural instruments rather than grounded within a coherent ontological framework.

The epistemological gap therefore lies not in the absence of normative concern but in the absence of ontological integration. Planning theory continues to operate within frameworks that separate empirical rationality from deeper metaphysical coherence. This study addresses that gap by developing a Tawhidic Epistemology of Planning that integrates empirical inquiry, ethical orientation, and ontological unity within a coherent theoretical model relevant to Malaysian development governance.

RESEARCH METHODOLOGY

This study adopts a qualitative conceptual research design grounded in comparative epistemological analysis. Unlike empirical studies that rely on quantitative data, surveys, or case-based fieldwork, conceptual research seeks to clarify foundational assumptions, refine theoretical constructs, and construct integrative frameworks through systematic analysis of ideas (Jabareen, 2009). The research problem concerns the ontological and epistemic grounding of planning rationality. Such a problem is philosophical in nature. It requires examination of foundational assumptions embedded within planning theory and Islamic epistemology rather than empirical measurement of planning outcomes. The methodology is therefore designed to uncover structural differences in epistemic orientation and synthesize them into a coherent theoretical model.

Research Design: Comparative Epistemological Analysis

The research design proceeds in two sequential phases:

Comparative epistemological examination

The first phase systematically compares two bodies of knowledge:

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i. Dominant paradigms within Western planning theory (rational–comprehensive, communicative, sustainability-oriented approaches)
ii. Islamic epistemology centered on the concept of al-'ilm and grounded in Tawhid

The comparison is structured across three analytical dimensions:
(a) Ontology – What assumptions are made about the nature of reality?
(b) Epistemology – What constitutes legitimate knowledge and authority?
(c) Teleology – What is the ultimate purpose or orientation of knowledge and development?

This structured comparison avoids superficial juxtaposition. Instead, it interrogates deep structural premises. For example, in secular planning theory, ontology is typically immanent and socially constructed; epistemic authority derives from empirical verification or discursive legitimacy; teleology is often implicit and instrumental. In Islamic epistemology, ontology is unified (Tawhidic), epistemic authority integrates revelation and reason, and teleology is explicitly moral and purposive.

The aim of this phase is not to declare one tradition superior to another but to identify structural contrasts and latent complementarities. Both traditions are treated analytically rather than polemically.

Conceptual synthesis and framework construction

Following comparative analysis, the second phase involves conceptual synthesis. This phase draws upon framework-building methodologies articulated in conceptual research literature (Jabareen, 2009), which emphasize identification, categorization, and relational integration of core concepts.

The synthesis proceeds through three steps; abstraction, translation, and structuring as illustrated in **Figure 1**.

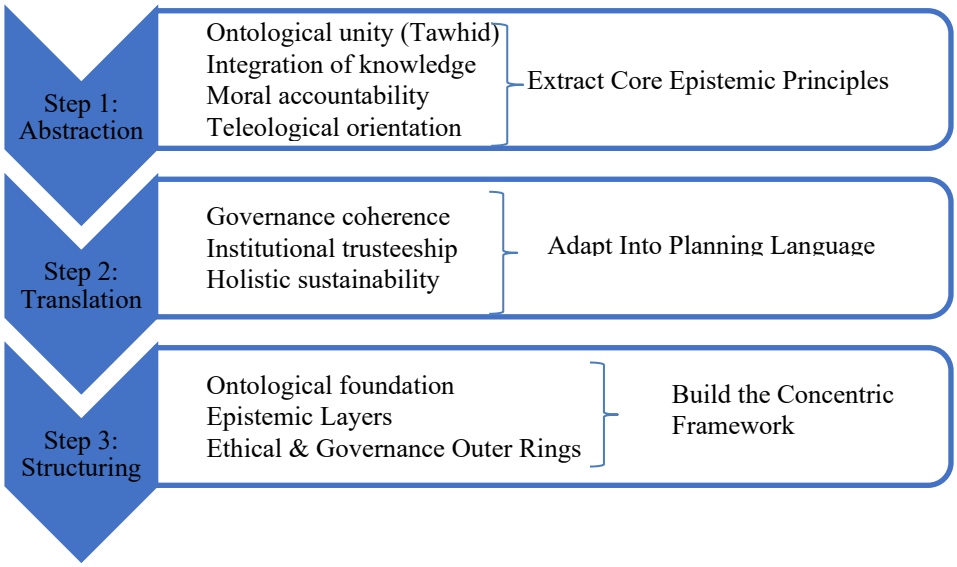


Figure 1: Methodological synthesis process for constructing the Tawhidic Epistemology of Planning framework
Source: Authors' conceptual synthesis

As illustrated in **Figure 1**, the synthesis begins with abstraction, where core epistemic principles derived from Islamic thought are identified. These principles are then translated into planning-relevant concepts and subsequently structured into a layered framework linking ontology, ethics, and governance practice.

Normative Reconstruction

A further methodological dimension is normative reconstruction. Planning theory already incorporates normative aspirations sustainability, equity, and public interest. However, these aspirations often lack ontological anchoring. Normative reconstruction seeks to reposition such commitments within a coherent epistemological structure.

Rather than imposing external moral doctrine, this approach examines whether existing planning values can be stabilized through ontological integration. The objective is coherence, not replacement. Normative reconstruction thus functions as a bridge between civilizational epistemology and contemporary governance systems. It avoids both technocratic reductionism and theological imposition.

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Scope and Limitations

As a conceptual study, this research does not empirically test the proposed framework through case studies or quantitative analysis. Its contribution lies in epistemological clarification and theoretical construction through comparative analysis of Western planning theory and Islamic epistemology. While the framework is developed with reference to the Malaysian governance context, it is presented as an epistemic orientation that can coexist within plural and constitutional planning systems. Future research may operationalize the framework empirically by examining its implications for sustainability assessment, spatial planning instruments, and governance accountability mechanisms.

RESULTS AND DISCUSSION

As this study adopts a conceptual and comparative design, the "results" presented here refer to structural findings derived from epistemological analysis rather than empirical data. The findings emerge from systematic comparison between dominant secular planning paradigms and Islamic epistemology structured around Tawhid. These findings are then synthesized into a layered Tawhidic Epistemology of Planning framework.

Comparative Epistemological Findings

The comparative analysis reveals three primary structural contrasts that shape planning rationality at its deepest level: (1) ontological configuration, (2) epistemic authority, and (3) teleological orientation. These dimensions do not merely differentiate philosophical traditions; they influence how planning knowledge is validated, how sustainability is conceptualized, and how governance decisions are justified.

Ontology: Fragmented Immanence versus Ontological Unity

Secular planning theory operates within an immanent ontology in which reality is treated as materially constituted and socially organized, and knowledge derives primarily from empirical observation and institutional procedures. Even communicative paradigms remain largely confined to socio-political domains, leaving transcendental dimensions outside formal planning rationality.

Economic growth, environmental protection, and social equity are conceptualized as competing domains requiring balancing mechanisms (Campbell, 2016). Sustainability becomes a negotiation among interests rather than an expression of integrated order.

Malaysian planning scholarship reflects similar structural balancing. For example, Dali, Abdullah, and Ahmad Sarkawi (2016) emphasize the need to

reconcile housing development with environmental sustainability. Their analysis acknowledges ecological responsibility but situates integration within regulatory instruments and policy frameworks. The ontological question of whether development objectives derive from a unified moral order remains outside the analytical scope.

Similarly, recent Malaysian planning studies have explored compact city elements as approaches to enhancing sustainable urban development and spatial efficiency (Nor'Azmi & Sahrir, 2024).

By contrast, Tawhid establishes ontological unity. Reality is understood as coherent within a single moral and metaphysical order. Economic, social, and ecological domains are not separate spheres requiring negotiation but interconnected dimensions of a unified creation. Development is therefore not a balancing exercise among competing sectors but an expression of maintaining harmony within an integrated system.

This ontological distinction has significant implications. Where secular planning seeks equilibrium among fragmented objectives, a Tawhidic ontology frames integration as foundational. Fragmentation is interpreted not merely as policy inefficiency but as epistemic misalignment.

Epistemic Authority: Procedural Legitimacy versus Moral Accountability

Contemporary planning systems derive epistemic authority primarily from procedural legitimacy. Knowledge is validated through institutional processes: expert consultation, public participation, regulatory compliance, and empirical evidence (Head, 2016). Legitimacy is procedural and internally justified.

The communicative paradigm reinforces this orientation by emphasizing stakeholder dialogue as the basis of rational agreement (Healey, 1997). Decisions are considered legitimate when they emerge from inclusive deliberation. While procedural safeguards are essential for transparency and democratic accountability, they do not necessarily ensure moral coherence. Public participation may legitimize decisions that satisfy short-term interests yet undermine long-term ecological balance.

Malaysian planning scholarship has also examined housing affordability and urban governance challenges, particularly in relation to low-middle income housing and sustainable urban development (Kamal et al., 2020). Nevertheless, such analyses remain largely framed within institutional and regulatory rationalities.

In contrast, a Tawhidic epistemology expands epistemic authority beyond procedural validation. Knowledge must align with justice ('adl), balance (mizan), and trusteeship (amanah). Governance is conceptualized as a moral trust rather than merely administrative function. This does not negate participatory governance or empirical analysis. Instead, it introduces a dual evaluative horizon.

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Decisions must satisfy both procedural legitimacy and moral accountability. Evidence remains necessary, but it is interpreted within an ethical framework that transcends institutional consensus.

Teleology: Instrumental Optimization versus Holistic Flourishing

Modern planning rationality is predominantly instrumental, defined by policy objectives and measurable indicators. Even sustainability initiatives frequently reduce wellbeing to quantifiable outputs.

Resilience discourse illustrates this orientation. Urban resilience is defined in terms of adaptive capacity and system functionality (Meerow et al., 2016). While valuable, such definitions prioritize system performance rather than ultimate purpose. Datola (2023) demonstrates how resilience is often operationalized through managerial metrics. Similarly, Malaysian sustainability research emphasizes performance indicators and compliance frameworks (Adanan, N. Q. A. et al., 2021).

Islamic epistemology introduces teleology as central to knowledge. Development is oriented toward holistic flourishing, encompassing material sufficiency, moral integrity, social cohesion, and spiritual consciousness. Knowledge is purposive, directed toward sustaining balance within creation.

Teleological orientation reframes sustainability. Rather than merely managing resources efficiently, sustainability becomes stewardship grounded in ontological unity. Long-term wellbeing is evaluated not only through quantitative indicators but also through alignment with justice and balance.

Table 1: Comparative Epistemological Dimensions of Planning

Dimension	Secular Planning Rationality	Tawhidic Epistemology of Planning
Ontology (Nature of Reality)	Fragmented Immanence: Reality is viewed as materially constituted and socially organized, often bracketing transcendental dimensions.	Ontological Unity: Reality is understood as a coherent, unified moral and metaphysical order grounded in Tawhid.
Epistemology (Source of Authority)	Procedural Legitimacy: Knowledge is validated through institutional processes, empirical evidence, and stakeholder consensus.	Moral Accountability: Knowledge integrates empirical inquiry with revelation and intellect, emphasizing justice ('adl), balance (mizan), and trust (amanah).
Teleology (Purpose of Knowledge)	Instrumental Optimization: Focused on achieving measurable policy targets, efficiency, and system functionality.	Holistic Flourishing: Oriented toward sustaining harmony in creation and achieving material, moral, and spiritual well-being.

Dimension	Secular Planning Rationality	Tawhidic Epistemology of Planning
Sustainability Approach	Equilibrium of Fragments: A negotiation or "balancing act" between competing economic, environmental, and social sectors.	Stewardship as Unity: Integration is foundational; sustainability is an expression of maintaining the inherent balance of a unified system.

Source: Author's synthesis based on the comparative epistemological analysis

Unlike communicative, collaborative, or justice-oriented planning frameworks, the Tawhidic Epistemology of Planning does not derive legitimacy solely from procedural consensus, stakeholder participation, or distributive negotiation. Instead, it grounds planning rationality within an ontological conception of unity in which empirical inquiry, ethical accountability, and governance are integrated within a coherent metaphysical framework. In this sense, the framework extends beyond procedural normativity toward epistemological reconstruction.

Development of the Tawhidic Epistemology of Planning Framework

Building upon the comparative findings, this study constructs the Tawhidic Epistemology of Planning as a four-layered concentric framework, as illustrated in Figure 2. The concentric structure reflects hierarchical coherence, with outer layers deriving direction from inner foundations.

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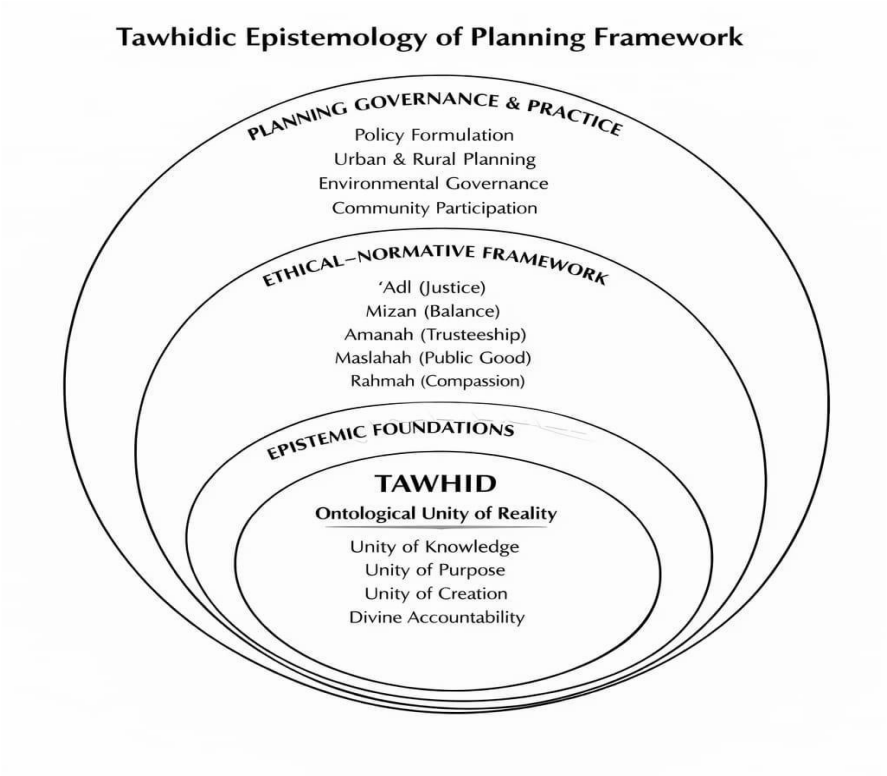


Figure 2: Concentric framework of the Tawhidic Epistemology of Planning
Source: Authors

As shown in **Figure 2**, the framework is structured hierarchically, beginning with Tawhid as the ontological core, followed by integrated epistemic foundations, ethical–normative orientation, and governance translation.

In practical planning terms, the framework may inform the ethical interpretation of statutory planning instruments in Malaysia, including development control decisions, sustainability assessment mechanisms such as MURNInets, and spatial planning guidelines under the Town and Country Planning Act 1976. Rather than treating sustainability solely as technical compliance, the framework repositions planning evaluation within broader considerations of justice ('adl), balance (mizan), and public wellbeing (maslahah).

The Ethical-Normative Orientation: Applying ‘Adl and Mizan in the Malaysian Context

The principles of ‘Adl (Justice) and Mizan (Balance) within the Tawhidic framework provide a robust evaluative tool for contemporary planning challenges in Malaysia. For instance, in the rapid urbanization of Greater Kuala Lumpur, the drive for high-density commercial development often creates a tension between economic growth and social equity. From a Tawhidic perspective, ‘Adl necessitates that planning is not merely a negotiation of market forces, but a proactive commitment to ensuring the "right to the city" for all social strata, preventing the marginalization of low-income communities in favor of luxury enclaves.

Furthermore, the preservation of Environmentally Sensitive Areas (ESAs or KSAS - Kawasan Sensitif Alam Sekitar) in states like Selangor and Pahang serves as a critical application of Mizan. While secular planning might view forest reserves as "undeveloped land" with potential opportunity costs, the Tawhidic epistemology views these areas as vital components of a unified ecological balance. Encroachment into KSAS for short-term development is seen as a disruption of the Mizan, violating the Amanah (trust) of stewardship. Thus, the framework justifies more stringent protection of KSAS not just as a regulatory requirement, but as a fundamental ontological necessity to maintain the harmony between man, nature, and the Creator.

CONCLUSION

Planning theory has undergone significant methodological evolution, yet its epistemological foundations remain largely implicit. From rational-comprehensive models to communicative and sustainability-oriented paradigms, the discipline has refined tools and expanded normative commitments without systematically interrogating the ontological assumptions that underlie planning rationality. This article has argued that such epistemological neutrality is neither conceptually sufficient nor contextually coherent, particularly within societies where civilizational worldviews continue to shape governance discourse.

Through comparative epistemological analysis, this study identified three structural contrasts between dominant secular planning rationality and Islamic epistemology: fragmented immanence versus ontological unity, procedural legitimacy versus moral accountability, and instrumental optimization versus teleological orientation toward holistic flourishing. These contrasts are not merely philosophical distinctions; they shape how sustainability, public interest, and justice are conceptualized within planning systems.

Building upon these findings, the study developed the Tawhidic Epistemology of Planning as a layered concentric framework integrating ontological unity, epistemic foundations, ethical–normative orientation, and

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governance translation. At its core, Tawhid affirms unity of reality and knowledge, preventing fragmentation between material development and moral aspiration. Surrounding this core, integrated epistemic sources preserve empirical inquiry while situating it within moral accountability. Ethical principles of justice ('adl), balance (mizan), trusteeship (amanah), and public good (maslahah) translate ontological coherence into evaluative criteria. Finally, governance translation operationalizes these commitments within spatial planning instruments, sustainability assessment, and institutional practice.

Importantly, the framework does not reject empirical science or participatory governance. Rather, it re-situates them within a broader evaluative horizon. Evidence-based policy, stakeholder engagement, and sustainability metrics remain essential components of planning practice. However, their legitimacy is expanded beyond procedural compliance to include moral coherence and long-term stewardship. Planning rationality thus becomes integrative rather than fragmented.

The study contributes to theoretical pluralism by demonstrating that civilizationally grounded epistemologies can engage rigorously with contemporary planning discourse. By foregrounding ontology as a legitimate dimension of inquiry, the article invites renewed reflection on the philosophical foundations of governance. Planning therefore emerges not merely as the technical coordination of land use but as a normative enterprise shaping collective futures.

For Malaysian development governance, the framework offers a basis for aligning planning practice with broader civilizational and ethical commitments, including recent governance discourse in Malaysia such as the Malaysia MADANI emphasis on ethical governance, societal balance, and sustainable wellbeing. Rather than replacing empirical science or statutory institutions, it provides a deeper evaluative horizon through which sustainability, justice, and professional responsibility may be interpreted more coherently.

Although this study remains conceptual, it establishes a structured foundation for future empirical work. Subsequent research may operationalise the framework within specific planning instruments, sustainability assessments, and development control processes. The Tawhidic Epistemology of Planning thus offers both a theoretical contribution and a pathway for strengthening planning coherence.

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TAYYIB-BASED ETHICAL EVALUATION FRAMEWORK FOR URBAN PLANNING GOVERNANCE IN MALAYSIA

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Abstract

Urban planning governance shapes whether cities develop in ways that are sustainable, inclusive, and socially responsible. In Malaysia, development proposals are typically assessed through statutory planning controls such as zoning, density, and land-use requirements. Although these mechanisms provide legal certainty and procedural consistency, they do not on their own ensure ethically adequate development outcomes. This study therefore conceptualises the Islamic ethical concept of *tayyib* as a post-compliance evaluative framework for urban planning governance. Using a qualitative conceptual design, the study draws on document analysis and thematic synthesis of three bodies of material: scholarship on urban planning governance and sustainable cities; Malaysian planning legislation and policy, including the Town and Country Planning Act 1976 (Act 172) and the Second National Urbanisation Policy (NUP2); and Islamic ethical scholarship on *tayyib*. The analysis develops a multi-layered framework comprising regulatory compliance, sustainability performance, and ethical sufficiency. It also proposes operational indicators for environmental integrity, spatial justice, housing equity, community well-being, and governance accountability. Within this framework, *tayyib* functions primarily as an ex ante ethical filter during development control, with additional ex post use in post-approval monitoring and ethical audit. The framework offers a value-based complement to existing regulatory and sustainability assessments and supports a more holistic evaluation of urban development outcomes.

Keywords: urban governance; *tayyib*; ethical evaluation; sustainable urban planning; Malaysia

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INTRODUCTION

Governance in urban planning plays a central role in urban development, management, and sustainability. In Malaysia, local authorities are the principal administrative bodies responsible for regulating urban planning, monitoring development, and implementing urban policies within their respective jurisdictions (Yusup et al., 2016). Urban planning decisions are governed primarily by statutory mechanisms under the Town and Country Planning Act 1976 (Act 172), which sets out the planning control and approval framework. In terms of policy, national policies such as the Second National Urbanisation Policy (NUP2) focus on sustainability, liveability, and spatially balanced urban developments (PlanMalaysia, 2016).

These governance arrangements operate within a wider national development strategy aimed at improving urban competitiveness while promoting sustainable urbanisation. Governance of urban areas has been identified as central to enhancing the efficiency, transparency, and sustainability of the planning system (Jusoh & Rashid, 2009). However, rapid urbanisation and marketisation also create governance challenges related to socio-spatial inequality and environmental sustainability. The expansion of metropolitan areas has increased pressure on green spaces and natural ecosystems, as reflected in the loss of urban forests and fragmentation of landscapes in Greater Kuala Lumpur (Hosen & Shukri, 2024; Yusof & Rakhshandehroo, 2016).

Although statutory planning provides an important regulatory framework, compliance with legal standards alone does not necessarily ensure socially and environmentally responsible development outcomes. Planning approval procedures primarily assess whether development proposals meet technical planning standards such as zoning regulations, density requirements, and land-use classifications. However, development initiatives may comply with these requirements while still producing socially inequitable or environmentally harmful outcomes (Zahir & Khamidi, 2025). This limitation highlights the need to move beyond regulatory compliance towards a more substantive evaluation of development outcomes.

While sustainable urban governance has received increasing attention in planning scholarship, relatively few studies have developed explicit frameworks capable of extending planning evaluation beyond technical compliance and performance-based sustainability indicators (Kanasan & Hassan, 2023; Rahman et al., 2025). Although sustainability-oriented evaluation frameworks exist, they rarely provide explicit criteria for assessing distributive justice, ethical legitimacy, or normative sufficiency in planning decisions. As a result, planning evaluation continues to rely largely on technical indicators without clearly addressing ethical sufficiency or the stage at which such

evaluation should be systematically incorporated into decision-making processes (Kurzi et al., 2024; Roslan et al., 2025; Somasundram et al., 2018).

This study therefore aims to develop an ethical evaluation framework for urban planning governance based on the concept of *tayyib*. To address this gap, the study conceptualises *tayyib* as a post-compliance ethical evaluation tool operating primarily ex ante during development control and secondarily ex post through post-approval monitoring. By integrating Islamic ethical principles with contemporary sustainability discourse, the study develops an analytical perspective for evaluating whether urban development outcomes contribute to holistic human well-being, environmental sustainability, and socially responsible urban development. The article makes two interrelated conceptual contributions to planning governance theory: first, by conceptualising *tayyib* as an explicit post-compliance evaluation framework, and second, by proposing a multi-layered model of planning evaluation in which regulatory compliance, sustainability performance, and ethical sufficiency operate as complementary dimensions of assessment.

LITERATURE REVIEW

Urban Planning Governance and Sustainable Cities

Urban governance refers to the institutional arrangements that guide the planning, regulation, and management of urban development. In contemporary planning theory, urban governance is closely associated with sustainable urban development, which emphasises environmental sustainability, participatory decision-making, and equitable distribution of urban resources (Titov, 2021). In this context, governance involves coordination among multiple stakeholders including planning authorities, government agencies, private sector actors, and civil society organisations (Bajracharya & Khan, 2020).

Effective urban governance is fundamental to achieving sustainable and inclusive urban environments. In reality however, planning systems act as a balancing mechanism for three main areas; namely the promotion of economic development, environmental constraint and sustainability goals (Teriman et al., 2009).

Although participation mechanisms are formally included within the planning process with the intention of enhancing democratic response (Saporito, 2016), empirical evidence indicates that the assessment of planning continues to be based upon mainly technical compliance indicators. Regulatory frameworks and performance indicators remain primarily focused upon the attainment of compliance with spatial planning regulations and infrastructure provision rather than the pursuit of normative considerations relating to social justice, environmental responsibility and community well-being (Tomer & Kaushik, 2026).

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In Malaysia, the importance of environmental governance and sustainable development has grown significantly for planners with respect to developing policies on sustainability and green infrastructure resiliency. However, there continue to be barriers to implementing these concepts, namely because of the fragmentation of institutions and the decentralised nature of government (Nizarudin & Zakariya, 2025). Public participation is also an important component of decision-making processes under the Town and Country Planning Act of 1976, but this type of participation typically occurs procedurally rather than substantively (Zanudin et al., 2021).

The above findings demonstrate how the limitations of planning governance frameworks create structural limitations in evaluating the substantive merit or fairness of final development outcomes. This indicates a long-standing deficiency within the area of evaluating plans, specifically an absence of systematic method to determine the ethical adequacy of plans relative to non-technical and non-sustainability-based measures.

Ethical Dimensions of Urban Development

Urban development decisions have ethical implications as they affect the provision of housing, accessibility to infrastructure services, public facilities, and environmental quality. This implies that such decisions always have a direct impact on social justice, social welfare, and environmental sustainability. There has been a growing focus in the field of planning theory that the impact of development decisions must be evaluated not only in terms of efficiency and economic performance but also in relation to social welfare and sustainability in development (Barrett et al., 2016).

Environmental sustainability can be identified as a major ethical issue in the field of planning. Rapid urbanisation processes often generate conflicts between economic development, environmental sustainability, and social justice. Sustainable planning strategies such as compact development, mixed land use strategies, and the development of green spaces have been advocated to resolve the conflicts between development and environmental sustainability (Akther & Islam, 2020; Kosoe & Ogwu, 2025). Urban development also reflects diverse and sometimes competing social values. Cities function as complex governance systems in which economic, social, and environmental interests must be balanced through planning processes. Ethical planning governance therefore requires decision-making processes capable of accommodating competing interests while promoting socially beneficial urban development outcomes (McAuliffe & Rogers, 2019).

Accordingly, the central ethical issue in urban planning is not merely whether development complies with regulatory and performance-based criteria, but whether the resulting distribution of costs and benefits can be justified as fair,

responsible, and socially beneficial. This reinforces the need for an evaluative framework that explicitly addresses ethical sufficiency within planning decision-making.

The Concept of *Tayyib* in Urban Development

In this study, the concept of *tayyib* is an evaluative principle that could guide urban planning governance through the promotion of socially beneficial and environmentally sustainable development outcomes. In Islamic ethics, the concept of *tayyib* refers to goodness and wholesomeness, and it encompasses the idea of ethics and morality, which go beyond the idea of permissibility and legality and into the realm of positive consequences and beneficial impacts on individuals, societies, and the environment (Idris et al., 2022; Islam & Islam, 2025; Nordin et al., 2026). The Islamic concepts of halal and *tayyib*, as derived from the Qur'an, implies the idea of legality and permissibility and the promotion of the well-being and welfare of individuals and societies, and the positive consequences of actions and deeds on the individual and the community. Therefore, the concept of *tayyib* could introduce the idea of the evaluative principle, which promotes justice and well-being and the positive consequences of all human activities and deeds (ISRA, 2024; Nordin et al., 2024; Yasmeen et al., 2024).

Applied to urban planning governance, *tayyib* provides a conceptual basis for evaluating development outcomes in terms of their ethical sufficiency rather than regulatory admissibility alone. Thus, this changes the focus for assessing how well development improves societal wellbeing, environmental sustainability and good governance. *Tayyib* is positioned as an evaluative framework with specific ethical standards that are used to evaluate development against existing regulatory frameworks. It does so by providing an additional layer of evaluation based on ethics, which addresses the noted difference between meeting the requirements of current planning regulations and meeting the ethical requirements of developments.

RESEARCH METHODOLOGY

Research Design and Materials

This study employed a qualitative conceptual research design with the aim of developing a normative framework for assessing the ethical aspects of urban planning governance. Conceptual research aims to clarify concepts and synthesise theoretical approaches in order to develop an analytical framework rather than test a hypothesis or theory (Jabareen, 2009; Snyder, 2019). The study is based on document analysis and conceptual synthesis. The documents were grouped into three types. First, the literature on urban planning governance, sustainable cities, and evaluation frameworks for planning. Second, the

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documents on the Malaysian planning legislation and policy instruments that guide the planning governance system and urban development priorities. These policy documents include the Town and Country Planning Act 1976 (Act 172) and the national policy documents on planning that guide the planning system with the aim of promoting sustainability-oriented goals and spatial development priorities within the Malaysian planning system. These documents include the Second National Urbanisation Policy (NUP2) 2016-2025. The third category consists of Islamic ethical literature on the concept of *tayyib* as a normative principle for evaluating social welfare and ethical outcomes.

Document analysis is a commonly employed qualitative method for examining policy documents and scholarly literature in order to identify the conceptual patterns and governance logics embedded in them (Bowen, 2011). The selected documents were analysed in terms of three domains of analysis: governance evaluation in planning systems, sustainability evaluation in urban development, and normative ethical principles in planning evaluation.

Analytic Procedure

Following the document review, thematic interpretation was used to identify recurring patterns of evaluative concepts related to regulatory legality, sustainability performance, and ethical governance. Thematic analysis is a scientific approach to thematic identification in qualitative data sets (Braun & Clarke, 2006). Three steps were involved in the thematic analysis process.

The literature and policy documents identified some important evaluative concepts such as regulatory legality, environmental performance, distribution of planning benefits, and governance accountability. These concepts were subsequently grouped into more general evaluative themes such as environmental integrity, spatial justice, community well-being, and governance transparency. The interrelationship between these evaluative themes was then synthesised into a multi-layered evaluation model that includes regulatory compliance, sustainability performance, and ethical sufficiency.

In this manner, ethical concepts related to *tayyib* were transformed into analytical indicators pertinent to urban planning governance. These analytical indicators became the basis for the evaluative framework presented in the research. The research presented a conceptual study, and the proposed framework has not been subject to empirical testing. Future research on the applicability of the proposed framework can be examined.

ANALYSIS AND DISCUSSION

Compliance-Based Planning Governance and Ethical Implications

Malaysia's planning governance system primarily operates through a regulatory compliance model, whereby the planning proposal is assessed against the

planning regulations and procedures. This model offers the advantages of legal security and procedural predictability through conformity with planning regulations (Roosli & O'Keefe, 2011). However, the planning regulations and procedures mainly focus on the assessment of the compliance of the planning proposal with the technical planning standards and not the ethical standards. Consequently, compliance with regulatory requirements does not automatically ensure ethically responsible development outcomes. Research on governance regulation and environmental assessment shows that conformity-oriented systems may approve projects that satisfy legal standards while still generating environmental or social harm due to insufficient evaluation of wider impacts (Bedi, 2013; Naime, 2017). These limitations have prompted increasing calls for governance approaches that incorporate ethical considerations into development evaluation processes (Barrett et al., 2016).

Accordingly, urban planning governance increasingly requires evaluative approaches that extend beyond procedural compliance to incorporate broader societal and environmental considerations. Integrating ethical considerations into planning evaluation allows development outcomes to be assessed not only in terms of regulatory conformity but also in relation to their wider consequences for communities and ecosystems (Santoianni et al., 2023).

Tayyib as an Ex Ante Post-Compliance Tool with Ex Post Audit Potential

Building on these limitations, this study conceptualises *tayyib* as a post-compliance ethical evaluation tool applied primarily ex ante, after legal and technical conformity has been established but before final planning approval. In this sense, post-compliance evaluation refers to a further stage of assessment in which development proposals are examined in terms of their broader ethical, social, and environmental consequences rather than regulatory admissibility alone. The framework may also be used ex post as a post-approval monitoring and audit reference where local authorities seek to evaluate whether implementation continues to meet ethical expectations. Within planning governance, *tayyib* therefore functions as a normative filter: while legal compliance establishes admissibility, *tayyib* asks whether development outcomes are socially desirable, environmentally responsible, and ethically justifiable. In Islamic ethical studies, *tayyib* denotes goodness and wholesomeness that extend beyond mere legal permissibility (Islam & Islam, 2025; Mohd Sirajuddin & Mahaiyadin, 2022). Applied to urban planning, it provides a normative perspective for evaluating development outcomes in relation to sustainability, social welfare, and environmental responsibility (Idris et al., 2022; Yasmeen et al., 2024).

Under this framework, development outcomes may be evaluated not only from the point of view of their regulatory validity but also in relation to their

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contribution to human well-being, environmental sustainability, and socially responsible urban development. While the sustainability approach to evaluation primarily deals with environmental and socio-economic performance, the introduction of the concept of *tayyib* adds a moral dimension to the evaluation of the development outcomes. From this perspective, planning evaluation can be understood as consisting of three interconnected dimensions: regulatory validity, sustainability performance, and ethical sufficiency. While the concept of regulatory validity focuses on ensuring that development outcomes are valid from the perspective of the regulations in place, the concept of sustainability performance addresses the environmental performance of these development outcomes. On the other hand, the concept of ethical sufficiency deals with the moral performance of the development outcomes in relation to their contribution to the well-being of society.

Within this framework, ethical sufficiency is a distinct evaluation layer which addresses the limitations of compliance, regulatory and sustainability-based evaluations by adding an explicit set of normative criteria for assessing the justice of development outcomes, the welfare of society and responsibility to the environment. This layered evaluation approach allows the assessment of development proposals within the context of planning governance to evaluate the legal validity, sustainability performance, and ethical implications of those proposals on the broader community and urban environment. Overall, the framework proposes a staged evaluation process for assessing development proposals, where the first step is to ensure compliance with regulations, second to assess sustainability performance, and lastly to assess ethical sufficiency through the *tayyib* viewpoint. This layered structure provides a clear relationship between legality, sustainability and ethical responsibility in terms of planning governance. Figure 1 presents the conceptual understanding of the interconnectedness between the different dimensions of evaluation.

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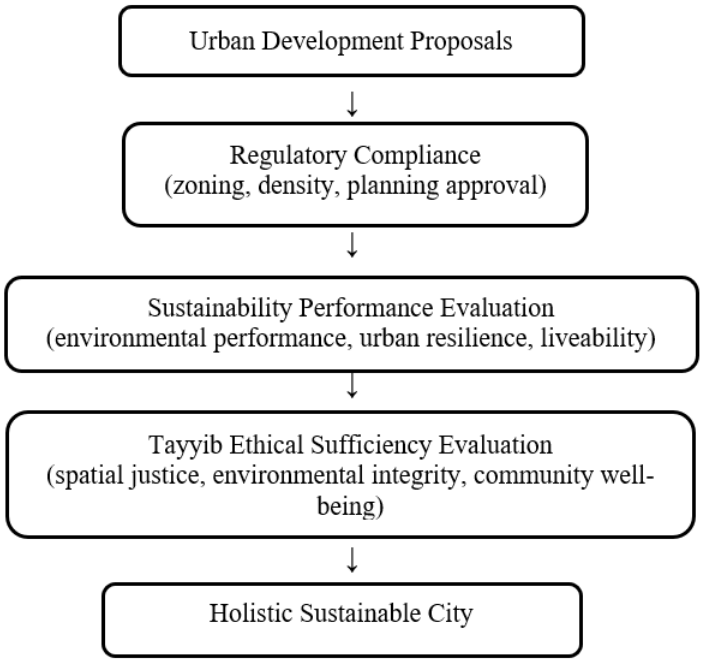


Figure 1: *Tayyib*-Based Ethical Urban Planning Governance Framework
Source: Author's conceptualisation based on the ethical concept of tayyib and urban planning governance literature

Figure 1 presents a stratified evaluative structure for planning governance. In the proposed structure, regulatory compliance is the first level in the evaluation process for development approvals, sustainability evaluation is the second level that examines environmental and functional sustainability, while the *tayyib*-based level is a post-compliance level that examines distributive justice, environmental integrity, and governance accountability.

To operationalise the proposed structure, the study proposes a set of planning governance indicators that can be used as an evaluative tool to link ethical principles with planning practice. This set of indicators can be used as an additional level of evaluation by planning authorities for development applications that are already evaluated as compliant with regulatory and sustainability requirements.

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Table 1: *Tayyib*-Based Urban Planning Governance Indicators

***Tayyib* Dimension**	**Planning Governance Indicator**	**Illustrative Minimum Threshold**	**Assessment Note**
Environmental integrity	Protection of ecological systems	No development in environmentally sensitive or protected areas; no significant unmitigated ecological harm to drainage, green corridors, or tree cover	Fail if material ecological harm remains unmitigated
Spatial justice	Equitable access to transport and services	Safe pedestrian access to public transport and basic daily services for the majority of residents	Fail if access benefits are spatially exclusionary or unevenly concentrated
Housing equity	Provision of affordable and inclusive housing	Affordable housing provision meets the applicable local or state requirement; lower-cost units are spatially integrated rather than segregated	Fail if affordability requirement is not met
Community well-being	Access to public spaces and facilities	Accessible public open space and basic community facilities are provided, and major noise, traffic, or safety harms are mitigated	Fail if public benefit is outweighed by clear unmitigated harm
Governance accountability	Transparency and public participation	At least two documented engagement stages and a written response matrix to material objections	Fail if engagement is merely procedural or undocumented

Source: Author's synthesis based on the ethical concept of tayyib and urban planning governance literature.

The thresholds in Table 1 are intended as illustrative minimums for ethical sufficiency and should be calibrated by local authority requirements, state planning policies, and site-specific conditions. Ethical sufficiency follows a non-compensatory rule: a proposal must meet the minimum threshold in every *tayyib* dimension, and failure in any one dimension means that it cannot yet be classified as ethically sufficient. Taken together, these thresholds and indicators provide a structured basis for assessing ethical sufficiency alongside regulatory and sustainability-based planning assessments, consistent with calls for normative evaluation in urban governance (Chapman et al., 2024; Saraswat et al., 2025).

The framework is analytically distinct from Environmental, Social and Governance (ESG) criteria, sustainable appraisals and social impact assessments

by way of scope, application and decision-making methodology. In terms of focus, ESG is organization-focused and focused on disclosures, whilst the *tayyib* framework is decision-focused and utilized as an appraisal tool at the stage of development control. Sustainable appraisal evaluates options according to predetermined outcomes, whilst the *tayyib* framework uses a non-compensatory ethical sufficiency test that utilizes principles of justice, wholesome governance and accountability.

Social impact assessment identifies potential negative impacts of projects and develops measures to mitigate them. The *tayyib* framework combines social, environmental and governance factors into one evaluative lens and can serve as a complementary ethical layer versus the other frameworks as substitutes. Table 1 illustrates indicators synthesized from planning governance literature, sustainability evaluation models and Islamic ethics related to *tayyib*. Indicators illustrated in Table 1 represent a variety of normative concerns in urban planning such as environmental protection, equitable access, inclusive housing, community well-being and transparency in governance. The *tayyib* framework transforms ethical principles into operative criteria that enable ethical sufficiency to be systematically evaluated through development decision-making.

Under this framework, all minimum thresholds must be met across all *tayyib* dimensions. Therefore, no minimum threshold-based classifications are possible due to partial compliance. The project could meet zoning requirements and meet sustainability standards, but still not be considered ethically sufficient if it does not provide equitable housing or allow for meaningful community participation.

Illustrative Application in Development Evaluation

To demonstrate the operational application of the framework within a Malaysian planning context, consider that a local government council assesses a proposal for a mixed-use redevelopment project located on brownfield land adjacent to a railway station in the Greater Kuala Lumpur area. The proposed redevelopment meets all the relevant criteria regarding zoning and density as outlined by the Town and Country Planning Act 1976 (Act 172). Additionally, the proposal complies with some of the sustainable development objectives set out in the Second National Urbanisation Policy (NUP2) particularly those related to transit-oriented development and compact cities.

Next, a *tayyib* assessment is carried out ex ante at the development control phase before final approval. In terms of environmental integrity, the proposal does not impact ecologically sensitive sites; it includes adequate drainage mitigation measures. With respect to spatial justice, residents have proximity to public transportation and other essential services through walking distance, which corresponds to NUP2's focus on accessibility and liveability. In

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contrast, however, the proposal does not meet housing equity as the percentage of affordable housing included is less than required by local planning authorities. Furthermore, governance accountability is lacking because only one public meeting was held during the consultation process and there is no documented response outlining to stakeholder objections, even though Act 172 contains specific provisions for public participation.

Consequently, using this model, the redevelopment proposal would need to be revised or approved conditionally until the affordable housing requirements were satisfied; adequate publicly accessible open spaces had been provided; and community engagement activities had been documented. This example illustrates how *tayyib* framework operates as an ethical filter after compliance in statutory planning decision making processes both ex ante to assist with determining approvals and ex post as a benchmark for evaluating implementation performance.

CONCLUSION

This study reconceptualises urban planning evaluation by positioning *tayyib* as an ethical layer that operates alongside regulatory compliance and sustainability performance. The proposed framework clarifies that legal conformity, while necessary, is insufficient to establish whether development outcomes are socially equitable, environmentally responsible, and ethically defensible. Its main conceptual contribution lies in translating *tayyib* into evaluative dimensions that can be used to assess environmental integrity, spatial justice, housing equity, community well-being, and governance accountability. In practical terms, the framework may guide local authorities in introducing an additional post-compliance filter during development control and, where relevant, in post-approval monitoring. The study remains conceptual, however, and the framework has not yet been empirically validated. Future research should therefore test the indicators in real planning cases, examine their feasibility across different local authority contexts, and identify appropriate thresholds for ethical sufficiency. Overall, the framework advances a more holistic model of planning governance by linking legality, sustainability, and ethics within a single evaluative structure.

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ISLAMIC SOCIOECONOMIC PLANNING AND DEVELOPMENT: AN ANALYSIS OF THE PROPHET SULAYMAN'S APPROACHES IN THE QUR'AN

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Abstract

Contemporary discourse on socioeconomic planning and development has largely evolved within modern economic and technocratic frameworks that emphasize material growth, institutional efficiency, and policy management. From an Islamic perspective, development is understood as a holistic process that integrates moral values, social justice, societal well-being, and material prosperity within the framework of divine guidance. This study examines the approaches to Islamic socioeconomic planning and development based on the narrative of Prophet Sulayman (peace be upon him) in the Qur'an. Employing a qualitative approach grounded in textual analysis, the study applies the methodology of *tafsīr al-mawḍū'iy* or thematic analysis to verses related to Prophet Sulayman (pbuh) supported by hadith as well as classical and contemporary exegetical sources. The findings identify 51 verses across seven *surah*s in the Qur'an and demonstrate that the developmental approach of Prophet Sulayman (pbuh) encompasses three main dimensions, namely developmental worldview (*tasawur*), development principles, and forms of developmental approach. The study concludes that this Qur'anic narrative provides an integrated and value-based developmental framework that enriches the theory of Islamic socioeconomic planning and development.

Keywords: Islamic Socioeconomic Development, Islamic Planning Theory, Prophet Sulayman, Qur'anic Governance, Thematic Exegesis

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INTRODUCTION

Contemporary discussions on socioeconomic planning and development have increasingly evolved within modern economic and technocratic governance frameworks that emphasize material growth, institutional efficiency, and policy management. While these frameworks have made substantial contributions to development theory and practice, recent scholarship suggests that genuinely sustainable development cannot be assessed solely through material indicators. Instead, development must also be evaluated in terms of ethics, value orientation, social justice, and institutional responsibility. Within Islamic development discourse, this shift is increasingly reflected in efforts to construct sustainable development frameworks grounded in Islamic values, as well as in studies that highlight the significance of Islamic epistemology and ethics in broadening the understanding of sustainable development (AlQashouti & Shah, 2025; Raimi, 2024).

From an Islamic perspective, development is understood as a comprehensive and integrated process encompassing economic, spiritual, moral, social, and institutional dimensions within the framework of divine guidance. This approach is often articulated through the framework of *maqāṣid al-sharī'ah*, which emphasizes the preservation and enhancement of the essential dimensions of human life. Previous studies show that Islamic socioeconomic development is concerned not only with growth and distribution, but also with balanced human well-being and the development of evaluative measures that are sensitive to value-based dimensions (Zailani et al., 2022). In applied contexts, this framework has also been used to assess the performance of Islamic financial institutions beyond conventional financial indicators by incorporating ethical, social, and public welfare considerations (Okumus, 2024).

These developments have also influenced the field of planning, as reflected in studies on public housing, *waqf* land development, Malay-Islamic urban design, and *sharī'ah*-compliant infrastructure (Abdul Latip et al., 2020; Mat Hassan et al., 2021; Shuid & Mohd Zamin, 2018; Sunandar et al., 2025). Nevertheless, much of this scholarship remains concentrated on sectoral applications. A more fundamental question still requires further investigation: how might a genuinely comprehensive development model be constructed on the basis of the approaches demonstrated by the prophets in the Qur'an? In this regard, the narrative of Prophet Sulayman (pbuh) is especially significant, as it reflects knowledge-based leadership, resource management, institutional coordination, diplomacy, and justice. Although recent studies recognize the governance value embedded in this narrative, their analyses remain largely focused on good governance or partial *maqāṣidiy* interpretation (Fikri & Khamim, 2025; Rizal et al., 2025). It is therefore appropriate to employ the *tafsīr al-mawḍū'iy* approach in order to systematically assemble and analyse all

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Qur'anic verses related to Prophet Sulayman (pbuh), and thereby formulate a more coherent development framework that contributes to the strengthening of Islamic planning theory (Abu Bakar et al., 2023).

LITERATURE REVIEW

This section reviews literature related to the concept of socioeconomic planning and development from an Islamic perspective, as well as its relationship to the approaches discussed in the Qur'an. The discussion begins with the concept of Islamic socioeconomic planning and development, followed by the framework of Islamic-based development. It then analyses literature on the Qur'anic narrative of Prophet Sulayman (pbuh) in order to examine existing discussions on his leadership and governance. Based on this review, the section identifies gaps in previous scholarship, particularly with regard to the construction of an Islamic socioeconomic development model grounded in thematic analysis of Prophet Sulayman's developmental approach in the Qur'an.

Islamic Socioeconomic Development and Planning

Socioeconomic planning and development constitutes an important field within contemporary development studies, focusing on the enhancement of social well-being through resource management, institution-building, and the implementation of economic and social policies. Within modern development frameworks, this field is commonly associated with economic growth, institutional development, and public policy efficiency. However, development literature has long emphasized that effective development should not be measured solely in economic terms; it must also take into account human freedom, social well-being, and long-term sustainability (Sachs, 2015; Sen, 1999; Todaro & Smith, 2020).

In the Islamic context, socioeconomic development is understood more comprehensively because it is closely linked to moral and spiritual dimensions. Chapra (2008) argues that development in Islam cannot be separated from *maqāṣid al-sharīʿah* and the pursuit of holistic human well-being. In a similar vein, Raimi (2024) demonstrates that Islamic epistemology and ethics have the potential to enrich sustainable development discourse through the concepts of trust, social responsibility, and balance between human beings and nature. Islamic socioeconomic development may therefore be understood as a framework that integrates economic, social, ethical, and spiritual dimensions within a coherent value system.

This approach has increasingly attracted attention in planning and public policy. Shuid and Mohd Zamin (2018) show that the *maqāṣid al-sharīʿah* framework can be used to assess public housing well-being more holistically. Abdul Latip et al. (2020) demonstrate that the principles of Malay-Islamic

urbanism may be derived from Islamic values translated into spatial and cultural forms. In the field of Islamic finance, Okumuş (2024) further shows that the *maqāṣid* framework can be employed to evaluate institutional performance beyond conventional financial measures by incorporating social and ethical dimensions. These developments indicate that Islamic socioeconomic development is not merely a normative construct, but increasingly has empirical applications in contemporary planning and institutional practice.

Nevertheless, much of the existing scholarship remains focused on contemporary policy applications, modern institutional development, and *maqāṣid*-based measurement. Development models derived directly from revelation, particularly from Qur'anic narratives, remain underexplored in the literature on Islamic development and planning.

Islamic-Based Development

Islamic-based development refers to the process of societal development guided by Shariah principles and moral values derived from the Qur'an and Sunnah. In Islamic development literature, this concept is commonly associated with the framework of *maqāṣid al-sharīʿah*, which emphasizes the preservation and enhancement of the essential dimensions of human life, including religion, life, intellect, lineage, and property (Chapra, 2008). Chapra (2008) explains Islamic development as a process aimed at realizing human well-being through justice, balance, and value orientation, rather than through material growth alone.

Recent scholarship also suggests that Islamic-based development is increasingly being discussed in relation to sustainable development. Raimi (2024) concludes that Islamic ethics and epistemology can broaden the understanding of sustainability, while AlQashouti and Shah (2025) propose an *Islamicity Sustainable Development Index* that integrates economic, social, and ethical dimensions. In this sense, Islamic-based development has the potential to contribute to global development discourse through its emphasis on social justice, accountability, balance, and moral responsibility toward society and the environment.

However, a significant portion of the literature still focuses on general normative frameworks, contemporary institutions, or sector-specific performance measurement. Although these developments are important, studies that systematically construct development models on the basis of Qur'anic narratives remain relatively limited, particularly in the context of socioeconomic planning.

Prophet Sulayman in the Qur'an

The narratives of the prophets in the Qur'an contain important insights into leadership, governance, and societal development. Among the most significant of these in the context of governance is the story of Prophet Sulayman (pbuh),

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who is portrayed as a prophet and ruler endowed with knowledge, wisdom, and authority. Rizal et al. (2025) show that the Qur'anic account of Prophet Sulayman contains principles of governance related to administrative order, statecraft, and governance values.

In Surah al-Naml, the narrative of Prophet Sulayman (pbuh) also reflects knowledge-based leadership, information verification, diplomatic communication, justice, and institutional coordination. Fikri and Khamim (2025) argue that this narrative may be read through a *maqāṣidiy* lens as a model of *good governance* highlighting social responsibility, accountability, and justice. However, most studies on Prophet Sulayman remain limited to leadership themes or the interpretation of specific passages, and have not yet developed into a comprehensive model of socioeconomic development.

Research Gap and Contribution of the Study

Based on the literature reviewed, several research gaps may be identified. First, although there is extensive scholarship on Islamic development, most of it concentrates on *maqāṣid al-sharīʿah*, sustainable development, or the evaluation of contemporary institutions (AlQashouti & Shah, 2025; Okumuş, 2024; Raimi, 2024). Second, scholarship in Islamic planning remains largely focused on sectoral applications such as public housing, Malay-Islamic urbanism, or Islamic economic institutions (Abdul Latip et al., 2020; Shuid & Mohd Zamin, 2018). Third, studies on Prophet Sulayman (pbuh) continue to emphasize governance dimensions and *maqāṣidiy* interpretation rather than constructing a comprehensive socioeconomic development framework from the full range of verses related to him (Fikri & Khamim, 2025; Rizal et al., 2025).

Accordingly, this study occupies a clear position within the literature by examining Islamic socioeconomic planning and development through the Qur'anic narrative of Prophet Sulayman (pbuh). Specifically, this study seeks to add value to existing maqāṣid frameworks by extending the focus from the preservation of essentials toward a proactive model of developmental mastery. Methodologically, the *tafsīr al-mawḍūʿiy* approach has a strong basis in contemporary scholarship, including the discussion by Abu Bakar et al. (2023) on the strength of thematic exegesis in producing systematic and integrated understanding. Through the application of this methodology, the study strengthens the bridge between revealed narrative and contemporary governance by offering an ethically stable framework that complements modern technocratic planning for the benefit of a diverse global audience. Consequently, the study seeks to strengthen Islamic development theory and enrich the relationship between Qur'anic narrative and contemporary development thought.

RESEARCH METHODOLOGY

This study adopts a qualitative approach centred on textual analysis in order to examine Islamic socioeconomic development through the narrative of Prophet Sulayman (pbuh) in the Qur'an. A qualitative design enables an in-depth interpretation of revealed texts, clarifies the principles of governance and planning embedded in prophetic guidance, and relates them to contemporary Islamic development frameworks. The study is descriptive-analytical in nature, emphasizing context, values, and the ethical implications embedded in the Qur'anic verses and relevant exegetical sources (Creswell & Poth, 2018).

The primary data were drawn from both primary and secondary sources, particularly Qur'anic verses concerning Prophet Sulayman (pbuh) and hadiths that serve as interpretive sources for the Qur'an. The exegetical sources used fall into three categories. First, classical *tafsīr bi al-ma'thūr*, namely *Tafsīr al-Ṭabariy* and *Tafsīr Ibn Kathīr*. Second, *tafsīr bi al-ra'y*, namely *Mafātīḥ al-Ghayb*. Third, modern exegesis, namely *Fī Ẓilal al-Qur'ān* and *al-Tafsīr al-Munīr*. These works were used to understand the historical, linguistic, and juristic contexts of the relevant verses. In addition, contemporary exegetical scholarship, including academic studies and journal articles, was employed to relate the prophetic narrative to principles of development and modern Islamic governance (Zailani, Mohd Satar, & Zakaria, 2022; Sunandar, Abd Karim, & Zolkafli @ Zulkifly, 2025). Data collection was conducted through purposive sampling, involving the selection of verses and exegetical materials relevant to the objectives of the study in order to ensure analytical precision and depth.

Data were analysed through thematic analysis and the *tafsīr al-mawḍūʿiy* approach. In the thematic analysis, the collected Qur'anic verses and exegetical materials were coded according to major themes such as worldview, principles, and forms of developmental approach. These themes were then analysed inductively to identify recurring patterns, principles, and strategies in the prophetic narrative. At the same time, the *tafsīr al-mawḍūʿiy* approach enabled the relevant Qur'anic verses to be organized and interpreted systematically in relation to Islamic socioeconomic development.

The validity and reliability of the study were ensured through source triangulation, combining Qur'anic verses with both classical and contemporary exegesis in order to achieve a balanced and comprehensive interpretation. These procedures ensure that the findings are not merely theoretical and normative, but also credible and grounded in robust data, in line with the standards of high-indexed academic journals.

FINDINGS

This study identified 51 Qur'anic verses related to Prophet Sulayman (pbuh). These verses were selected on the basis of narratives that directly concern his life

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and role. Overall, the verses are distributed across seven surahs, as presented in Table 1.

Table 1: List of Verses Related to Prophet Sulayman in the Qur'an

Number by *Muṣḥaf* order	Surah Name	Surah Category		Total Verses in Surah	Related Verses	Verse Numbers
		Makkiyah	*Madaniyyah*			
2	*Al-Baqarah*		√	286	1	102
4	*Al-Nisā'*		√	176	1	163
6	*Al-An'ām*	√		165	1	84
21	*Al-Anbiyā'*	√		112	4	78, 79, 81 & 82
27	*Al-Naml*	√		93	30	15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43 & 44
34	*Saba'*	√		54	3	12, 13 &14
38	*Ṣād*	√		88	11	30, 31, 32, 33, 34, 35, 36, 37, 38, 39 & 40
	Total	**5**	**2**	**974**	**51**	

Table 1 presents the Qur'anic verses related to Prophet Sulayman (pbuh). These verses were identified and collected based on narratives that directly concern him. A total of 51 verses related to Prophet Sulayman (pbuh) in the Qur'an were identified from seven different surahs. Of these seven surahs, only two fall into the category of Madaniyyat verses, namely *al-Baqarah* and *al-Nisā'*, while the remaining five—*al-An'ām, al-Anbiyā', al-Naml, Saba'*, and *Ṣād*—belong to the *Makkiyyah* category.

Subsequently, the collected verses on Prophet Sulayman's developmental approach in the Qur'an were found to correspond to three aspects: worldview, principles, and forms of developmental approach. All 51 verses mentioned above were analyzed and linked to these three aspects.

Developmental Worldview of Prophet Sulayman's Approach

In essence, the term tasawur refers to a conception, perception, or worldview regarding all things. In this context, the developmental worldview of Prophet Sulayman's approach may be understood as a comprehensive and essential conception of his developmental approach in terms of its primary concepts, which serve as the foundation for all of his developmental activities. In other words, all the principles, forms, and elements of Prophet Sulayman's developmental approach are shaped by his distinctive worldview.

An examination of all 51 collected verses shows that Prophet Sulayman's developmental approach is anchored in three major worldviews. First, Allah SWT as the Creator and Owner of all power. This worldview element is explained through the identification of verses describing the divine attributes and power of Allah SWT. These include verses mentioning Allah SWT as the Creator (*al-Naml*, 27:25), the All-Observing (*al-Anbiyā'*, 21:78), the All-Powerful (*al-Anbiyā'*, 21:79), the All-Knowing (*al-Anbiyā'*, 21:81), the All-Controlling (*al-Anbiyā'*, 21:82), the Giver (*al-An'ām*, 6:84; al-Naml, 27:15 & 16; *Ṣad*, 38:30, 35 & 39), the One (*al-Naml*, 27:26), the Owner of the Throne (*al-Naml*, 27:26), the Most Compassionate, Most Merciful (*al-Naml*, 27:30), the Self-Sufficient, Most Generous (*al-Naml*, 27:40), the Lord of all worlds (*al-Naml*, 27:44), the One whose bounty is ever-abundant (*Ṣād*, 38:35), the Rewarder (*al-An'ām*, 6:84), the Giver of death (*Saba'*, 34:14), the One who caused a spring of molten copper to flow (*Saba'*, 34:12), and the One who subjected the wind (*Ṣād*, 38:39). All of these are encompassed under the first worldview: Allah SWT as the Creator and Owner of all power.

Second, Prophet Sulayman (pbuh) as a prophet, servant, and vicegerent of Allah SWT in carrying out development. This worldview element is explained through the identification of verses that describe the attributes of Prophet Sulayman (pbuh), covering his prophetic and servanthood qualities as well as his actions in developing the kingdom. He is portrayed as a prophet who received revelation (4:163 & 6:84), one who did not commit disbelief or *kufr* (2:102), a judge who adjudicated disputes (*al-Anbiyā'*, 21:78–79), a servant who expressed gratitude and praised Allah SWT (27:15–16), one who prayed and repented to Allah SWT (27:19 & 38:35), and a leader who managed the army (27:17).

Third, natural resources as instruments of development. This worldview element is explained through the identification of verses that describe the natural resources utilized by Prophet Sulayman (pbuh). Seven verses mention the resources used by him in carrying out development, such as wind (21:81, 34:12 & 38:36), glass (27:44), copper (34:12), the produce of the earth (27:25), and pearls (34:12).

Principles of Prophet Sulayman's Developmental Approach

Five principles of Prophet Sulayman's developmental approach were identified. First, *al-tawḥīd*, or the oneness of Allah SWT (4:63; 6:84; 21:78, 79, 81–82; 27:15, 16, 24, 25, 26, 30, 36, 40 & 44; 38:35). Second, *al-'ubūdiyyah*, or servitude/worship of Allah SWT (2:102; 27:15, 16, 19 & 40; 34:13; 38:30, 32 & 35). Third, *khilāfah fi al-arḍ*, or vicegerency on earth (21:78, 79 & 82; 27:15, 17, 18, 19, 20, 21–41; 34:12–14; 38:31, 34, 37–38). Fourth, *mawārid al-tābi'i*, or natural resources (21:81, 27:25 & 44; 34:12; 38:36). Fifth, *marḍāt Allāh*, or seeking the pleasure of Allah SWT (27:19).

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Forms of Prophet Sulayman's Developmental Approach

At least seven forms of Prophet Sulayman's developmental approach are mentioned in the Qur'an. These are education, economy, security, environment, society, technological advancement, and politics. Through the educational approach, at least four elements were implemented by Prophet Sulayman (pbuh): first, instilling sound faith among all levels of society (27:16, 24, 25 & 26); second, recognizing the status of knowledge and its people (21:78, 79; 27:15, 22 & 40); third, educating through exemplary conduct (38:30, 32 & 35); and fourth, shaping the moral character of the people (27:21).

In the economic approach, two elements identified are inculcating the concept of *syukr* or gratitude (27:15 & 40) and utilizing natural resources (21:81; 34:12; 38:36). Regarding the security approach, four elements were identified: upholding justice (21:78 & 79; 27:20, 21 & 27), strengthening the security system (21:82; 27:17, 41; 34:12; 38:31, 33 & 38), monitoring the condition of the people (27:20; 34:14), and safeguarding national sovereignty (27:28, 29, 30 & 31). Furthermore, Prophet Sulayman (pbuh) also adopted an environmental approach by preserving Allah's natural creation (27:18). In relation to the social approach, two elements were identified: caring for the welfare of the people (34:13) and preserving social harmony (27:34). In developing technology, the elements employed were building infrastructure (27:44; 34:12–13; 38:37) and generating public expertise for national development (21:82; 27:38–40; 34:12; 38:37). The next approach is the political approach. Through this approach, Prophet Sulayman (pbuh) implemented *shura* (27:32–35, 38–40), cultivated efficient governance (27:20 & 28), upheld integrity (27:36–37), and practiced the politics of *da'wah* (27:23–26, 30–31 & 41; 38:34).

DISCUSSION

The findings of this study show that the developmental approach of Prophet Sulayman (pbuh) as recorded in the Qur'an forms a comprehensive and integrated development framework. The analysis reveals that his developmental approach is not fragmented; rather, it is formed through a systematic relationship between developmental worldview, principles, and operational forms. This hierarchical relationship indicates that development in the Qur'anic perspective is rooted in a particular epistemological foundation before being translated into normative principles and subsequently into operational strategies for societal development.

This is illustrated in the following figure:

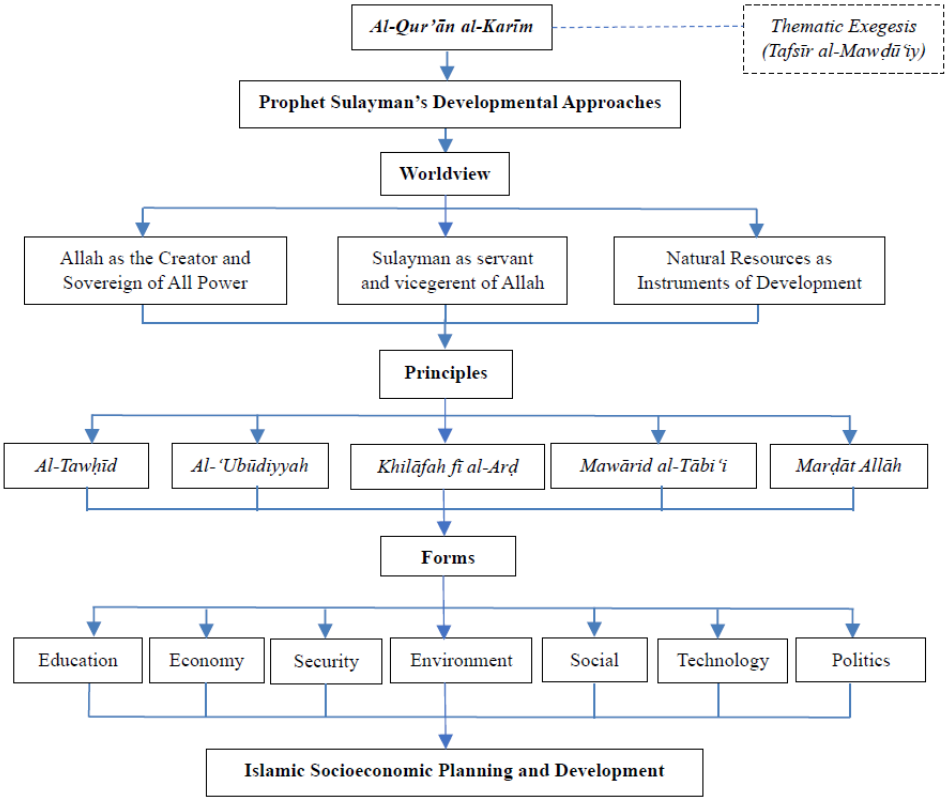


Figure 1: The Conceptual Framework of The Prophet Sulayman Developmental Approaches

Figure 1 illustrates the conceptual framework derived from the Qur'anic narrative, structured into several interconnected layers. At the epistemological level, the Qur'an serves as the primary source of knowledge guiding the framework. From this foundation emerges the developmental worldview (*tasawur*), which emphasises divine sovereignty, human stewardship, and the utilisation of natural resources. This worldview subsequently shapes the normative principles, namely *al-tawḥīd, al-ʿubūdiyyah, khilāfah fi al-arḍ, mawārid al-tābiʿi*, and *marḍāt Allāh* which then guide the operational domains of development encompassing education, economy, security, environment, social organisation, technology, and politics.

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Implications for the Theory of Islamic Socioeconomic Planning and Development

The findings carry several important implications for the discourse on Islamic socioeconomic planning and development. First, the study shows that the Qur'anic planning contains a comprehensive development framework integrating worldview, principles, and forms of developmental approach. This framework demonstrates that development in the Islamic perspective is based on a clear relationship between epistemology, normative values, and operational strategy.

Second, the study shows that Prophet Sulayman's development model may be understood as a form of Qur'anic development model that connects the dimensions of the relationship with the Creator, relationships among human beings, and the relationship with nature within an integrated development system.

Third, this study also contributes to the development of Islamic socioeconomic planning theory by showing that the concept of development in Islam is not limited to economic or Islamic finance frameworks alone, but involves a broader approach encompassing education, economy, security, environment, society, technology, and politics.

Overall, the findings show that the narrative of Prophet Sulayman (pbuh) in the Qur'an can serve as a conceptual foundation for constructing a more comprehensive and value-based framework of Islamic socioeconomic planning and development.

Bridging Revelation to Contemporary Planning and Governance

The narrative of Prophet Sulayman (pbuh) provides a robust conceptual bridge to contemporary governance by demonstrating how knowledge-based leadership and institutional coordination can be operationalized. While modern planning and governance have increasingly integrated aspects of morality and integrity, the Sulaymanic model complements these efforts by anchoring ethics in a revealed, absolute truth that offers a higher degree of certainty and consistency in decision-making. In this framework, technocratic efficiency is not merely a managerial goal but is harmonized with a profound sense of moral accountability. For instance, the deployment of advanced technology and infrastructure is balanced with the universal principles of gratitude and justice, ensuring that development serves a transcendent ethical purpose. This approach invites all stakeholders, including those from diverse belief systems, to appreciate a model where material progress is inextricably linked to the preservation of social harmony and the protection of the vulnerable, ultimately leading to a more stable and inclusive form of societal well-being.

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Distinction and Contribution to Existing Maqāṣid-Based Models

The framework derived from the narrative of Prophet Sulayman (pbuh) offers a significant value-added dimension to existing *maqāṣid al-sharīʿah* discourses. While established frameworks provide a robust foundation centered on the preservation (*ḥifẓ*) of essential needs, this model extends that trajectory toward proactive developmental mastery. It builds upon contemporary sectoral applications—such as those in Islamic finance and public housing—by offering a macro-level synthesis that integrates security, technology, environment, and diplomacy into a unified planning system. By doing so, it elevates technological advancement and resource optimization from mere economic instruments to a strategic fulfillment of the *khilāfah* (stewardship) mandate, thus providing a more expansive and operational roadmap for holistic Islamic development.

Integrated Synthesis of the Sulaymanic Framework

To further operationalize the conceptual transitions between these revealed dimensions and their practical applications, a systematic synthesis is undertaken to align the foundational worldview and principles of the Sulaymanic model with their functional processes and modern governance impacts. Consequently, Table 1 provides a comprehensive matrix that translates the integrated components of this framework into tangible strategies for contemporary socioeconomic planning, emphasizing ethical stewardship and industrial sovereignty.

Table 1: Integrated Framework of Sulaymanic Socioeconomic Development and Modern Planning Relevance

Framework Component (Integrated System)	**Operational Synthesis (The Process)**	**Modern Planning Relevance (The Impact)**
Worldview: (Allah as Sovereign, Vicegerency (Khilafah), Resources as Instruments)	Development is a Divine Trust (*Amānah*). Economic assets are not ends in themselves, but instruments to test the steward's gratitude and obedience to the Creator.	**Ethical Stewardship:** Shifts planning from profit-centric models to Divine-centric Accountability. It redefines "success" as achieving *Marḍāt Allāh* (Divine Pleasure) through ethical processes, rather than just GDP or material gain.
Principles: (*Al-Tawḥīd, Al'Ubūdiyyah, Khilāfah fi al-Arḍ, Mawārid al-Tābi'i, Marḍāt Allāh*)	These principles act as an Integrated Moral Filter. Each socioeconomic decision must prioritize social justice (*'Adl*) and the preservation of all creations to ensure the path to Divine Pleasure is maintained.	**Inclusive Stakeholder Management**: Just as Prophet Sulayman's governance protected the smallest entity (the ants), modern socio-economic planning must ensure social equity and the protection of the vulnerable (B40/marginalized) as a religious obligation.
Forms: (Education, Economy, Security, Environment, Social, Technology, Politics)	These seven forms function as an Integrated Industrial Complex. Strategic intelligence and advanced technology are deployed to build a sovereign, self-sufficient, and value-driven economy.	**Industrial Sovereignty & Smart Growth**: The mastery of resources (e.g., copper smelting) and data (e.g., strategic intelligence/GIS) represents Supply Chain Sovereignty. It promotes high-tech industrialization for economic self-sufficiency, aimed at strengthening the Ummah's position.

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Table 1 synthesizes the hierarchical integration of the Sulaymanic framework and its direct relevance to contemporary socioeconomic planning. This system transforms natural resources into a divine trust (*amānah*) managed through an "Integrated Moral Filter" that prioritizes social justice and stakeholder inclusivity. Consequently, technological and data mastery are elevated from mere economic tools to drivers of industrial sovereignty, complementing modern governance by offering a stable, universal roadmap for inclusive and sustainable societal well-being.

CONCLUSION

This study analyzes Islamic socioeconomic planning and development based on the narrative of Prophet Sulayman (pbuh) in the Qur'an through the methodology of *tafsīr al-mawḍūʿiy*. The analysis found that his developmental approach is structured through an integrated worldview, principles, and various forms of approaches. This developmental worldview emphasizes the recognition of Allah SWT as the Creator and Owner of all power, the position of human beings as servants and vicegerents of Allah, and natural resources as instruments of development. These elements are translated into core principles that govern diverse developmental approaches, ranging from faith-based education to advanced technology and efficient governance. Ultimately, the narrative of Prophet Sulayman (pbuh) provides a comprehensive framework that integrates spiritual, ethical, and institutional dimensions. Therefore, Prophet Sulayman's development model has the potential to strengthen the discourse on Islamic socioeconomic planning and development by offering a more integrated and value-based perspective grounded in revelation.

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TRUST IN USER-GENERATED CONTENT FOR SMART TOURISM DEVELOPMENT IN MALAYSIA

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Abstract

The increasing use of digital platforms has transformed the tourism industry, with user-generated content (UGC) becoming a key source of information for tourists. As tourists increasingly rely on online reviews, social media, and shared experiences, trust has emerged as a critical factor in decision-making and destination perception. This study aims to examine the significance of trust in UGC for smart tourism development in Malaysia, particularly in shaping tourists' perceptions, behaviour, and engagement within digital environments. Adopting a qualitative approach through document analysis, this study reviews relevant literature on UGC, trust, and smart tourism to identify key themes and relationships. The findings reveal three key insights. First, a trust deficit exists in UGC, where the abundance of digital information does not necessarily translate into user confidence, given concerns about credibility and reliability. Second, trust acts as a mediating mechanism, determining whether UGC is accepted and utilised in tourist decision-making. Third, trust plays a critical role in supporting the effectiveness of smart tourism systems, as it influences user engagement, information utilisation, and overall system performance. The study highlights that while digital technologies are essential in smart tourism development, their effectiveness depends largely on the trustworthiness of information shared among users. Strengthening trust in UGC is therefore crucial for supporting informed decision-making, enhancing the tourist experience, and ensuring sustainable tourism development. This study contributes by offering a clearer understanding of how trust shapes the relationship between digital information and smart tourism outcomes, particularly within the Malaysian context.

Keywords: User-Generated Content, Trust, Trust Deficit, Tourism Development, Smart Tourism

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INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the tourism industry by revolutionising tourism initiatives, products, experiences, business ecosystems, and destinations, as well as changing interaction practices (Gutierriz et al., 2025). Particularly through the emergence of smart tourism, information and communication technologies are integrated to enhance tourist experiences and improve destination management. This process generates large volumes of data, often referred to as Big Data, which can be analysed to better understand tourist behaviour and preferences. By leveraging such data, smart tourism destinations can deliver more personalised services that align with visitors' needs and expectations. Understanding these preferences is increasingly important for enhancing tourist experiences and maintaining destination competitiveness (Buhalis & Amaranggana, 2015).

Smart tourism development is driven by the integration of digital technologies that enable real-time data collection, exchange, and analysis to enhance tourism experiences. Through interconnected systems and advanced data processing, destinations can deliver more personalised and efficient services that align with tourists' preferences. This capability is increasingly important for improving destination competitiveness and the overall visitor experience (Gretzel et al., 2015).

The tourism industry in Malaysia is currently facing stagnation due to remaining in its comfort zone and an over-reliance on traditional marketing and promotion. This situation has left Malaysia behind its ASEAN neighbours in adopting smart tourism (MOTAC, 2020). To address this issue and elevate Malaysia to a top-ten global tourism destination, embracing smart tourism has been identified as a key strategy in the National Tourism Policy 2020-2030.

To this end, Malaysia is committed to embarking on a comprehensive digitalisation journey to transform its tourism industry toward smart tourism. The strategy involves optimising e-marketing through smart partnerships between the government and the tourism industry, encouraging innovation within the sharing economy, utilising Big Data analytics for planning and management, and consolidating the visitor economy across the tourism value chain (MOTAC, 2020). While the document does not explicitly mention User-Generated Content (UGC), the acknowledgement that current promotional strategies rely too heavily on traditional marketing indicates a clear gap in optimising UGC to boost tourism in Malaysia.

The emergence of Web 2.0 technologies has significantly transformed tourism marketing, shifting tourists from passive consumers of information to active content creators. Within this environment, UGC, such as online reviews, social media posts, and shared travel experiences, has become a major source of influence in shaping destination image and travel decisions. Compared to traditional marketing, UGC is often perceived as more authentic and relatable,

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making it a trusted source of information for travellers. As a result, tourism marketing has evolved into a more interactive and participatory process, in which tourists play an active role in creating and sharing destination narratives (Sujatmiko et al., 2025).

While UGC provides valuable information and enhances decision-making, it also presents both benefits and challenges for tourism consumers. On the one hand, UGC is perceived as credible because it reflects real experiences shared by independent users, making it more trustworthy than traditional promotional content. On the other hand, concerns about reliability persist, particularly due to the risk of fake reviews, biased opinions, or commercially motivated content. This dual nature of UGC highlights the importance of trust in determining whether such content is accepted and used in travel decision-making (Burgess et.al., 2009).

While reliance on UGC continues to grow in tourism, concerns about its credibility, consistency, and potential bias have created a trust deficit in digital information environments. This highlights that while information is increasingly abundant and accessible, it is not always perceived as reliable by tourists. In the context of smart tourism, where digital platforms and real-time information play a central role, the effectiveness of UGC depends largely on the level of trust users place in it. Therefore, understanding how trust in UGC is formed and how it influences tourist behaviour becomes essential in supporting smart tourism development. This study aims to examine the significance of trust in UGC for smart tourism development in Malaysia, particularly in shaping tourists' perceptions, decision-making, and engagement within digital environments. The following section reviews relevant literature to provide a deeper understanding of the relationship between UGC, trust, and smart tourism.

LITERATURE REVIEW

Trust in UGC

Previous research has highlighted the growing importance of trust and credibility in shaping how tourists interpret and use online information. Rather than merely serving as a passive backdrop, trust functions as a critical psychological filter that determines the effectiveness of UGC. When users encounter digital content, they engage in continuous cognitive risk assessment. Trust acts as the mechanism that mitigates this perceived risk by validating the authenticity of the information, thereby transforming passive reading into active behavioural intentions Filieri, 2016).

In the context of online consumer reviews, Filieri (2016) examines how users assess the trustworthiness of digital content, particularly in environments where deceptive or promotional reviews may be present. The study finds that users rely heavily on message-related cues such as specificity, internal consistency, plausibility, and tone when evaluating credibility. In addition,

individual factors such as prior experience and level of involvement, as well as the type of platform hosting the content, influence how these cues are interpreted. Importantly, reviews perceived as untrustworthy tend to be discounted in decision-making, reinforcing the central role of trust in digital information use.

Alshamayleh et al. (2025) analyse how social media marketing, destination attributes, technological integration, and sustainability practices influence tourists' visit intentions in Malaysia. Their findings indicate that trust and credibility function as key mediating mechanisms that translate these factors into behavioural outcomes. In particular, transparent communication and a strong destination image are shown to enhance trust, which in turn strengthens tourists' intention to visit. However, the study does not differentiate between various forms of UGC or examine how authenticity cues at the platform level may shape trust formation.

Tiwari (2025) examines consumer trust in verified versus non-verified online reviews within a broader e-commerce context. The findings show that verified reviews are associated with higher levels of trust and stronger purchase intentions, suggesting that verification mechanisms serve as important credibility signals. Such signals function as both central and peripheral cues, reducing perceived risk and enhancing confidence in decision-making. While the study offers useful insights into the role of verification in strengthening trust, it is not tourism-specific and adopts a descriptive approach, limiting its ability to capture deeper behavioural dynamics.

Tourism Development

Tourism has grown as one of the largest global economic sectors and a significant contributor to many national and local economies, with tremendous growth in both domestic and international tourism. Tourism development encompasses various efforts to improve tourism infrastructure, services, and destination management to support sustainable tourism growth while bringing positive economic and social benefits to the community (Goeldner & Ritchie, 2012). Traditionally, tourism development is affected by factors such as political globalisation and stability, economic growth, environmental factors such as environmental taxes and natural disasters, social factors such as safety and holiday, and technological factors such as transportation and infrastructure (Degirmenci et al., 2026; Scott & Gossling, 2015).

Tourism development in the digital era is increasingly influenced by the role of information and communication technologies (ICT), particularly the digital platforms in shaping tourist experiences and decision-making. The ICT involves mobile reservation, automation and robotics in service delivery, marketing systems, and expansion of informal tourism provision (Scott & Gossling, 2015).

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Digital media, particularly social network sites (SNS) such as Instagram, YouTube, and Facebook, have been found to be effective tools for promoting destinations and increasing awareness, although their ability to translate engagement into actual tourist participation remains limited (Yanti et al., 2023). Similarly, in cultural and religious tourism, the use of interpretive tools such as signage and digital media enhances visitors' understanding and engagement; however, limitations in content depth, accessibility, and interactivity may reduce their overall effectiveness (Raja Othman et al., 2025).

Beyond information delivery, tourism is also shaped by broader contextual and structural factors. Seasonal variations influenced by climate, institutional schedules, and socio-economic conditions continue to affect tourism demand, highlighting the need for strategic planning and diversification (Momani et al., 2023). At the same time, community-based tourism has the potential to support local economic development, though issues of unequal benefit distribution suggest the need for more inclusive and transparent practices (Amir et al., 2017).

From a behavioural perspective, tourist decisions are shaped by perceptions, expectations, motivations, and prior experiences, which are often influenced by information obtained from various media and social platforms (Asbollah et al., 2017). However, while the importance of information is widely recognised across these studies, limited attention has been given to its credibility, trustworthiness, and ethical dimensions. The development of the tourism sector has contributed significantly to the growth of UGC in digital environments. Kitsios et al. (2022) mentioned that as tourism activities become increasingly digitalised, tourists actively share their travel experiences, opinions, photographs, videos, and recommendations through social media platforms, review websites, blogs, and video-sharing applications.

Consequently, UGC has emerged as an important source of tourism information that influences destination image and tourist decision-making, and has become integral to the tourism ecosystem, reflecting the increasing reliance on peer-generated content in tourism communication and engagement. Studies show that the development of UGC on SNS has undoubtedly affected the whole travel process, i.e., before, during, and after their travel (Kitsios et al., 2022). This indicates that existing tourism research tends to focus on the availability and impact of information rather than on how trust in information, particularly in UGC, can be strengthened, thereby highlighting an important gap for further exploration.

Smart Tourism

Smart tourism is characterised by the integration of information and communication technologies (ICTs) that support the collection, exchange, and intelligent use of large volumes of data. These technologies enable the

transformation of data into valuable insights that enhance tourism experiences through personalisation, real-time interaction, and context-aware services. In this context, tourists are no longer passive consumers but active participants who contribute to data creation and value co-creation within the tourism ecosystem. The effectiveness of smart tourism, therefore, depends on the interconnectedness of stakeholders, technological infrastructure, and the ability to utilise data to support decision-making and service innovation (Gretzel et al., 2015).

Azmadi et al. (2023) examine how tourists engage with smart tourism technologies, particularly QR codes, in Kuala Lumpur, integrating perspectives on technology adoption and sustainability. The findings show that tourists' habitual use of technology and their sustainability attitudes significantly influence satisfaction and behavioural intention, whereas perceived risk and hedonic motivation are not significant predictors.

Amir et al. (2020) examine the challenges of implementing smart tourism in Malaysia, particularly in eco-tourism destinations such as Langkawi and Cameron Highlands. The findings reveal that key challenges include low awareness, limited digital infrastructure, the high cost of devices, and concerns about security and privacy, which collectively hinder the effective adoption of smart tourism technologies. The findings suggest that while digitalisation offers significant potential for tourism development, issues related to accessibility, trust, and stakeholder readiness remain critical barriers.

Despite the increasing availability of UGC in tourism, concerns regarding credibility, inconsistency, and potential bias have contributed to a growing trust deficit in digital information environments. This suggests that while information is abundant, it is not always perceived as reliable, limiting its effectiveness in supporting tourist decision-making. While existing studies have provided valuable insights into UGC, tourism development, and smart tourism, these areas are often examined in isolation. Research on UGC emphasises its influence on credibility and decision-making, whereas tourism studies focus more on information delivery, behaviour, and destination performance. At the same time, smart tourism research highlights the role of digital technologies and data-driven systems in enhancing tourism experiences.

However, limited attention has been given to how trust in UGC connects these domains, particularly in shaping the effectiveness of digital information within smart tourism environments. This gap is further reinforced by a trust deficit, where the abundance of information does not necessarily lead to user confidence or meaningful engagement. Therefore, a more integrated understanding of how trust in UGC influences tourist behaviour and supports smart tourism development is required. To address this gap, the present study adopts a document analysis approach, as discussed in the following section.

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Conceptual Framework

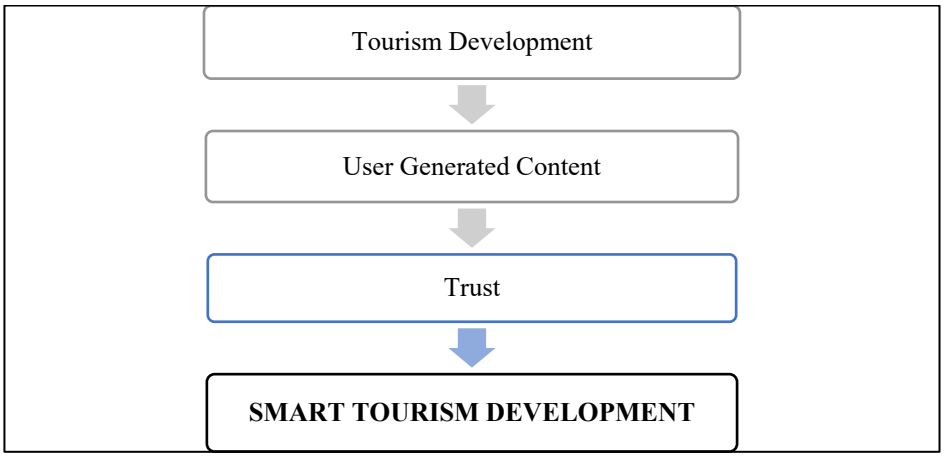


Figure 1: Conceptual Framework of Smart Tourism Development

The proposed conceptual framework explains the relationship between tourism development, UGC, trust, and smart tourism development. As tourism development becomes increasingly digitalised, tourists rely more heavily on UGC as a source of information and travel guidance. However, the effectiveness of UGC depends largely on the level of trust users place in the information shared online. Trust, therefore, functions as a mediating mechanism that influences the acceptance and utilisation of digital tourism information. Higher levels of trust contribute to more effective smart tourism development by enhancing tourist engagement, informed decision-making, and the development of digital tourism ecosystems.

RESEARCH METHODOLOGY

Research Design

This study adopts a qualitative research design using a document analysis approach to examine the role of trust in UGC for smart tourism development in Malaysia. Document analysis refers to a systematic approach to examining and evaluating documents in various forms, including both printed and electronic materials. The process involves an initial review of the content, followed by a more detailed reading, and ultimately the interpretation of the information to derive meaningful insights (Bowen, 2009).

Data Sources and Selection Criteria

The data for this study were derived from secondary sources, including peer-reviewed journal articles, conference papers, and selected policy-related

documents relevant to tourism, digital platforms, and UGC. The selection of documents was guided by specific inclusion criteria, namely relevance to key constructs such as trust, UGC, and smart tourism; publication in recognised academic outlets; and contribution to theoretical or empirical discussions within the tourism domain.

Data Extraction and Analysis

The selected documents were analysed using thematic analysis, which enables the identification and interpretation of recurring patterns across the data. Thematic analysis involves systematically examining datasets, such as interviews, focus groups, or textual materials, to identify recurring patterns of meaning. The form and outcomes of thematic analysis may vary depending on the research context and objectives. Therefore, it is important for researchers to carefully consider the analytical approach and guiding questions throughout the process (Braun & Clarke, 2006). In this study, the analysis was conducted in several stages. First, the documents were reviewed to become familiar with their content. Second, relevant concepts related to trust, information credibility, and tourism development were coded. Third, these codes were grouped into three broader themes: trust deficit in UGC; trust as a mediating mechanism in decision-making; and the roles of trust in smart tourism development. These themes were then interpreted to develop a coherent understanding of how trust influences the effectiveness of UGC within digital tourism environments.

ANALYSIS AND DISCUSSION

This study explores how trust in UGC shapes the trajectory of Malaysia's smart tourism ecosystem. The findings are organised into three main themes that explain the role of trust in UGC within smart tourism development. The themes are trust deficit in UGC; trust as a mediating mechanism in tourist decision-making; and the roles of trust in enhancing smart tourism development.

Trust Deficit in UGC

This trust deficit occurs because digital tourism ecosystems are inherently plagued by information asymmetry. When tourists encounter fake positive feedback or conflicting reviews, they do not simply abandon the platform; instead, they employ active cognitive-management strategies. By cross-referencing multiple platforms, analysing the internal consistency of reviews, and seeking peripheral verification cues, tourists actively attempt to reconstruct reliability. Therefore, the 'trust deficit' is not just a lack of confidence, but a psychological catalyst that forces tourists to engage in more complex, multi-layered information processing before arriving at a decision.

In practice, this means tourists are more likely to compare multiple reviews, seek confirmation across platforms, or rely on personal judgment before

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making decisions. While this behaviour reflects a more careful evaluation process, it also indicates that UGC alone is not always sufficient to support confident decision-making.

The UGC reviews as a means to reduce information asymmetry may, in some cases, introduce new forms of uncertainty. Tourists often rely heavily on platforms such as TripAdvisor, Google Reviews, and online travel agency websites when making travel decisions. However, the credibility of such reviews is frequently questioned due to fake positive feedback, unverified negative comments, and a lack of contextual information. This situation can lead tourists to form unrealistic expectations based on exaggerated recommendations, which may ultimately result in dissatisfaction when actual experiences do not align with what was anticipated. From this perspective, information asymmetry remains a persistent issue in digital tourism environments, shaping how tourists evaluate and interpret available information. While UGC is intended to reduce uncertainty, it may also create confusion and risk when the quality of the information is inconsistent. This indicates that information asymmetry alone does not fully explain tourist satisfaction, as the process also involves how individuals assess credibility, manage uncertainty, and compare expectations with actual experiences (Elshaer et al., 2025).

The literature analysis reveals a trust deficit in UGC within digital tourism environments. Although tourists are increasingly exposed to large volumes of information through online reviews, social media, and digital platforms, this abundance does not necessarily translate into higher levels of trust. Concerns related to credibility, inconsistency, and potential bias in UGC contribute to uncertainty among tourists when evaluating information.

Trust as A Mediating Mechanism in Tourist Decision-Making

Trust acts as a mediating mechanism, influencing how tourists interpret and utilise UGC. In other words, the impact of UGC on decision-making depends on whether the information is perceived as credible and trustworthy.

The findings further indicate that trust serves as a mediating factor in the relationship between UGC and tourist decision-making. While UGC provides valuable information, its influence on behaviour depends largely on whether it is perceived as credible and trustworthy. In this context, trust acts as a filter through which tourists interpret and evaluate information before making travel-related decisions.

Studies on tourism behaviour suggest that perceptions and expectations are shaped by information obtained from various sources, including digital platforms (Asbollah et. al., 2017). However, the present analysis extends this understanding by highlighting that information alone is insufficient to influence behaviour unless it is trusted. When trust is present, tourists are more likely to rely on UGC for planning and decision-making. Conversely, when trust is

lacking, such content is often disregarded, regardless of its accessibility. This indicates that trust is not merely an outcome of information use but a critical mechanism that determines whether information is accepted and utilised. As such, strengthening trust in UGC is essential to enhance its effectiveness in influencing tourist behaviour.

The Roles of Trust in Enhancing Smart Tourism Development

In smart tourism, trust emerges as a fundamental element that supports the effectiveness of digital systems and platforms. Smart tourism relies heavily on real-time information, user interaction, and digital connectivity, all of which are largely driven by UGC. However, the findings suggest that the success of these systems is closely linked to the level of trust users place in the information provided.

Existing research highlights that while technological adoption and digital infrastructure are important in supporting smart tourism initiatives, challenges such as limited user confidence, security concerns, and low engagement continue to hinder their effectiveness (Amir et al., 2020; Azmadi et al., 2023). These challenges can be partly explained by trust issues, where users may hesitate to fully engage with digital platforms due to uncertainty about the reliability of information.

Therefore, trust plays a dual role in smart tourism development. Trust extends beyond individual cognitive processing to dictate the macro-level efficiency of smart tourism ecosystems. When users perceive digital platforms as reliable sources of information, their engagement shifts from passive consumption to active value co-creation, such as leaving accurate reviews, interacting with prompts, and sharing location-based data. This reciprocal trust-building loop feeds high-quality data back into the smart tourism infrastructure, thereby improving algorithmic recommendations, enhancing real-time service personalisation, and driving the long-term sustainability of the destination.

In the context of smart tourism, this trust deficit becomes particularly significant, as digital platforms depend heavily on user-generated information to function effectively. When trust is lacking, the potential of smart tourism systems to support informed decision-making and enhance user experience is consequently reduced.

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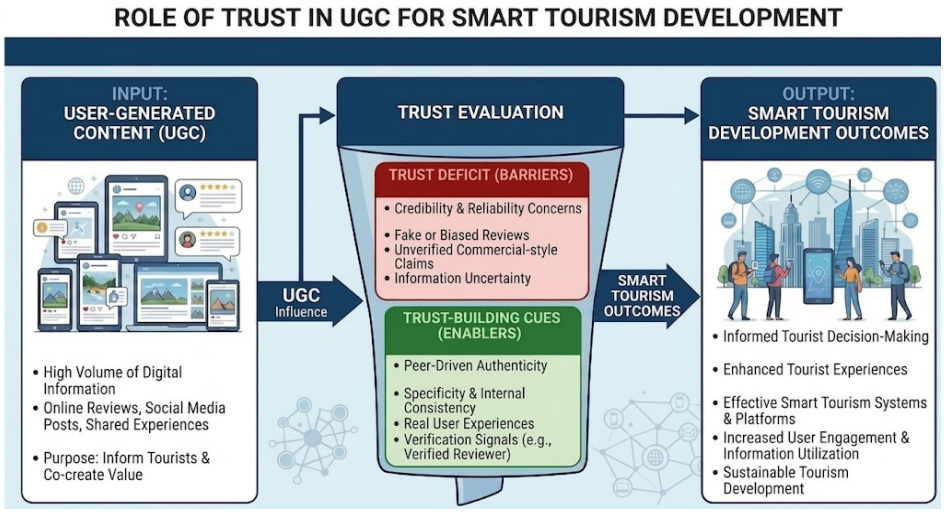


Figure 2: Role of Trust in UGC for Smart Tourism Development
Source: Original model by the authors, generated with Gemini.

Figure 2 presents a conceptual model illustrating the role of trust in translating UGC into effective outcomes in smart tourism development. The model maps the digital tourism ecosystem into three interconnected phases: Input, Core Filter (Trust Evaluation), and Output.

In the Input (UGC), the left panel represents the starting point of the tourist's digital journey, characterised by a high volume of digital information. This includes online reviews, social media posts, and shared travel experiences. While the primary purpose of this information is to inform other potential tourists and co-create value within the ecosystem, the abundance of information alone does not automatically drive positive tourism outcomes.

Meanwhile, in the Core Filter, the central panel of the model conceptualises Trust Evaluation as the critical filtering mechanism. Before UGC can influence tourist behaviour or the effectiveness of smart platforms, it must be cognitively evaluated. This evaluation process involves balancing two opposing forces:

i. *Trust Deficit (Barriers):* These are factors that hinder information acceptance, including concerns over credibility and reliability, the presence of fake or biased reviews, unverified commercial-style claims, and overall information uncertainty.
ii. *Trust-Building Cues (Enablers):* To overcome this deficit, tourists rely on specific cues to validate the digital content. These enablers include peer-driven authenticity, the specificity and internal consistency of the reviews, reliance on real user experiences, and the presence of verification signals (e.g., verified reviewer badges).

The model posits that the degree to which these enablers overcome the barriers dictates whether the digital information is ultimately trusted and utilised. In the Output (Smart Tourism Development Outcomes), the right panel demonstrates the behavioural and systemic outcomes that occur when UGC successfully passes through the trust evaluation filter. When trust is firmly established, it directly influences the smart tourism ecosystem by facilitating informed decision-making by tourists and enhancing the overall tourist experience. At a broader level, trusted digital information drives increased user engagement, ensures the effective utilisation of smart tourism platforms, and supports sustainable tourism development.

In summary, this model demonstrates that trust is an active filtering mechanism rather than a passive outcome. By mapping this process, the model highlights that mitigating the trust deficit and strengthening credibility cues are essential strategies for optimising smart tourism ecosystems in Malaysia.

CONCLUSION

This study examines the role of trust in UGC within the context of smart tourism development in Malaysia. The findings highlight that although digital platforms provide abundant, easily accessible information, their effectiveness is largely influenced by their perceived credibility and reliability. The presence of a trust deficit indicates that information availability alone is insufficient to support tourist decision-making, as users remain cautious when evaluating UGC.

The study further demonstrates that trust functions as a critical mechanism that mediates the relationship between information and tourist behaviour. UGC influences decision-making only when it is perceived as trustworthy, suggesting that trust plays a central role in determining whether digital information is accepted and utilised. In this regard, trust is not merely an outcome but a key factor that shapes how tourists interpret and engage with information in digital environments.

In smart tourism, trust becomes even more significant as digital systems rely heavily on real-time information and user interaction. The findings suggest that the effectiveness of smart tourism initiatives is closely linked to the level of trust users place in digital content and platforms. When trust is strengthened, it can enhance user engagement, improve decision-making, and support more efficient and sustainable tourism development.

Therefore, this study highlights the need to prioritise the credibility and management of UGC in digital tourism strategies. Efforts to improve the quality, consistency, and transparency of information can help reduce the trust deficit and enhance the overall effectiveness of smart tourism systems. Future research may further explore practical approaches to strengthening trust in digital tourism environments and examine their implications across different tourism contexts.

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Ultimately, to overcome the current stagnation and over-reliance on traditional marketing, Malaysia must recognise that digital infrastructure alone is insufficient for achieving the goals of the National Tourism Policy 2020-2030. Policymakers, Destination Management Organisations (DMOs), and platform developers must actively design digital ecosystems that amplify trust-building cues, such as verified user experiences and transparent content moderation, to overcome the existing barriers to the trust deficit. By treating trust not just as a consumer outcome, but as a core filtering mechanism that must be strategically managed, Malaysia can successfully leverage UGC to co-create a highly engaging, competitive, and sustainable smart tourism destination.

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WAQF-BASED AFFORDABLE HOUSING MODEL: A SUSTAINABLE ISLAMIC PROPERTY DEVELOPMENT FRAMEWORK FOR URBAN MALAYSIA

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Abstract

The persistent gap between urban housing prices and household income in Malaysia has rendered homeownership increasingly unattainable for the B40 and M40 income groups. Despite numerous government-led initiatives, including PR1MA and the People's Housing Programme (PPR), structural limitations in public financing capacity and land availability continue to constrain meaningful progress. This article proposes a waqf-based affordable housing model as a sustainable Islamic property development framework for Malaysian urban contexts. Drawing upon a systematic review of existing literature, institutional reports, and comparative case analyses, this study critically examines the theoretical foundations of productive waqf, its financing instruments including Sukuk Ijarah and Cash Waqf Linked Sukuk (CWLS), and the governance structures of State Islamic Religious Councils (Majlis Agama Islam Negeri, MAIN) and the Department of Awqaf, Zakat and Hajj (JAWHAR). The proposed model integrates the principles of Maqasid al-Shariah with contemporary urban planning imperatives, particularly in alignment with Sustainable Development Goal 11 (SDG 11). The analysis reveals that while waqf land represents a significant and underutilised asset base exceeding 30,000 hectares nationally, institutional fragmentation, legislative constraints, and limited professional capacity among MAIN have impeded productive development. This article argues that a reformed governance architecture, combining centralised oversight with decentralised project delivery through public-private partnerships, offers the most viable pathway for scaling waqf-based housing in urban Malaysia.

Keywords: waqf, affordable housing, Islamic property development, urban Malaysia, sustainable development

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INTRODUCTION

The housing affordability crisis in Malaysia is neither new nor narrowly defined. For several decades, the nation's urbanisation trajectory has been accompanied by a structural divergence between the pace of house price appreciation and median household income growth. Bank Negara Malaysia acknowledged as early as 2019 that Malaysian homes are "seriously unaffordable" by international benchmarks, with the median house price exceeding three times the threshold typically associated with housing stress (Kamal & Ating, 2020). The consequences of this divergence are not merely economic; they extend into dimensions of social equity, intergenerational mobility, and the spatial organisation of cities.

Urbanisation in Malaysia accelerated sharply from 34.2% in 1980 to approximately 75% by 2020, generating sustained pressure on urban housing markets (Abidin & Basrah, 2019; Arif et al., 2021). This demographic trajectory has been matched by an increase in the demand for affordable housing units that neither the private sector, bound by profit maximisation imperatives, nor the public sector, constrained by fiscal limitations, has been able to satisfy adequately. Government programmes such as PR1MA, MyHome, and PPR have provided partial relief, yet their scope remains limited to first-time buyers or households within specific income thresholds, leaving a large and structurally vulnerable segment of the urban population inadequately served (Kamal & Ating, 2020).

It is within this context that waqf, the Islamic institution of philanthropic endowment, presents itself as a theoretically and practically compelling alternative mechanism. Waqf involves the permanent dedication of an asset, typically land or property, for charitable, religious, or social purposes, with its corpus remaining inalienable and its usufruct directed toward beneficiaries (Qurrata et al., 2025). In Malaysia, an estimated 30,000 hectares of land are registered under waqf, yet according to YWM and JAWHAR data, only approximately 13% of this total has been productively developed (Productive Waqf Development Model, 2023). This represents both a governance failure and an extraordinary untapped resource.

This article proceeds from the premise that the underutilisation of waqf land in Malaysia is not primarily a problem of asset scarcity but of institutional design, legislative architecture, and financing innovation. The article develops three interconnected arguments. First, the principles of Maqasid al-Shariah provide a normative foundation that aligns waqf-based housing provision with broader sustainable urban development objectives. Second, contemporary Islamic financial instruments, particularly Sukuk Ijarah and CWLS, offer viable mechanisms for mobilising capital toward waqf housing development without compromising the perpetual and inalienable character of waqf assets. Third, the

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existing governance structures of MAIN and JAWHAR require significant reform to enable effective delivery at scale, with a particular emphasis on professionalisation, transparency, and inter-institutional coordination.

Maqasid al-Shariah and Housing as a Public Good

The normative foundation of this study is grounded in the classical Islamic jurisprudential framework of Maqasid al-Shariah, which refers to the higher objectives or essential purposes underlying Islamic law. These objectives, as systematised by al-Ghazali, al-Shatibi, and Ibn Ashur, encompass five primary domains: the preservation of religion (hifz al-din), life (hifz al-nafs), intellect (hifz al-aql), progeny (hifz al-nasl), and property or wealth (hifz al-mal) (Yazid et al., 2025; Chapra, 2008). Contemporary scholars such as Jasser Auda have extended this framework into a systems-oriented model capable of addressing complex socio-economic challenges (Auda, 2008, as cited in Aziz et al., 2024).

Table 1 maps the five dimensions of Maqasid al-Shariah to their specific housing imperatives and corresponding SDG 11 targets. This mapping is not merely rhetorical. It operationalises the Maqasid framework as an evaluative tool for housing policy, providing concrete criteria against which any proposed model may be assessed for normative adequacy.

Table 1: Maqasid al-Shariah Dimensions and Their Correspondence to Affordable Housing Imperatives

Maqasid Dimension	Arabic Term	Housing Imperative	SDG 11 Alignment
Preservation of Life	Hifz al-Nafs	Safe, structurally sound, and hazard-free shelter for all income groups	Target 11.1: Adequate and safe housing
Preservation of Progeny	Hifz al-Nasl	Family-appropriate unit size; proximity to schools and social services	Target 11.7: Inclusive and safe public spaces
Preservation of Wealth	Hifz al-Mal	Affordable pricing; elimination of speculative and exclusionary land use	Target 11.3: Sustainable urbanisation and land management
Preservation of Intellect	Hifz al-Aql	Access to educational and community facilities within housing precinct	Target 11.4: Safeguarding cultural and natural heritage
Preservation of Religion	Hifz al-Din	Communal prayer facilities; halal built environment governance	Target 11.b: Inclusive, integrated, and sustainable policies

Sources: Yazid et al. (2025); Aziz et al. (2024); Chapra (2008); United Nations SDG 11 Framework.

The relevance of Maqasid al-Shariah to housing policy is most explicitly articulated through *hifz al-nasl*, which encompasses the protection of family and progeny, and *hifz al-nafs*, the preservation of human life and dignity.

Adequate and secure shelter is a precondition for the realisation of both objectives; without stable housing, the conditions necessary for family formation, child development, and dignified human life are systematically undermined (Yazid et al., 2025). Scholars surveying the integration of Maqasid al-Shariah into sustainable development frameworks have also noted strong convergences between these objectives and the principles enshrined in the United Nations' 2030 Agenda, particularly SDG 11, which targets inclusive, safe, resilient, and sustainable cities and communities (Aziz et al., 2024; Hasan & Zulkifli, 2021).

Critically, however, this framework does more than assert the moral importance of housing. It articulates a set of substantive standards against which housing policies and development models may be evaluated. Housing that is financially inaccessible to large segments of the urban population violates hifz al-mal insofar as it concentrates wealth among property owners and developers while denying the majority of citizens access to a fundamental asset class. Housing that is structurally insecure, poorly maintained, or located without regard for community services undermines hifz al-nafs and hifz al-aql. A Maqasid-informed approach therefore demands not only that housing be physically available but that it be affordable, dignified, durable, and embedded within functional urban communities (Sarkawi et al., 2006, as cited in Investigating Islamic Urban Development, 2024). This multi-dimensional standard places the proposed waqf housing model under considerable normative pressure that purely economic models of housing provision are not designed to bear.

LITERATURE REVIEW

The Affordable Housing Deficit in Urban Malaysia

The academic literature on housing affordability in Malaysia consistently documents a structural imbalance between supply and demand that is particularly acute in major urban agglomerations. Khazanah Research Institute data cited in multiple studies indicates that the median house price to income ratio in Kuala Lumpur and its environs has reached levels that classify the market as "severely unaffordable" under internationally recognised thresholds (Ali et al., 2024). This condition is most damaging for the M40 group, households earning between RM4,851 and RM10,971 per month, who are typically ineligible for social housing programmes yet unable to service mortgages at prevailing market prices (Kamal & Ating, 2020). The M40 thus occupies a structural lacuna in Malaysian housing policy, too wealthy for the state and too poor for the market.

Government programmes have delivered outputs in absolute terms, with 458 public affordable housing projects recorded as constructed on waqf land through JAWHAR cooperation with state governments and local authorities (Arif et al., 2021). However, comparative analyses of PR1MA, PPR, and MyHome suggest that their limited eligibility criteria, concentration in non-strategic urban

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locations, and reliance on direct government financing constrain their long-term scalability and distributional reach (Ali et al., 2024). There is broad consensus in the literature that alternative institutional arrangements, particularly those engaging the Islamic social finance sector, are needed to complement state-led provision (Kamal & Ating, 2020; Abidin & Basrah, 2019). Critically, however, few studies have offered a sufficiently operationalised model capable of bridging the gap between conceptual advocacy for waqf and the complex institutional realities of Malaysian property development. This article directly addresses that gap.

Waqf as a Property Development Instrument

The historical record of waqf as a mechanism for urban development is extensive. In classical Islamic civilisations, waqf endowments funded hospitals, schools, markets, and housing in cities from Baghdad to Istanbul, providing infrastructure that combined religious obligation with social utility (Qurrata et al., 2025). The Ottoman waqf system, in particular, has attracted scholarly attention as a model of integrated urban financing in which revenues from commercial waqf properties cross-subsidised social services including housing for the poor (Productive Waqf Development Model, 2023).

In the Malaysian context, the literature distinguishes between traditional waqf, which is largely immovable and directed toward mosques or graveyards, and productive or contemporary waqf, which seeks to generate income from endowed assets through development, leasing, or investment (Productive Waqf Development Model, 2023). The distinction is analytically important because productive waqf introduces a fundamentally different institutional logic. Rather than simply holding an asset in perpetuity, productive waqf requires active management, capital mobilisation, and revenue generation, capacities that have historically been underdeveloped in Malaysian MAIN (Ismail et al., 2015, as cited in Governance, Location, Size and Waqf Efficiency in Malaysia, 2020).

Table 2 presents the current status of waqf land in Malaysia, illustrating both the scale of the asset base and the magnitude of the governance failure in its utilisation.

Table 2: Status and Development Potential of Waqf Land in Malaysia

Category	Area (Hectares)	Share of Total (%)	Estimated Revenue Potential if Developed (RM Billion)	Current Status
Wakaf Am (General Waqf)	4,317.88	38.9	8.5 – 12.0	Partially active
Wakaf Khas (Specific Waqf)	4,543.27	40.9	9.0 – 13.5	Largely restricted
Other Registered Waqf	~21,138	20.2	7.5 – 14.5	Predominantly idle
Total Registered Waqf Land	**~30,000**	**100**	**25 – 40**	—
Productively Developed	~3,900	~13	Already generating	Active
Underdeveloped / Idle	~26,100	~87	Unrealised	Dormant

Note: Revenue potential estimates are based on conservative urban land yield calculations assuming mixed-use development at prevailing market rates. Sources: JAWHAR Annual Report (2013); Governance, Location, Size and Waqf Efficiency in Malaysia (2020); Productive Waqf Development Model (2023).

Abidin and Basrah (2019) proposed a development framework for affordable housing on waqf land identifying five critical elements: concept, sources of funding, participants, structural arrangement, and social impact. Their conceptual model highlighted the potential of waqf land as a foundation for low-cost housing development, particularly in urban areas where land prices form the primary barrier to affordability. Ali et al. (2016) similarly argued that waqf real estate development represents a viable social welfare alternative to market-led housing provision. Kamal and Ating (2020) extended this analysis by proposing a collective waqf framework that integrates earning sustainability, resilient management, and social impact dimensions, noting that existing waqf models in Malaysia largely fail to embed investment channels for income generation or long-term fund sustainability. What the existing literature has not adequately addressed, however, is the political economy of reform: why institutional inertia has persisted despite decades of scholarly advocacy, and what specific reform pathway is needed to overcome it.

Islamic Financial Instruments for Waqf Development

A significant strand of recent literature focuses on the Islamic financial instruments available for developing waqf properties. Ijarah, broadly translated as a lease or rental contract, allows the development of waqf land by enabling investors to provide capital in exchange for rental returns, with the waqf asset remaining the property of the endowment and thus preserving its perpetual character (BIX Malaysia, 2024). Under the Sukuk Ijarah structure, a Special Purpose Vehicle (SPV) can raise funds through sukuk issuance, use those funds

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to develop housing units on waqf land, and lease the completed units to beneficiaries, with rental income servicing the sukuk and residual revenue flowing back to the waqf institution (Hussin & Muhammed, 2012).

Abdullah and Meera (2018, as cited in Kamal & Ating, 2020) explored the adoption of al-hikr, a long-term lease financing instrument, for waqf and state lands in Malaysia as a mechanism to provide affordable public housing. This instrument is particularly relevant because it allows structured long-term occupancy without transferring ownership of the underlying land, preserving the integrity of the waqf corpus while delivering housing to end users. The Cash Waqf Linked Sukuk (CWLS) model, pioneered in Indonesia and gaining traction in Malaysia through initiatives such as the Makmur myWakaf Fund, combines cash waqf contributions with sukuk investment structures to generate sustainable income streams for socio-economic projects including housing (IIUM Journal of Islamic Social Finance, 2024).

Critically, the literature also identifies substantive limitations in these instruments. Bureaucratic constraints within State Islamic Religious Council (SIRC) regulations impose restrictions on permissible financial instruments for waqf purposes, limiting institutional flexibility in accessing the full range of Shariah-compliant capital markets products (IIUM Journal of Islamic Social Finance, 2024). Moreover, public familiarity with investment-based waqf models remains low, with many potential donors viewing structured financial instruments as inconsistent with traditional waqf principles. This perception problem is not merely a communication challenge; it reflects a genuine tension between the communal, non-transactional ethos of classical waqf and the commercial logic of contemporary Islamic capital markets that policymakers have not adequately resolved.

Governance Challenges in Malaysian Waqf Institutions

The governance literature on Malaysian waqf institutions is largely critical, documenting persistent deficits in capacity, transparency, coordination, and accountability. According to JAWHAR data from 2013, Malaysia held 8,861.15 hectares of waqf land, yet empirical studies consistently report that only approximately 10% to 13% of total waqf assets have been productively developed (Governance, Location, Size and Waqf Efficiency in Malaysia, 2020; Productive Waqf Development Model, 2023). The establishment of JAWHAR in 2004 and Yayasan Wakaf Malaysia (YWM) in 2008 represented significant steps toward centralising and professionalising waqf administration (JAWHAR Governance, 2023). However, the constitutional arrangement in Malaysia, which places waqf administration under state jurisdiction through the Ninth Schedule of the Federal Constitution, creates inherent tensions between federal coordination ambitions and state-level institutional autonomy.

This constitutional fragmentation is analytically important and deserves emphasis beyond the perfunctory acknowledgement it typically receives in the waqf literature. It means that JAWHAR, despite its federal mandate, possesses no enforcement power over MAIN. Its role is advisory, coordinative, and capacity-building, not directive. This structural weakness has persisted across multiple Malaysia Plans and successive government administrations, suggesting that it cannot be overcome by policy commitment alone but requires a constitutional or legislative framework that has thus far been politically untenable.

FINDINGS

A Waqf-Based Affordable Housing Model for Urban Malaysia

The proposed model conceptualises waqf-based affordable housing as a four-stage system integrating asset activation, financing, delivery, and sustainability. Figure 1 illustrates the complete conceptual architecture of this model, grounded in the normative foundation of Maqasid al-Shariah and aligned with SDG 11 imperatives.

Figure 1: Four-Stage Waqf-Based Affordable Housing Model

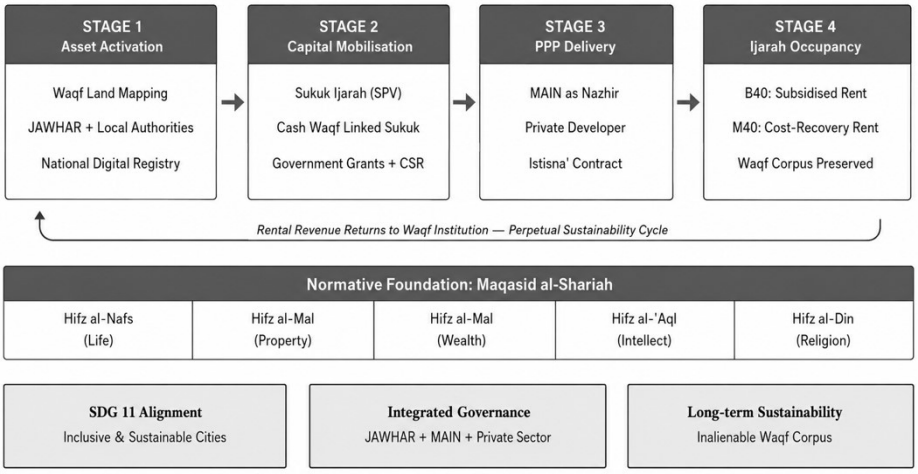


Figure 1: Four-Stage Waqf-Based Affordable Housing Model.
Source: Authors' compilation adapted from Kamal & Ating (2020); Abidin & Basrah (2019); Qurrata et al. (2025).

Stage 1 involves systematic mapping and classification of urban waqf land by JAWHAR in coordination with state planning authorities and local governments. This mapping exercise must prioritise strategic urban locations with access to public transport, employment centres, and community services, since the Maqasid principle of *hifz al-nafs* demands that housing provision serve

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not only physical shelter but also the broader conditions of dignified urban life. A national waqf digital registry, potentially underpinned by blockchain technology, would provide the transparency and accountability infrastructure necessary for productive development (Qurrata et al., 2025).

Stage 2 concerns capital mobilisation through Sukuk Ijarah or CWLS structures, enabling development without requiring MAIN to bear the full financial burden. Stage 3 delivers construction and management through public-private partnerships (PPP), in which MAIN as nadzhir retains ownership of the waqf land while engaging professional property developers under istisna (construction contract) arrangements. The UDA Waqf joint venture with Kedah Islamic Religious Council (MAIK) at Telok Chengai, Alor Star, provides a Malaysian precedent for this model (Kamal & Ating, 2020). Stage 4 makes housing units available on ijarah or long-term lease arrangements rather than for sale, preserving the waqf corpus across generations. Figure 2 presents the complete financing architecture underpinning Stages 2 and 3.

Figure 2: Waqf-Based Affordable Housing Financing Architecture (Blended Islamic Finance Model)

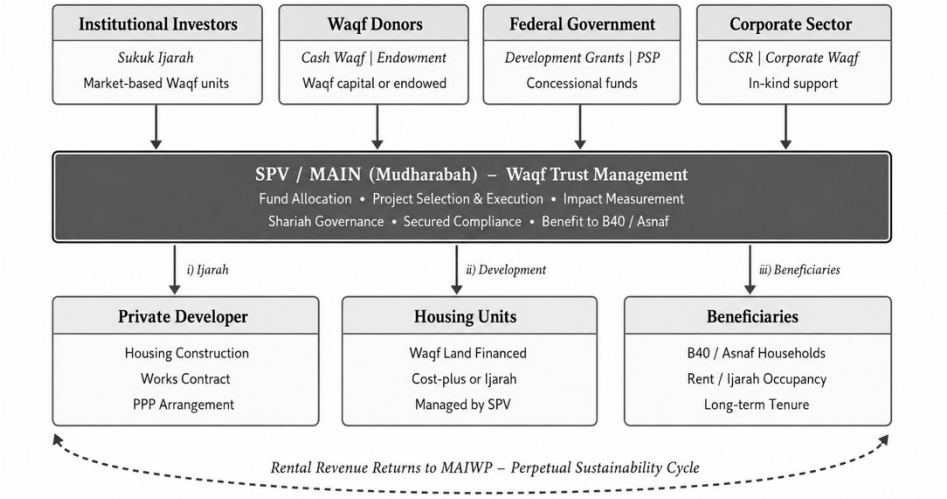


Figure 2: Waqf-Based Affordable Housing Financing Architecture (Blended Islamic Finance Model).
Source: Hussin & Muhammed (2012); IIUM Journal of Islamic Social Finance (2024); Kamal & Ating (2020).

Financing Architecture

The financing architecture of the proposed model requires careful design to balance Islamic jurisprudential requirements with commercial viability. Three primary instruments are proposed in combination. First, Sukuk Ijarah bonds issued through a dedicated SPV provide the primary capital for housing construction, with investors receiving rental yields from the ijarah contracts with occupants. Second, CWLS instruments mobilise philanthropic capital from retail and institutional donors, with the waqf corpus preserved and the income directed toward project development. Third, government grants and development bank financing, particularly from Bank Pembangunan Malaysia Berhad and the Ministry of Housing and Local Government, provide concessional capital to reduce the cost of housing below market rates.

This blended finance approach distributes risk across multiple institutional actors while aligning incentive structures with the social mission of affordable housing provision. Private investors in the sukuk receive market-competitive returns from rental income, removing the charity premium that often restricts institutional investment in social housing. The government's fiscal contribution is reduced relative to direct housing development programmes, since public funds serve a catalytic or gap-filling function rather than providing the totality of project finance. MAIN, as nadzhir, receives a residual income stream that can finance institutional capacity-building and further asset development.

DISCUSSION

Structural Constraints and Contested Assumptions

The most fundamental structural constraint on the proposed model is the documented institutional weakness of MAIN as property development and asset management entities. As the data in Table 2 illustrates, only approximately 13% of waqf land in Malaysia is productively developed, a statistic that reflects not merely resource constraints but a profound deficit in professional capacity, strategic vision, and organisational culture (Governance, Location, Size and Waqf Efficiency in Malaysia, 2020; Productive Waqf Development Model, 2023). MAIN were established primarily as religious administrative bodies, and their transformation into sophisticated property development institutions capable of structuring sukuk transactions, managing PPP contracts, and overseeing large-scale housing projects represents a qualitative organisational transformation that goes far beyond incremental capacity building.

This challenge is compounded by a structural problem that the literature has acknowledged but not sufficiently interrogated: the absence of a competitive market mechanism to discipline waqf institutions into better performance. Private property developers face market sanctions for poor project delivery; MAIN do not. Their revenues, to the extent they exist, are not contingent on development

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performance, and their political accountability is directed toward state religious authorities rather than toward the Muslim communities whose assets they administer. This accountability deficit is arguably the core governance problem, and it cannot be resolved by technical assistance or training programmes alone. It requires institutional restructuring that creates genuine performance accountability, whether through independent nadzhir oversight boards, public reporting requirements, or competitive tendering for waqf development mandates.

The Legislative Fragmentation Problem

A second critical constraint involves the legal status of waqf land within Malaysia's dual land administration system. Waqf land is registered under the National Land Code, but the waqf restriction creates significant complications for developers seeking project financing, since lenders typically require the land title to serve as collateral. The perpetual and inalienable nature of waqf land, which is precisely its most valuable social characteristic, becomes a financial liability under conventional and even Islamic property finance logic. This creates a genuine structural tension: the very feature that makes waqf normatively superior to market housing as a mechanism for intergenerational equity simultaneously impedes its integration into contemporary capital markets.

The resolution of this tension requires legislative innovation that goes beyond the current framework. The introduction of a waqf development easement, a legal instrument that separates development rights from the underlying corpus while preserving the inalienability of the land itself, would enable structured financing without compromising waqf doctrine. Alternatively, a state or federal guarantee mechanism that replaces land title as collateral in waqf sukuk transactions could unlock capital market access without requiring legislative amendment of the National Land Code. Neither option has been seriously pursued at the policy level, reflecting a broader pattern in which legal innovation in the waqf sector lags considerably behind financial and institutional innovation.

The constitutional dimension compounds this problem. Since waqf is a state matter, each of Malaysia's 13 states operates under its own State Islamic Administration Enactment, producing significant variation in what types of development, financing, and beneficiary arrangements are legally permissible. A developer or sukuk arranger working across multiple states must navigate 13 different regulatory environments, none of which are designed with large-scale affordable housing development in mind. This regulatory fragmentation imposes transaction costs that effectively price many potential development partners out of the waqf housing market.

The Ownership Culture Problem

A third constraint, frequently underestimated in policy-focused analyses, concerns the deep cultural embedding of homeownership as a life goal in Malaysian society. The aspiration for homeownership is not simply an economic preference; it is a social and familial imperative reinforced by decades of government policy, parental expectation, and institutional infrastructure, including the Employees Provident Fund withdrawal facility for housing, which implicitly treats ownership as the normative housing outcome. A model that offers long-term ijarah occupancy rather than ownership asks urban households to reorient their housing aspirations in a direction that has few social precedents and limited cultural legitimacy.

This challenge is more profound than the communication problem it is sometimes reduced to in the waqf literature. It is not merely a matter of educating potential beneficiaries about the virtues of secure tenancy under Islamic principles. It is a matter of addressing the legitimate rational preferences of households for whom ownership represents asset accumulation, collateral value, and inter-generational wealth transfer that a waqf ijarah arrangement cannot replicate. The model must therefore offer compensating benefits sufficiently attractive to override these ownership preferences, particularly among the M40 households it primarily targets. Possible compensating mechanisms include tenure security through long-term irrevocable ijarah contracts, community governance rights, priority in allocation to family members, and the spiritual dimension of residing within a waqf community. Whether these benefits will prove sufficient in practice is an empirical question that the existing literature has not addressed.

POLICY IMPLICATIONS

The foregoing analysis generates a set of policy implications addressed to multiple institutional actors within Malaysia's waqf and housing governance landscape. These implications are deliberately sequenced to reflect institutional prerequisites: governance reform must precede financing innovation, and both must precede scaled project delivery.

For the federal government and JAWHAR, the most urgent priority is the development and implementation of a national waqf asset registry that provides comprehensive, publicly accessible information on the location, tenure status, development potential, and current use of all registered waqf land in Malaysia. Without this informational infrastructure, strategic development planning remains impossible. JAWHAR should simultaneously lead the development of a model waqf housing enactment in collaboration with state governments and the Council of Rulers, establishing minimum standards for project governance, financial reporting, and beneficiary targeting. The political

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obstacles to this reform are not trivial: state governments and their MAIN have historically resisted federal encroachment on Islamic affairs. A negotiated framework that provides federal technical and financial support in exchange for state compliance with minimum standards, rather than direct federal oversight, may be more politically achievable.

For state governments and MAIN, the critical investment is in professional capacity in the form of dedicated property development units staffed by qualified planners, property managers, financial analysts, and legal professionals, operating distinctly from religious administrative functions. The evidence from MAIPP Penang and MAIS Selangor suggests that MAIN with adequate professional capacity can deliver viable waqf housing projects; the challenge is replicating this capacity in less-resourced states. Federal-state matching grant arrangements for institutional capacity-building, drawing on Tenth Malaysia Plan precedents, provide a feasible funding mechanism.

For the Securities Commission Malaysia and Bank Negara Malaysia, the regulatory priority is the development of a framework specifically designed for waqf-linked sukuk and CWLS instruments that addresses credit enhancement, collateral substitution for waqf land, and investor protection requirements. Tax incentives for corporate donors to waqf housing trusts, analogous to those available for approved charitable donations under the Income Tax Act, would significantly expand the philanthropic capital base available to MAIN.

For urban planners and local authorities, the integration of waqf land into strategic development plans and local plans represents both an obligation and an opportunity. Waqf parcels located within areas of high housing demand should be designated for affordable housing development through local plan provisions that facilitate expeditious planning approval, infrastructure provision, and density uplift. The failure to integrate waqf land into statutory planning frameworks means that its development potential is frequently overlooked in urban growth management, resulting in waqf parcels being surrounded by private development in ways that reduce their accessibility and attractiveness for housing purposes.

CONCLUSION

This article has argued that waqf represents an underutilised institutional resource of significant potential for addressing Malaysia's urban affordable housing deficit, but that its realisation depends on a suite of institutional, legislative, and cultural reforms that go substantially beyond the financing and normative innovations emphasised in the existing literature.

The normative case for waqf-based housing, grounded in the principles of Maqasid al-Shariah and operationalised provides a legitimating framework for policy reform within Malaysia's Islamic governance context. The empirical case, demonstrates that the asset base exists at the scale required for meaningful

impact. Meanwhile, the financing architecture proposed drawing on Sukuk Ijarah, CWLS, and blended government-philanthropic finance, offers a technically viable pathway for mobilising capital without compromising the perpetual character of waqf endowments.

However, the critical analysis has established that the implementation barriers to this model are not primarily technical or financial. They are institutional, constitutional, and cultural. The institutional capacity deficits of MAIN, the constitutional fragmentation of Islamic affairs governance, the legal incompatibility between waqf inalienability and conventional collateral requirements, and the cultural primacy of homeownership in Malaysian housing aspiration collectively constitute a structural environment that is deeply resistant to the kind of waqf housing model proposed here.

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ISLAMIC SOCIAL FINANCE AND COMMUNITY-BASED TOURISM: A ZAKAT-WAQF MODEL FOR RURAL TOURISM DEVELOPMENT IN TERENGGANU

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Abstract

Rural tourism in Terengganu represents one of Malaysia's most culturally significant and ecologically rich tourism corridors, yet the communities that inhabit its landscapes remain structurally marginalised from the economic benefits of tourism development. Conventional financing mechanisms, reliant on private capital and government grants, have proven insufficient to bridge the gap between tourism potential and community economic participation. This article proposes an integrated Zakat-Waqf model for financing and governing community-based tourism (CBT) development in rural Terengganu, drawing on the complementary functions of zakat as a short-term redistributive instrument and waqf as a long-term asset endowment. Through a systematic review of the literature, institutional analysis, and comparative case examination, the article critically evaluates the theoretical coherence and practical viability of integrating Islamic social finance instruments into CBT planning frameworks. The analysis demonstrates that while the Zakat-Waqf model offers genuine potential for financing eco-tourism infrastructure, cultural heritage tourism, and homestay programme development, its implementation confronts substantive obstacles rooted in jurisdictional fragmentation between the Majlis Agama Islam dan Adat Melayu Terengganu (MAIDAM) and state tourism authorities, the governance limitations of current zakat distribution systems, and the cultural dependencies of local communities on government patronage. This article argues that the transformative potential of Islamic social finance in rural tourism development can only be realised through a restructured governance architecture that integrates religious financial institutions into the formal tourism planning system.

***Keywords*:** community-based tourism, Islamic social finance, zakat, waqf, rural tourism, Terengganu, eco-tourism.

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INTRODUCTION

Terengganu occupies a distinctive position in Malaysia's tourism geography. Its coastline encompasses some of the most biologically diverse marine environments in the South China Sea, its interior forests shelter Lake Kenyir, one of Southeast Asia's largest man-made lakes, and its villages preserve traditions of batik craftsmanship, boat-building, and Malay cultural practice that have few equivalents elsewhere in peninsular Malaysia. Tourism Malaysia has consistently promoted Terengganu as a heritage and nature destination, and visitor arrivals to the state grew steadily in the years preceding the COVID-19 pandemic. Yet this tourism richness has not translated proportionally into rural community welfare. The benefits of tourism development in Terengganu have historically been concentrated among urban operators, external investors, and government-linked entities, while the rural communities whose cultural assets and natural environments underpin the tourism product remain net observers rather than net beneficiaries of the industry (Bhuiyan et al., 2016; Wondirad, 2019).

Community-based tourism (CBT) offers a development paradigm specifically designed to address this distributional failure. Defined broadly as tourism that is owned and managed by the community, with the primary purpose of benefiting resident populations rather than external capital (Wondirad, 2019), CBT has attracted sustained policy and scholarly attention in Malaysia since the launch of the Rural Tourism Master Plan in 1995. The government's homestay programme, administered through the Ministry of Rural Development, represents the most institutionally developed expression of CBT in Malaysia and has been operational in Terengganu for more than two decades (Ishak et al., 2025). Nonetheless, scholars and practitioners have consistently identified financial sustainability as the primary constraint on CBT development, with community operators lacking access to startup capital, infrastructure financing, and working capital during off-peak seasons (Kayat and Zainuddin, 2016; Ishak et al., 2025).

It is at this intersection of financial constraint and Islamic institutional capacity that the present article locates its central argument. Terengganu is an overwhelmingly Muslim-majority state with active zakat and waqf institutions under MAIDAM. These institutions collectively manage significant financial resources directed at asnaf (zakat-eligible) households and waqf-endowed land parcels distributed across the state. The argument advanced here is that the current deployment of these resources, largely siloed within religious administrative frameworks disconnected from tourism planning systems, represents a misalignment between institutional capacity and development need. A deliberate integration of zakat and waqf instruments into a CBT financing architecture could address rural tourism's funding gap while simultaneously fulfilling the redistributive and community-building mandates of Islamic social finance.

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This article proceeds in six sections following this introduction. Section 2 establishes the theoretical framework grounding the Zakat-Waqf model in the principles of Maqasid al-Shariah. Section 3 reviews the relevant literature on CBT financing, Islamic social finance, and tourism development in Terengganu. Section 4 proposes the integrated model with its financing architecture and governance structures. Section 5 provides a critical analysis of the model's structural constraints. Section 6 offers policy implications, and Section 7 concludes.

Maqasid al-Shariah and the Ethics of Tourism Development

The theoretical foundation of the proposed model rests on the Maqasid al-Shariah framework, which identifies five primary objectives of Islamic law: the preservation of religion (hifz al-din), life (hifz al-nafs), intellect (hifz al-aql), progeny (hifz al-nasl), and property or wealth (hifz al-mal) (Yazid et al., 2025; Chapra, 2008). Applied to tourism development, this framework generates a distinctive normative standard that diverges substantially from the utilitarian and growth-centred criteria that typically guide conventional tourism planning.

The Maqasid framework is relevant to tourism development along three distinct axes. First, the objective of hifz al-mal, the preservation and equitable distribution of wealth, directly challenges the structural tendency of tourism economies to concentrate returns among capital owners while externalising costs onto host communities and ecosystems. An Islamic ethical framework grounded in Maqasid does not merely endorse rural tourism as an income-generating activity; it demands that the distribution of tourism revenues conform to principles of social justice and that the poorest and most marginalised community members, the asnaf, are primary beneficiaries rather than incidental participants (Razak, 2020). Second, the objective of hifz al-nafs extends beyond physical survival to encompass dignity, quality of life, and freedom from exploitation. CBT development informed by this objective must therefore ensure that community participants are genuine co-owners and decision-makers in the tourism enterprise, not merely service providers in a value chain controlled by external operators. Third, hifz al-din, the preservation of religious and cultural heritage, provides normative grounding for the conservation of Islamic cultural heritage sites, traditional craft practices, and the intangible religious dimensions of Malay village life that constitute some of Terengganu's most distinctive tourism assets.

Table 1 maps these Maqasid dimensions to specific tourism development imperatives and their correspondence to the United Nations' Sustainable Development Goals most directly relevant to rural tourism in Terengganu.

Table 1: Maqasid al-Shariah Dimensions and Rural Tourism Development Imperatives

Maqasid Dimension	Arabic Term	Tourism Development Imperative	Relevant SDG Target
Preservation of Life	Hifz al-Nafs	Equitable income distribution; dignified community participation in tourism	SDG 1: No Poverty; SDG 8: Decent Work
Preservation of Religion	Hifz al-Din	Conservation of Islamic heritage sites; preservation of cultural intangibles	SDG 11.4: Cultural and Natural Heritage
Preservation of Wealth	Hifz al-Mal	Community ownership of tourism assets; prevention of revenue leakage to external operators	SDG 10: Reduced Inequalities
Preservation of Intellect	Hifz al-Aql	Entrepreneurship and skills development; environmental education for guides	SDG 4: Quality Education
Preservation of Progeny	Hifz al-Nasl	Intergenerational transfer of cultural knowledge; sustainable resource management for future generations	SDG 15: Life on Land

Sources: Yazid et al. (2025); Chapra (2008); Aziz et al. (2024); United Nations SDGs Framework.

This Maqasid-grounded framework carries critical implications for the design of the proposed model. It establishes that the measure of success for a Zakat-Waqf CBT model is not simply the volume of tourist arrivals or aggregate tourism revenue generated, but the extent to which tourism development fulfils these five normative objectives for rural Terengganu communities. This is a more demanding evaluative standard than those typically applied in tourism economics, and it implies that a tourism model achieving high revenues through community dispossession or cultural commodification would be normatively deficient even if commercially successful.

LITERATURE REVIEW

Community-Based Tourism: Potential and Persistent Constraints

Community-based tourism has occupied a prominent position in Malaysian rural development policy since the 1990s, yet the evidence on its distributional outcomes is decidedly mixed. Studies focusing on Terengganu consistently document the state's exceptional natural and cultural tourism assets while simultaneously identifying structural barriers to equitable community participation. Bhuiyan et al. (2016) assessed ecotourism sustainability at Lake Kenyir, a flagship Terengganu destination, and found that while employment opportunities and homestay accommodations generated positive socio-economic impacts, degradation of natural resources and disruption of religious traditions emerged as significant negative externalities of unmanaged tourism growth. This finding points to a fundamental tension in CBT development: the very cultural and natural assets that make rural Terengganu attractive to visitors are simultaneously the most vulnerable to tourism-induced deterioration.

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Wondirad (2019) examined CBT stakeholder participation in Pulau Redang, Kuala Terengganu, and found that community inclusion in decision-making processes improved when two conditions were present: the existence of strong CBT organisations and committed leadership. This finding is analytically important because it shifts the analytical emphasis from financing alone to governance structure as a determinant of CBT outcomes. Communities with adequate financing but weak organisational infrastructure consistently underperform relative to their endowment of tourism assets. A model that addresses financing without simultaneously building governance capacity is therefore likely to reproduce the patronage dependencies and elite capture problems that have characterised many earlier rural tourism initiatives.

The sustainability literature on Malaysian homestays reinforces this governance-centred analysis. Saafii et al. (2023), examining homestay sustainability on the East Coast including Terengganu and Kelantan, found that the local community's influence was the most significant determinant of homestay sustainability, while resource management remained the least developed dimension. This suggests that local social capital is a genuine competitive asset in rural Terengganu tourism, but that this asset is currently underinvested relative to its potential. Critically, the study also noted that financial fragility during off-peak seasons constitutes the single most recurrent threat to homestay viability, precisely the gap that a Zakat-Waqf financing model could address.

Zakat and Waqf as Development Instruments

Zakat and waqf are complementary instruments within the Islamic social finance ecosystem, distinguished primarily by their temporal orientation and asset characteristics. Zakat is an obligatory annual levy on qualifying wealth, distributed to eight designated categories of recipients (asnaf) as specified in the Quran. Its redistributive function is immediate and consumption-oriented: zakat resources flow from wealthy households to deserving recipients within a defined time horizon, addressing poverty, debt, and immediate welfare needs (Razak, 2020; Abdulquadri and Quadri, 2025). Waqf, by contrast, is voluntary, permanent, and asset-based. Its defining jurisprudential characteristic is the inalienability of the endowed corpus: the original asset must be preserved in perpetuity, with only its usufruct directed toward charitable purposes (Ishak et al., 2025; Qurrata et al., 2025).

This structural complementarity makes zakat and waqf analytically suited to different phases and dimensions of CBT development. Zakat resources are appropriate for addressing the immediate financial needs of asnaf community members entering the CBT economy, including startup grants for homestay operators, working capital for craft producers, and training subsidies for tourism

guides. Waqf resources, and the longer-term financing instruments they underpin, are more suited to infrastructure investment: the development of eco-lodges, visitor centres, cultural heritage sites, and tourism access infrastructure on waqf-endowed land parcels. Table 2 presents the key characteristics of each instrument and their specific applications in the CBT context.

Table 2: Comparative Characteristics of Zakat and Waqf as CBT Financing Instruments

Characteristic	Zakat	Waqf
Obligation	Obligatory (fard) on nisab holders	Voluntary (sunnah)
Asset Type	Cash (liquid)	Land, property, or cash (waqf tunai)
Temporal Horizon	Annual; short to medium term	Permanent; intergenerational
Corpus Status	Distributed; consumed by beneficiaries	Preserved in perpetuity; only usufruct distributed
Primary Beneficiaries	Eight asnaf categories (Quran-designated)	Specified by waqif; may include community broadly
Administering Body in Terengganu	MAIDAM Zakat Division	MAIDAM Waqf Division
CBT Application	Startup grants; skills training; working capital; asnaf micro-enterprise	Eco-lodge construction; heritage site management; waqf land development
Key Constraint	Limited to asnaf recipients; not recyclable	Inalienability complicates collateralisation; slow MAIDAM capacity
Relevant Financing Mode	Direct grant	Ijarah; Istisna'; Cash Waqf Linked Sukuk

Sources: Razak (2020); Abdulquadri and Quadri (2025); Ishak et al. (2025); Qurrata et al. (2025).

Ishak et al. (2025), writing specifically on the potential of waqf in strengthening CBT in Terengganu, identified three principal strategies available to waqf administrators: developing existing waqf assets directly for CBT purposes, mobilising funding from government ministries and industry players, and pursuing collaborative investments with Islamic banking institutions. Their qualitative research, grounded in interviews with relevant authorities including a District Officer of Setiu and MAIDAM officials, confirmed that waqf land in rural Terengganu is available and potentially suitable for CBT development but that institutional coordination failures between MAIDAM and state tourism authorities have prevented systematic activation of this potential.

Ratnasari et al. (2024), examining waqf models for tourism industry sustainability in Malaysia and Indonesia, found through mixed-methods research that the waqf model can help governments reduce tourism expenditure while sustaining the industry's growth. However, their findings also highlighted that the effectiveness of waqf in tourism is contingent on the quality of governance arrangements linking waqf institutions to tourism operators and community

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beneficiaries. An inadequately governed waqf-tourism linkage risks reproducing the patronage and elite capture dynamics that have historically constrained Malaysian CBT outcomes.

FINDINGS

Integrated Zakat-Waqf CBT Development Framework

The proposed Integrated Zakat-Waqf CBT Development Model conceptualises Islamic social finance instruments as structured inputs into a community-governed tourism development system, rather than as separate institutional functions that occasionally intersect with tourism. Figure 1 illustrates the full architecture of the model.

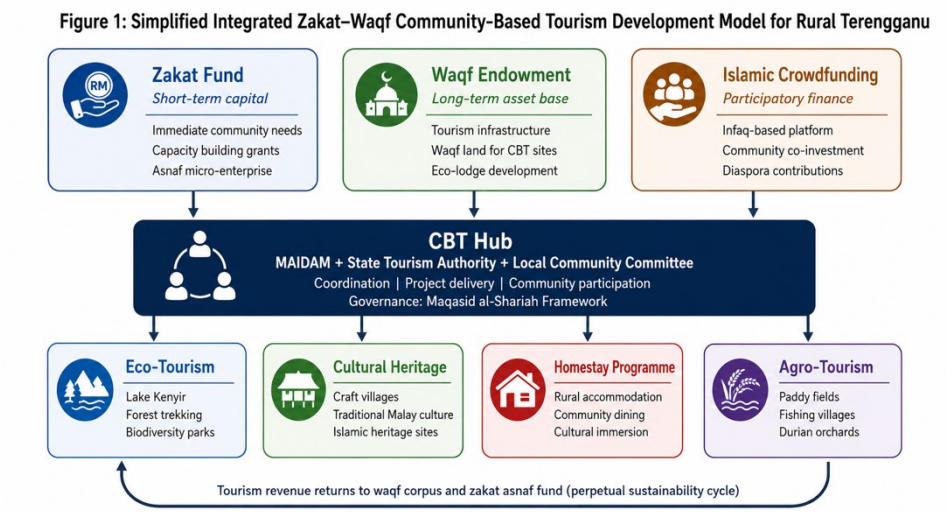


Figure 1: Integrated Zakat-Waqf Community-Based Tourism Development Model for Rural Terengganu.

The model operates through three financing pillars converging on a central CBT Governance Hub. The first pillar, the Zakat Fund, provides short-term, grant-based capital administered by MAIDAM's Zakat Division for immediate community needs including startup costs for asnaf-owned homestay operations, skills training subsidies, and working capital support during off-peak periods. The second pillar, the Waqf Endowment, provides long-term asset financing through the development of waqf-endowed land parcels for eco-tourism infrastructure, including eco-lodges, nature trails, and cultural heritage interpretation centres. The third pillar, Islamic Crowdfunding, mobilises participatory capital through infaq-based digital platforms, enabling diaspora

Terengganu communities, urban Malaysian Muslims, and international Islamic social investors to contribute to rural CBT development.

The CBT Governance Hub, jointly administered by MAIDAM, the State Tourism Authority, and a representative Local Community Committee, coordinates fund allocation, project delivery, and community benefit distribution across four tourism product clusters: eco-tourism centered on Lake Kenyir and Terengganu's forest environments, cultural heritage tourism drawing on Islamic heritage sites and traditional craft villages, the homestay programme, and agro-tourism anchored in paddy landscapes, fishing villages, and orchard economies. A Maqasid al-Shariah Compliance Board provides normative oversight, ensuring that tourism development across all four clusters conforms to the evaluative standards.

Financing Architecture

Figure 2 presents the detailed financing architecture of the model, illustrating the flow of capital from four funding sources through the governance hub to three categories of tourism output.

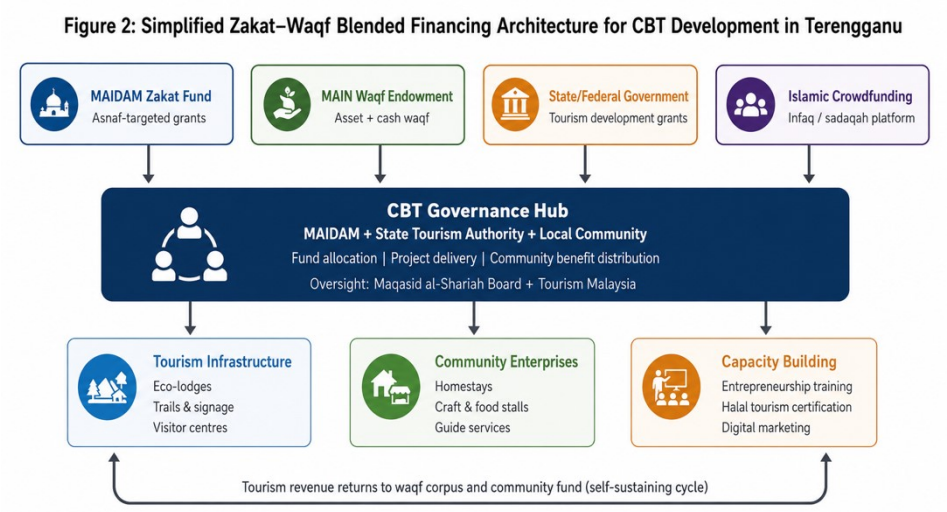


Figure 2: Zakat-Waqf Blended Financing Architecture for CBT Development in Terengganu.

The financing architecture operates as a blended model combining non-repayable zakat grants with waqf ijarah instruments, state matching funds, and crowdfunding contributions. Zakat grants flow directly to community enterprises through MAIDAM's asnaf assistance programme, categorised as productive

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zakat (zakat produktif) rather than consumptive welfare transfers. This distinction is critical: productive zakat directs resources toward income-generating activities that enhance the long-term economic capacity of asnaf households, rather than simply providing subsistence support. Waqf ijarah instruments enable the construction of tourism infrastructure on waqf land, with completed facilities leased to community operators at concessional rates, generating a rental income stream that flows back to MAIDAM for reinvestment. The self-reinforcing character of this cycle, in which tourism revenues strengthen the waqf corpus for further development, is the defining sustainability feature of the model.

Tourism Product Clusters and Terengganu's Asset Base

Table 3 presents an assessment of Terengganu's principal rural tourism assets, the Islamic social finance instrument most appropriate for each, and the development priority level based on current infrastructure gaps and community readiness.

Table 3: Terengganu Rural Tourism Asset Assessment and Zakat-Waqf Instrument Mapping

Tourism Cluster	Key Sites / Assets	Primary Finance Instrument	Development Priority	Community Readiness	Key Gap
Eco-Tourism	Lake Kenyir; Sekayu Waterfall; Tasik Beris	Waqf Ijarah (eco-lodge construction)	High	Medium	Infrastructure; trained guides; access roads
Cultural Heritage	Losong Craft Village; Zainal Abidin Mosque; Traditional Malay Timber Houses	Waqf Endowment (site conservation)	High	High	Conservation funding; interpretation facilities
Homestay Programme	Setiu Wetlands; Terengganu Craft Cultural Complex vicinity	Zakat Productive Grant + Crowdfunding	High	High	Working capital; off-peak financing; digital marketing
Agro-Tourism	Besut paddy landscape; Marang	Zakat Micro-Enterprise Grant	Medium	Medium	Skills training; branding;

Tourism Cluster	Key Sites / Assets	Primary Finance Instrument	Development Priority	Community Readiness	Key Gap
	fishing villages; Dungun durian orchards				market linkages
Marine / Island Tourism	Pulau Redang; Pulau Perhentian; Pulau Kapas	State Grant + PPP (waqf limited role)	Medium	Low-Medium	Environmental governance; community benefit-sharing

Sources: Bhuiyan et al. (2016); Wondirad (2019); Ishak et al. (2025); Saafii et al. (2023).

DISCUSSION

The Zakat Eligibility Problem

The most immediate technical constraint on the proposed model concerns the eligibility rules governing zakat distribution. Under classical fiqh, zakat may only be distributed to eight designated asnaf categories, of which the most relevant to CBT development are the fuqara (the poor), masakin (the needy), and fi sabilillah (those serving in the way of God, interpreted broadly in contemporary Malaysian practice to include productive development activities). The productive zakat concept, under which zakat funds are deployed as grants or equity contributions for income-generating enterprises rather than as direct welfare transfers, has gained increasing acceptance in Malaysian zakat jurisprudence and is recognised by several SIRC fatwas. MAIDAM itself has deployed productive zakat through micro-enterprise support programmes.

However, the eligible beneficiary pool under any zakat scheme is restricted to asnaf households, and the majority of potential CBT operators in rural Terengganu are not asnaf by current assessment standards. This creates a perverse selection effect in which zakat-based CBT financing reaches the most economically marginalised community members, who may lack the organisational capacity and assets to develop viable tourism enterprises, while excluding the slightly better-resourced households whose participation would be most economically productive for the CBT cluster as a whole. A model that restricts zakat-based tourism financing to strict asnaf eligibility criteria may therefore inadvertently exclude the middle tier of rural households whose entrepreneurial participation is most critical to CBT cluster development. Resolving this tension requires either a broadening of productive zakat eligibility criteria, which has jurisprudential implications that extend beyond the tourism sector, or the development of a parallel non-asnaf financing stream within the model, funded through waqf and crowdfunding instruments.

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The Institutional Coordination Problem

The governance framework proposed in this article depends critically on effective coordination between MAIDAM, the State Tourism Authority, and local community committees, three institutional actors whose current mandates and incentive structures do not naturally align. MAIDAM's primary accountability runs upward to the Sultan of Terengganu and downward to the state Muslim community through the administration of Islamic law and religious endowments. Its performance is not measured against tourism development outcomes, and its professional staff are trained in Islamic law and religious administration, not in tourism planning, destination management, or community enterprise development.

This institutional mismatch is not merely a matter of training gaps that can be addressed through capacity-building programmes, though such gaps are real. It reflects a fundamental difference in institutional culture, professional identity, and accountability framework between religious administrative bodies and development agencies. The risk in proposing a coordinated governance hub that brings these actors together is that institutional coordination will be nominal rather than substantive, with each actor continuing to operate according to its own priorities while formally participating in a joint committee structure that produces meeting minutes but not integrated action. This form of institutional theatre is well documented in the Malaysian development governance literature, particularly in relation to rural development programmes that require cross-sectoral coordination.

Critically, the problem is compounded by the political economy of Islamic religious administration in Malaysia. MAIDAM, like all MAIN, derives its authority and resources from the state royal household and state government. Its institutional priorities are shaped by these political relationships, not by community tourism development needs. A proposal to redirect zakat funds toward tourism enterprise development, even under the productive zakat framework, will be scrutinised against competing demands from asnaf welfare, mosque administration, and religious education. In a constrained fiscal environment, tourism development is unlikely to be the highest priority use of zakat resources from the perspective of MAIDAM's principal stakeholders.

The Community Dependency Problem

A third structural constraint, frequently under-theorised in the Malaysian CBT literature, concerns the deep dependency of rural Terengganu communities on government patronage as the primary modality of development support. The Rural Tourism Master Plan, the homestay programme, and successive Malaysia Plans have collectively constructed an institutional environment in which rural community tourism operators expect government facilitation, subsidised training,

and grant-based funding as preconditions for participation. This expectation is rational given the historical pattern of Malaysian rural development policy, but it creates a problematic baseline for a model premised on community ownership, Islamic social finance self-sufficiency, and market-oriented enterprise development.

The community dependency problem manifests in specific ways that the proposed model must address. Rural CBT operators in Terengganu are typically risk-averse, as rational responses to the economic precariousness of rural livelihoods, and may be resistant to the equity participation and revenue-sharing arrangements that waqf-based tourism development would require. Community committees responsible for managing tourism revenues and reinvesting them in waqf corpus maintenance represent a form of institutional responsibility that has few precedents in the village governance structures of rural Terengganu. The Majlis Agama Islam's administrative culture, oriented toward charitable distribution rather than productive investment management, is not well-suited to mentoring community enterprises through the operational complexities of tourism management.

This dependency problem also has a generational dimension. The cultural knowledge assets most central to Terengganu's heritage tourism proposition, batik craftsmanship, traditional boat-building, keris-making, and the intangible performances of traditional Malay arts, are concentrated among older community members whose successors have in many cases migrated to urban employment. A CBT model premised on cultural heritage tourism confronts an accelerating intergenerational knowledge transfer crisis that no financing innovation, however sophisticated, can resolve by itself. Cultural revival requires a broader social commitment to knowledge preservation that sits outside the scope of the proposed model but conditions its viability in fundamental ways.

CONCLUSION

This article has argued that Islamic social finance instruments, specifically zakat and waqf, offer a theoretically coherent and practically significant financing alternative for community-based tourism development in rural Terengganu. The proposed Integrated Zakat-Waqf CBT Development Model, grounded in the normative framework of Maqasid al-Shariah and operationalised through a blended financing architecture involving zakat grants, waqf ijarah instruments, and Islamic crowdfunding, addresses the structural funding gap that has consistently constrained CBT development in the state.

Tourism development that distributes benefits equitably among asnaf communities, preserves Islamic cultural heritage, and ensures intergenerational sustainability of natural and cultural assets fulfils the objectives of Maqasid al-Shariah in ways that conventional tourism financing cannot. Terengganu's waqf

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land holdings, MAIDAM's zakat funds, and the state's exceptional tourism endowment represent a combination of resources that, properly integrated, could finance a distinctive and sustainable CBT economy.

However, the model's implementation confronts obstacles that are structural, institutional, and cultural in character. The zakat eligibility problem, the institutional coordination problem, and the community dependency problem collectively represent a set of constraints that cannot be overcome by financing innovation or normative advocacy alone. They require institutional restructuring, legislative reform, and long-term investment in community governance capacity that goes substantially beyond any single planning cycle.

The central contribution of this article lies in articulating the conditions under which the Zakat-Waqf CBT model can succeed. It is not sufficient to establish the theoretical coherence of integrating Islamic social finance with CBT planning or to demonstrate that the asset base exists. Success requires a governance architecture that creates genuine accountability linkages between MAIDAM, state tourism authorities, and local community committees, a productive zakat framework with clear jurisprudential legitimacy, and a patient, long-term development commitment that accepts slow early progress as the price of genuine community ownership. Rural Terengganu's tourism potential is extraordinary. Realising that potential in a manner that fulfils the Maqasid-grounded imperatives of justice, dignity, and sustainability requires institutional innovations that are as ambitious as the normative vision that motivates them.

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WAQF EMPOWERMENT-BASED GREEN CAMPUS MODEL: TOWARDS ALTERNATIVE SUSTAINABLE FINANCING FOR SUSTAINABILITY INITIATIVES IN HEI

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Abstract

Environmental sustainability has become an important agenda that requires the involvement of various stakeholders, including higher education institutions. However, funding remains a significant challenge in establishing green campuses. Waqf possesses relevant characteristics to support sustainability and has the potential to serve as an alternative funding source for green campus development. This research aims to construct a model for green campus development based on waqf empowerment. A qualitative approach is utilized in this study, relying on primary data collected from in-depth interviews with several individuals who were involved in waqf management and research. The secondary data was also used and gathered from various written documents concerning sustainability, green campuses, and waqf empowerment. The findings indicate that collected waqf can be allocated for the procurement of various facilities and equipment needed for green campus projects, including waste management, water management, and the provision of essential infrastructure to support green initiatives. Moreover, cash waqf can be developed through investment schemes in green sukuk and financing schemes for green SMEs or agriculture and plantations. These waqf-based facilities and equipment are intended to support academic and operational activities on campus. This study recommends a novel concept for optimizing the collaborative management of waqf to develop green campuses in various regions, thereby maximizing the potential of waqf to support environmental sustainability initiatives.

Keywords: Empowerment, Green Campus, Literacy, Sustainability, Waqf

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INTRODUCTION

Higher Education Institutions (HEI) are one of the vital stakeholders who play a role in achieving sustainable development goals. As a science development center that produces scientists from various cross-disciplinary disciplines, HEI, through its various campuses, is required to play an active role in campaigning for environmental conservation programs to support sustainable development. Not only contributing to socialization activities, the campus community is also required to become role models in developing sustainability within the internal campus, in order to provide a multiplier effect to all stakeholders and also the wider community (Bulut, 2021). Good practices implemented by the campus in advancing the concept of sustainability include the development of a green campus.

The green campus concept is one of the concrete steps to encourage sustainability starting from the scope of higher education. This concept is implemented in various academic activities, operational activities, infrastructure and facilities, as well as other supporting programs oriented towards environmental preservation, cleanliness and efficient use of energy (Dono et al., 2023). Currently, several universities in the world have transformed into green campuses by implementing several sustainability criteria. There are at least six criteria that are implemented as basic aspects in assessing and evaluating the implementation of green campus which have been formulated by UI GreenMetric.

In practice, implementing a Green Campus requires a certain funding allocation to finance various sustainability programs (Anthony Jnr, 2021). Regarding this matter, the implementation of sustainability is still faced with financial constraints in several aspects, especially in the HEI sphere, because the costs required are quite large (González-Ramírez et al., 2021; Musari, 2022). In this condition, alternative sources of financing are needed to support the implementation of green campus as a concrete step to implement sustainability and socialize it to the wider community. One opportunity option to become an alternative source of funds is the use of funds collected from the community dedicated to supporting the concept of sustainability within the campus. These options include Islamic social fund management schemes such as waqf which can be allocated to finance sustainability programs.

Waqf has an important role in maintaining the principles of environmental sustainability considering that waqf itself has special characteristics as an Islamic financial instrument that must be maintained eternally and oriented towards sustainability (Pitchay, Rahman, et al., 2018). Empowering waqf to support sustainability has been widely practiced in various countries. Like the practice of green waqf based on sharia crowdfunding which is empowered for the development of green industry in the agricultural sector.

Nevertheless, several previous studies still focused on waqf management in specific sectors partially in implementing sustainability. There have not been many studies regarding the optimization of waqf for the development of a green campus that is oriented towards environmental conservation and sustainability as far as the author has searched, especially in relation to the development of waqf management models in the scope of green campus implementation. This research aims to present a green campus development model based on mixed funding from Islamic social funding instruments in the form of waqf which is integrated into various sustainability programs in the campus environment, starting from *Tridharma* activities (three pillars of higher education), operational activities, to other supporting activities.

The presence of specific studies regarding the empowerment of waqf for the development of a green campus is an alternative solution for developing and promoting sustainability within the campus with the support of funding based on Islamic social funds. Apart from that, the waqf-based green campus development model has the opportunity to become a direct practical laboratory to increase education, literacy, and promote the importance of protecting and caring for nature and the environment through direct practice on campus which will have an impact on economic and social development. This waqf-based green campus model is an important means to contribute to increasing public awareness, especially within the campus area regarding the urgency of waqf and its relevance to nature and environmental conservation efforts.

LITERATURE REVIEW

Overview of Waqf Empowerment

Waqf is defined as a form of giving property such as buildings, plots of land, or other assets for public purposes. Waqf is carried out by holding and setting aside a person's assets in a way that ensures the benefits are distributed to certain beneficiaries (Rahman & Awang, 2018). Waqf is an important institution in the Islamic economic system to overcome the problem of poverty in society in addition to zakat and other alms instruments. In this case, waqf can play an intermediary role in improving community welfare which is part of the goals of sustainable development and also maqasid sharia. This is implemented by implementing the waqf empowerment program.

In implementing several empowerment programs, waqf has become an effective system for increasing the productivity of services and community needs such as health services, education, and also providing access to public facilities and goods. These various waqf empowerment programs make it an effective instrument to be used for economic and social improvement for the community. This can be seen from the management of waqf which is directed at providing public goods and services including supporting business and business operations

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to help the poor, to helping provide employment opportunities, especially in the sector. agribusiness and industry (Majid, 2022).

Waqf and Sustainability

Waqf has now been optimized to contribute to environmental sustainability programs such as forest planting, renewable energy development, and green infrastructure projects. This is because efforts to preserve resources through conservation of seas, oceans, climate, ecosystems, water and energy coupled with increasing economic growth and industrialization are goals that are relevant to *maqasid sharia* and SDGs. Apart from that, waqf has also been widely used to develop education, research and technology development related to climate change mitigation and adaptation (Sukmana & Rusydiana, 2023). Moreover, the Cash Waqf Linked Sukuk (CWLS) instrument has been optimized to support sustainable development programs (Paul et al., 2021). Initiation of waqf management that supports sustainability programs has been carried out by various parties, until the emergence of the green waqf initiative. Green waqf refers to resource endowments that are specifically for environmental and ecological purposes, emphasizing sustainability and responsible management of natural resources.

Green Campus

The green campus program is a comprehensive program that requires active participation from the entire academic community, starting from students, lecturers, education staff and all stakeholders. Concrete steps are needed to increase understanding and awareness from all parties regarding the importance of sustainability so that it can be implemented on campus (Dono et al., 2023). Implementation of the green campus program shows the commitment of the campus community as a whole in minimizing negative impacts on the environment that arise due to natural damage, exploitation of natural resources and energy, ineffective waste processing, and increased pollution. On the other hand, the implemented green campus program will contribute to improving the welfare of the campus community by improving health, more efficient spending, and other positive impacts from implementing a green campus (Bandeira & Lobão, 2023). To make this happen, several green initiatives need to be carried out on campus, such as reducing and processing effective waste, waste management, efficient use of energy, managing water use, providing a healthy work environment and clean indoor air (Anthony Jnr, 2021). These various programs need to be carried out by the university by involving all academics on campus.

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RESEARCH METHODOLOGY

This research uses a qualitative approach through documentation techniques which are applied by reviewing and analyzing several documents such as journal articles, books, reports and other official documents. In this research, the author focuses on the potential of waqf in financing sustainability programs, especially at the campus level by developing a waqf empowerment model for green campuses. To strengthen the analysis, the author conducted in-dept interviews with five experts with their respective competencies and capabilities. To obtain a comprehensive perspective, this research involved several informants including representatives of regulators, practitioners and academics who are concerned with waqf expertise and sharia economics. The input notes from these experts also became a basis for the author in formulating and developing the proposed model.

Table 1. In-Depth Interview Informants

No	Informant	Affiliation	Representation
1	DS	Trubus Iman IBS	Waqf Practitioner
2	LH	Waqf Millenials and YARSI University	Waqf Practitioner
3	NH	Indonesian Waqf Board	Regulator
4	NA	Tazkia University, Bogor, Indonesia	Academics
5	RL	Productive Waqf Forum	Waqf Association

Source: Authors' processed data, 2024

The data used in this research are primary and secondary data. Primary data was obtained from in-depth interviews with respondents who included regulators, practitioners and academics in the fields of waqf and sharia economics. Apart from that, the author also uses secondary data collected from several reputable international journals (Scopus-Indexed), reports, books, regulations published by relevant authorities, and also other official documents. In the next stage, the collected secondary data is analyzed using content analysis techniques to provide in-depth understanding and relevant knowledge related to the problems discussed in this research. The results of in-depth interviews and literature reviews are used by the author as a basis for designing a model that will be implemented by waqf managers and universities in optimizing waqf empowerment to build green campuses.

ANALYSIS AND DISCUSSION

The Proposed Waqf Empowerment-based Green Campus Model

The growth in population tends to have an impact on several sustainability problems, such as an increase in the amount of waste which is not accompanied by good waste management. Likewise, the amount of plastic used is increasingly widespread, giving rise to various characteristics and types of waste and tends to become a problem in its management. This also includes the problem of water

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use which tends to be wasteful and not managed well. This condition also occurs within the campus community where the population of the campus community is also relatively large, which has an impact on the emergence of various environmental sustainability problems on campus and its surroundings (Najad et al., 2018). These various sustainability problems require campuses to carry out effective management of waste and waste, water, and environmentally friendly management of infrastructure. This is one of the driving factors for presenting a green campus.

This research proposes a waqf empowerment model called the Waqf Empowerment-based Green Campus (Web Cam) Model which raises novelty in the form of the idea of developing a green campus based on integrative waqf empowerment, through the use of waqf assets (goods) and cash waqf. There are at least four activities depicted on the Web Cam Model related to the distribution and utilization of waqf in the green projects sector on campus, namely waste management, water management, green infrastructures and green investments. The four green projects are also linked to mechanisms for collecting waqf on campus, as well as utilizing the results of green projects for literacy and outreach activities on campus so that they provide real beneficial impacts. Table 2 summarizes several aspects of the use of waqf in implementing green projects on campus which were validated using in-depth interviews and also a literature review of previous research results.

Table 2. Aspects of Utilizing Waqf for Green Projects

No	Utilization Program	Informants' Statement	Supporting Literatures
1	Waste Management	*At that time, we conceptualized how this waste could be converted into renewable energy. We see that this waste is a problem in Indonesia and other countries. We want the existing waste, both organic and non-organic, to be converted into electrical energy.* (Informant 2) *In the future, waqf can also be used for waste management, to manage waste. That requires machines, requires land and so on.* (Informant 4)	Najad et al. (2018); Thaker et al. (2022); Riani et al. (2023); Wildana et al. (2022); Hamdani et al. (2022)
2	Water Management	-	Thajudeen et al. (2018); Sugesti et al. (2023); Roslan et al. (2024)
3	Green Infrastructures	*Almost at (the Islamic boarding school we manage) Trubus, the infrastructure comes from the proceeds (utilization and empowerment) of waqf. So we don't burden*	Ari et al. (2021); Bulut et al. (2023); Majid et al. (2022); Bandeira

No	Utilization Program	Informants' Statement	Supporting Literatures
		students (with additional costs). (Informant 1) *There are only a few institutions that have focused, such as the Al-Quran Waqf Board which uses solar panel waqf in 3T (Tertinggal, Terdepan, Terluar-Disadvantaged, Frontier, Outermost). The Istiqlal Mosque also uses green energy using a waqf basis.* (Informant 2) *The first starts with asset waqf, for example there are people who waqf land to use for solar panels. That's possible. There is also the building waqf, building waqf, that is much more important in my opinion for beginnings like this. If we talk about costs, it can reduce the costs of higher education.* (Informant 4)	et al. (2023); Najad et al. (2018)
4	Cash Waqf Program	*The core is in agribusiness, the core is in plantations. Whatever the activity, the connection is integrated with the core. Our program is called Trubus Sentra Agribusiness. This is all pure empowerment of waqf assets.* (Informant 1) *How forests in Aceh can restore the ecosystem through reforestation. So the Aceh forest waqf, Bogor forest waqf, and Bandung forest waqf were born.* (Informant 2) *What is currently developing is forest waqf in the Bogor area, in Aceh and in Pekanbaru.* (Informant 3) *Waqf money can be allocated to small projects first on the green campus, because green campus projects are quite expensive.* […] *The risk is quite big, you need to be careful.* […] *Can be invested first, the results can be allocated to renewable energy.* […] *So for the green project aspect, it seems that it must be through financial instruments, for example through the issuance of sukuk and so on to ensure security.* (Informant 4)	Khan et al. (2023); Siregar et al. (2024); Ascarya (2023); Kachkar (2017); Azizan et al. (2022); Musari (2022)
5	Literacy and Socialization Program on Waqf and Sustainability	*There is mutual benefit between the campus and the waqf management in the synergy between the two, therefore if you look at it from the Tridharma, everything is included, from waqf education is needed, then community service should be like that, then*	

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No	Utilization Program	Informants' Statement	Supporting Literatures
		research. It would be a shame if the waqf nazhir had to research it himself. (Informant 1) *We have implemented the collaboration between the waqf institution and campus in community service. There has also been a lot of research, we collaborated with several lecturers.* (Informant 2) *Campus can enter from the perspective of community service. And the second is from the research side. Contribute ideas related to Green Waqf for publication. And thirdly, from an educational perspective, the campus has started to obtain operational permits for the zakat waqf study program by including the Green Waqf topic.* (Informant 3) *If we look at the earliest, it was more about awareness. And this is not enough. Then evaluate development. Campuses can play a role on all fronts. We can carry out campaigns, outreach. […] You can establish a Study Center that combines the knowledge of many lecturers, so that it is used to develop waqf, both in terms of research, then awareness outreach to the community, by creating a pilot project, by creating a green campus.* (Informant 4)	

Source: Authors' processed data, 2024

Waqf Collection

Waqf collection is carried out in the form of waqf in the form of assets/goods or money. The asset waqf receipt scheme is implemented either in the form of direct transfer of assets or through a cash waqf scheme, by collecting funds from the waqif for the procurement of specified goods. This waqf collection is carried out both from internal campuses such as leaders, lecturers, education staff, students, and other parties as well as from external circles or the general public. Technically, the collection of cash waqf within the campus area, especially from leaders, lecturers and also educational staff, can be done in the form of regular salary deductions based on the agreement of campus employees, or through direct payments through the channels provided (Pitchay, Thaker, et al., 2018). This mechanism provides an opportunity to determine predictions of the potential for waqf collection so that it can become a basis for developing empowerment programs.

Waqf Utilization

Waqf utilization is carried out within the campus to support the development of a green campus by being allocated according to the waqf designation desired by the wakif. Empowerment of waqf in the form of assets and endowments through money for asset purchases is carried out through waqf offering and socialization programs to the campus community, both internally and externally. In its use, waqf assets are allocated to at least three programs, namely waste management, water management, and the provision of green infrastructure as depicted in the Web Cam Model as shown in Figure 1.

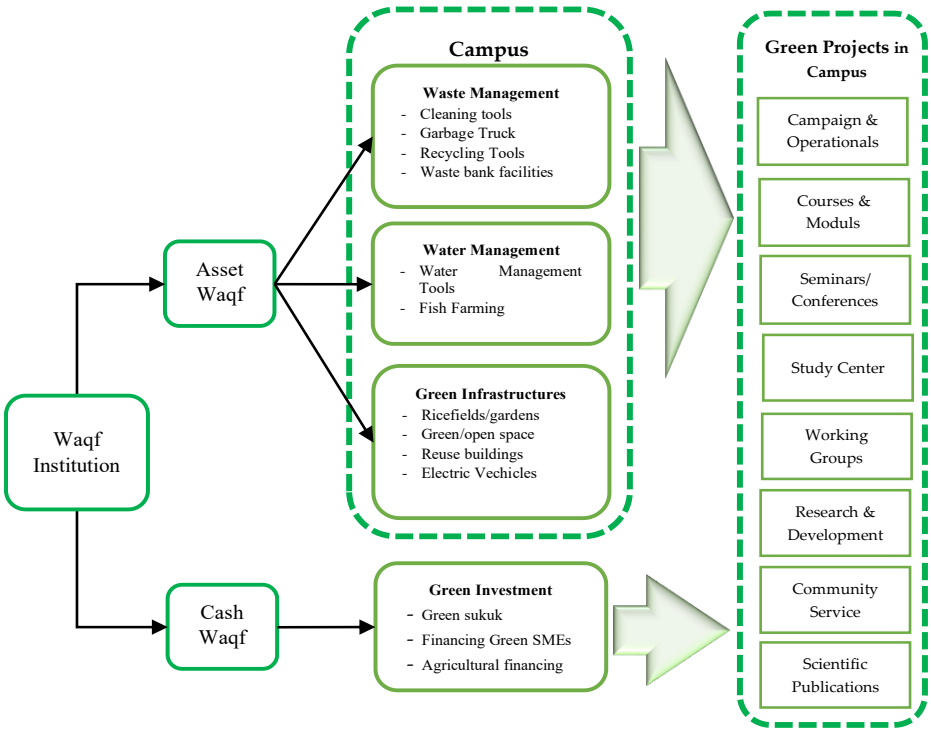


Figure 1. Waqf Empowerment-based Green Campus (Web Cam) Model

Waste Management

The larger the population of the campus community, the amount of waste production per day will also increase rapidly (Najad et al., 2018). This condition will become a problem if it is not managed and mitigated properly. Waqf needs to be optimized to overcome these problems by optimizing the procurement of various facilities and equipment to support waste management (Thaker et al., 2022). In practical terms, waqf is allocated for the procurement of cleaning

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equipment including trash cans for separating types of waste between organic and non-organic waste. The waste sorting process is continued by dumping the waste to the final disposal site using a rubbish truck which is also provided by the waqf. Apart from that, the waste processing process also needs to be carried out using a waste recycling scheme so that there is a need for waste recycling facilities and equipment, starting from traditional and modern recycling systems. Furthermore, waqf also needs to be allocated to support the provision of a waste bank that can be utilized by the campus community.

Water Management

The issue of water scarcity has been experienced by several countries (Roslan et al., 2024). An effective water management mechanism is needed to preserve water by utilizing existing water resources, including optimizing waste water management so that it can be reused in several activities. Water management is needed by utilizing clean water and waste water to be used according to its intended purpose as a concrete step to support water conservation. Utilization of rainwater is also required through a filter process so that it can be used daily (Sugesti et al., 2023). Efficient use of clean water and effective management of waste water will be able to increase water conservation efforts, especially on campus. This program is supported by the provision of filter equipment and water distillation or irrigation channels to distribute waste water within campus areas such as canteens, mosques and pantries in campus rooms. These various equipment can be provided through a waqf scheme which is collected in the form of direct asset waqf or cash waqf. As a development option, the distributed water can also be collected into ponds built on waqf land and used for fish farming or other productive businesses.

Green Infrastructures

Waqf is a potential source of funds in developing sustainability programs, including infrastructure development and environmentally friendly projects. Utilizing land in the form of waqf land owned by the campus as agricultural land and plantations is an alternative for developing agricultural laboratories and plantations as well as an option for productive waqf development. Agricultural and plantation management patterns have also been developed by prioritizing environmental conservation principles by minimizing the use of chemicals that can pollute the soil (Majid, 2022). To increase the optimization of existing buildings, waqf is allocated to the construction of new buildings with environmentally friendly designs and architecture. As another option, old unused buildings can be redesigned to accommodate environmentally friendly concepts so that they can be optimized properly (Bulut, 2021). In the aspect of providing infrastructure, the electronic goods used need to prioritize the aspect of efficient

use of electricity. Waqf assets can be allocated by procuring several energy efficient equipment and electronic goods thereby reducing electricity consumption. This also includes the need to transform alternative energy sources such as solar panels which may become waqf objects (Bandeira & Lobão, 2023). Apart from electronic goods, campuses also need to be supported by environmentally friendly transportation facilities such as electric vehicles or bicycles. The use of environmentally friendly means of transportation is expected to reduce carbon emission levels (Najad et al., 2018). Later, these environmentally friendly vehicles can be used by the entire campus community.

Green Sukuk

Waqf management as an Islamic social funding instrument has now developed through an integration process with commercial funds, through sharia banking institutions. It cannot be denied that sharia banking as an intermediary institution has great potential in collecting and managing waqf funds, which will increase economic growth. This synergy and integration can be applied at the campus level by involving sharia banking to participate in collecting and managing waqf funds from the campus community. Apart from that, waqf management has also been studied to be combined with sukuk through various contracts that are in line with sharia principles (Khan et al., 2023). Furthermore, the waqf collected from the campus community is channeled and invested in green sukuk instruments which will be used in sustainability development sectors. This includes an integration scheme for managing green sukuk and CWLS (Musari, 2022). The benefits received are to support the implementation of campaign and education activities as well as sharia-based sustainable financial literacy as well as other green project activities on campus, especially Tridharma activities. With the characteristics of waqf which must prioritize the prudential aspect, the sukuk instrument is a priority aspect in empowering cash waqf. Apart from that, waqf fund distribution activities are also currently being studied to be developed into an investment process through share ownership in sharia banks (Siregar et al., 2024).

Financing Green SMEs

Management of waqf funds must be carried out comprehensively and provide a positive and sustainable impact on society. Integration between social and commercial funds also needs to be implemented in the microfinance aspect. Among the forms of integration that can be carried out is an integrative waqf management application at *Baitul Mal wa Tamwil* (BMT). In the aspect of financing distribution, the best scheme that can be applied is the distribution of financing to SMEs, especially those who are members of the BMT. (Ascarya, 2023). Specifically in the sustainability aspect, the distribution of cash waqf funds is also carried out to SMEs who implement the Go Green principles (Green

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SMEs). In general, waqf has been optimized as a source of microfinance funds that can contribute to improving the socio-economic conditions of society (Kachkar, 2017). Providing capital assistance to run a business will create individuals who are enthusiastic about fighting to make a living. This will have a positive impact on the entry of poor people into the workforce and have a positive impact on economic growth. The distribution of waqf funds to the SME financing sector needs to be carried out through a feasibility study, monitoring and evaluation process so that waqf management can run as expected.

Farming Financing

Empowering cash waqf for the agricultural and livestock sectors can help farmers and livestock breeders from local communities to finance the development of their agriculture and livestock. This includes the use of idle waqf land for use as agricultural land or livestock as well as fattening livestock (Azizan et al., 2022; Sukmana et al., 2024). The agricultural products obtained are distributed proportionally to the waqf managers and also the farmers. This pattern is one solution for agricultural financing which is often faced by farmers. However, as with distribution to SMEs, agricultural financing also needs to be carried out with strict feasibility studies, ongoing monitoring and evaluation to monitor the agricultural processes carried out so that they are productive and produce optimal harvests.

Academic and Operational Activities related to Waqf-based Sustainability

Various activities, programs and operational activities to support the implementation and development of sustainability are carried out on campus by utilizing various green infrastructure facilities built with waqf. This shows the contribution of waqf in developing sustainability and the suitability between waqf development and sustainability. Apart from that, all operational costs required to implement the various programs are supported by waqf which is the result of the development and management of waqf assets in the form of money, as well as waqf assets in the form of goods whose use has been made productive. This scheme can be seen from Figure 2 which shows the management of cash waqf funds into several sharia investment and financing instruments, where the results of these investments are allocated to support the implementation of academic programs and other supporting activities. Among the first programs that need to be carried out are promotional and educational activities about sustainability to the entire campus community. Education and outreach are important to build awareness among the campus community so that they will support the implementation of green programs.

These educational activities also need to be supported by real action activities to support sustainability in the form of an invitation to the entire campus

community to reduce plastic consumption, save energy through the use of lights, air conditioning and other electronic devices, as well as an invitation to maintain cleanliness and sort waste through the trash cans provided by the waqf. To increase education and literacy related to sustainability, the campus organizes learning about the concept of sustainability through various classroom lecture sessions, public lectures, and also practitioner lectures. Apart from that, various scientific meetings such as seminars and conferences, both national and international, are also important media in socializing and developing sustainability literacy to the campus community and external parties in general. In order to increase studies and discussions related to sustainability, the campus has formed several working groups and sustainability study centers. The formation of these scientific groups can become the center of a scientific ecosystem related to sustainability, thereby making studies and discussions related to sustainability more lively.

Sustainability studies also need to be included in the Tridharma activities carried out by lecturers, through teaching, research, community service, until the output of each of these activities is in the form of scientific or other publications. Teaching is carried out by including sustainability topics in several courses, or by teaching special courses related to sustainability. The lecture is supported by lecturer research activities directed at sustainability research topics. Apart from that, teaching and research activities are also strengthened by community service which refers to sustainability education to the community, especially to promote and campaign for sustainability to the community.

CONCLUSION

Green campus development has become a necessity in line with the increasing amount of waste generated from academic and operational activities on campus. However, these efforts are still faced with several obstacles such as the lack of public awareness and knowledge regarding sustainability, the lack of participation and collaboration from the academic community, as well as the funding aspect which is the main challenge, considering that implementing a green campus requires quite large funds. Waqf Empowerment-based Green Campus (Web Cam) Model is the answer to this problem. In its implementation, the Web Cam Model formulates the collection of waqf from internal and external campuses, in the form of cash waqf, asset waqf, or asset waqf through money. Furthermore, the collected waqf is allocated to several green initiative programs in developing a green campus. Waqf assets are collected and campaigned to the campus community and external parties to procure several facilities and equipment to support waste management and water management projects. Apart from that, asset waqf is also promoted to the community to provide infrastructure that supports green initiatives in general. Meanwhile, cash waqf is distributed and

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developed through investment in green sukuk, as well as channeled to finance SMEs that implement green business. Opportunities are also open to channel cash waqf funds to the agricultural financing sector. All cash waqf distribution processes are carried out with the principle of caution and regular monitoring and evaluation are carried out. The development of the Web Cam Model is expected to be a new perspective in developing the implementation of environmental sustainability within the campus area based on waqf empowerment, so that it can provide benefits to the wider community.

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EXPLORING KEY DETERMINANTS OF GREEN PROCUREMENT IMPLEMENTATION FOR CONSTRUCTION PROJECTS: A MEASUREMENT MODEL IN STRUCTURAL EQUATION MODELLING (SEM)

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Abstract

Green procurement procures goods and services and works to minimize negative impacts throughout their life cycle. It is a concept introduced as a way forward towards a greener approach aligned with Agenda 21 towards sustainable development. The 12th Malaysia Plan emphasized the Malaysian government's strategic commitment to integrate environmental considerations into its procurement processes. This shows Malaysia's commitment towards sustainable development and promoting environmentally responsible practices in the sectors. However, there are several challenges faced by the industry in green procurement (GP) implementation, such as lack of commitment, low awareness and knowledge of green procurement and policy enforcement. This study explores the key determinants, focusing on authority, accountability, policy, and knowledge, that influence green procurement implementation. This study employs quantitative methods, and a questionnaire survey was used as the data collection technique. The data was analyzed using a measurement model in Structural Equation Modelling (SEM) Analysis of Moment Structure (AMOS) version 28 to identify and analyze the interrelationships among influential determinants such as authority, accountability, policy and knowledge of green procurement implementation. The findings highlight the key determinants of green procurement that significantly affects green procurement implementation. Critical insights of the findings provide strategic recommendations to overcome the limitations of current green procurement practices, and by addressing these gaps, this study contributes to more effective green procurement implementation practices in construction projects, highlighting planning & policy formation, compliance, stakeholder engagement, education and knowledge sharing, transparency and accountability, collaboration, management support, guidelines and construction stakeholders role throughout the construction phases.

Keywords: Green procurement; Structural Equation Modeling (SEM); AMOS; Construction; Projects

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INTRODUCTION

The construction industry plays an important role in developing infrastructure and physical facilities for people, and these activities contribute to significant environmental impacts. Transitioning to sustainable practices in the construction industry is now essential due to the rapid environmental changes (Rashid et al., 2022). The concerning impacts on the environment in the construction industry have made people to be more conscious of the importance of sustainable construction practices. Focusing on construction activities, various phases are involved, such as pre-and post-construction stages. During the pre-construction stage, procurement decisions were made, and Witek & Kuźniar (2021) mentioned that environmental considerations had become an important issue in the industry, especially purchasing.

Procurement delivery is crucial for construction projects to ensure adherence to the contract. Greening procurement delivery is particularly important in construction projects. Many strategies have been introduced to minimize environmental impacts, and one of them is the introduction of green procurement (GP). In the 12th Malaysia green growth for sustainability and resilience Plan (2021-2025), the Malaysian government has addressed the importance of advancing, where it highlighted enhancing implementation mechanisms for green practices. Moreover, short-term action plans and guidelines on government green procurement (GGP) will be introduced to foster green practices in the construction sector.

LITERATURE REVIEW

Overview of Green Procurement

Green procurement (GP) can be defined as the "sourcing of products and services that mitigates the potential threat to the environment and human health" (Najmi et al., 2020). As for Government Green Procurement (GGP), it has been defined as the "procurement of supplies, services and works by the government that takes into account environmental criteria to conserve and minimize the impact on the environment, accelerate the national economy and promote sustainable development" (Adham and Siwar, 2012). For construction, the green procurement for works was established, which encompasses the minimization of the environmental impacts of construction works in phases of the lifecycle and other physical infrastructure (Khan et al., 2018).

Green procurement is still in the infancy level in Malaysia, and the current process still suffers from fragmented efforts and insufficient integration of green practices into green procurement strategies (Razali et al., 2021). There are a few challenges in green procurement implementation that need to be addressed to ensure that green procurement can be successfully implemented. Al

Hazza et al. (2023) highlighted a lack of knowledge and awareness of GP, low commitment among construction stakeholders, lack of policy enforcement (AlNuami and Khan, 2019), and limited standard green procurement guidelines (Benjamin et al., 2016). To ensure that green procurement can be implemented effectively and successfully, it is crucial to investigate the key determinants of green procurements. Despite the potential benefits of GP, the implementation of GP practices still needs to be improved across industries, especially in the construction industry.

Key Determinants of Green Procurement Implementation in Construction Projects

Understanding key determinants of green procurement in construction projects within Malaysia is essential to promote sustainability practices and contribute to sustainable development in construction projects. Moreover, the construction stakeholders can adopt a more integrated framework for implementing green practices in construction projects. More empirical evidence and data validation are still needed to address the complex interplay among these critical determinants. Isolated interventions lead to fragmented and ineffective implementation strategies (Erdmenger, 2017). The construction stakeholders need to consider working in collaboration and considering their interdependencies to implement this strategy successfully. According to the theoretical perspectives of collaboration, Mattessich et al. (2001) highlighted authority and accountability as practical collaboration elements, and Pun (2006) highlighted policy as an environmental operations model. On the contrary, Bohari et al. (2020) highlight the importance of creating awareness and green education among construction stakeholders.

From a global perspective, an international awareness exists to achieve sustainable development goals in the construction sector. Most developed countries have national plans targeting public procurement to incorporate environmental considerations and mention public procurement in the national sustainability plan (Lewis et al., 2023). For example, France set a non-binding goal of 100% public procurements at every governance level to include a minimum of one environmental criterion by 2025 in the National Plan for Sustainable Purchases. As for Germany, the Federal Climate Change Act set a similar goal of a climate-neutral federation administration by 2030. In Malaysia, the government has many initiatives and strategies to address environmental issues. Focusing on green procurement for the construction sector, it started with the National Green Technology Policy (2009), which highlights purchasing environmentally friendly and green products and services, which developed through the years with the introduction of the MyHijau Program, a platform to encourage green technology and green purchasing. The Twelfth Malaysia Plan,

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2021-2025, emphasized enhancing the green practices implementation where a short-term action plan and guidelines on government green procurement for works will be introduced. While many policies on green procurement are available, compliance within the organization and government in Malaysia needs to be improved (Vejaratnam et al.,2023).

Authority and Accountability

Authority refers to entities or bodies responsible for developing, implementing, and enforcing policies and guidelines. As for accountability, it refers to "the quality or state of being accountable" (Merriam-Webster, 2019).

Policy

According to Bohari et al. (2020), in terms of green-related practices, the government must establish and enforce laws and regulations related to green procurement and provide incentives to promote green procurement. Moreover, the government must implement a code of practices, such as Environment Impact Assessment (EIA), in construction phases to ensure compliance with green procurement standards and regulations. Moreover, the government must set mandatory requirements and compliance for tenders, and it is crucial to obtain government approval to incorporate green practices in the early stages of the projects.

Knowledge

According to Bohari et al. (2020), it is essential to create awareness and educate the construction project stakeholders before the project commences and throughout the project's life cycle. Understanding and knowledge can facilitate participation and collaboration among construction stakeholders. Informal training, project meetings, and benchmarking can improve construction stakeholders' awareness of green procurement. By synthesizing these aspects, the key determinants of green procurement can be further investigated. A critical limitation exists in understanding how these determinants interact with and collectively impact green procurement implementation. Therefore, this study examines the essential determinants of green procurement implementation in Malaysia, driven by the need to enhance environmental sustainability and organizational efficiency.

RESEARCH METHODOLOGY

This study uses a quantitative approach for the primary data and an integrative review for secondary data. The primary data was collected through questionnaire surveys. The data collection technique used was hardcopy and online distribution

(web-based survey) using Google Forms, designed using a Likert scale of 1 to 5. The sampling technique used for this study involved a multistage approach, where purposive sampling was used to identify certified green building projects and choose types of construction stakeholders in Peninsula Malaysia (Klang Valley), Sabah, and Sarawak for the selection of the study areas by region cluster sampling. The sample size for this study was determined by using Krejcie and Morgan's (1970) table based on the respondents' population size of 180, and the recommended sample size for this study was 123. This study employs Covariance-Based Structural Equation Modelling (CB-SEM) with the use of the CB-SEM tool, Analysis of Moment Structures (AMOS) version 28, to systematically analyze the interdependencies among key determinants such as policy, commitment, knowledge and guidelines.

As for the data analysis, descriptive statistics will be used to summarize the demographic data, and as for SEM, the identification of model specifications is essential for developing structural Equation Modeling. The model types involved in this study are confirmatory factor analysis (CFA) to validate the procedure for measurement model and development of structural equations modelling (SEM). This study's exogenous (independent) variables are authority and accountability, and the endogenous (dependent) variables are green procurement implementation. The CFA will be assessed on the reliability and validity tests, such as construct validity, to examine the fitness indexes and test the convergent validity, composite reliability, and discriminant validity before developing the structural model. Analysis and interpretation of the data from the model are carried out to answer the formulated problem and the study's objective.

ANALYSIS AND DISCUSSION

Demographic Data

Table 1 and Table 2 show the demographic data for the respondents and no. of respondent’s involvement in green projects. The data indicates that Quantity Surveyors are the highest respondents in this study, with 50% in total. Civil and Structural Engineers represent 19% of the total, while Architects and Green Facilitators represent 9.5%. Mechanical and Electrical Engineers comprise 4.8%, and the remaining 7.1% fall into the "Others" category. "Others "in the category represent Green Building consultants, Environment Officers, Contract Administrators, and Procurement Executives.

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Table 1. Respondent's professional role

Professional role

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	12	9.5	9.5	9.5
	Civil and Structural Engineer	24	19.0	19.0	28.6
	Mechanical and Electrical Engineer	6	4.8	4.8	33.3
	Quantity Surveyor	63	50.0	50.0	83.3
	Green Facilitator	12	9.5	9.5	92.9
	Others	9	7.1	7.1	100.0
	Total	126	100.0	100.0	

Table 2 reveals most of the respondents have participated in the green projects fewer than three projects with 63.5%. About 11.1% have been involved in 4-6 projects, while 1.6% have participated in 7-9 projects. As a smaller group, 7.9% have been involved in more than ten projects. Additionally, 15.9% of respondents have not been involved in green projects. Overall, the data shows varying levels of engagement, with the majority having limited experience in green projects. From these green projects, involvement will provide insights from those with more involvement in green projects, and the respondents who have not participated in any green projects highlight the respondents who may have theoretical or outlying knowledge of green projects.

Table 2. No of Respondent's Involvement in Green Projects

Total of GP involvement

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 3 projects	80	63.5	63.5	63.5
	4-6 projects	14	11.1	11.1	74.6
	7-9 projects	2	1.6	1.6	76.2
	More than 10 projects	10	7.9	7.9	84.1
	No project	20	15.9	15.9	100.0
	Total	126	100.0	100.0	

This demographic data provides a foundational understanding of the respondents, allowing the study to identify and analyze the critical determinants of green procurement implementation from a diverse and representative sample.

Confirmatory Factor Analysis

After analyzing the descriptive statistics for this study. Next, the measurement model was validated by confirmatory factor analysis (CFA), and the constructs went through a validity test to ensure the model fit. Hair et al. (2010) and Holmes-Smith (2007) recommended using at least one fitness index from each category model: Absolute Fit, Incremental Fit, and Parsimonious Fit. Some modifications have been made to make the model fit according to the fitness category, and the fitness indexes used for this study are RMSEA, CFI and CMIN/Df. Figure 1 is the measurement model for this study;

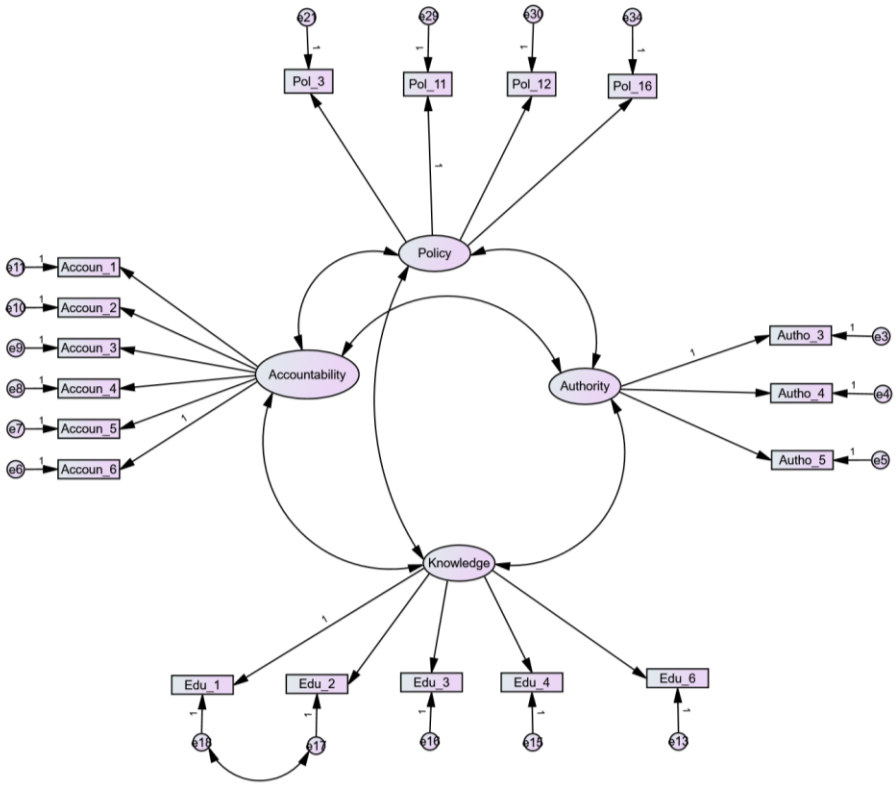


Figure 1. The measurement model

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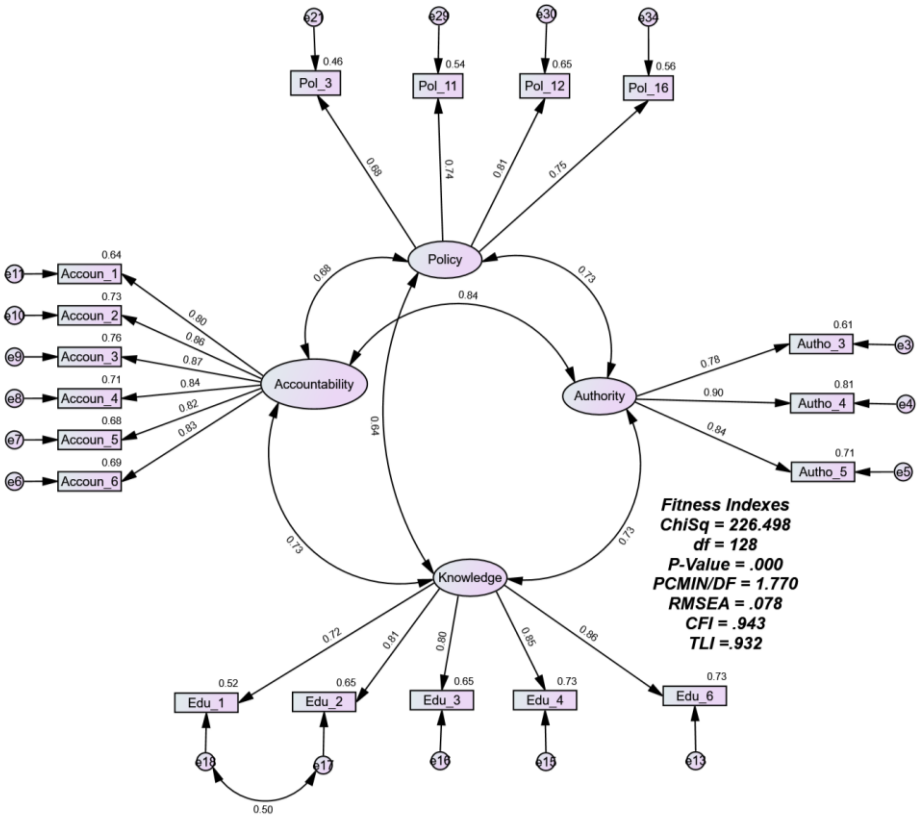


Figure 2. CFA results for the measurement mode

Figure 2 shows the CFA results for each component after model modifications for the measurement model. The variables for Authority are Autho_3, Autho_4 and Autho_5. Whereas the accountability is Accoun_1, Accoun_2, Accoun_3, Accoun_4, Accoun_5, and Accoun_6. Policy is Pol_3, Pol_6, Pol_11, Pol_12 and Pol_16 and Knowledge is Edu_1, Edu_2, Edu_3, Edu_4 and Edu_6. The assessment of Construct Validity is presented in Table 3, and the assessment shows the CFA model achieved the required level of fitness category for Absolute Fit, RMSEA = .078, Incremental Fit, CFI = .943 and Parsimonious Fit, CMIN/df = 1.770.

Table 3. The assessment of construct validity for the Measurement Model after modifications

The Measurement model				
Fitness Category	**Name of Index**	**Index Value**	**Threshold**	**Comment**
Absolute Fit	RMSEA	.078	<0.08	Achieved the level
Incremental Fit	CFI	.943	>0.95 – CFI>0.85 (acceptable)	Achieved the level
Parsimonious Fit	CMIN/Df	1.770	<3.00	Achieved the level

After the CFA procedure for the measurement model was completed, the factor loading for every construct was analyzed. The determination of convergent and composite reliability is assessed as below;

Table 4. The assessment of convergent and composite reliability

Construct	**Item**	**Factor Loading**	**CR (> 0.6)**	**AVE (>0.5)**
Authority	**Autho_3** Engaging construction stakeholders in decision-making processes	0.78	0.880	0.710
	Autho_4 Project guidelines for the construction stakeholders	0.90		
	Autho_5 Established work guidelines for the project delivery	0.84		
Accountability	**Accoun_1** Strong leadership, especially from a leader from each construction stakeholders	0.80	0.934	0.701
	Accoun_2 Clear contractual agreements about green procurement implementation	0.86		
	Accoun_3 Clear rules and regulations for the construction stakeholders	0.87		
	Accoun_4 Providing transparency to construction stakeholders on the whole process of green procurement implementation	0.84		
	Accoun_5	0.82		

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Construct	Item	Factor Loading	CR (> 0.6)	AVE (>0.5)
	Construction stakeholders should adhere to environmental regulations and standards			
	Accoun_6 Support from top management on green procurement implementation is important	0.83		
Policy	**Pol_3** Policy availability at the project level could encourage environmental awareness	0.69	0.831	0.552
	Pol_11 The government's initiative to implement green procurement for all large public projects	0.72		
	Pol_12 The community and government must have efforts and initiatives such as competition/awards, incentive schemes	0.79		
	Pol_16 Raising organisation awareness on green procurement (training and institutional organisations)	0.75		
Knowledge	**Edu_1** Awareness of green procurement's concept, importance, benefits, and opportunities through training programs or seminars.	0.72	0.905	0.656
	Edu_2 Educate the construction stakeholders on environmental consciousness through green procurement implementation	0.81		
	Edu_3 Benchmarking international best practices and lessons learned from different governments around the world.	0.80		
	Edu_4 Interaction between academia and practitioners to develop knowledge on green procurement	0.85		
	Edu_6	0.86		

Construct	Item	Factor Loading	CR (> 0.6)	AVE (>0.5)
	Collective learning at all levels within the organisation to adapt to environmental shifts and challenges			

Table 4 shows the factor loading is above 0.50, and the highest factor loading is 0.90. All measures for AVE are greater than 0.50 and all measures for CR is greater than 0.60. Thus, the Convergent Validity and Composite Reliability for all constructs in the study have been achieved. After the analysis of Convergent validity and Composite Reliability, the discriminant validity was assessed using the Fornell-Larcker Criterion. This criterion states that the correlation between a construct and another must be more significant than the square root of the average variance retrieved by the construct. The calculation of Discriminant Validity and Discriminant Validity Index Summary is shown in Table 5;

Table 5. The Discriminant Validity Index Summary for the construct using the Fornell-Larcker Criterion

	Knowledge	Authority	Accountability	Policy
Knowledge	**0.810**			
Authority	0.728	**0.842**		
Accountability	0.731	0.836	**0.837**	
Policy	0.639	0.733	0.675	**0.743**

Table 5 shows there are four (4) constructs involved in the model. A 4 by four matrix table was developed. The diagonal values in bold are the square root of the AVE of that construct, while other values are the correlation between the respective constructs. The discriminant validity is achieved when the diagonal value in bold is higher than other values in its row and column. It can be concluded that the discriminant validity for all four constructs (Knowledge, Authority, Accountability and Policy) is achieved. The value of 0.810 for Knowledge is more significant than 0.728, 0.731 and 0.639. The value of 0.842 for authority is greater than 0.836, 0.733 and 0.728. The value of 0.837 for Accountability is greater than 0.675, 0.731, 0.836. The value of 0.743 for Policy is greater than 0.675, 0.733 and 0.639.

From the key determinants and items in Table 6, it is important to consider the various phases and activities involved in construction projects to implement green procurement practices within the construction industry

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effectively. The importance of these key determinants of green procurement can enhance the integration of sustainable practices. By aligning specific actions and strategies with each phase, a more systematic and efficient implementation of green procurement can be determined. In this discussion, the key determinants of green procurement implementation were categorized based on construction phases to provide a straightforward approach for green procurement.

Table 6. Key Determinants of Green Procurement Implementation in Construction Projects throughout the Phases.

CONSTRUCTION PHASES					
	Pre-construction		**Construction**		**Post-construction**
Policy	**Planning & Policy Formation**	**Accountability**	**Implementation and Compliance**	**Educate**	**Review and Learning**
	Policy Availability		***Clear Contractual Agreements***		***Benchmarking Best Practices***
	Policies availability and establishment at the project level		Establish clear contracts which include sustainability requirements to ensure compliance.		After project completion, analyze results and compare them with best practices to identify areas for improvement.
Policy	***Government Initiatives***	**Accountability**	***Adherence to Environmental Regulations***	**Educate**	***Collective Learning***
	Government Initiatives to incorporate mandates for green procurement into project planning		Construction activities comply with all relevant environmental regulations and standard guidelines.		Continuous learning within the organization to adapt to environmental challenges and improve future green procurement practices.
Policy	***Government Efforts***				
	Government efforts to give incentive schemes, monetary or non-monetary reward				

	Stakeholder Engagement and Education		**Transparency and Accountability**		**Knowledge Sharing and Collaboration**
Authority	***Engaging construction stakeholders***	**Accountability**	***Transparency***	**Authority, Educate**	***Government-Academia-Construction Practitioner Interaction***
	Involve all relevant construction stakeholders in pilot projects and the planning process to ensure their input and commitment.		Maintain transparency throughout the construction process to build trust.		Encourage collaboration between these stakeholders to set the stage, provide standard guidelines for green procurement to drive innovation, disseminate knowledge, bridge information and knowledge gaps, and develop practical solutions for future projects.
Educate	***Training Programs***	**Accountability**	***Strong leadership***		
	Conduct training programs to raise awareness about the benefits and processes of green procurement.		Leadership is crucial in driving the green procurement agenda. Government/Clients should have sustainability initiatives and ensure adherence to green procurement practices.		
Educate	***Environmental Education***				
	Educate construction stakeholders on environmental issues.				
	Leadership and Management Support		**Construction Stakeholders Guidelines and Roles**		
Accountability	***Support from Top Management***	**Authority**	***Project Guidelines for Stakeholders***		
	Ensure top management's commitment to providing resources and prioritising sustainability.		Provide clear guidelines for construction stakeholders, defining construction stakeholders' roles and responsibilities in the green procurement process.		

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This approach for green procurement in construction phases highlights government initiatives that drive policy formation and integration of sustainability mandates into project planning, which is supported by adherence and compliance to environmental regulations and stakeholder's education. Clear contractual agreements during construction are essential to ensure compliance and are complemented by ongoing education and transparency among the construction stakeholders to enhance accountability and trust. In the post-construction phase, the results of the green procurement project need to be analysed and compared with the best practices to enable continuous learning and improvement. The construction stakeholder's collaboration drives innovation and knowledge sharing. Strong leadership and management support are essential to ensure commitment towards sustainability, and defining the roles and guidelines for construction stakeholders is also vital. These efforts establish a comprehensive approach to green procurement and provide strategic recommendations to overcome the limitations of current green procurement practices. Moreover, this promotes environmental responsibility among construction stakeholders across the construction industry.

CONCLUSION

This study has comprehensively explored the key determinants influencing the implementation of green procurement in construction projects, focusing these four (4) keys determinants, authority, accountability, policy and knowledge. Through the application of Covariance-Based Structural Equation Modelling (CB-SEM) and AMOS analysis, significant insights were gathered that highlight the importance of strong policy frameworks, commitment, and inclusive construction stakeholder education. The findings reveal that established project and work guidelines for construction stakeholders, authoritative support, and clear accountability mechanisms are crucial to enforce the green procurement practices and standards. The government must set the stage for green procurement implementation in terms of policy, whereby it has to be meticulously constructed and thoroughly enforced to ensure compliance among construction stakeholders. Without the enforcement, it will be challenging to implement green procurement. Moreover, transparency is vital to building engagement and trust among construction stakeholders. This study also highlights that ongoing dissemination of knowledge and continuous learning by expert academician is important for bridging information and filling knowledge gaps on green procurement. After the project completion, the evaluation and outcome of green procurement implementation in a project can be further improved by benchmarking against best practices and lessons learned from other countries. This study's critical insights and strategic recommendations provide a way forward to overcome the current limitations in green procurement practices within construction projects.

Addressing the gaps in the construction phases will enhance the effectiveness of green procurement implementation. Emphasizing the importance of education and knowledge sharing among stakeholders will enhance a more insightful understanding and commitment towards green practices. Further research should examine the deeper interactions between these determinants to refine green procurement strategies using structural model analysis. These efforts contribute towards environmental responsibility within the construction industry, paving the way for more sustainable development practices.

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PLANS AND STRATEGIES FOR ADAPTATION TO CLIMATE UNCERTAINTY FOR TRADITIONAL SALT FARMERS ON THE NORTHERN COAST OF JAVA

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Abstract

People around the world have reached a consensus regarding climate change and the occurrence of climate-related extreme events. This phenomenon directly impacts the production of salt, a vital commodity for both consumption and industry. The northern coast of Java produces salt with high fluctuations due to these erratic weather changes. Most salt farming communities consist of traditional farmers, with only a few having adopted technological innovations. This study aims to: (1) identify the climate change vulnerability of salt farming households on the northern coast of Java, and (2) analyze the adaptation strategies implemented to meet their economic needs. The study employed the Livelihood Vulnerability Index – Intergovernmental Panel on Climate Change (LVI-IPCC) method. Community adaptation was examined through field surveys involving 180 traditional salt farmers. Primary data were obtained through participatory observation, in-depth interviews, and documentation, supplemented by secondary data from relevant agencies. The results indicated that the climate variability component was the dominant factor in the LVI, at approximately 0.698. Based on the IPCC vulnerability components (exposure, adaptive capacity, and sensitivity), the overall LVI-IPCC ultimate value was 0.152. Production obstacles and price fluctuations forced salt farmers to adapt by diversifying their livelihoods, such as working as fishermen, cultivating milkfish or shrimp, rice farming, or providing construction and transportation services. Wealthy farmers utilized social networks to engage in interregional salt trading. This livelihood diversification served as a critical strategy for farmers to survive production constraints and price volatility.

Keywords: Climate, Coastal, Salt Farmers, LVI, Defense Mechanisms, Java Indonesia

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INTRODUCTION

Salt is always needed by humans in everyday life, primarily for consumption and industrial purposes. In Indonesia, salt is generally produced in coastal areas by evaporating seawater on a piece of land with the help of wind and sunlight as sources of evaporation energy. However, studies on salt-tolerant plants (Andriyano et al., 2013; Antwi-Agyei & Nyantakyi-Frimpong, 2021; Helmi & Sasaoka, 2018) reveal that not all coastal areas are suitable as salt production sites. Potential salt-producing areas in Indonesia include the northern coast of Java Island, coastal regions of Madura Island, parts of the eastern coast of Bali Island, and regions extending to West Nusa Tenggara (NTB) and East Nusa Tenggara (NTT). Some salt production by salt farmers in these regions uses traditional methods that depend on the season (hot weather), while some entrepreneurs or salt factories have adopted technology. Unfavorable climatic conditions, frequently changing weather, and government policies that do not favor the people often lead to low salt production for traditional farmers. The best time to cultivate salt is generally in the dry season, from June to August. The number of salt farmers working on the ponds varies; usually, one hectare of a pond can be cultivated by two to five farmers. Making salt takes approximately three to seven days. The process is faster if the weather is hot; otherwise, if the weather is changeable, it takes longer. The salt produced is 'krosok' salt and is usually sold by pond owners to middlemen.

Pond cultivators do not take part in the salt buying and selling process; they only receive wages from the pond owner (Asnawi, 2015). These individuals face structural problems at the farmer (producer) level, the market, and within government policies. At the production level, farmers deal with an unfair profit-sharing system because all decisions depend solely on the landowner. Additionally, the salt market structure is monopolistic and controlled by the owners of capital. Furthermore, inadequate protection for salt farmers prevents them from maintaining and developing their business (Ehiakpor et al., 2016; Sudaryana & Pramesti, 2018). Weather anomalies also pose significant obstacles to production. Under these conditions, salt farmers on the northern coast of Java undertake several side jobs to earn income and make ends meet. These economic constraints cause them to choose safe ways to fulfill their subsistence. Subsistence security is a principle that is more active in the choices and values of farmers than in maximizing average yields.

Farmers are reluctant to take risks and focus more on efforts to avoid falling production, rather than on maximizing the expected benefits (Ellis, 1998). Based on the background above, this study addresses: (a) the dynamics of the economic life of traditional salt farmers in several districts, especially in the northern coastal areas of Java ‘Pantai Utara Jawa (Pantura)’, and (b) the strategies for meeting the economic needs of these traditional salt farmers. The lack of

protection from the government is thought to have positioned salt farmers as subordinates to the rulers and owners of capital. Consequently, salt farmers have become very dependent on capital owners who are very influential on the welfare of salt farmers (Farahdina & Waridin, 2016). These owners of capital in the traditional salt industry exert a very significant influence on the welfare of salt farmers (Fuadi et al., 2016).

Some plans or strategies to combat the adverse effects of climate change can be implemented through various capabilities, such as using multiple cropping systems, planting crops that can withstand months of rain or flooding, and diversifying livelihoods (Hahn et al., 2009). Every household inevitably strives to survive in order to meet their needs. A livelihood strategy represents an alternative economic activity that households engage in to survive, which is basically implemented by utilizing diverse sources of income (Hidayati & Suryanto, 2015). In the context of salt farming, however, these strategies face significant challenges; according to Mafongoya (2015), the extended rainy season severely threatened the salt ponds in several regional administrative areas of the northern coast of Java.

In general, traditional salt farmers in Southeast Asia are vulnerable to weather changes. This research used a combination of the Livelihood Vulnerability Index – Intergovernmental Panel on Climate Change (LVI-IPCC) and purposive sampling methods to explore the case of traditional salt farmers on the northern coast of Java, Indonesia. Although this method has limitations because it tends to provide a portrait of vulnerability at one point in time (case study) and does not describe the dynamics of changes in vulnerability in the long term, the results of the field investigation are expected to strengthen the government's role in carrying out positive interventions. Additionally, government assistance, including equipment as well as additional knowledge and skills, is anticipated to increase farmers' resilience in facing extreme weather.

Climate variability in the context of traditional subsistence farming households is a vulnerability that causes changes in the composition of farm incomes; therefore, actions are needed to manage this vulnerability. The objectives of this study are: (1) to determine the vulnerability of salt farming households to climate change on the northern coast of Java, and (2) to identify adaptation strategies implemented to meet their economic needs.

RESEARCH METHOD

Research Sites

The study areas were chosen because they serve as salt storage hubs along the northern coast of Java Island. The seven selected locations were Indramayu, Cirebon, Brebes, Demak, Pati, Karawang, and Sumenep Regencies (Madura Island) (see **Figure 1**). The field survey for sampling was conducted in selected

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sub-districts representing these seven regencies. These sites were selected purposively because they are ecologically vulnerable, characterized by droughts and floods that occur irregularly each year.

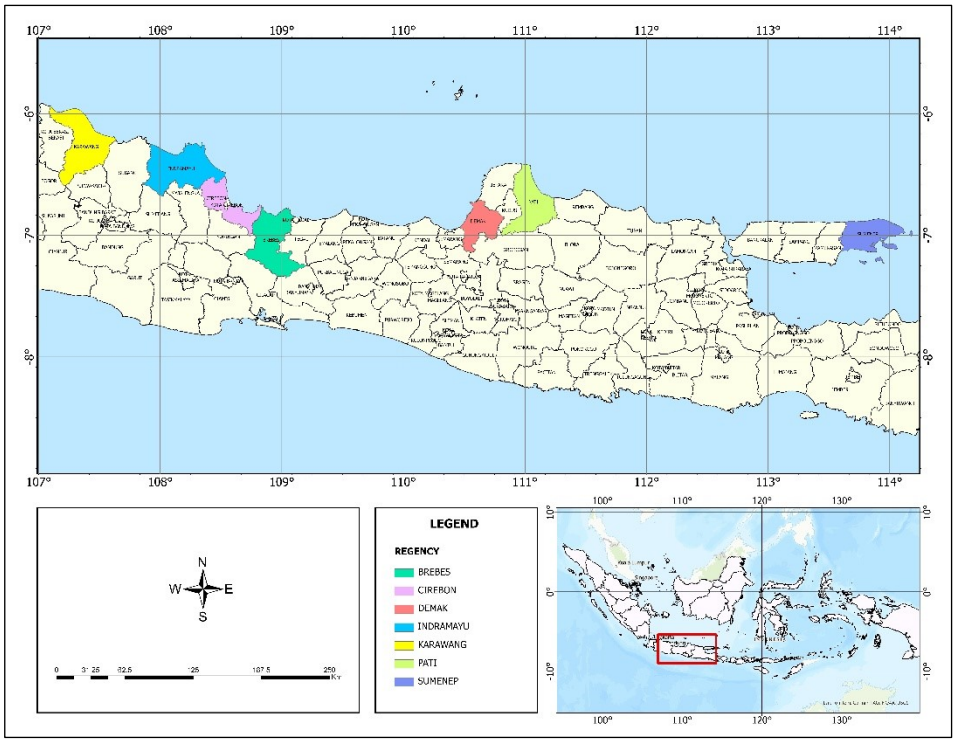


Figure 1. Study location of sampling area (Source: RBI, BIG).

Method

Vulnerability analysis in this study used the Livelihood Vulnerability Index – Intergovernmental Panel on Climate Change (LVI-IPCC) method developed by Jones & Thornton (2003) and descriptive analysis. The use of the LVI-IPCC method referred to the resilience of livelihood capacity to withstand pressure and disturbance factors while maintaining or enhancing essential functions. There were seven main components in this LVI research: socio-demographic profiles, livelihood strategies, social networks, health, access to food, access to water, and climate change.

In accordance with Hahn et al. (2009) and Zainab & Shah (2024), the LVI vulnerability value ranges from 0 (least vulnerable) to 1 (most vulnerable). Furthermore, the weight values of the LVI components were classified into three IPCC components: exposure (climate variability), adaptive capacity (socio-

demographic profile, social networks, and livelihood strategies), and sensitivity (access to food, water, and health). The final vulnerability score ranges from -1 (lowest vulnerability level) to +1 (highest vulnerability level) (Equation 1).

$$LVI - IPCCd = (ed - ad)*sd \quad \text{..... 1}$$

Where:

LVI-IPCCd	: Household vulnerability within the IPCC framework
Ed	: Total exposure score (average climate variability component values)
Ad	: Total adaptive capacity score (average value of social profile components of demography, social networks, and livelihood strategies)
Sd	: Total sensitivity score (average value of food, water, and health components)

The interpretation of the final score is that a value approaching 1 indicates a more vulnerable community, thereby requiring government intervention in the form of policy and community-based responses to mitigate the existing vulnerability. Conversely, a value closer to -1 represents a society that is less sensitive to climate change. This study employed a descriptive analysis to explain the climate change conditions on the northern coast of Java and Madura Island and how these shifts affected salt farmers in the formation of vulnerability variables.

Furthermore, a survey of respondents in the field identified the economic strategies used by the community to survive. Respondents were selected purposively, specifically traditional salt farming households (owners, cultivators, and farm laborers) who had experienced changing weather. The sample size was 180 participants, consisting of 30 respondents from each district, representing seven districts. Primary and secondary data were required in this research. The data collection method was implemented through field observation techniques, interviews, and literature studies. Key informants were deliberately selected from various relevant sources or institutions, including farmer group leaders, farmer representatives, agricultural field extension officers, village government, the Maritime Service, and the District Agriculture Service. To determine the economic impact caused by climate variability (rainfall), an analysis of the livelihood structure was carried out. The livelihood structure of the farm households measured included the structure of income, expenditure, and savings. Salt farmer household income (Ys) was calculated by adding up income for one year based on Equation 2.

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$$Ys = \sum Fs + \sum OFs + \sum NFs. \quad \text{.....2}$$

Where:
Ys: Salt farmer household income/year
∑ Fs: Income or income comes from own ponds
∑ Ofs: Income derived from work wages, sharing system, within the scope of farmers
∑ NFs: Income that is not derived from agriculture

Income referred to earnings from both agricultural and non-agricultural products, minus production costs. Household expenditure was calculated by adding up all food and non-food expenses, while savings were the result of income minus expenditures. After obtaining the income data from each respondent, a normal distribution curve was constructed to determine the classification level of the salt farming household strata. To identify the adaptation mechanism or pattern of farmer households in dealing with climate variability, a qualitative descriptive analysis was carried out. The adaptation mechanism analyzed was a strategy carried out either within the ponds and their surroundings or through the diversification of salt farming household livelihoods. The research data were presented in the form of narratives, graphs, and tables. The study was conducted in three stages, as shown in **Figure 2.**

The LVI-IPCC method and purposive sampling approach had limitations, as the index results depended on the availability and accuracy of primary and secondary data. To minimize these weaknesses, the following approaches were taken:

a. Combining the LVI-IPCC with qualitative methods, such as Focus Group Discussions (FGD) and in-depth interviews.
b. Utilizing time-series data to analyze vulnerability trends over time (historical).
c. Increasing the number of respondents to improve data representativeness and broaden the sample area distribution; in this study, 180 household respondents were surveyed (which was within the recommended range of 100–200 respondents).

The combination of the LVI-IPCC method and the purposive sampling approach provided rich, context-specific insights into individual cases; however, it had limitations regarding the generalizability of findings and may have introduced elements of subjectivity into the results.

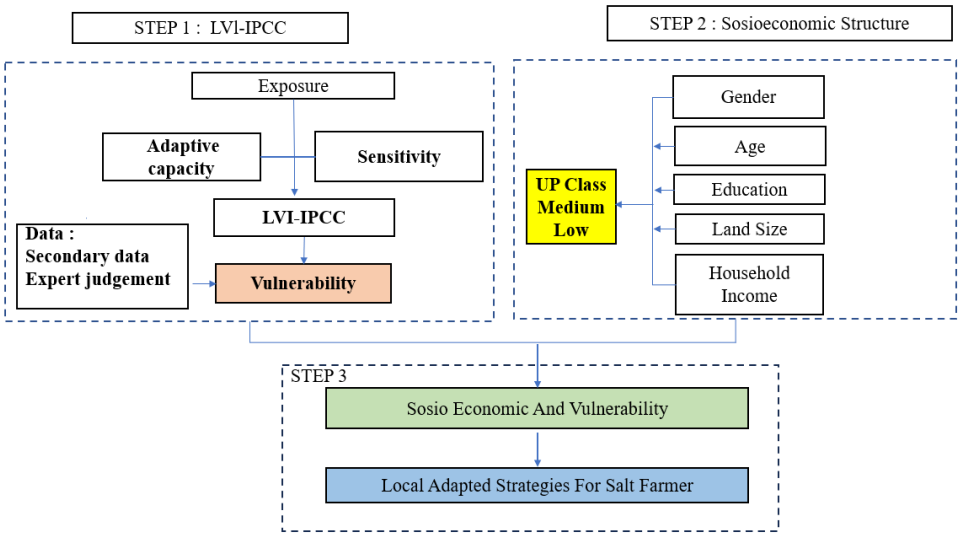


Figure 2. Research framework.

ANALYSIS AND DISCUSSION

Characteristics of Respondents

Field surveys for interviewing respondents were conducted in 2021. The total number of respondents in this study was 180 farmer households, with approximately 30 respondents representing each district. Respondents were, on average, between 40–60 years old, and the education level of most respondents was junior high school, with percentages of 56% and 44%. The average number of family dependents was 3–5 people. Respondents had varying land areas, ranging between 0.28 and 2.5 hectares. The status of land ownership was generally that of an owner (65%), while the rest were cultivators under a rental or profit-sharing system, or served as farm laborers.

Rainfall Variability

In 2022, increasing salt production became a priority as the industry began to recover following the COVID-19 pandemic. Programs receiving special attention included efforts to boost output through both integrated and traditional cultivation by incorporating membrane technology. In addition to technological advancements, production increases were achieved by monitoring water availability and accounting for weather factors (Karmilah, 2020). The average monthly rainfall in the study area is illustrated in **Figure 3**, where the highest average rainfall occurs in January, while the lowest is in September. Consequently, farmers generally conduct their activities from June to September.

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Sometimes the onset of the rainy season comes a month or two months later; **Figure 3** illustrates that the dry season is June–October. The low rainfall criteria occur when the amount of rainfall is 0–100 mm per month. Meanwhile, the period of November–May is included in the medium rain category with rainfall of 101–300 mm per month. Variations in annual rainfall that cause salt planting or harvest failure are mainly related to global climate variations caused by El Niño events (Kifli et al., 2015).

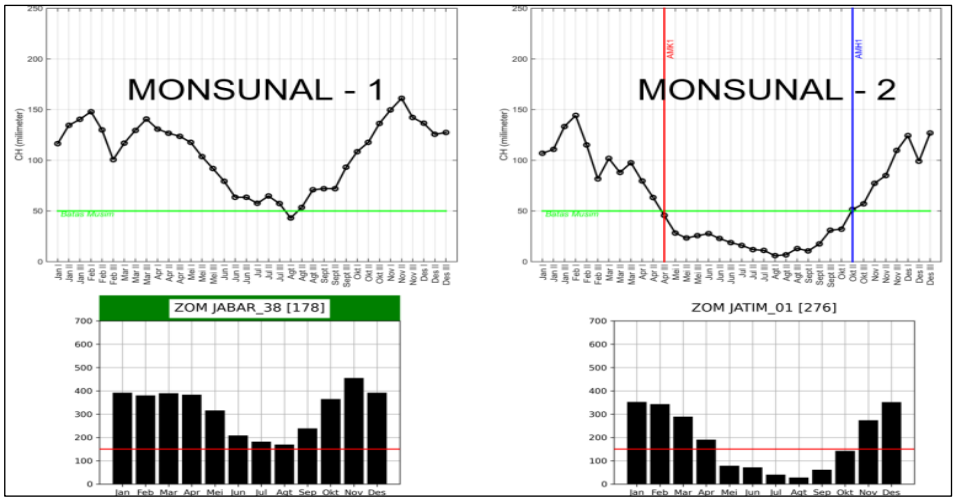


Figure 3. Annual rainfall variations influence the success or failure of salt cultivation (Source: BMKG, 2022).

Vulnerability of Livelihoods of Salt Farmers

Vulnerability was calculated using the LVI-IPCC method, which involved LVI calculations adjusted to the formulation of the Intergovernmental Panel on Climate Change (IPCC). The LVI, according to the IPCC (2014), indicates that vulnerability is influenced by exposure, sensitivity, and adaptive capacity. Salt farming households exhibited a high level of livelihood vulnerability, as demonstrated by the LVI-IPCC value of 0.152 for salt farming households throughout the northern coast of Java. The value of each parameter in the LVI-IPCC is presented in **Table 1**. Vulnerability indices are useful for monitoring vulnerabilities over time in each space. Identifying processes that contribute to vulnerability can be used to prioritize strategies to reduce it and evaluate strategies in social and ecological settings (Kim et al., 2017).

Table 1. LVI-IPCC values for the north coast salt farming households.

Parameter	Main indicators	Regency Index Value					
		Indramayu & Karawang	Cirebon	Brebes	Demak	Pati	Sumenep
Exposure	Natural Disasters & Climate Change	0.692	0.712	0.707	0.717	0.734	0.628
Adaptive Capacity	Socio Demographics	0.254	0.243	0.241	0.253	0.201	0.214
	Strategy & Social Network						
Sensitivity	Food	0.321	0.351	0.312	0.315	0.339	0.345
	Water						
	Land						
LVI-IPCC		0.140	0.164	0.145	0.146	0.180	0.142

Based on the analysis in **Table 1**, farming households on the northern coast of Java were exposed to unpredictable climate variability. The value of vulnerability was greater in the eastern region; specifically, the higher the LVI-IPCC index value, the higher the level of vulnerability. Even though the exposure was higher, it could be offset by superior adaptive capacity in dealing with drought. A farmer's household is considered resilient and strong when it possesses adaptation strategies and extensive knowledge or insight to manage possible disasters and negative impacts caused by climate change (Novan Ngutra et al., 2017). The livelihood strategy was the most influential factor in augmenting the adaptive capacity of farming households on the northern coast.

Fluctuations in Salt Production and Household Income

Disasters during the rainy season caused most salt farming lands to experience an excess of freshwater in their ponds, resulting in low salinity levels and crop failure. Other factors influencing salt scarcity in the market were the uncertain climate and flooding in production areas, which triggered a crisis in industries dependent on this salt (Nirwansyah, 2021; Purwanti et al., 2022). Interview results showed that salt fields experienced production fluctuations between 90–120 tons/ha/season for wealthy farmers, while traditional salt farmers generally produced 50–80 tons/ha/season. In general, the primary constraints faced were price, weather, and the market.

Salt processing technology in the field generally included traditional methods (subsoil) and membrane technology (plastic). Some farmers utilized

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isolators and sprinklers; while these were recognized for increasing production, they required significant investment. The primary challenges for salt production were rainfall and price instability. Consequently, farmers had to consistently receive weather information to ensure production certainty. The harvest season typically lasted between 3–4 months, starting in June. Furthermore, farmers required price standards to provide economic security for their production.

The largest cost component of the traditional salt business was labor, specifically processing costs (38.8%), harvesting costs (22.22%), and transport costs from the field to the roadside (11.11%). Processing labor costs were categorized as non-cash costs because the labor was provided by the salt farming households. Meanwhile, transportation and harvesting labor were classified as cash costs because they employed workers from outside the salt farming families.

The total income of salt farmers per hectare reached IDR 25,200,000–36,500,000 under favorable climatic conditions. With a total cost per hectare ranging from IDR 5,000,000 to 7,000,000, depending on the distance from the main road, the monthly average income was approximately IDR 1,650,000–2,458,000/ha. The results of the business analysis indicated a revenue-to-cost ratio (R/C) of 1.47, meaning that every rupiah spent by farmers in the salt business generated a revenue of 1.47 rupiah. Meanwhile, the profit-to-cost ratio of 0.47 indicated that for every additional rupiah spent, a profit of 0.47 rupiah was generated. This situation suggested that during that season, the traditional salt business was profitable.

According to public information, in 2014–2017, farmers enjoyed a good harvest season, while in 2017–2020, they were unable to harvest salt due to unfavorable weather and the COVID-19 pandemic, which disrupted production and price circulation. Traditional farming household respondents reported a yield of 50 tons/ha/season. Prices fluctuated significantly, ranging from IDR 350–750/kg on communal land, yielding an average income of IDR 25,000,000/ha/season. However, during the failed planting season in 2018, the average income decreased to IDR 12,500,000/ha. This decline in average income was due to exposure to climate variability, characterized by irregular droughts and rains that resulted in decreased salt production. Average monthly fluctuations in salt prices in 2017–2021 are shown in **Figure 4.**

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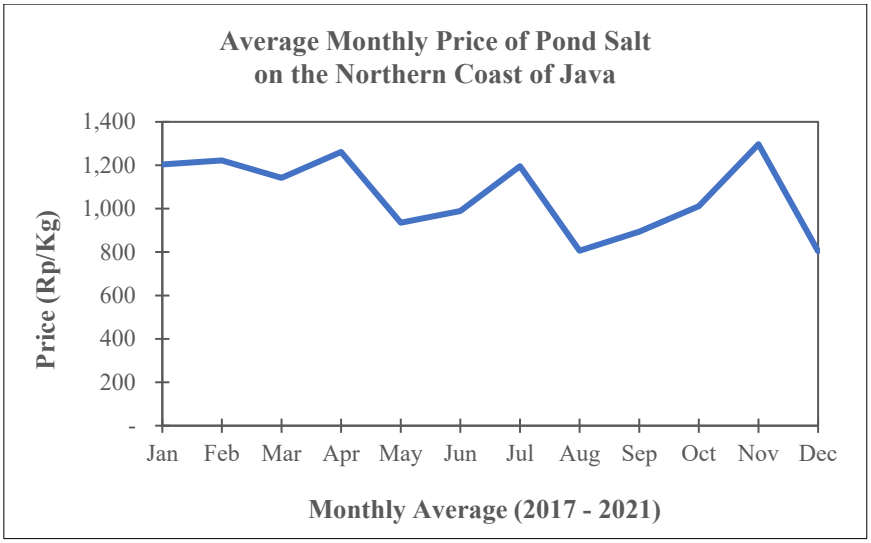


Figure 4. Average monthly price fluctuations of ready-to-transport salt during 2017-2021.

DISCUSSION

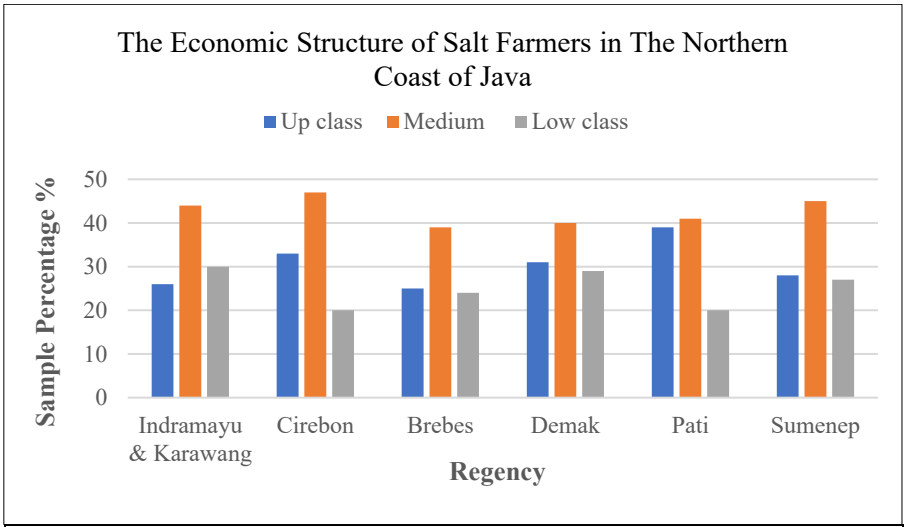
Farmer Household Livelihood Structure

A livelihood comprises assorted assets, activities, and access that together determine the living standards of individuals or households. Assets consist of various capitals owned by a household, including natural, physical, human, financial, and social capital (Nikmaturohmah, 2016; Shinbrot et al., 2019). The total income earned by a person reflects the resources required to generate that income. In accordance with Ellis (1998), there are three sources of income, collectively known as the income structure: farm, off-farm, and non-farm income. Farm income refers to income generated from farming on land one owns or operates through rent. Off-farm income refers to a farmer's income from wages or exchange of work in other agricultural fields, such as animal husbandry. Meanwhile, non-farm income refers to sources of income from outside the agricultural sector.

The results of the income structure analysis indicated that the income level of salt farming households on the northern coast was relatively good, with the bottom layer positioned just above the poverty line. The average total annual earnings of salt farming households on the northern coast ranged from IDR 17,720,000 to 40,900,750; this condition occurred under favorable or supportive climate conditions. Based on the calculation of the income structure, the stratification of farmer households was carried out. There were three categories of farmer households: upper, middle, and lower layers. Differences in the income

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structure per layer, influenced by landownership and tenancy, are presented in **Figure 5**.



The average income of salt farmers is Rp /year				
	Up class	Medium class	Low class	Average
Farm	42.000.000	28.000.000	7.200.000	25.733.333
Off-Farm	34.000.000	16.000.000	5.600.000	18.533.333
Non-Farm	27.000.000	13.000.000	4.800.000	14.933.333

Figure 5. The income structure of salt farmers on the northern coast of Java.

Based on **Figure 5**, it was evident that most salt farming households also derived income from non-farm sources, including agriculture, animal husbandry, and fisheries. This indicated that respondents who usually worked as salt farmers also engaged in non-agricultural sectors under certain conditions. Income from the livestock sector at all household levels was derived from raising chickens, ducks, and laying ducks.

Meanwhile, income from fisheries was only found in the upper and middle layers, specifically through the cultivation of shrimp or milkfish ponds and salt trading between regions. The off-farm income of upper-class households was obtained from milkfish and shrimp farming. In 2017, the extended dry season benefited salt farmers. In contrast, lower-layer farming households depended more on off-farm sources, such as working as sharecroppers, harvest workers, and farm laborers. Sources of non-agricultural income included salaries from employment as temporary workers, tractor rental businesses, rice mills, land rentals, building supply services, and kiosks.

Salt Farmer Household Poverty Rate

The impact of climate change diminishes the production of salt and food crops, potentially leading to poverty (Junaid et al., 2023; Rochwulaningsih, 2012). In subtropical and tropical regions, yields generally decrease by 10–20 percent due to global warming and drought (Scott, 1981; Tran et al., 2022). The results reported by Shah et al. (2013) showed a close relationship between poverty and climate change, affecting approximately 1.3 billion poor people worldwide. Measuring household poverty levels can be performed using a variety of instruments. In addition to BPS calculations, the World Bank's poverty line measurement can be used, which is based on an income of USD 2.00, or the equivalent of IDR 28,000 per day.

Based on the interviews, it was evident that the bottom layer of the northern coast household respondents remained above the poverty line, with an average per capita income of approximately IDR 48,000 per day. Only the upper and middle layers were significantly above the poverty line. Poverty is not just a matter of income but involves human capabilities that should be able to develop; due to limitations within both the individual and the surrounding environment, individuals may be unable to achieve their full potential.

Salt Farmer Household Adaptation Pattern

The pattern of adaptation was defined as a strategy implemented by farming households to address the negative effects of climate variability. These patterns were grouped into three categories: economic, social, and ecological adaptation. Research by Syafi'i (2006) states that adaptation strategies can be implemented by farmers in drought-prone areas to mitigate the adverse impacts of climate change. Adaptation is critical to reducing the likelihood of climate variability impacts on smallholder farmers (Hasibuan et al., 2023; Thornton et al., 2008). Furthermore, Bhuyan et al. (2024) and Yasin & Ma'shum (2006) argue that the vulnerability of small farmers will continue to intensify without adaptation. Essentially, adaptation responses aim to decrease vulnerability and increase resilience, enabling farmers to become more resistant to climate variability. The findings of Zakki & Sayyida (2016) showed that households used various off-farm adaptation strategies, including changing occupational patterns, crop diversification, support from family and friends, adjusting household consumption patterns, and livelihood diversification. Ecological adaptation strategies were carried out by salt farming households in the Pantura by utilizing available natural resources, such as land and water. These adaptations included adjusting plant varieties depending on the season and improving irrigation. Farmers with sufficient land and capital often transitioned into shrimp or milkfish pond farming to generate income. The dominant social adaptation implemented by farming households involved utilizing social relations, such as borrowing

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money from neighbors, relatives, or landowners, and utilizing government aid. The adaptive capacity of rural communities can be significantly strengthened if political, financial, and institutional support is targeted at households rather than at the individual or community level alone (Campos et al., 2014; Helmi & Sasaoka, 2018).

Respondents preferred to carry out social adaptation strategies based on mutual trust, while farmer groups primarily supported the procurement of subsidized fertilizers or seeds. Every farming household had a pattern of adaptation to cope with vulnerability resulting from climate variability, such as floods and droughts. To increase resilience, these households combined the three adaptation patterns. The specific pattern of adaptation carried out by a household depended on the livelihood capital available to them. Five types of livelihood assets can be utilized to maintain or enhance the level of capability to manage crises: human capital, social capital, natural capital, financial capital, physical capital, and government policy (Ellis, 1998; Nguyen & Bleys, 2023; Sudaryana & Pramesti, 2018).

Human capital was the second major challenge faced by farming households on the northern coast, after physical land capital, particularly for lower-level farmers. However, social networks (social capital) could compensate for low human capital in maintaining viability. The availability of capital influenced the capability of farming households to respond to the impact of climate variability. Mastery of natural capital by these households stemmed from land (rice fields or ponds), water, and other facilities for accessing natural resources, which supported their survival. The percentage of natural capital ownership varied, though the difference was minimal because most respondents were land-owning farmers. Specifically, the natural capital owned by farming households on the northern coast ranged from 1.15 to 2.5 ha of pond area. Salt farming workers were in the most vulnerable position; however, they accounted for only 18% of the sample and were accustomed to working part-time in motorcycle taxi services or as construction workers. Modification of traditional agricultural practices to diversify cultivation, efficient water management, and the improvement of other occupational skills were climate adaptation interventions specific to local conditions (Anzum et al., 2023; Dhanya et al., 2022; Kundu et al., 2024; Plaiphum & Tansuchat, 2023).

CONCLUSION

Climate variability had a detrimental impact on the household economy of salt farmers. The climate value was the most dominant variability component influencing the LVI, with an index value of 0.698. Based on the grouping of the seven LVI indicators into the IPCC vulnerability components (exposure, adaptive

capacity, and sensitivity), the ultimate value was 0.152. The various obstacles to salt production and price fluctuations led salt farmers to adapt by taking side jobs as fishermen, cultivating milkfish or shrimp, and engaging in rice farming, as well as providing construction and public transportation services in each district. Meanwhile, the salt farming households' annual income level on the northern coast ranged between IDR 17,720,000 and 40,900,750 under supportive climate conditions. Salt farming households implemented economic, social, and ecological adaptation patterns by utilizing available capital to mitigate the vulnerability arising from the negative effects of climate fluctuations. Ecological adaptation, which involves utilizing natural resources (land and water), is a key adaptation to salt farming. Economic adaptation includes utilizing savings, selling livestock, jewelry, or electronic goods, receiving transfers from families, and diversifying livelihoods. Finally, social adaptation involves utilizing social ties within society and accessing assistance from the government.

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ETHICAL STATEMENT

This study was conducted in accordance with the ethical standards for socio-economic field research. Informed consent was obtained from all respondents prior to data collection. Participants were informed of the study's purpose, and their participation was entirely voluntary. To ensure confidentiality and privacy, all personal identifiers were removed, and the data were anonymized before analysis.

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GEOSITES, BIOSITES, CULTURAL AND ARCHAEOLOGICAL SITES AND THEIR INTERRELATIONSHIPS FOR THE DEVELOPMENT OF KENYIR GEOPARK, TERENGGANU, MALAYSIA

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Abstract

Kenyir Geopark in Terengganu, Malaysia has been declared as a national geopark on 30 May 2023 due to its wealth of geological heritage complemented by its valuable and unique biological, cultural, as well as archaeological heritage. This national geopark contains the land and lake environments, where the Kenyir Lake is the largest man-made lake in Southeast Asia and is used as a hydroelectric reservoir. This study aims to identify and classify key geological, biological, cultural, and archaeological sites and their interconnections which play vital roles for the development of the geopark. So far, a total of 15 proposed geosites have been identified and categorized based on geodiversity types: mineral, igneous and sedimentary rocks, fossils, tectonics/structures, and morphology. There are also currently 11 proposed biosites have been identified and classified based on their unique flora, fauna, and combination of both existing in both natural and artificial ecosystems. At least 11 proposed cultural sites have been identified and categorized into tangible and intangible heritage. Meanwhile, one proposed archaeological site has also been identified within the geopark area. The synergy between all these key components of Kenyir Geopark is significant to support this geopark's development, including research and educational opportunities, sustainable tourism, conservation, community development, as well as ensuring its legacy for future generations.

Keywords: Geosite, Biosite, Cultural Site, Archaeological Site, Kenyir Geopark

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INTRODUCTION

Kenyir is the name of the largest man-made lake in Southeast Asia which was built from several rivers by constructing the dam on the Kenyir River, the upper stream of the Terengganu River (the main river in the state of Terengganu). The dam was constructed during the period 1978-1985 by inundating some villages then including the Kenyir Village to create the Sultan Mahmud Hydroelectric Power Station for the purpose of covering the electricity supply to Peninsular Malaysia. The lake covers an area of 370 km^2 within the district of Hulu Terengganu with the maximum water depth of 125 m and is underlain by granite (Hunt et al., 2013; Loganathan, 2014). Based on the Central Terengganu Development Authority (KETENGAH, 2024a), the Kenyir Lake area has been decorated by 340 islands and islets. It has been announced as a state park in 2018 which is situated next to the Taman Negara National Park (Terengganu State Park Management Council, 2018). However, it also becomes one of six areas with higher seismic activity in Peninsular Malaysia with mild earthquakes (M<3) occurred several times. After the establishment of the dam, the Kenyir Lake is the location of the first reservoir-induced earthquake in the region occurred in 1985, since there was no any report on earthquake activity prior to the dam construction (Nazaruddin and Duerrast, 2021).

The lake and its surrounding land environment are rich of important geological, biological, cultural and archaeological sites, so that this area has been declared as a national geopark in 2023. This geopark is located within the latitude 4.67° - 5.28°N and longitude 102.50° - 103.08°E and covers an area of 2.449 km^2 or around a half of the Hulu Terengganu district, in the state of Terengganu, Malaysia. The geopark area is bounded by the boundaries of several subdistricts including Hulu Terengganu, Tersat, Kuala Berang, Jenagor, and Hulu Telemung subdistricts (Kenyir Geopark Main Committee, 2023). Figure 1 shows the map of location and boundaries of Kenyir Geopark with all its geosites, biosites, cultural, and archaeological sites. The recognition and rebranding are expected to conserve and develop its geological, biological, cultural and archaeological heritage, and in the same time to raise the name of Kenyir Geopark in the national and international stages, to empower local and indigenous communities, and to stimulate the growth of tourism and other sectors.

The concept of geopark arose in the mid-1990s in response to the need to conserve and enhance the value of geologically significant areas in Earth history. Since the early 21st century, UNESCO initiated the geopark concept not only to conserve and enhance the geological heritage, but also natural and cultural heritage, offering sustainable economic and social development (Fornaro & Fernandes, 2018; Martini, 2009; UNESCO, 2015). GGN (2010) defined a geopark as a geographical area where geoheritage sites are managed with a holistic concept of protection, education and sustainable development. The

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connection between geological, biological, and cultural heritage must be highlighted as an integral part of each geopark. It is also necessary to include sites of ecological, archaeological, and historical values within each geopark. In many societies, natural, cultural and social history is inextricably linked and cannot be separated.

In order to propose this area to become a national geopark, the State Government of Terengganu with its mandate has established three types of committee and their management structures for Kenyir Geopark, namely the Main Committee, the Working Committee, and the Sub-Committee. The Kenyir Geopark Scientific Sub-Committee lead by Universiti Malaysia Terengganu (UMT) has been actively conducting research works to investigate all potential geosites, biosites, and cultural as well as archaeological sites within the geopark area. This study aims to identify and classify important geological, biological, cultural, and archaeological sites and their linkages for the sustainable development of the geopark area.

ESTABLISHMENT OF KENYIR GEOPARK

TRDI (2023) reported that the planning to propose Kenyir area to become a national geopark started in 2015. During 2017, several discussions and meetings have been organized to prepare all necessary documents needed to be raised to the National Geopark Committee. The State Government of Terengganu has approved the proposal to establish Kenyir Geopark based on their meeting on 4 October 2017. However, the progress became slow for several years due to several factors, mainly there was no agency or institution agree to lead the team and the Covid-19 pandemic during 2020-2021. In 2022, the efforts to propose Kenyir area to be a national geopark were reactivated after the state government through the Terengganu State Economic Planning Unit (UPEN Terengganu) approved that the Hulu Terengganu District Officer would lead the plan. During 2022, a lot of activities including meetings, workshops, and courses, have been conducted by stakeholders to promote the Kenyir Aspiring Geopark to public. In early 2023, the complete and final application dossier of Kenyir Aspiring Geopark has been submitted to the National Geopark Committee. The assessment session for this aspiring geopark has been organized on 7-11 March 2023. On 30 May 2023, the National Geopark Committee has certified the decision of the evaluation panel and declared this area as the ninth national geopark in Malaysia with the official name “Kenyir Geopark”.

METHODOLOGY

The study employed an exploratory, multidisciplinary research design that combined desk-based review, field surveys, expert consultation, and geospatial

analysis to identify and classify geosites, biosites, cultural sites, and archaeological sites within the Kenyir Geopark area. Secondary data from geological maps, biodiversity inventories, archaeological reports, and local historical records were first compiled to establish a preliminary list of potential heritage sites. These sites were subsequently verified through field observations and classified according to their diversity types, allowing the development of an integrated inventory to support geopark planning. In Kenyir Geopark, geodiversity types consist of minerals, igneous rocks, sedimentary rocks/stratigraphy, fossils, tectonics/structures, and morphology (landfroms/landscapes). Biodiversity types comprises fauna, flora, and the combination of fauna and flora in a site. Meanwhile, the cultural heritage types can be divided into tangible and intangible heritage.

Several limitations should be acknowledged. Site identification and classification were based primarily on qualitative expert judgment because a universally standardized framework for assessing and comparing geoheritage, biodiversity, cultural, and archaeological values in an integrated geopark context is still lacking, particularly in Malaysia and Southeast Asia. The study did not employ quantitative sampling or statistical analyses, as its main objective was to produce a comprehensive baseline inventory rather than test hypotheses. In addition, some areas were difficult to access due to dense forest cover, rugged terrain, reservoir conditions, and weather constraints, which may have limited the documentation of certain sites and indicate that additional surveys may reveal further heritage resources in the future.

Several international studies provide a strong theoretical and methodological foundation for the integrated classification and management of geoheritage, biodiversity, and cultural resources in geopark development. Zouros (2016) discussed the role of the Global Geoparks Network in establishing internationally recognized criteria for site identification, heritage interpretation, and territorial management. Integrated heritage management is supported by Gordon (2019), who demonstrates that geoconservation principles should be applied alongside biodiversity conservation and cultural landscape management in protected areas, including UNESCO Global Geoparks (UGGp). In the Malaysian context, Abdul Aziz et al. (2011) argued that geoparks require integrated planning and management to conserve geological, biological, and cultural heritage while promoting local development, using Langkawi UGGp as a pioneering example.

GEOSITES OF KENYIR GEOPARK

Geology of Kenyir Geopark is generally dominated by sedimentary rocks (clastic and carbonate), metamorphic/metasedimentary rocks, igneous rocks (intrusive and extrusive rocks), and alluvium as shown in Figure 2. To date, a total of 15

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geological sites have been proposed to be geosites of Kenyir Geopark and classified based on their geodiversity types. Each geosite has also been characterized directly during the field visits in 2023. All geosites are listed in Table 1 and their locations can be seen in Figure 1.

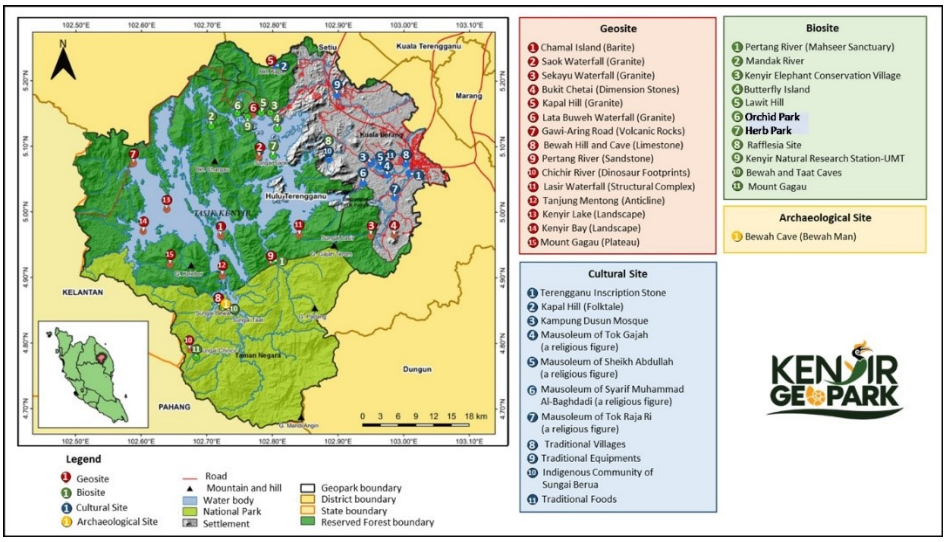


Figure 1: Location map of Kenyir Geopark with its proposed geosites, biosites, cultural, and archaeological sites, along with its official logo (Nazaruddin & Ab Manaf, 2024)

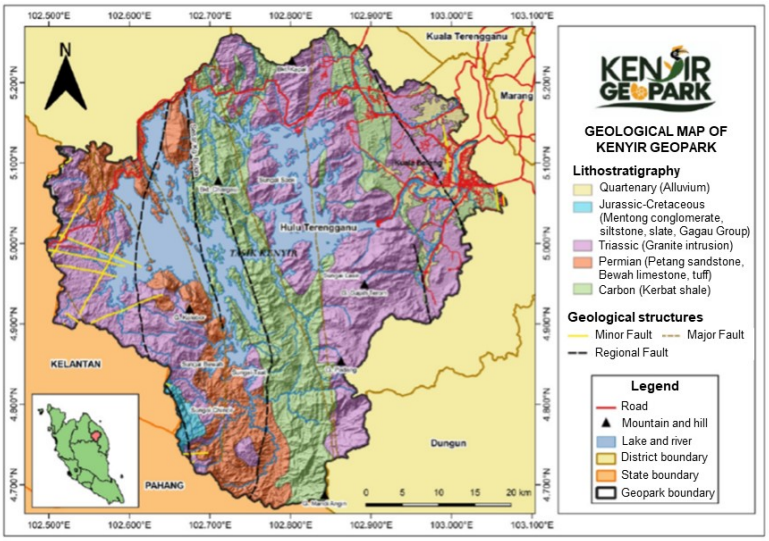


Figure 2: Geological map of Kenyir Geopark

Table 1: Geosites of Kenyir Geopark

No.	Code	Geodiversity Type	Geosite Name and Main Feature	Location (Subdistrict)
1	GS-1	Minerals	**Camal Island (Barite)**	Hulu Terengganu
2	GS-2	Igneous Rocks	**Saok Waterfall (Granite)**	Hulu Terengganu
3	GS-3		**Sekayu Waterfall (Granite)**	Tersat
4	GS-4		**Chetai Hill (Dimension Stone)**	Tersat
5	GS-5		**Kapal Hill Rock (Granite)**	Hulu Terengganu
6	GS-6		**Lata Buweh Waterfall (Granite)**	Hulu Terengganu
7	GS-7		**Gawi-Aring Road (Volcanic Rocks)**	Hulu Terengganu
8	GS-8	Sedimentary Rocks/ Stratigraphy	**Bewah Hill & Cave (Limestone)**	Hulu Terengganu
9	GS-9		**Petang River (Sandstone)**	Hulu Terengganu
10	GS-10	Fossils	**Chichir River (Dinosaur Footprints)**	Hulu Terengganu
11	GS-11	Tectonics/ Structures	**Lasir Waterfall (Structural Complex)**	Hulu Terengganu
12	GS-12		**Tanjung Mentong (Anticline)**	Hulu Terengganu
13	GS-13	Morphology (Landforms/ Landscapes)	**Kenyir Lake (Landscape)**	Hulu Terengganu
14	GS-14		**Kenyir Bay (Landscape)**	Hulu Terengganu
15	GS-15		**Mount Gagau (Plateau)**	Hulu Terengganu

Geosite of minerals

Camal Island (GS-1; Figure 3A) was proposed as a geosite due to its former barite ($BaSO_4$) mining site in Kenyir area. The mining operation was conducted by the company of TP Barite Sdn. Bhd. since 1981 and stopped in 1983 due to the impounding of the Kenyir Dam. The barite is hosted within a thick sequence of the Carboniferous-Permian black or dark gray siliceous shale, mudstone, with minor chert and siltstone (known as Kerbat Shale; Sum, 2001; Figure 3B). The ex-mining site is located atop this hilly and forested island with the maximum elevation of around 350 m above sea level. According to JMG (2009), the barite is associated with the granite intrusion into overlying sedimentary formation. Barite is formed as a result of several processes in different environments leading to their types of deposit, including marine sedimentary (bedded/stratiform) deposits, hydrothermal veins, and residual deposits with variety of colour from white and light to dark grey. This mineral is widely used in oil exploration as a mixture in drilling muds. Figure 3C shows an example of barite veins in Camal Island.

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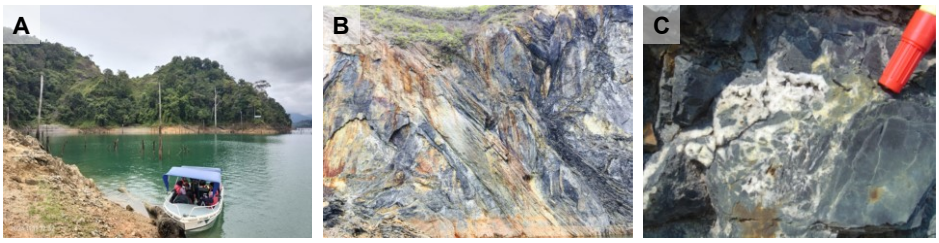


Figure 3: (A) Camal Island (GS-1); (B) Dark grey Kerbat Shale exposed in the island; (C) Barite veins in the shale

Geosites of igneous rocks

Igneous rocks in Kenyir area consist of intrusive and extrusive rocks. Intrusive rocks are exposed well in waterfalls and hills that are represented in several proposed geosites: Saok Waterfall (GS-2), Sekayu Waterfall (GS-3), Lata Buweh Waterfall (GS-4), Kapal Hill (GS-5), and Chetai Hill (GS-6). All these geosites consist of Triassic Kapal Granite as the dominant rock and a series of large-scale dolerite dike. The Kapal Granite is one of the largest granitic bodies (around 161 km long and between 19-38 km wide) in the Eastern Belt extending from the Setiu River area in the north (Terengganu) to Gunung Irong (Pahang) in the south. It takes its name after the Kapal Hill in the north but this hill is not the highest in the granite unit (Rajah et al., 1977). The composition of Kapal Granite ranging from diorite to monzogranite and dominated by granodiorite. This batholith body consists of several smaller granitic plutons such as Saok Granite, Chengal Granite, and Kesing Granite (Ghani, 2004). These granites are linked to the uplifting phenomena of the Eastern Belt Granite in the Mesozoic era as a result of subduction of the Tethys oceanic crust. The result of this tectonic activity has created various geological structures namely joints and faults, as well as other features such as schlieren, apophysis and xenoliths.

All above-mentioned waterfalls were created by a series of normal faults that cut across streams forming tiered waterfalls. These features combined with their main rivers and waterfall pools formed beautiful panorama and added value to these geosites. The **Saok Waterfall** (Figure 4A) is located within the Kenyir Lake and can be accessed by boat from Pengkalan Gawi Jetty. The underlying rock of this geosite is the Saok Granite which is part of the Kapal Granit. **Sekayu Waterfall** (Figure 4B) and **Lata Buweh Waterfall** (Figure 4C) are located outside the Kenyir Lake and can be accessed by the land transportation. The main rock components in the Sekayu Waterfall are granite (known as light gray monzogranite) and dolerite dikes. Meanwhile, the Lata Buweh Waterfall consists of granite, tamolite, and dolerite.

The **Kapal Hill** (Figure 4D) and **Chetai Hill** (Figure 4E) are located outside Kenyir Lake. The Kapal Hill is located within a reserve forest in

Kampung Gerdong, Hulu Telemong subdistrict, in the district of Hulu Terengganu, about 40 km from Kuala Berang town. The hill is around 800meter above sea level high and takes around 45 minutes hiking to the rock outcrop. It consists of a unique granite rock boulder with 21meter long and 4.5meter high that resemble a broken or split ship. In a geological context, the formation of such rock boulders requires millions of years through various processes, not only the intrusion of granite, but also chemical, physical, and biogenic weathering. The Chetai Hill is composed of light gray to gray (occasionally dark gray) granodiorite and green to dark green dolerite existing as small boulders less than 1 meter with a fine grain size. The Chetai Hill has once mined to produce dimension stones during 2008 to 2014 to supply within the country with the commercial names are Sekayu White and Terengganu Green (Anchor Resources Limited, 2017) referring to granite and dolerite, respectively.

The extrusive (volcanic) rocks are found in the **Gawi-Aring Road** (GS-7), and can be observed in the roadside (Figure 4F). The volcanic rocks are dated back to the early Permian and represented by trachyte, hornblende rhyolite, tuff, agglomerate, and andesite. Roselee et al. (2018) revealed that the volcanic rocks in this area consist of both pyroclastic and lava flow type of basaltic and andesitic composition with subordinate of slightly metamorphosed limestone and argillaceous rocks. These volcanic rocks mostly show dark colour and formed as aphanitic to less common porphyritic texture. There are also structures such as faults, fractures, and xenoliths. The occurrences of the volcanic rocks have the potential to be studied to unravel the volcanic history of Terengganu.

Geosites of sedimentary rocks/stratigraphy

There are two localities with significant sedimentary rocks or stratigraphic features selected as geosites due to their sedimentary or stratigraphic features in Kenyir Geopark: Bewah Hill & Cave (GS-8) and Petang River (GS-9). The **Bewah Hill & Cave** (Figure 5A, B, and C) and together with the neighbouring Taat Hill (Figure 5D) with its cave (Figure 5E and F) is characterized by two mogote hills with steep vertical cliffs composed of limestone formation that was formed in marine environment during the Permian. This geosite (both hills and caves) is located within the southern part of Kenyir Lake and is particularly unique as it is the only limestone hill area found in the state of Terengganu. Prior to the creation of the lake, there were several caves and some of archaeological remains. However, after flooding, most of them were lost underwater leaving only the Bewah and Taat Caves accessible to the public. Sometimes Taat Cave also can't be accessed due to the seasonal high level of the lake water. Sum (2001) elaborated that the round-shaped Bewah Hill rises from the floor at an elevation of 150 m to the peak at an elevation of 600 m, while the northeast-trending ridge Taat Hill rises at an elevation of 280 m and peaking at an elevation of 615 m.

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According to Mohd Sharoum et al. (2015), there is another cave namely Tok Bidan Cave situated beneath the Bewah Cave, however, the Tok Bidan Cave is submerged under water at present after the completion of the Kenyir dam. The Bewah limestone consists of dolomite and calcite with several limestone facies and estimated to be Middle Permian (270-260 mya) in age and is believed to be the ancient mainland seabed. However, the tectonic uplift made the seabed to rise and formed the limestone hill (Mohd Sharoum et al., 2015). This geosite has an international significant due to the discovery of the rare giant clam species *Shikamaia sp.* (Figure 5G) in the Bewah Hill, which was found only in a few places in the world, and the discovery of artifacts and a prehistoric creature in the Bewah Cave called the "Bewah Man" dating back 16,000 years, the oldest of this kind in Malaysia. The finding of marine fossils such as corals (Figure 5H) as well as cephalopods, gastropods, bivalves, and foraminifera add the value to this geosite. The limestone hill also exhibits a karst landscape with various morphological features e.g. mounds and pinnacles as well as caves with various cave structures (stalagmites, stalactites, columns, rimmed pools, curtains, and flowstones). There is a mini gallery near the Bewah Cave entrance displaying geological, biological, cultural, and archaeological aspects of Bewah area.

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Figure 4: Geosites of igneous rocks: **(**A) Saok Waterfall (GS-2); (B) Sekayu Waterfall (GS-3); (C) Lata Buweh Waterfall (GS-4); (D) Kapal Hill (GS-5); (E) Chetai Hill (GS-6); and (F) Gawi-Aring Road (GS-7)

The **Petang River** ((Figure 5I) is a geosite with Carboniferous-Permian sandstone that was uplifted during the intrusion of Triassic granitic rocks. The arenaceous rocks are known as the Petang River Sandstone and are composed of dark grey to greyish brown or light brown sandstones which contain fine to coarse-grained, fairly well sorted quartz grains representing shallow water (near-shore) environment (Sum, 2001). The very massive and thick sandstone (Figure 5J) deposited here is intensely jointed, reaching a thickness of up to five meters and forms a distinct segment of the Petang Sandstone formation. The sandstone

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is interbedding with minor shale, slate, and hornfels. Additionally, the river contains beautiful river landscape, including river channels, sandbars, mid-channel bars, and being a strategic location for Mahseer fish sanctuary.

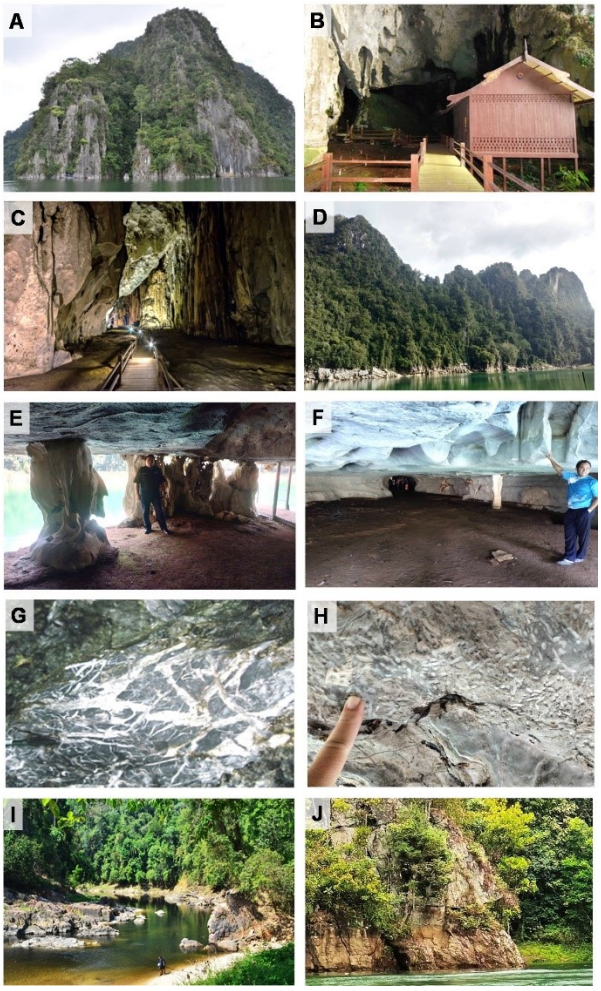


Figure 5: Geosites of sedimentary rocks/stratigraphy in Kenyir Geopark consist of Bewah Hill & Cave (with the Taat Hill & Cave; GS-8) and Pertang River (GS-9) with interesting features: (A) Bewah Hill, (B) Main entrance of Bewah Cave, (C) Main chamber of Bewah Cave, (D) Taat Hill, (E) Main entrance of Taat Cave, (F) Main chamber of Taat Cave, (G) Fossils of giant bivalves of *Shikamaia sp.* from the Bewah Hill, (H) Coral fossils inside Taat Cave, (I) Pertang River, (J) Typical sandstone outcrop in Pertang River (Pertang Formation)

Geosite of fossils

Chichir River (GS-10) is located within Mount Gagau area which is part of the *Taman Negara* National Park. Rishworth (1974) formalized several rocks units in Mount Gagau area as the Gagau Group which consists of a thick succession of Jurassic-Cretaceous continental (terrigenous) sedimentary deposits: the older Badong Conglomerate and the overlying younger Lotong Sandstone as well as the associated volcanic rocks. The Chichir River geosite is very significant due to the discovery of a dinosaur tooth fossil of Iguanodon species within a conglomerate block (Figure 6A and B) and three species of dinosaur footprints of Iguanodon (Figure 6C and D), Sauropod (Figure 6E), and Tetrapod (Figure 6F) on the surface of three different sandstone blocks. The discovery of these dinosaur fossils indicates the existence of dinosaurs in the state of Terengganu. In addition, this river is also the place where trace fossils of burrows known as Scoyenia were found. All these fossils found during the Jurassic-Cretaceous Expedition in 2014 organized by a group of local geologists.

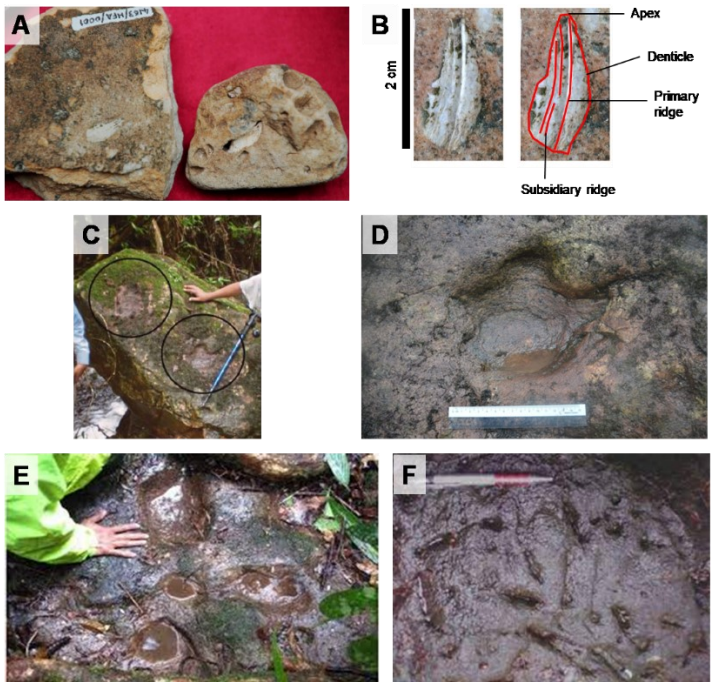


Figure 6: Dinosaur fossils found in Chichir River geosite (GS-10): **(**A) Fossils of Iguanodon teeth found in two conglomerate blocks; (B) A close-up view of one of the Iguanodon teeth; (C) A pair of Iguanodon footprints; (D) A close-up view of one of the Iguanodon footprints; (E) Sauropod footprints; and (F) Tetrapod footprints

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Geosite of tectonics/structures

Two localities were proposed as geosites of tectonic deformation or geological structures, namely Lasir Waterfall (GE-11) and Tanjung Mentong (GE-12). The **Lasir Waterfall** geosite is another tiered waterfall within the Kenyir Lake which is similar to other waterfalls which are composed of Triassic Kapal Granite (Figure 7A). However, it also contains quartzite and hornfels due to Triassic granite intrusion into the Carboniferous-Permian sedimentary rocks. As the effect of granite intrusion, this geosite also showcases a structural complex with various geological features such as faults, joints, veins, rock boundaries, dikes, apophyses, and xenoliths. This highest waterfall in Kenyir area formed from a set of faults resulting in a step fault and creating a beautiful landscape (Figure 7B). Lasir Waterfall is the most famous waterfall in Lake Kenyir which is located 16 km from Pengkalan Gawi Jetty and takes 30 minutes by speedboat. The waterfall has a height of up to 500 feet (https://tourism.ketengah.gov.my/tasik-kenyir/air-terjun-lasir/show),

Meanwhile, the **Tanjung Mentong** (Figure 7C) is a geosite with important tectonic or structural feature, that is the folding of Petang Formation forming an anticline ridge (Figure 7D) in the N340E direction. This ridge also separates the Kapal Batholith in the eastern part from the western pluton. This anticline is believed to have formed due to tectonic activity during the Permian-Triassic period. This site is formed by the Early Permian Petang Sandstone Formation (Figure 7E) with the main lithology of massive sandstone and minor shale, siltstone, and hornfels (due to nearby granite intrusion). The presence of dolerite dikes, lamprophyre, and aplite is common in this area. Tanjung Mentong is the gateway to the National Park, where Plan Malaysia (2019) included Tanjung Mentong and the National Park as an ecotourism attraction in Terengganu. Tanjung Mentong is selected as one of the conservation areas with no development, farming or logging allowed except for low impact nature tourism activities, research and education. Department of Wildlife and National Parks (DWNP/PERHILITAN) Peninsular Malaysia (2024) stated that Tanjung Mentong can be reached from Pengkalan Gawi through the Kenyir Lake which will takes about 45 minutes by speed boat.

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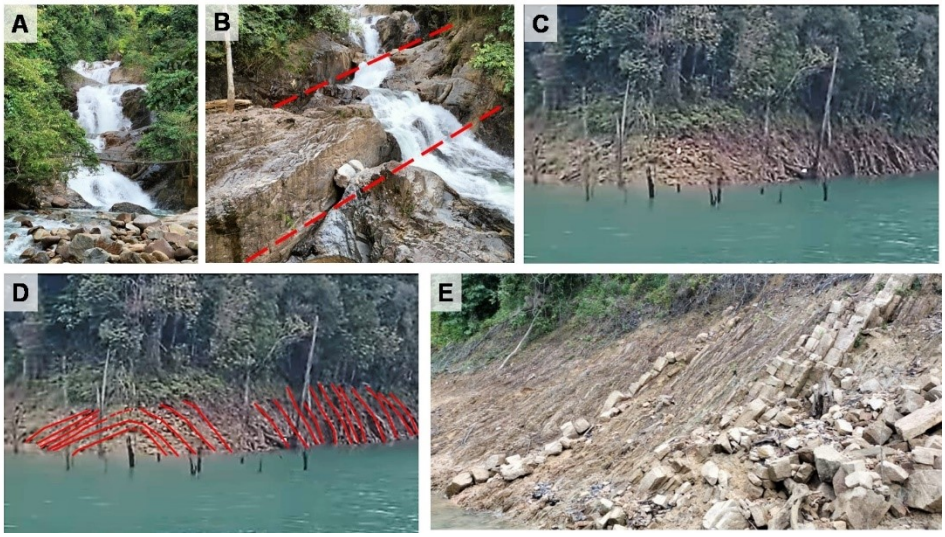


Figure 7: Geosite of tectonics/structures: (A) Lasir Waterfall (structural complex) geosite (GS-11); (B) A series of NS-trend normal faults forming the Lasir Waterfall; (C) Tanjung Mentong (GS-12); (D) An anticline feature in Tanjung Mentong; and (E) Outcrop of interbedded sandstone, siltstone, shale at Tanjung Mentong

Geosites of morphology (landforms/landscapes)

There are at least three prominent landscapes in Kenyir area which are suitable to be geosites, namely Kenyir Lake (GS-13), Kenyir Bay (GS-14), and Mount Gagau (GS-15). The **Kenyir Lake** formed by the damming of the Kenyir River and some other rivers in the upstream of Terengganu. The lake is very large and showcases a chain of partially submerged hills, creating around 340 islands scattered within the lake. It is surrounded by lush tropical rainforest and is renowned for its stunning and beautiful landscape (Figure 8A). The lake, as one of the areas under the Central Terengganu Development Authority, is so special as a tourism destination due to its clear water and the green environment from the tropical rain forest in the surrounding hills. The lake is also a favorite destination for fishing, boating, kayaking, jet skiing, rafting and so on.

Meanwhile, the **Kenyir Bay** landscape (Figure 8B) displays a panoramic and beautiful bay landscape adorned with the remnants of submerged tree trunks. This aesthetic landscape is exclusive to the Kenyir Lake. The landscape of Kenyir Bay that was selected as one of geosites is located on the west side of the Kenyir Lake (Abdullah and Omar, 2017).

Additionally, **Mount Gagau** or Gagau Mountain Ridge showcases the largest plateau landscape in Peninsular Malaysia (Figure 8C), where the plateau is located along the border Terengganu-Kelantan. Th mountain was formed by

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Late Mesozoic continental sedimentary rocks overlying Late Paleozoic sedimentary rocks to the west and east, with Triassic granite intrusions in between. The rock formations here consist of conglomerates, sandstones, mudstones, and siltstones with very gently inclined layers. Mount Gagau, which is located nearby the Kenyir Lake, is part of Taman Negara National Park which is shared in three states: Kelantan, Terengganu, and Pahang (https://tourism.ketengah.gov.my/tasik-kenyir/gunung-gagau-tasik-kenyir/show). Other than a plateau, Mount Gagau area has also cuesta landscapes with different dip slopes (Nazaruddin, 2016).



Figure 8: Geosite of morphology (landforms/landscapes): (A) Kenyir Lake (GS-13); (B) Kenyir Bay (GS-14); and (C) Mount Gagau plateau (GS-15)

BIOSITES OF KENYIR GEOPARK

Kenyir area has a lot of iconic and endemic species of fauna, some are nearly endangered, some are endangered, and some others are critically endangered, including Asian elephant (*Elephas maximus*), Malayan tiger (*Panthera tigris jacksoni*), Asian tapir (*Tapirus indicus*), pangolin (*Manis javanica*), snail (*Kenyirus sodhii* and *Pearsonia tembatensis*), insect bat (*Kerivoula minuta, K. papilosa, Miniopterus schreibersi, Murina aenea, Myotis ridleyi* and *Hipposideros ridleyi*), fruit bat (*Dyacopterus spadiceus*), cricket-frog (*Fejervarya nicobariensis*), frog (*Limnonectes blythii, L. malesianus, Nyctixalus pictus,* and *Rhacophorus reinwardtii*), tortoise (*Heosemys spinosa* and *Manouria emys*), cave-dwelling rat snake (*Orthriophis taeniurus ridleyi*), bird (*Emberiza*

aureola and *Meiglyptes tristis*), hornbill (*Anthracoceros malayanus, Buceros bicornis, B. rhinoceros, B. vigil*), clown knifefish (*Chitala chitala*), and cyprinid fishes (*Poropuntius deauratus, Neolissochilus hexagonolepis*). Kenyir area has also many iconic and endemic species of flora such as Fairy Lanterns (*Thismia domei, Thismia terengganuensis*), Altenanthera (Famili Amaranthaceae), Begonia *(Begonia reginula),* Melunak tree (*Pentace excelsa*), Cat's claws (*Caesalpinia sumatrana*), Rafflesia (*Rafflesia cantleyi*), Rhizanthes (*Rhizanthes infanticida*), cycas or bogak tree (*Cycas macrocarpa*), Johore Banana (*Musa gracilis*), and palms (*Johannesteijsmannia altifrons*).

Eleven sites have been identified and proposed as biosites within the Kenyir Geopark area based on their types of biodiversity: fauna, flora, and both fauna and flora (Table 2). During the field visits in 2023, all biosites have also been characterized. The locations for all biosites can be seen in Figure 1.

Table 2: Biosites of Kenyir Geopark

No.	Code	Biodiversity Type	Biosite Name and Main Feature	Location (Subdistrict)
1	BS-1	Fauna	**Pertang River (Mahseer Sanctuary)**	Hulu Terengganu
2	BS-2		**Mandak River (Fish)**	Hulu Terengganu
3	BS-3		**Kenyir Elephant Conservation Village (Asian elephant)**	Hulu Terengganu
4	BS-4		**Butterfly Island**	Hulu Terengganu
5	BS-5		**Lawit Hill (Hornbills)**	Hulu Terengganu
6	BS-6	Flora	**Orchid Park**	Hulu Terengganu
7	BS-7		**Herb Park**	Hulu Terengganu
8	BS-8		**Rafflesia Site**	Hulu Terengganu
9	BS-9	Fauna and Flora Combination	**Kenyir Natural Research Station UMT**	Hulu Terengganu
10	BS-10		**Bewah and Taat Caves**	Hulu Terengganu
11	BS-11		**Mount Gagau**	Hulu Terengganu

Biosites of fauna diversity

There are five proposed biosites selected due to their fauna diversity: Pertang River (BS-1), Mandak River (BS-2), Kenyir Elephant Conservation Village (BS-3), Butterfly Island (BS-4), and Lawit Hill (BS-5). **Pertang River** is a sanctuary for Mahseer fish (*Tor tambroides*) or Kelah fish (local lingo) (Figure 9A) which has an estimated population of more than 5000 adults. The river has 91 streams flowing into it. This sanctuary is about 45 minutes from Pengkalan Gawi Jetty. It is an exciting place due to the chance for visitors to swim, catch the fish by hand,

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and have their feet nibbled by the fish. Fishing is prohibited in this place. This fish species does not have a stomach but has a long intestine. This species eats by sucking as an adaptation to the structure of its mouth (Sopha, 1999). In terms of nutrition, this species is omnivorous. Despite not having a stomach, adult Mahseers eat small fish (2-5 cm long), shrimp, as well as brown and green algae, in addition to ripe fruit and seeds of some types of trees near the river bank such as neram tree *(Dipterocarpus oblongifolius)*. Neram fruits are often used as bait to catch this lucrative species. Juvenile species eat various types of zooplankton, algae and aquatic insect larvae. Meanwhile, **Mandak River** (Figure 9B) is one of the rivers in Kenyir that is a paradise for anglers and inhabited by various fish populations such as giant snakehead or 'toman' (*Channa micropeltes*), hampala barb or 'sebarau' (*Hampala macrolepidota*), clown knifefish or 'belida' (*Chitala chitala*), giant gourami or 'kaloi' (*Osphronemus goramy*), and river carp or 'kelah' (*Tor tambra*). There are also other fish species found in the river, such as *Notopterus notopterus*, *Acanthopsoides molobrion*, *Cyclocheilichthys apogon*, *Labiobarbus leptocheilus*, *Mystacoleucus obtusirostris*, *Osteochilus vittatus*, and so on (Aqmal-Naser et al., 2023). Developed as a breeding area for mussel (*Anodonta woodiana*) which was later developed for the production of freshwater pearls. There are dead trees underwater as breeding grounds for fish, while tree branches as the main nutrition for fish here.

Kenyir Elephant Conservation Village (KECV) is a conservation village for local Asian elephants *(Elephas maximus)* (Figure 9C) as one of endangered mammals in Kenyir area (Afiq Ramlee et al., 2020). This biosite is located in a part of Telemong River, a tributary of Terengganu River, near Pengkalan Gawi Jetty. It opened in 2012 by the Elephant Management Unit under the authority of the DWNP/PERHILITAN, KETENGAH, and the Terengganu State Government. Only 10% from 256 hectares of this area is developed, while the remaining 90% is maintained to protect and display the natural conditions of the tropical forest suitable as an elephant habitat. The main concept of this place is to educate people about the habitat and behavior of elephants in addition to bringing visitors closer to nature. For that purpose, a canopy path is provided for visitors to see the elephant habitat from various angles while enjoying the amazing scenery natural forest. Various activities are also provided for visitors to interact with elephants such as shows, riding, bathing, feeding and playing with these animals (https://tourism.ketengah.gov.my/tasik-kenyir/perkampungan-konservasi-gajah-tasik-kenyir/show).

There is a butterfly park in Kenyir area which is located in Lubuk Geras Island or also known as the **Butterfly Island** (Figure 9D). The island showcases live and preserved butterfly specimens of a wide variety of species. There are more than 100 specimens of butterfly on display including species of Rajah Brooke *(Trogonoptera brookiana)* and Golden Birdwing *(Troides aeacus)*. The

park also has an informative and interactive insect museum that attracts visitors to learn more about butterflies and other insects. For the whole Kenyir area, Afiq Ramlee et al. (2020) discovered around 217 butterfly species from 6 families.

Lawit Hill (695 meters above sea level) is located in the north of the Kenyir Lake, a few kilometers northwest of Pengkalan Gawi Jetty (the main entrance to the Kenyir Lake). The hill elongates until the point near the boundary between Besut, Setiu, and Hulu Terengganu districts. This location is a focal point for hornbills (Figure 9E) and various other endangered species. The southern part of this hill is the location for bird watching activity where bird watchers and enthusiasts can see a wide variety of bird species here, mainly hornbills. There is a spot here called the Hornbill Valley where visitors can hear hornbills call. This area is the location of the most complete hornbill species in Malaysia, where nine out of 10 hornbill species can be found here (Afiq Ramlee et al., 2020): bushy-crested hornbill (*Anorrhinus galeritus*), oriental pied hornbill (*Anthracoceros albirostris*), black hornbill (*Anthracoceros malayanus*), great hornbill (*Buceros bicornis*), rhinoceros hornbill (*Buceros rhinoceros*), helmeted hornbill (*Rhinoplax vigil*), wrinkled hornbill (*Aceros corrugatus*), wreathed hornbill (*Aceros undulatus*), and white-crowned hornbill (*Aceros comatus*). The spot is easily accessible from Pengkalan Gawi Jetty via a pleasant drive along a small paved road that crosses the edge of the Kenyir reservoir. The road is now used by visitors for nature walks and to access houseboats, while researchers use it to access the UMT research station. The slope and its surroundings are covered by the lowland dipterocarp and hill dipterocarp forests which are locations of two forest reserves – Tembat Permanent Forest Reserve and Hulu Telemong Permanent Forest Reserve. The existence of the great hornbill in this area then becomes a part of the Kenyir Geopark logo.

Biosites of flora diversity

Three sites with significant flora diversity have been identified as biosites including Orchid Park (BS-6), Herb Park (BS-7), and Rafflesia Site (BS-8). The **Orchid Park** (Figure 10A) includes three islands within the Kenyir Lake: Hulu Selimbar, Hilir Selimbar, and Belit Islands which are interconnected by hanging bridges. It is located about 20 minutes from Pengkalan Gawi Jetty. In the Orchid Park, there are various orchids of local, international, and hybrid species for more than 700 species. Among the orchid species are *Brassia maculata*, Vanda Miss Joaquim (*Papilionanthe* Miss Joaquim), Moth orchids *(Phalaenopsis)*, Catasandra Fanfare (hybrid orchid), *Oncidium papillao* and Terengganu's very own rarely-found orchid known as *Dendrobium roslii* (https://www.gayatravel.com.my/10-activities-to-do-for-a-a-fun-trip-in-kenyir/, https://www.kenyirtravel.com/interesting-places/). The orchids here are grafted and bloom beautifully which make visitors mesmerized by their colors. The

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Orchid Park was established as a hub for orchid cultivation, preservation and research. The park maintains a natural ecosystem to allow the wonders of nature to survive and reproduce (KETENGAH, 2024b). Visitors can buy the orchids here.



Figure 9: Biosites of fauna diversity: (A) Pertang River (Mahseer sanctuary; BS-1); (B) Mandak River (BS-2); (C) Kenyir Elephant Conservation Village (BS-3); (D) Butterfly Island (BS-4); and (E) Lawit Hill with hornbill species (BS-5)

The **Herb Park** ((Figure 10B) is located in Sah Kecil Island and it takes around 10 minutes to go here from Pengkalan Gawi Jetty. The park has an arboretum that stores and showcases various species of herbs with more than 200 species of traditional herbs, such as long jack or 'tongkat Ali' *(Eurycoma logifolia)*, Fatimah's betel cutter or 'Kacip Fatimah' *(Labisia pumila)*, cat's whiskers or Java tea or 'Masai Kucing' *(Orthosiphon aristatus)*, mistletoe fig or 'mas cotek' *(Ficus deltoidei)*, and God's crown or 'mahkota dewa' *(Phaleria macrocarpa)*. In addition to the interpretation center for detailed information about herbs, the park also provides fresh herbal drinks for visitors to try, such as long jack, Fatimah's betel cutter, and God's crown (KETENGAH, 2024c).

Rafflesia Site is a jungle trekking site to observe rafflesia in Kenyir Geopark area (Figure 10C). Rafflesia, or *Bunga Pakma* as the locals call the flower, was found in part of Tembat Forest Reserve compartment 231, nearby the indigenous people (Orang Asli) community in Kampung Sungai Berua in Jenagor subdistrict since 2019. According to Britannica (2024), Rafflesia (genus *Rafflesia*) is parasitic plants native to Southeast Asia and contains the world's largest flowers. All Rafflesia species parasitize the root of *Tetrastigma* vines (the

host plant). Rafflesia flowers are commonly have five tepals (undifferentiated petals and sepals) surrounding the sex organs (unisexual) in the central cup. Siti Munirah et al. (2020) stated that in Peninsular Malaysia, Rafflesia species found in lowland to hill dipterocarp forests in Terengganu and other states (Kedah, Perak, Kelantan, and Pahang). Rafflesia species found in this area is *Rafflesia cantleyi* which grow abundantly due to the suitable condition of the host plant. Nais (2001) stated that this species needs six to 21 months for flower buds to mature and bloom within five to eight days before it decays. Due to the increase number of tourists from within and outside Terengganu after the discovery of this unique flower, Terengganu State Government (2023) has to put the rules for the visitors who want to see the flower. Among the rules is that the visitors have to get a permit first from the Hulu Terengganu Forestry Department, the government agency which is responsible to preserve the flower's habitat, before entering the forest reserve.



Figure 10: Biosites of flora diversity: (A) Orchid Park (BS-6); (B) Herb Park (BS-7); (C) Rafflesia Site (BS-8)

Biosites of fauna and flora combination

Three sites have been identified as biosites based on the combination of fauna and flora diversity: Kenyir Natural Research Station – Universiti Malaysia Terengganu (BS-9), Bewah and Taat Caves (BS-10), and Mount Gagau (BS-11). **Kenyir Natural Research Station UMT** (Figure 11A) is one of UMT's research stations which intends to become an internationally recognized main centre of reference for Kenyir Lake's biodiversity. The establishment of this research station was started by the establishment of the Centre for Socio-Economic Development (CSD) in 2011 as UMT, in line with its function as a university for society, endeavours to excel in research that is multi-disciplinary and social-

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innovation oriented. CSD was then upgraded to Kenyir Research Institute (IPK – abbreviation in Malay) in 2013 due to the research development at UMT. In 2021, the institute was renamed to Kenyir Natural Research Station (SPAK – abbreviation in Malay) which was placed under the Institute of Tropical Biodiversity and Sustainable Development UMT. This research station aims to become a leading research and knowledge transfer centre in the country, mainly in the uniqueness that Lake Kenyir has, such as biological varieties, an array of aquatic resources, tourists' attractions, and authentic cultural heritage. The station, with modern building design adapting the tropical elements and Terengganu's traditional architecture, offers world-class research, teaching and learning facilities, such as two academic blocks that have research labs, lecture rooms, research rooms for postgraduate and postdoctoral students, lecturers' and researchers' rooms, two hostel blocks, and six guest houses. There are also two specimen galleries that are used to display a variety of biological specimens, natural history, and sociocultural elements at the lake. The station welcomes visitors from local and overseas universities, schools, other institutions, and the public to fulfil their research interest at Kenyir Lake. In terms of transport to access the Kenyir Lake, the research station has a jetty equipped with facilities such as boat houses and speed boats to enable researchers to explore the lake and locate specimens (UMT Highlight, 2022).

Another biosite of fauna and flora diversity is the **Bewah and Taat Caves**. The name of Bewah Cave is believed from the name of the hill housing the cave, the Bewah Hill (Figure 11B). The word "bewah" means "feast" where local people believe that it refers to the activity that people nearby the cave liked to do in the past. It is also known as "bat guano cave" due to plenty of bat droppings in the floor of the cave. Meanwhile, another cave, the Taat Cave ("taat" means very loyal, obedient, and respect to somebody referring to loyal villagers for their leader) was formed in the Taat Hill (kenyirlake.com/attraction_cave.htm). The flora in the area consists of various types of plants, from tall trees, medicinal plants, forest fruit trees, to moss species, ferns and climbing plants. Among the species found in the Bewah Cave are Elephant Ears, Tiger's Betel (*Piper porphyrophyllum*), False Ivy-Palm (*Aralidium pinnatifidum*), Smooth parameria (*Parameria laevigata*), Fig (*Ficus vasculosa*) and Monkey Jackfruit (*Artocarpus rigidus*). There is also a unique green luminous or fluorescent moss *(Schistostega pennata)* inside of the Bewah Cave (Figure 11C). Among the fauna found in Bewah and Taat Caves are bats, crickets, large cockroaches, cave centipedes, several large crabs (Figure 11D), and large spiders (Figure 11E). Mohd Azmir et al. (2021) have discovered that there are 12 species of herpetofauna (reptiles and amphibians), 24 species of birds, and 15 species of bats in this area. There is also a Melunak tree *(Pentace microlepidota)* nearby the Tanjung Bewah, a plain area separating the two caves,

where visitors have to go through a hiking trail to reach the giant tree. According to KETENGAH's website (https://www.ketengah.gov.my/10-activities-to-do-for-a-fun-trip-in-kenyir/), the 340- years-old tree is the biggest tree of its kind in Malaysia (Figure 11F) with circumference equaling to around 20 hugging adults combined.

Meanwhile, **Mount Gagau** is the second highest peak in the National Park after Mount Tahan and renowned for its pristine rainforest (Figure 11G) and rich biodiversity. At the top of this mountain, which is at a height of 1,376 meters, three states that are within the borders of the National Park, namely Kelantan, Terengganu and Pahang can be seen. This mountainous area has diverse flora and fauna. The forest area in Mount Gagau is divided into three main types of forest: hill dipterocarp, upper dipterocarp, and montane forests. Mount Gagau contains also mossy forest (Figure 11H). Various types of flora and fauna are recorded in Mount Gagau which includes 97 species of mosses, 89 species of ferns and lycophytes, 111 species of seed plants, 18 species of amphibians, 14 species of reptiles and 2 other animal species. The diversity of flora and fauna that inhabit Mount Gagau makes it a conservation site for all these three types of forest. According to All Trails (2024), visitors who wish to climb Mount Gagau will have the chance to hike from Camp Gagau through the breathtaking green hills, which offer a scenic background and conceal an abundance of medicinal herbs.



Figure 11: Biosites of fauna and flora diversity: (A) Kenyir Natural Research Station – Universiti Malaysia Terengganu (BS-9), (B) Bewah Caves (BS-10), Fluorescent moss inside Bewah Cave, (D) A large crab inside Bewah Cave, (E) A large spider inside Bewah Cave, (F) The largest Melunak tree in Peninsular Malaysia, (G) Rainforest of Mount Gagau (BS-11), (H) Mossy forest atop Mount Gagau

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CULTURAL SITES OF KENYIR GEOPARK

Cultural heritage consists of two concepts, namely tangible and intangible heritage. Tangible heritage is something that can be permanently seen and held whether stationary or moveable, for example historical buildings, sites, and objects, including monuments, places of worship, mausoleums, villages, equipment, etcetera which are considered important to be conserved. Meanwhile, intangible heritage refers to knowledges, expertises, languages, and lingual utterances which are interpreted via verbal traditions, languages, musics and songs, foods, and traditional games. Both of these concepts are used in Malaysia based on the National Heritage Act 2005, and Kenyir Geopark offers both types of heritage. Table 3 lists all cultural sites and their locations can be seen in Figure 1.

Table 3: Cultural sites of Kenyir Geopark

No.	Code	Cultural Heritage Type	Cultual Site Name and Main Feature	Location (Subdistrict)
1	CS-1	Tangible heritage	**Terengganu Inscription Stone**	Kuala Berang
2	CS-2		**Kapal Hill (Folktale)**	Hulu Terengganu
3	CS-3		**Kampung Dusun Mosque**	Kuala Berang
4	CS-4		**Mausoleum of Tok Gajah**	Kuala Berang
5	CS-5		**Mausoleum of Sheikh Abdullah**	Kuala Berang
6	CS-6		**Mausoleum of Syarif Muhammad Al-Baghdadi**	Jenagor
7	CS-7		**Mausoleum of Tok Raja Ri**	Kuala Berang
8	CS-8		**Traditional Villages**	Kuala Berang
9	CS-9		**Traditional Equipment**	Hulu Telemung
10	CS-10	Intangible heritage	**Indigenous Community**	Kuala Berang
11	CS-11		**Traditional Foods**	Kuala Berang

Cultural sites of tangible heritage

At Kenyir Geopark, in line with the significance of the Hulu Terengganu district as the earliest governing center of Terengganu and an entrepot back then, the cultural remains can still be seen around the river banks in Kuala Berang and nearby areas, such as Terengganu Inscription Stone (CS-1), Kapal Hill (Folktale) (CS-2), and Kampung Dusun Mosque (CS-3). There are also several mausoleums of national heroes and prominent figures within the geopark, including Mausoleum of Tok Gajah (CS-4), Mausoleum of Sheikh Abdullah (CS-5), Mausoleum of Syarif Muhammad Al-Baghdadi (CS-6), and Mausoleum of Tok Raja Ri (CS-7). In

additions, traditional villages (CS-8) and traditional equipment (CS-9) are also cultural heritage that can still be found there.

The **Terengganu Inscription Stone** (*Batu Bersurat Terengganu* in Malay) is assumed as the oldest artifact bearing Malay text inscribed in Arabic script (Jawi writing). The original inscription stone was kept in the *Muzium Negeri Terengganu* (Terengganu State Museum; Figure 12A), meanwhile its memorial was built close to where the original one was discovered in Kuala Berang, Hulu Terengganu District (Figure 12B). Nik Abd Rahman et al. (2012) and Abdul Rahman (2016) described that the inscription stone has a dimension of 84 cm in height, 53 cm wide at the top, 27 cm wide at the bottom, 24 cm in thickness, and a weight of around 215 kg. Based on the writing on the tablet, it was written in 702 AH (Hijri) or 1303 CE. It was first discovered accidentally after partially submerged after the flash flood receded at the bank of Tersat River, in Kampung Buluh, a village about 3 km from Kuala Berang town, Hulu Terengganu district in 1887. After its first discovery, the stone was used as a stepping stone to enter a *surau* (a small place of worship used by Muslims). It was then rediscovered in 1902 by an Arab-Malay trader from Riau-Lingga, Syed Hussin bin Ghulam Al-Bukhari, when he washed his feet to prepare the midday prayer and he noticed the stone was inscribed with Jawi words. He had the stone moved to Kuala Terengganu and presented it to Sultan Zainal Abidin who then placed it on Bukit Puteri. It was moved to Raffles Museum in Singapore in 1920s and was returned to *Muzium Negara* (National Museum) in 1960s and finally sent back to Terengganu State Museum. Among the writings inscribed in the stone are the declaration and enforcement of Islamic Laws as the official religion of the state of Terengganu during the reign of King Mandalika and the teachings of Prophet Muhammad. It also consists of several Islamic Laws and their punishments. The following texts are the translation of the inscriptions:

- Panel A: *"The Messenger of Allah (Prophet Muhammad), together with those who have faith in the Supreme God (Allah), have been enslaved to implant the religion of Islam; with truth they have spoken of the Laws binding upon all the servants of the Supreme God here in my domain. The arbiters of the faith of the Messenger of Allah (peace be upon him) are the King Mandalikas who speak the truth on the side of the Supreme God here on earth. To decide on the right knowledge is statutory upon all the Muslim King Mandalikas, in accordance with the decrees of the Supreme God who speaks the truth; that the correct way for the two determiners of knowledge is to be in solitary seclusion. Thereupon, I, Seri Paduka Tuan declare that this edict be erected in this country of Terengganu on Friday, in the month of Rejab, year 702, in the era of the Messenger of Allah."*

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- Panel B: *"Families in distant lands give those who come. Fourth Law: Debtors must never take... where have you lost the gold. Fifth Law: Whosoever must never take the mould for the making of money, if he takes then he must forfeit his gold. Sixth Law: Whosoever... of trouble makers, be they male or female, as decreed by the Supreme God, if they are free persons and bachelors then give them 100 strokes of the cane. If they are free persons with wives, or women with husbands, then bury them up to the waist and stone them to death. If they revolt then torture them; if the bachelor son of a chieftain then..."*
- Panel C: *"The penalty is ten and a half sagas. If an unmarried minister, the penalty is seven tahils and one paha...half a saga. If an unmarried headman the penalty is five tahils...seven tahils and one pahagoes into the Treasury.....If....a free person. Seventh Law: A woman who wants...has not got a husband, if she causes trouble...."*
- Panel D: *"Not true, the penalty is one tahil and one paha. Ninth Law: Seri Paduka Tuan punishes those who fail to prepare the fine... if my son, of my playmate, or my grandchildren, or my family, or child...this edict, and whosoever ignores its contents shall be damned by the Supreme God, cursed by the Supreme God, all those who disregard this articles of this ordinance."*

Abdul Rahman (2016) stated that this discovery proves that Islam has reached Terengganu in or before the 14th century. The stone is the oldest Malay text in Arabic script that is still exists and the earliest record of the introduction of Islam into the Peninsular Malaysia. It was listed as one of the eligible items for world heritage recognition during the UNESCO International Advisory Committee meeting in Barbados in 2009. This inscription stone is made up of dolerite, a dark greenish gray, fine-grained, homogeneous igneous rock that is frequently found in Hulu Terengganu District as small intrusions or dykes.

The **Kapal Hill**, as already explained before in the part of Geosites of Kenyir Geopark, is a unique granite outcrop that looks like a ship deck is stranded near its summit, with a clear stream flowing beside it amidst pristine nature, making it a captivating place of attraction. This hill is located in a forest reserve area in Kampung Gerdong, Hulu Telemong subdistrict. This hill is frequently visited by geologists and researchers who want to examine its distinctive rock features and forms. For travelers, it is an uncommon sight that undoubtedly makes their trip more special. Hiking is the popular activity here for nature lovers and adventure enthusiasts looking for a beautiful scenery with lush green trees and soothing fresh air (Discovery Terengganu, 2024a). The hill is maximum 800meter above sea level high. It takes around 45 minutes hiking to the rock outcrop that is approximately 21meter long and 4.5 meter high (TRDI, 2020). According to the myth among the villagers, the ship-like rock (Figure 12C) was originally a large ship owned by

Chinese merchants passing through the area to have a trade transaction in Kuala Berang and stranded on the sand bar when Terengganu hit by a big flood hundreds of years ago. Eventually, the ship turned into a rock such that it became known as the ship rock, and the area became a hill with a thick forest.

Kampung Dusun Mosque is one of 80 mosques in Hulu Terengganu district which is located in Kampung Dusun, Jenagor subdistrict. This mosque was built by a communal work since 1326 Hijri (1908) (http://emasjid.terengganu.gov.my/viewmasjid.php?daerah=7; https://masjid.islam.gov.my/maklumatDetailMS/1/1106035). This 116-year-old mosque is among the oldest mosques in Terengganu and built with chengal *(Neobalanocarpus)* wood and without nails. It still preserves the architectural features of a traditional house (Figure 12D). A *beduk* (a drum used to call for Muslim prayers) is still hung at the edge of the veranda (Figure 12E). It is generously decorated with khat calligraphy, especially at the air vents on the doors and walls (Figure 12F).

Mausoleum of Tok Gajah (Figure 12G)**,** which houses the tomb of the Malay hero, is a historical place that holds the story of bravery and fighting spirit of a famous Malay warrior namely Tok Gajah or his real name is Imam Rasul Abdul Salam bin Shahrum, or known as *"Orang Kaya Imam Indera Gajah Pahang"*, or *"Khatib Rasul"*. It is located in Kampung Pasir Nering, near Kuala Berang town, Hulu Terengganu, around 4 km from the Terengganu Inscription Stone memorial site. Based on the history, Tok Gajah is one of the warriors of Pahang who was actively involved in the resistance against British colonialism at the end of the 19th century. He was born in Temau Village, Raub, in the state of Pahang. He received early education in the field of religion and became a respected *imam* (leader) in his community. A solid religious education gave him a strong foundation in ethical values and justice as motivation in his struggle against the colonialists. Tok Gajah is known as a leader who is brave, intelligent, and strongly adheres to the principle of defending the homeland and the dignity of the nation. He was a very strategic person in planning attacks against the British. He often held meetings with other warriors to strategize and gather strength. One of the famous battles was the Semantan War in 1891, where Tok Gajah together with his son, Mat Kilau, successfully defeated the British forces. In 1892, the British colonialists issued an order to arrest Tok Gajah, so he fled to Hulu Kelantan and then to Hulu Terengganu where he died in 1901 and was buried here. This burial place is a symbol of appreciation and respect for his services and sacrifices in defending the motherland. This tomb is often visited by those who want to remember the services of this Malay warrior as well as to learn more about the history of the struggle against colonialism. This tomb is not only the focus of local tourists, but also foreign tourists who are interested in the history and culture of Malaysia. In addition, this tomb is also a place of study for historians and students who want to

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delve into the history of the struggle of the Malay nation (Discovery Terengganu, 2004b).

Meanwhile, the **Mausoleum of Sheikh Abdullah** (Figure 12H) is located in Kampung Pauh, around 6 km from Kuala Berang town, Hulu Terengganu. Sheikh Abdullah, or his complete name is Sheikh Abdullah bin Abdul Qahar bin Syarif Muhamad Al Baghdadi, or also known as Tok Pauh, was of Arab descent and a famous scholar in Terengganu in the 1660s. He is the father of a famous scholar, Sheikh Abdul Malik or also known as Tok Pulau Manis.

Mausoleum of Syarif Muhammad Al-Baghdadi (Figure 12I) is located about 15 km from Kuala Berang town, just on the left bank of the Kenyir Dam, in Jenagor subdistrict. Syarif Muhammad Al-Baghdadi came from Baghdad and is believed to be an early Islamic preacher and a scholar in Terengganu, estimated to be around the year of 1600. He is also the ancestor of Sheikh Abdullah and Sheikh Abdul Malek bin Abdullah. He spread the teachings of Islam to the local population during the era of Islamic rule in Kuala Berang, Hulu Terengganu. His tomb is the first tomb of the Ahlul Bayt discovered in this settlement. Apart from the tomb of Syarif Muhammad al-Baghdadi, there are also tombs believed to be his descendants, also buried around his tomb (https://geopark.ketengah.gov.my/makam-syarif-muhammad-al-baghdadi/).

In additions, **Mausoleum of Tok Raja Ri** (Figure 12J) is located on a hill in Kampung Kuala Por, about 2 km from Kuala Berang town, Hulu Terengganu. It is believed that he was a ruler who was once powerful and carried out Islamic administration at that time. He is likely the person who proclaimed the law at the Terengganu Inscription Stone. Another opinion states that Tok Raja Ri was a preacher and a palace official. On his tombstone, there is Arabic Persian writing containing the history of the arrival of Islam in Terengganu (Zainuddin, 2024).

There are several **traditional villages** that have been identified as cultural heritage within the Kenyir Geopark area, such as Kampung Gaung (Figure 12K) which is famous for growing corns (Figure 12L) and selling the corns and other fruits; Kampung Dusun which grows duku, dokong, langsat *(Lansium domesticum)* and durian; and Kampung Pasir Nering which is famous for its traditional orchards that are hundreds of years old with 200 Perah (Elateriospermum tapos) trees. In additions, there are also other traditional villages in the area such as Kampung Basung, Kampung Langgar, and Kampung Buluh (https://ganupedia.com/?p=915).

The local people are still practising and using **traditional equipment** in their daily life, such as the bamboo and rattan handicrafts to make fish trap (*bubu* – in local lingo), fishing net *(tangguk)*, *taking* (a basket made of bamboo and used by the locals to carry their catches such as fish and shrimps from the river) in Kampung Chapu; *chekalok* (a bamboo slat into which a bubu may be placed to catch fish in the river) in Kampung Basung; and *derong* (a bearer worn on the back

of the body and used to carry heavy items) in Kampung Pasir Dula; screwpine mat and basket weaving (Figure 12M) in Kampung Nibong; and art activities using a traditional musical instrument known as *kertuk* (Figure 12N) which is made of bamboo in Kampung Payang Kayu.



Figure 12: Cultural sites of tangible heritage: (A) The original Terengganu Inscription Stone (https://www.wonderfulmalaysia.com/attractions/batu-bersurat-terengganu.htm), (B) The memorial of the Terengganu Inscription Stone (CS-1), (C) The Kapal Hill (CS-2), (D) Kampung Dusun Mosque (CS-3), (E) A *beduk* (a drum used to call for prayers) hung in the veranda of the mosque, (F) Decoration of calligraphy at air vents of the doors and walls, (G) Mausoleum of Tok Gajah (CS-4), (H) Mausoleum of Sheikh Abdullah (CS-5), (I) Mausoleum of Syarif Muhammad Al-Baghdadi (CS-6), (J) Mausoleum of Tok Raja Ri (CS-7), (K) Kampung Gaung as one of traditional villages (CS-8). (L) Corns as a product of Kampung Gaung, (M) Screwpine basket as a traditional equipment (CS-9), and (N) *Kertuk*, a traditional musical instrument from the area (CS-9)

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Cultural sites of intangible heritage

There are at least two cultural sites of intangible heritage in Kenyir Geopark: indigenous community (CS-10) and traditional foods (CS-11). In Kenyir area, the **indigenous community (**called the *Orang Asli* in Peninsular Malaysia) resides in Kampung Sungai Berua, Kuala Berang subdistrict, in Hulu Terengganu district. They are mostly of the Semaq Beri tribe (90%) and the rest is the Batek tribe. Their original village has been inundated by the man-made Kenyir Lake and they have been resettled to the newly-opened village in Kampung Sungai Berua in in 1977 (Abdullah et al., 2018). The government has provided permanent and cemented houses for their settlement (Figure 13A) and primary school for their children (Figure 13B). The number of the indigenous community living in the area is 334 people, with 172 males and 162 females. This indigenous community has rich customs and a living culture that are related to nature. For this community, particularly the Semaq Beri tribe, the rivers and forests are important for their life. Fish and other river products were initially taken for food sources for themselves, however, some of them are also sold to outsiders for the financial need. The indigenous community also carries out traditional agricultural activities on a small scale. They cultivate several types of plants near their homes and around the village. They also collect forest products such as agarwood *(gaharu)*, bamboo, and rattan, besides making handicrafts from bamboo and screwpine leaves.

Hulu Terengganu has many unique **traditional foods** such as *susu kerbau masam* (sour buffalo milk that is processed in bamboo sticks; Figure 13C) in Kampung Pelandan and Kampung Ceting; *emping padi* (paddy crackers or chips produced from half-ripe paddy that is eaten with coconut milk cooked with sweetener and eggs); *lemang* (the traditional heritage of rice bamboo) of Kampung Nering; *sambal kepayang* (kepayang chili sauce produced from the kepayang fruit, *Pangium edule*, which is savoured with rice and grilled fish) in Kampung Dura; and other dishes based on the fish found in the rivers and lake which are available at the eateries around Kampung Telaga. Besides, there are also *ikan baung masak tempoyak* (Mystus catfish cooked in durian paste gravy), *ikan lampan goreng* (fried tinfoil barb fish), and *ikan lampan pekasam* (fermented tinfoil barb fish) which are popular around the lake and Kampung Basung (Figure 13D).

ARCHAEOLOGICAL SITE OF KENYIR GEOPARK

There is only one archaeological site proposed for the development of Kenyir Geopark, i.e. the Bewah Cave (AS-1) which is located in the southern part of Kenyir Lake area in Hulu Terengganu district. This cave is famous for its important archaeological discoveries. In 2009, excavation activities were conducted by the State Museum of Terengganu which successfully discovered an

ancient human skeleton of the Hoabinhian or Mesolithic period and it is believed that the skeleton was a teenager girl estimated to be over 16,000 years old based on a radiocarbon dating in 2010. During the discovery, most of the bones were already decayed and covered with the limestone. This discovery provides a glimpse into prehistoric human life in this area. In additions, there are also artifacts such as stone tools, such as stepping stones, knocking stones, inlay stones, pottery fragments, and food scraps found in this cave (Discovery Terengganu, 2024c; Terengganu State Museum, 2024). This skeleton was discovered at the site closest to the cave mouth (Figure 14A). It was observed that the exposed bones were a part of a femur that was folded to the tibia. Based on the position of these bones, it appears that the body was buried in a kneeling position (Figure 14B). Changes in the environment have caused many other bones, such as the skull, to be missing.



Figure 13: Cultural sites of intangible heritage: (A) The settlement of the indigenous community in Kampung Sungai Berus (CS-10), (B) The indigenous students in their school, (C) The *susu kerbau masam* (sour buffalo milk) as one of traditional foods from Kenyir Geopark (CS-11), and (D) Several fish-based traditional dishes from the area (CS-11)

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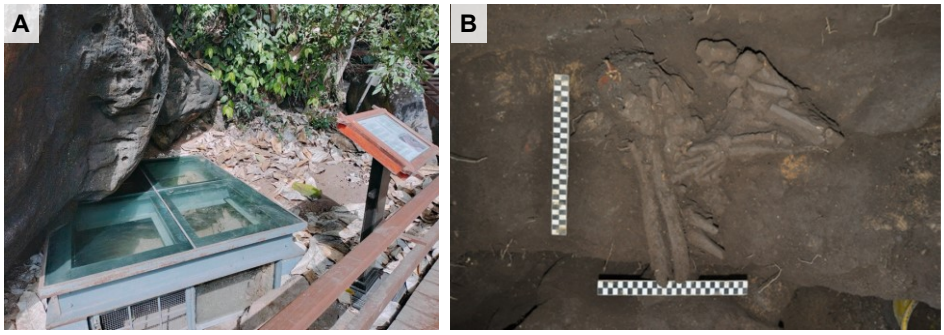


Figure 14: The one and only archaeological site in Kenyir Geopark is the Bewah Cave (AS-1): (A) The location where a prehistoric human skeleton was found near the cave entrance, (B) The 16,000-year-old skeleton

INTERRELATIONSHIPS BETWEEN COMPONENTS OF KENYIR GEOPARK

The key components within Kenyir Geopark are interconnected through a harmonious blend of geological, biological, cultural and archaeological elements that define its unique identity. The geopark's geosites, such as the cave, the river, and other landforms, serve as the foundation of its ecosystem, influencing soil types, water systems, and other life factors that support diverse flora, fauna, cultural as well as archaeological aspects. Biosites which thrives in this environment contributing to the rich biodiversity, including endemic and rare species, can be used for human life. The richness of its components and their interrelationships ensure the holistic management and sustainability of Kenyir Geopark as a living landscape of natural and cultural heritage. Additionally, these components and their linkages are potential for research and educational opportunities, sustainable tourism development, and increase global recognition of the geopark. Table 4 lists some interconnections of key components of the geopark.

Table 4: Examples of interrelationships between key components of Kenyir Geopark

No.	Interrelationship between components		Example
1	Geosite	Biosite	1. Bewah Hill & Cave as the main geosite of Kenyir Geopark is the home for various flora (such as moss, medicinal plants, ferns, caladiums, etc.) and fauna (bats, crickets, centipedes, crabs, large spiders, etc.).
			2. Pertang River is one of rivers in Kenyir area with massive sandstone outcrops and a strategic location for Mahseer fish sanctuary.
			3. Mount Gagau is the biggest plateau in Peninsular Malaysia and has recorded different types of flora

No.	Interrelationship between components		Example
			(97 moss species, 89 fern species, etc.) and fauna (18 amphibia species, 14 reptile species, etc.)
			4. Lata Buweh Waterfall (geosite) supplies its water to fulfill the need of water to the Kenyir Natural Research Station UMT (biosite)
2	Geosite	Cultural site	Kapal Hill has the ship-like granite outcrop atop the hill and is closely related to a folklore of a large ship that belonged to Chinese traders who were traveling through the region to conduct business in Kuala Berang and ended up stranded on the sandbar when Terengganu was struck by a big flood hundreds of years ago. In the end, the ship transformed into a rock, hence the "ship rock."
3	Geosite	Archaeological site	Bewah Hill & Cave geosite is the location of the discovery of the oldest (16,000 years) pre-historic creatures and archaeological artifacts in Peninsular Malaysia.
4	Biosite	Cultural site	Rafflesia site in Tembat Reserved Forest is situated near the settlement of indigenous community in Sungai Berua village. The indigenous people have long used the plant for medicinal purposes.
5	Biosite	Archaeological site	Biodiversity in Bewah Cave and Taat Cave is thought to be the foods for pre-historic creatures found in these two caves.

CONCLUSION

This study reaffirms Kenyir Geopark's significance as a vital resource for research and educational opportunities, sustainable tourism development, conservation, community development, as well as ensuring its legacy for future generations. This study makes a distinctive contribution to the geopark development literature by integrating key components (geological, biological, cultural, and archaeological heritage) into a single spatial and conceptual framework to demonstrate the interdependence between natural and cultural systems and to evaluate their interrelationships and collective significance for geopark planning. Within the Malaysian and Southeast Asian context, this holistic approach provides a more comprehensive model for identifying and managing multi-heritage resources to support sustainable development, education, conservation, economic growth, and community-based tourism.

The findings of this study provide an evidence-based inventory and spatial framework that can assist state agencies, planners, and conservation bodies in identifying priority areas for conservation and development within Kenyir Geopark area. By demonstrating the interrelationships among geological, biological, cultural, and archaeological sites, the study supports the designation of conservation zones, the development of integrated management plans, and the

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formulation of land-use policies that balance heritage conservation with infrastructure development and community livelihoods. For tourism planning, the results can guide the design of thematic geotourism routes, educational programs, and visitor facilities that connect multiple heritage values in a coherent and attractive manner.

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Ethical Statement

All fieldwork conducted for this study complied with relevant institutional guidelines and national regulations governing research, conservation, and heritage documentation in Malaysia. Site visits and data collection were carried out with the permission and cooperation of the relevant authorities, including the Terengganu State Government, *Lembaga Kemajuan Terengganu Tengah* (KETENGAH, Central Terengganu Development Authority), *Jabatan Kebajikan Orang Asli* (JAKOA, Department of Orang Asli Development), and other agencies responsible for protected areas, biodiversity, and cultural heritage management. Where field investigations involved visits to indigenous communities, customary lands, or culturally sensitive locations, prior consent was obtained from community leaders or representatives and local stakeholders, and all interactions were conducted with respect for local customs, knowledge systems, and confidentiality.

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EXPLORATORY STUDY ON THE INFLUENCE OF PERSONALITY TRAITS OF PROJECT MANAGERS IN PUBLIC INFRASTRUCTURE IN MALAYSIA

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Abstract

Public infrastructure projects have an important role in Malaysia's economic development and increasing gross domestic product (GDP), however, the public infrastructure regularly faces challenges such as delays, overspending, and insufficient quality. The effectiveness of project managers' skills and behaviors plays a crucial role in determining the success or failure of these projects. This study aims to enhance the efficiency and success of infrastructure projects by understanding the influence of project managers' personality traits on project management practice. Thus, the objectives are (1) to identify the personality traits among project managers, (2) to explore the relationship between these traits and project outcomes, and (3) to formulate a framework for implementing these traits into project management practices. Semi-structured interviews were conducted with twelve experienced project managers via a qualitative approach. Five core personality qualities emerged from a thematic analysis of the interview data. These include neuroticism, conscientiousness, extraversion, agreeableness, and openness to new experiences. These traits significantly affect decision-making, stakeholder satisfaction, team dynamics, and flexibility, among other elements of project management. The impact of the findings will be a useful indicator to formulate a framework for developing training programs that are especially suited to the demands of the workforce, conducting ongoing evaluation and monitoring, and including personality assessments in HR procedures. This study provides valuable insights for enhancing project management tactics in public infrastructure projects in Malaysia

Keywords: personality traits, project manager, project management, public infrastructure

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INTRODUCTION

Large infrastructure projects present significant challenges in terms of project management because they are highly complex and fraught with high levels of uncertainty regarding geology, technical solutions, and societal dynamics (Flyvbjerg, 2014; Whyte et al., 2016). Mitigating these obstacles requires managing a suite of stakeholders, sometimes with different and competing priorities and needs. Besides project-related barriers, project actors need to recognize that societal expectations for costs, quality, and sustainability are continuously increasing. Global sustainability goals exert significant pressure, necessitating the integration of sustainable solutions directly into projects. Therefore, effective project management becomes crucial for optimal resource utilization in alignment with industry growth.

Challenges in managing large infrastructure projects are multifaceted. Geology can pose unexpected issues, such as unstable ground conditions or unforeseen underground obstacles, requiring flexible and adaptive technical solutions. Societal dynamics, including community opposition or varying regulatory requirements, further complicate project execution (Whyte et al., 2016). Additionally, sustainability readiness requires project managers to consider environmental impacts and implement eco-friendly practices, adding to the project's complexity and cost (Flyvbjerg, 2014). Project managers must navigate these challenges while balancing the expectations of diverse stakeholders, from government agencies to private investors and the general public. Different stakeholders often have conflicting priorities, making effective communication and negotiation skills essential to align these interests and ensure project success (Toor and Ogunlana, 2010).

Infrastructure projects are essential for the economic growth of Malaysia, significantly contributing to the country's GDP. Despite their importance, these projects often encounter significant challenges, including delays, cost overruns, and quality concerns. According to Ramli et al., (2018), only 20% of government projects in Malaysia adhere to both starting and completion timescales, while 79.5% of government projects and 66.7% of private projects fail to complete as per the specified time. These issues highlight systemic gaps in the way infrastructure projects are managed, resulting in non-completion of numerous infrastructure projects with increased timelines, leading to higher costs.

One of the biggest problems compounding these challenges is the lack of understanding of how the personality traits of project managers affect the success of public infrastructure projects in Malaysia. Consequently, this deficiency in knowledge hinders the application of the capability approach because it limits the identification and activation of the informed project management requirements that lead to effectiveness (Nijhuis et al., 2018). There

is a necessity to develop specific methods in combination with the selection and training, as well as a harmonization of the competencies of well-chosen project managers to cope with the intricate nature of an infrastructure project.

LITERATURE REVIEW

Personal Traits

Personality traits refer to the recurring patterns in thoughts, emotions, and actions that define individual behavior (Diener & Lucas, 2019). These traits are fundamental characteristics along which individuals differ (Matthews et al., 2003). Trait psychologists identify a limited number of these dimensions, such as Extraversion, Conscientiousness, or Agreeableness, and individuals fall somewhere on each dimension, manifesting as low, medium, or high on specific traits. An essential aspect of personality traits is that they denote continuous distributions rather than distinct personality types. In other words, when trait psychologists discuss traits like Introversion and Extraversion, they are not referring to entirely different and qualitative categories of individuals. Personality traits adhere to three defining criteria (Diener and Lucas, 2019): (1) consistency, (2) stability, and (3) individual differences. Firstly, for a personality trait to be present, individuals must exhibit some consistency across different situations in their behaviors related to the trait. For instance, if someone is talkative at home, they tend to display a similar trait of talkativeness at work. Secondly, individuals with a particular trait also exhibit stability over time in behaviors related to that trait. For example, if someone is talkative at age 30, they are likely to maintain a talkative demeanor at age 40. Thirdly, individual differences characterize people in terms of behaviors related to the trait. While activities like speech or walking on two feet are not considered personality traits, as they are nearly universal, differences arise in how frequently individuals talk or their activity levels, leading to the existence of personality traits like Talkativeness and Activity Level.

The trait approach faced a challenge in identifying the fundamental traits on which all individuals differ. Over several decades, scientists generated a multitude of new traits, making it increasingly challenging to manage and comprehend the vast array of traits developed. For example, one psychologist might concentrate on individual differences in "friendliness," while another might delve into the closely associated concept of "sociability." In response to this proliferation of traits, scientists sought systematic methods to streamline the number of traits and uncover the core traits that could account for the majority of individual differences between people.

The Five -Factor Model of Personality

The Big Five personality model has its origins in the lexical hypothesis proposed by Galton (1884), which suggests that significant differences in individual

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characteristics are reflected in language. Allport and Odbert (1936) utilized the lexical approach to scrutinize dictionary words associated with personality and personal behaviors, identifying approximately 18,000 such words, with around 4,500 deemed descriptive of personality traits. Cattell (1943) further refined this trait list, ultimately forming 35 personality variable clusters, which, upon factor analysis, resulted in 12 factors. Tupes and Christal (1992) consistently identified a five-factor model; Surgency, Agreeableness, Dependability, Emotional Stability, and Culture while analyzing personality in various samples. Subsequently, Goldberg (1981) introduced the term "Big Five" to describe this five-factor model of personality. Although the exact wording and interpretation of these five personality factors may vary slightly, the Big 5 model and the conceptually similar Five-Factor Model generally encompass openness, conscientiousness, extraversion, agreeableness, and neuroticism. Various scales have been developed to measure these factors, including the Big Five Inventory, different forms of the NEO Personality Inventory, and the Big-Five Factor Markers (Costa Jr. and McCrae, 1992; Goldberg, 1992; John and Srivastava, 1999).

Project Manager Personality Traits (PMPTs)

Belassi and Tukel (1996) highlight that project managers are pivotal to a project's success, particularly in the construction industry, by emphasizing the importance of effective project management for delivering high-quality service. The non-technical skills of a project manager play a vital role in determining success, as highlighted by Cheong and Mustaffa (2017). Despite this importance, past research on project management has given limited attention to the psychological factors influencing project success (Hassan, Bashir and Abbas, 2017). Research indicates that soft skills, especially psychological traits, play a more significant role in determining project success than technical expertise alone. However, the focus on these skills, particularly the project manager's personality, remains insufficient (Noor and Esa, 2021). Thal and Bedingfield (2010) also advocate for a comprehensive examination of how personality traits significantly impact project success. In a different perspective, Ceric (2014) highlights the substantial role of working experience in the success of project managers, a notion supported by Hodgson and Paton (2016), who argue that project managers' experience influences their knowledge, training, and overall project success.

Previous research suggests that high levels of Openness to Experience (O), Conscientiousness (C), and Agreeableness (A) are positively linked to project success (Amoozegar, 2025; Hassan et al., 2017). A meta-analysis by Kang et al., (2023) indicates a strong relationship between (C) and job success. On the contrary, Extraversion (E) and Neuroticism (N), two other personality traits in the "Big Five," have been found to be negatively associated with project success

in various studies (Barrick et al., 2001; Ameer et al., 2022). However, the findings may differ from a study conducted by Masood, Khan and Shaikh (2018), which investigated the impact of personality traits of project managers on project success. The results demonstrated that out of the five traits, only three; Extraversion, Neuroticism, and Openness to Experience had a significant association with project success. Conscientiousness and Agreeableness showed no significant association with project success. Therefore, one of the objectives of this research is to identify the personality traits exhibited by project managers in infrastructure projects.

Association Between Project Manager Personality Traits (PMPTs) and Management Style

Research conducted by Ling, Zhang and Wong (2020) revealed that project managers in the construction industry exhibit high concern for both people and production in their project management styles. The big five personality traits were found to be significantly correlated with "Concern for people". Extraversion, Conscientiousness, Neuroticism, and Openness showing significant correlations with "Concern for production". Additionally, the research adds to personality theory by suggesting that certain traits, such as agreeableness, conscientiousness, and neuroticism, may change with age, while others, like extraversion and openness, remain constant. The study's final contribution lies in demonstrating that personality traits can be used to explain or predict project managers' management styles. The study's final contribution lies in demonstrating that personality traits can serve as valuable indicators for explaining or predicting project managers' management styles. Therefore, in this research, the objective is to explore the relationship between personality traits and project management styles within the realm of infrastructure projects.

Existing studies have established associations between project managers' Big Five personality traits and project success across various industries and international settings. For instance, Hussain et al. (2021) found that extraversion and openness positively predicted project success, while conscientiousness, agreeableness and neuroticism showed no direct relationship. In contrast, Noor and Esa (2021), in the Malaysian small public construction project context, found that conscientiousness and agreeableness were more prominent predictors of project success. These mixed findings indicate that inconsistencies remain regarding which personality dimensions most strongly influence project outcomes, particularly within construction and infrastructure-related environments.

Moreover, recent literature suggests that successful project delivery increasingly depends on behavioural and interpersonal competencies such as leadership, communication, collaboration, adaptability and relationship-building,

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rather than technical capability alone (Rehan et al., 2024). This is especially relevant in public infrastructure projects, where stakeholder management, governance complexity and accountability demands are central to project performance (Waris et al., 2022). In the Malaysian context, public-sector construction projects continue to face issues related to planning, monitoring, delivery method selection and project delays, suggesting that managerial behaviour should be examined within its local institutional and regulatory environment. Therefore, this study addresses a contextual and empirical gap by exploring how personality traits influence project management practices and outcomes in Malaysian public infrastructure projects.

METHODOLOGY

This study used a qualitative research technique to collect the primary information necessary to achieve its aims and objectives. A qualitative approach was selected because it offers detailed insights into the complex and nuanced relationships between project managers' personality traits and the success of public infrastructure projects in Malaysia. The main data collection method was semi-structured interviews due to the advantages offered, namely open- ended and flexible, blending structured and unstructured elements. (McCombes and George, 2022). In addition, interviews were employed to gather subjective insights, opinions, and motivations from participants (Busetto et al., 2020). Using snowball sampling, twelve semi-structured interview sessions were conducted. This method is particularly effective for recruiting hard-to-reach participants or those within specific professional networks (Noy, 2008).

Informed consent was obtained from all respodents prior to their participation in the study. The participants were fully informed of the purpose of the research, their voluntary participation, and their right to withdraw at any time without consequence. The targeted respondents were project managers meeting the following criteria: (i) at least five years of experience in project management roles, especially in public infrastructure sectors like transportation, water supply, sewage, and municipal facilities, and (ii) typically holding key decision-making positions such as project leads or senior project managers. The thematic analysis process involves familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report (Braun and Clarke, 2006). It begins with a thorough reading of the updated interview transcripts to familiarize with the data and identify initial ideas and potential patterns. Next, the interview transcripts have been summarized, and identify the keywords. After that, the keywords were then combined into related codes.

Although the qualitative design and thematic analysis are appropriate for the study, several limitations should be acknowledged to enhance the transparency of the methodology. First, the sample size was relatively small, with only twelve participants, which limits the generalizability of the findings. Second, the use of snowball sampling, while effective in reaching hard-to-find participants, may introduce respondent bias, as those recruited may share similar characteristics or perspectives, which could skew the results. Lastly, the absence of triangulation the use of multiple data sources or methods to validate findings means that the findings are based solely on participant interviews, potentially limiting their robustness. Future studies could address these limitations by increasing the sample size, incorporating a wider range of data sources, and employing triangulation to enhance the credibility and generalizability of the results.

RESULTS

The five core personality traits emphasized in the analysis are openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Each trait will be presented to provide a clearer view of how these unfold with the management of public infrastructure projects. Table 1 shows the summary of the findings.

Table 1: Summary of Dominant Personality Traits and Their Influence on Public Infrastructure Project Management

Personality Traits	Key Findings
Openness to Experience	-adaptable, innovative, and proactive in embracing new ideas and technologies -facilitate problem-solving and continuous improvement, leading to enhanced project performance
Conscientiousness	- meticulous planning, organization, and a strong sense of responsibility - detail and proactive risk management ensure that projects are completed within defined timelines and budgets, contributing to overall project stability and success
Extraversion	-excel in communication and leadership, fostering a collaborative and motivated team environment -engaging with stakeholders and maintain high levels of team coordination is essential for effective project execution.
Agreeableness	- skilled in conflict resolution and maintaining positive Relationships -empathetic and cooperative nature helps create a harmonious team atmosphere, improving team cohesion and stakeholder satisfaction.
Neuroticism	- present challenges, develop strong stress management techniques and resilience

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Personality Traits	Key Findings
	-heightened awareness of potential risks and proactive approach to mitigating them contribute to project stability and success

The Relationship between these Traits and Project Outcomes

This subsection discusses how the project management practices involved by the project managers influence the project outcome for public infrastructure work. They were asked how the project management practices based on their personality traits could affect the project outcome. After that, the thematic analysis began with codes, used to explore the influence of these traits on project outcomes as per Figure 2. This figure visually represents the thematic relationship between personality traits and project outcomes identified through thematic coding analysis.

Openness to Experience

Project managers with high openness to experience significantly influence project outcomes through adaptability, creativity, and a willingness to embrace new technologies. Their ability to implement innovative solutions, such as BIM for project tracking, enhances execution efficiency. Interview responses from R2 and R12 highlight how adopting modern tools improves project success. Research by Müller and Turner (2010) and Lee-Kelley and Kin Leong (2003) supports this, showing that open project managers foster learning environments, drive innovation, and improve adaptability. Dvir et al. (2006) further link openness to higher team performance and project success by encouraging creative problem-solving.

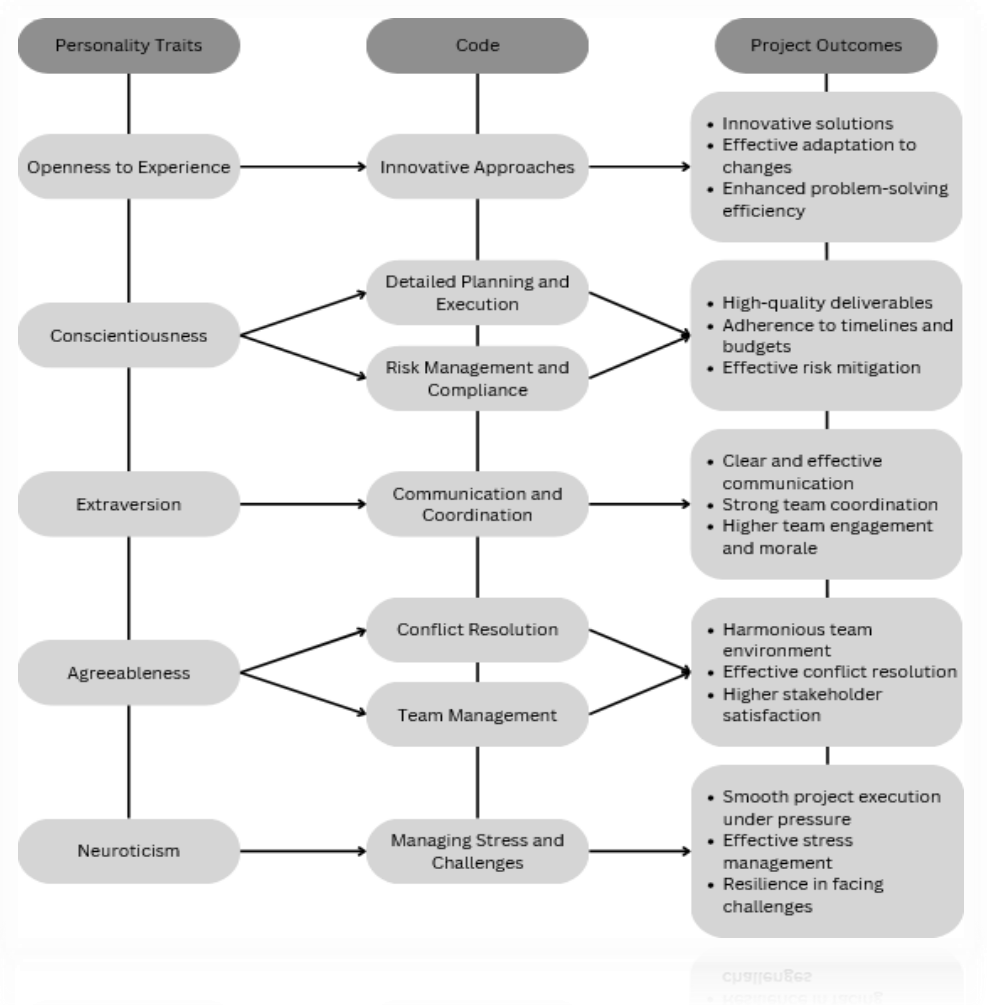


Figure 2: The relationship between these traits and project outcomes

In addition, openness to experience equips project managers to handle complex challenges, improve stakeholder engagement, and create a culture of continuous improvement. DeRue et al. (2012) found that open leaders navigate uncertainties effectively, ensuring well-informed decisions in infrastructure projects. This adaptability allows them to anticipate risks and develop proactive solutions. Openness also enhances team dynamics by fostering collaboration, morale, and innovation. These findings reaffirm openness to experience as a

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critical trait for project managers in Malaysia, driving success and innovation in public infrastructure projects.

Conscientious

Conscientiousness plays a vital role in achieving successful project outcomes by ensuring thorough planning, organization, and strict adherence to deadlines.. A conscientious project manager ensures projects stay on schedule and within budget while maintaining quality and reliability. R4 emphasized the importance of clear objectives, comprehensive schedules, and well-planned resources, along with proactive risk management to ensure project stability and success.

These findings align with prior studies by Dulewicz and Higgs (2005), highlighting that the diligence and reliability of conscientious managers, leading to better project performance. Chen et al. (2014) found that conscientious planning reduces uncertainties and improves outcomes. Similarly, LePine et al. (2000) associate conscientiousness with effective risk management, reliability, and minimal project overruns.

A conscientious project manager carefully plans all aspects of a project, reducing the risk of oversight and increasing efficiency. Their reliability fosters trust among stakeholders and team members, ensuring smooth project execution. They proactively identify risks, implement contingency plans, and maintain high-quality standards, particularly in public infrastructure projects where precision is crucial. Ultimately, conscientiousness enhances planning, organization, and risk management in public infrastructure projects in Malaysia, leading to higher project success rates. These findings align with past research, reinforcing the importance of conscientiousness in effective project management.

Agreeableness

Agreeableness significantly influences project outcomes by fostering cooperation and a harmonious team environment. Project managers with high agreeableness effectively mediate conflicts, build strong relationships, and maintain team productivity. For instance, Interviewee R3 facilitated a resolution between engineering and procurement teams, while Interviewee R6 emphasized open communication and mutual respect, reinforcing teamwork and collaboration. Research supports these findings, with Judge and Bono (2000) linking agreeableness to leadership effectiveness and team cohesion. Fisher (2011) highlighted that agreeable project managers enhance interpersonal relationships and conflict resolution, leading to better project performance. Similarly, Hogan and Holland (2003) found that agreeableness improves job performance, particularly in roles requiring teamwork and cooperation. Agreeable project managers promote inclusivity, ensuring all voices are heard and valued, which boosts team morale and innovation. Their empathetic approach strengthens

stakeholder trust and engagement, crucial for public infrastructure projects. By maintaining a supportive work climate and resolving conflicts proactively, they enhance team satisfaction and project success. Ultimately, agreeableness is a key trait for project managers in Malaysia's public infrastructure sector, facilitating conflict resolution, stakeholder management, and team cohesion. Organizations can improve project management practices by leveraging this trait to enhance collaboration and overall project outcomes.

Neuroticism

Neuroticism can have a nuanced effect on project results. Although high levels of neuroticism can pose challenges, project managers who effectively manage it often develop excellent stress management and resilience strategies. They are often more risk-aware and proactive in contingency planning. For instance, Interviewees R5 and R7 emphasized the need for emotional balance and rational decision-making in high-pressure projects, while others highlighted the resilience required for managing complexity. Contrary to literature linking neuroticism to poor job performance (Clarke and Robertson, 2005), this study found that managers with moderate neuroticism can thrive under stress if they develop coping strategies (O'Neill and Allen, 2011). Effective stress management allows neurotic managers to anticipate risks, enhance project stability, and maintain performance. Research by LePine et al. (2000) also supports the idea that neurotics can contribute positively to team performance when given adequate support. Neurotic project managers excel in proactive risk management, contingency planning, and attention to detail, which are crucial in uncertain environments like public infrastructure projects. Their cautious nature helps identify risks early and implement mitigation strategies, fostering stability and stakeholder confidence. This study highlights neuroticism as a potential asset in project management if properly managed. Organizations can leverage this trait to enhance resilience, improve stress management, and optimize public infrastructure project outcomes.

Formulation of Framework for Implementing these Traits into Project Management Practices

This framework is designed to utilize insights into project managers' personality traits to improve the outcomes of public infrastructure projects in Malaysia. This framework integrates insights from the identified personality traits; openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism into practical project management strategies. This framework is composed of three main components: Identification and Assessment of Personality Traits, Tailored Project Management Strategies, and Continuous Development and Support that work collectively to assure that the strengths of different personality traits are put

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into consideration to assure the better results of a project. Based on the thematic findings, Figure 3 presents the proposed implementation framework.

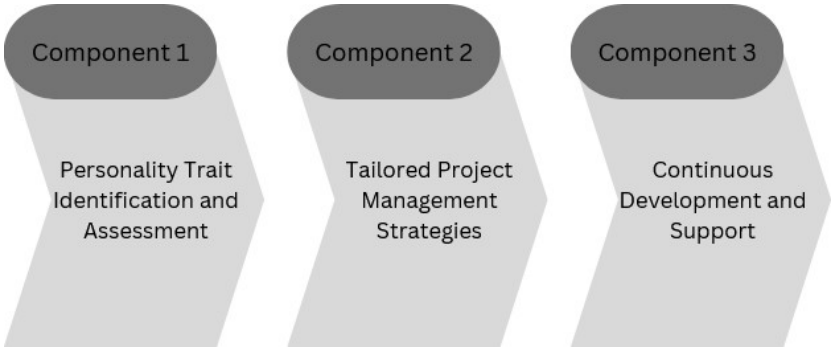


Figure 3: Component of Framework

The anticipated benefits of this framework include enhanced project performance, improved decision-making, better team dynamics, increased adaptability, higher stakeholder satisfaction, and significant personal and professional growth for project managers. These benefits collectively contribute to the successful delivery of public infrastructure projects in Malaysia, ensuring that they meet their objectives and deliver value to the community.

Table 2: Detail of Framework Component

Component	Description	Details
Personality Trait, Identification, and Assessment	Utilizing validated psychometric tools to measure key traits and develop detailed profiles	**Psychometric Tools**: Big Five Personality Test and other relevant tests. **Personality Profiles:** Comprehensive reports highlighting strengths and areas for improvement **Initial Training**: Sessions to help managers understand and leverage their traits
Tailored Project Management Strategies	Aligning project management strategies with individual traits to optimize performance	**Openness to Experience:** Encourage innovation and flexibility **Conscientiousness:** Emphasize meticulous planning and organization **Extraversion:** Focus on team coordination and stakeholder communication **Agreeableness:** Promote conflict resolution and team harmony

Component	Description	Details
		Neuroticism: Develop stress management and resilience strategies
Continuous Development and Support	Ensuring ongoing professional growth through training, mentorship, feedback and performance reviews	**Ongoing Training:** Regular workshops, seminars, and training session. **Mentorship Programs:** Pairing less experienced managers with seasone mentors **Feedback mechanism:** Implement 360-degree feedback and regular check-ins **Performance review:** Conduct formal reviews, create development plans and recognize high performance

CONCLUSION

This study highlights the significant impact of personality traits on project management, with a particular focus on improving the success of public infrastructure projects in Malaysia. By incorporating these traits into project management practices, organizations can optimize strategies, leading to more consistent outcomes. The proposed framework provides a practical guide for improving the selection, development, and performance of project managers, contributing to the successful delivery of infrastructure projects. This research offers both theoretical and practical contributions, emphasizing the integration of personality traits, HR strategies, and training programs to enhance project outcomes. Additionally, the focus on mentorship and peer support systems reinforces the importance of a supportive work environment in achieving success. The study deepens the understanding of project management in Malaysian public infrastructure projects by linking project managers' personality traits with the complexities of governance, stakeholder diversity, and regulatory pressures. Infrastructure projects are marked by multi-layered governance, coordination among multiple agencies, and varying regulatory expectations, all of which elevate project complexity (Omotayo et al., 2024). Effective stakeholder engagement is crucial for success, as diverse stakeholders including government bodies, contractors, and community representatives play significant roles in resource allocation and compliance (Prebanic & Vukomanovic, 2023). Research using the Big Five personality model suggests that traits like extraversion and openness positively predict project success, especially when influenced by external environmental factors such as political, economic, and social conditions (Hussain et al., 2021). Construction managers, in particular, often exhibit higher levels of extraversion, agreeableness, conscientiousness, and openness, which promote collaborative leadership and facilitate complex decision-making (Ling,

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Zhang and Wong, 2020). By integrating personality psychology with governance and stakeholder frameworks, this study underscores the importance of adaptive behavioral traits in project management. It suggests that project managers' competencies should extend beyond technical skills to include traits that aid stakeholder engagement, risk management, and regulatory compliance. Future research should aim to broaden the sample size, include diverse data sources to mitigate biases, and explore the role of personality traits across different sectors and types of projects. Additionally, future studies should investigate how organizational culture, economic conditions, and regulatory environments influence project management practices and outcomes.

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THE ABILITY-PARTICIPATION PARADOX IN GREEN TOURISM: AN SOR-BASED STUDY OF TOURIST PARTICIPATION IN HA GIANG, VIETNAM

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Abstract

Green tourism has become an important pathway for promoting sustainable destination development, yet tourists' actual participation in green tourism practices remains uneven. Existing studies have mainly explained sustainable tourist behavior through environmental awareness, attitudes, and intentions, but less attention has been paid to how external opportunities and tourists' engagement ability jointly shape participation. Drawing on the Stimulus-Organism-Response (SOR) framework, this study examines how green tourism opportunities, engagement ability, perceived green tourism, and motivation influence tourists' participation in green tourism. Data were collected from 522 domestic tourists in Ha Giang, Vietnam, an emerging mountainous destination with strong potential for green tourism development. PLS-SEM was used to assess the measurement and structural models. The findings show that perceived green tourism positively influences both motivation and participation, while motivation is the strongest direct predictor of participation. Green tourism opportunities significantly enhance motivation and participation, but do not significantly affect perceived green tourism, suggesting that opportunities mainly function as motivational and behavioral enablers rather than perception-changing stimuli. Engagement ability strongly increases perceived green tourism, but does not significantly affect motivation and has a significant negative effect on participation. This counterintuitive result suggests that more capable tourists may become more critical when green tourism practices appear inconvenient, superficial, or poorly implemented. The study contributes to green tourism literature by extending SOR theory, clarifying the perception-motivation-participation mechanism, and revealing the paradoxical role of engagement ability in emerging green destinations.

Keywords: green tourism, SOR theory, tourist behavior, engagement ability, green perception, green tourism opportunities.

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INTRODUCTION

Green tourism has become an important pathway for reducing the environmental costs of tourism while supporting more responsible forms of destination development (Ezeh & Dube, 2025; Xuan et al., 2024). As tourists increasingly encounter ecological degradation, climate-related risks, and sustainability campaigns, their participation in green tourism practices has become a central concern for both researchers and destination managers (Han et al., 2024; Vicente, 2024; Zhang et al., 2024). Recent studies show that sustainable tourist behavior is shaped by environmental concern, perceived effectiveness, green value, personal norms, motivation, and contextual opportunities ((Brian) Lin et al., 2022; Han, 2021; Li et al., 2024; Passafaro, 2020; Wut et al., 2023). However, despite this growing literature, an important question remains insufficiently explained: why do tourists who recognize the importance of green tourism not always participate in green tourism practices?

Prior research has largely examined green or pro-environmental tourist behavior through established frameworks such as the Theory of Planned Behavior (TPB), the Norm Activation Model (NAM), the Value-Attitude-Behavior (VAB) framework, and the Stimulus-Organism-Response (SOR) model (Hansen et al., 2024; He et al., 2023; Nguyen et al., 2024; Tang et al., 2022). These studies have clarified the roles of attitudes, norms, environmental awareness, and perceived behavioral control. Yet, they often underemphasize how tourists' engagement ability (AB) and available opportunities (OP) jointly shape the movement from perception and motivation to actual participation. This omission is important because tourists may support green tourism in principle but still fail to participate when green options are unclear, inconvenient, costly, weakly implemented, or disconnected from meaningful experiences (Li et al., 2024; MacInnes et al., 2022; Wut et al., 2023).

To address this gap, this study investigates tourists' participation in green tourism in Ha Giang, Vietnam, an emerging mountainous destination where natural and cultural assets create strong potential for green tourism but also raise concerns about sustainability management. Drawing on the SOR framework, the study examines how perceived green tourism (PE), motivation (MO), engagement ability (AB), and opportunities (OP) influence participation (PA) among 522 domestic tourists.

This study contributes to the literature in three ways. First, it extends SOR theory by integrating both external opportunities and internal enabling ability. Second, it clarifies the mechanism through which PE, MO, OP, and AB shape PA. Third, it reveals a counterintuitive finding: AB strengthens PE but may reduce PA, suggesting that capable tourists can become more critical when green tourism practices lack credibility or accessibility.

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LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

This study adopts the Stimulus-Organism-Response (SOR) framework to explain tourists' participation in green tourism (Qiu et al., 2023). Within this logic, green tourism opportunities (OP) represent external stimuli, tourists' perceived green tourism (PE), engagement ability (AB), and motivation (MO) represent organismic conditions, and participation (PA) is the behavioral response. The SOR model is useful because sustainable tourist behavior is rarely driven by a single factor; rather, it emerges from the interaction between environmental perception, contextual cues, motivation, ability, norms, and perceived control ((Brian) Lin et al., 2022; Han, 2021; Li et al., 2024; Tang et al., 2022; Wut et al., 2023).

Perceived green tourism (PE) refers to the extent to which tourists recognize and internalize the ecological, cultural, and social value of green tourism (Han et al., 2024; Khairy et al., 2023). Prior studies show that environmental concern, awareness, green value, perceived effectiveness, and sustainability perception are key antecedents of pro-environmental tourist behavior ((Brian) Lin et al., 2022; Han, 2021; Ibnou-Laaroussi et al., 2020; Passafaro, 2020). From the Value-Belief-Norm (VBN) perspective, tourists with stronger environmental values are more likely to develop personal responsibility toward sustainable action. Similarly, studies using the Theory of Planned Behavior (TPB) confirm that favorable attitudes and perceived green value strengthen sustainable tourism intention and behavior (Demirović Bajrami et al., 2025; Hansen et al., 2024; Nguyen et al., 2024). PE may also activate motivation because tourists are more likely to participate when green tourism is perceived as meaningful, ethical, and personally relevant (Han, 2021; Wut et al., 2023; Yaja et al., 2026). Thus, PE is both a cognitive evaluation and a motivational resource.

H1: Perceived green tourism (PE) positively influences tourists' motivation (MO) to engage in green tourism.
H2: Perceived green tourism (PE) positively influences tourists' participation (PA) in green tourism.

Engagement ability (AB) refers to tourists' perceived capacity to participate in green tourism, including knowledge, resources, confidence, time, financial capacity, and perceived ease of action (Fauzi et al., 2024; Zhang et al., 2025). AB is closely related to perceived behavioral control in TPB, which reflects whether individuals believe they have sufficient ability and resources to perform a behavior (Fauzi et al., 2024). Previous research suggests that perceived behavioral control, self-efficacy, internal environmental locus of control, and perceived effectiveness can strengthen environmental attitudes, intentions, and responsible behavior (Han, 2021; Luong, 2025; Passafaro, 2020; Xu et al., 2023).

However, recent studies also show that ability does not always translate into action. Tang et al. (2022) found that participation ability did not significantly enhance tourists' pro-environmental behavior (Tang et al., 2022), while research on the attitude-behavior gap shows that capable tourists may still fail to act when sustainable options are inconvenient, costly, unclear, or poorly implemented (Li et al., 2024; MacInnes et al., 2022; Wut et al., 2023). Nevertheless, AB is expected to enhance tourists' perception, motivation, and participation because it increases their confidence in acting sustainably.

H3: Tourists' engagement ability (AB) positively influences their motivation (MO) to engage in green tourism.
H4: Tourists' engagement ability (AB) positively influences their participation (PA) in green tourism.
H5: Tourists' engagement ability (AB) positively influences their perceived green tourism (PE).

Opportunities (OP) refer to the availability, visibility, and accessibility of green tourism products, services, infrastructure, and programs, such as eco-certified accommodation, recycling facilities, conservation activities, environmental education, green transport, and community-based tourism options (Hansen et al., 2024; Tang et al., 2022). According to the Motivation-Opportunity-Ability (MOA) perspective, behavior occurs when individuals are motivated, have opportunities to act, and possess sufficient ability (Jiao & Wang, 2025; Tang et al., 2022). In tourism, OP can reduce practical barriers, increase convenience, and turn abstract environmental concern into concrete action. Environmental communication research further shows that nature-based settings provide opportunities for place-based messages and interventions to influence tourists' perceptions and behaviors (He et al., 2023). Broader studies also emphasize that destination infrastructure, service systems, social interaction, and cultural norms shape sustainable tourist behavior (Abdullah et al., 2024; Hansen et al., 2024; Li et al., 2024). Therefore, OP may strengthen PE, stimulate MO, and directly facilitate PA.

H6: Opportunities (OP) positively influence tourists' perceived green tourism (PE).
H7: Opportunities (OP) positively influence tourists' participation (PA) in green tourism.
H8: Opportunities (OP) positively influence tourists' motivation (MO) to engage in green tourism.

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Finally, motivation (MO) is expected to directly influence participation (PA). Motivation represents the internal psychological drive that initiates and sustains behavior (Han, 2021). Recent studies and meta-analyses identify motivation, personal norms, anticipated positive emotions, moral obligation, and willingness to change as strong drivers of sustainable tourist behavior ((Brian) Lin et al., 2022; Gao et al., 2023; Hansen et al., 2024; Yaja et al., 2026). MO is therefore conceptualized as the key organismic mechanism linking perception and opportunity to green tourism participation.

H9: Motivation (MO) positively influences tourists' participation (PA) in green tourism.

Based on these arguments, the proposed model positions OP as the external stimulus, PE, AB, and MO as organismic conditions, and PA as the behavioral response. The hypothesized relationships are shown in Figure 1.

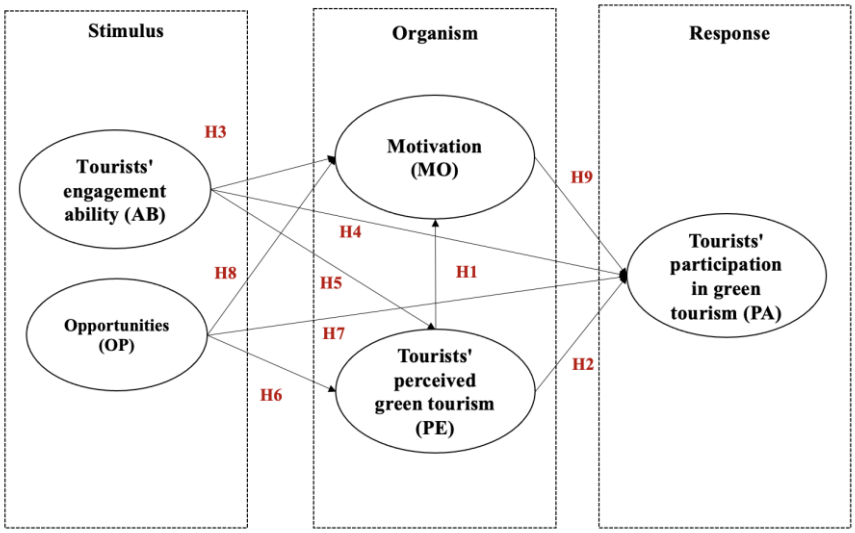


Figure 1. Proposed research model
Source: Authors' own work.

METHOD

This study employed a quantitative research design to examine the factors influencing tourists' participation in green tourism. The proposed model investigates the relationships among green tourism opportunities (OP), engagement ability (AB), perceived green tourism (PE), motivation (MO), and

participation (PA) using Partial Least Squares Structural Equation Modeling (PLS-SEM).

Before the main survey, a preliminary study was conducted in July 2024 with 150 domestic tourists through an online questionnaire. This pilot phase helped assess the clarity, relevance, and reliability of the measurement items. Minor wording adjustments were made before the final survey.

Main data were collected from 522 domestic tourists who had visited or expressed interest in green tourism activities in Ha Giang, a mountainous province in northern Vietnam known for its natural landscapes and emerging green tourism potential. Data collection took place from July to December 2024 using both online and face-to-face surveys. A convenience sampling approach was adopted. Online questionnaires were distributed through tourism-related websites and social media channels, while face-to-face surveys were administered at major tourist sites in Ha Giang.

PLS-SEM was selected because it is suitable for testing complex models, handling non-normal data, and assessing measurement and structural models simultaneously (Hair et al., 2021). Ethical procedures included informed consent, voluntary participation, anonymity, and confidentiality.

RESULTS AND DISCUSSION

Demographic characteristics of the sample

The survey results reveal several key demographic characteristics of the sample. In terms of gender, 231 participants were male, accounting for 44.3% of the sample, while 291 were female, representing 55.7%. This indicates a higher proportion of female participants in the survey.

Regarding age, the majority of participants were under 25 years old, comprising 49.6% of the sample with 259 individuals in this category. The other age groups included 16.9% aged between 25 and 34 years (88 participants), 16.1% aged between 35 and 44 years (84 participants), 14.9% aged between 45 and 54 years (78 participants), and 2.5% were 55 years or older (13 participants). Thus, younger individuals made up the largest portion of the sample.

When examining monthly income, the majority of participants, 51.7% (270 individuals), reported a monthly income of up to 10 million VND. The next largest group, 30.8% (161 participants), earned between 10 million and 18 million VND monthly, followed by 15.7% (82 participants) who earned between 18 million and 32 million VND, and 1.7% (9 participants) whose monthly income exceeded 32 million VND.

As for educational attainment, 12.3% (64 participants) had education levels below undergraduate, 49.0% (256 participants) held a undergraduate degree, and 38.7% (202 participants) had completed postgraduate. This demonstrates that a significant portion of the sample possessed at least a

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university degree, with a noteworthy proportion having postgraduate qualifications.

Measurement model assessment

The measurement model was assessed in terms of indicator reliability, internal consistency reliability, convergent validity, discriminant validity, and multicollinearity. First, indicator reliability was evaluated using the outer loadings of the indicators for each construct. Following Hair et al. (2021), loadings above 0.708 indicate acceptable indicator reliability. The initial assessment showed that one item, PA8, had a loading below the recommended threshold and was therefore removed. After re-estimating the model, all remaining items exhibited satisfactory loadings, ranging from 0.731 to 0.910. This result indicates that the retained indicators adequately represent their corresponding latent constructs.

Second, internal consistency reliability was examined using Cronbach's alpha and composite reliability (CR). The values for all constructs exceeded the recommended threshold of 0.70, demonstrating satisfactory reliability. Convergent validity was then assessed through the average variance extracted (AVE). All AVE values were above the minimum threshold of 0.50, ranging from 0.642 for motivation (MO) to 0.797 for engagement ability (AB). These results confirm that the constructs achieved adequate convergent validity.

Discriminant validity was assessed using both the heterotrait-monotrait ratio (HTMT) and the Fornell-Larcker criterion. All HTMT values were below the conservative threshold of 0.85, with the highest value observed between AB and perceived green tourism (PE) (0.830). In addition, the Fornell-Larcker results showed that the square root of the AVE for each construct was greater than its correlations with other constructs. Thus, discriminant validity was established.

Finally, multicollinearity was examined using variance inflation factor (VIF) values. All VIF values ranged from 1.012 to 2.663, well below the critical threshold of 5. This indicates that multicollinearity was not a serious concern in the structural model.

Structural model assessment and hypothesis testing

The results of the analysis, using a significance level of 5% and a bootstrap sample size of 10,000, show that the adjusted R^2 value is 34.3% (see Figure 2). This suggests that the model effectively captures the key factors that influence tourists' engagement in green tourism, with a significant portion of the variation in motivation, engagement ability, and participation being accounted for by the constructs involved.

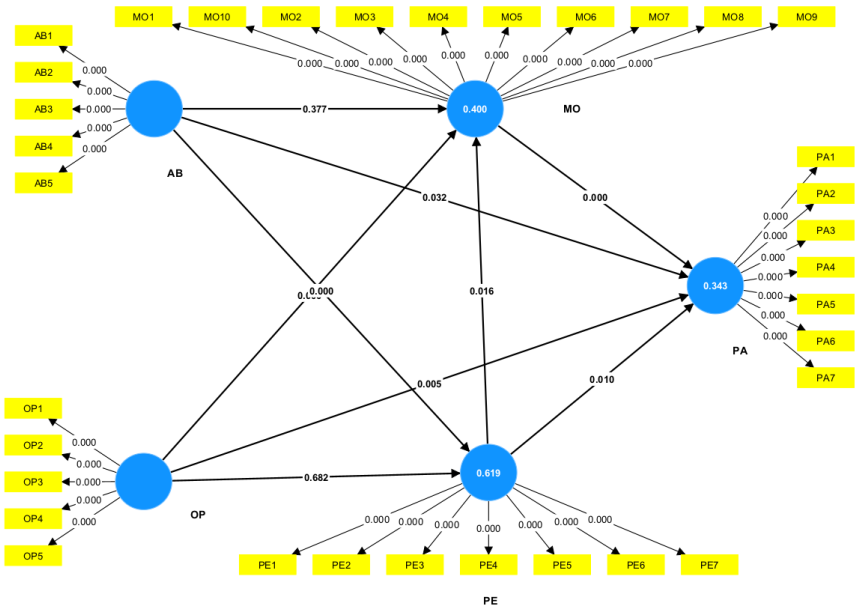


Figure 2. Empirical testing of the study's model.
Source: Authors' own work.

The following Table 1 presents the original sample values (O), sample means (M), and p-values for the hypotheses tested:

Table 1. Structural model assessment: hypotheses testing

Hypotheses		Original sample (O)	Sample mean (M)	P-values	Reference
H1	PE -> MO	0.123	0.123	0.016	Support
H2	PE -> PA	0.169	0.167	0.010	Support
H3	AB -> MO	-0.047	-0.047	0.377	*Not support*
H4	AB -> PA	-0.142	-0.140	0.032	*Reject*
H5	AB -> PE	0.787	0.785	0.000	Support
H6	OP -> PE	0.011	0.011	0.682	*Not support*
H7	OP -> PA	0.162	0.162	0.005	Support
H8	OP -> MO	0.622	0.620	0.000	Support
H9	MO -> PA	0.458	0.459	0.000	Support

Source: Authors' own work.

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The structural model was evaluated by examining the path coefficients and their statistical significance. The results indicate that perceived green tourism (PE) had a positive and significant effect on motivation (MO) ($\beta = 0.123$, $p = 0.016$), supporting H1. PE also positively influenced participation (PA) ($\beta = 0.169$, $p = 0.010$), thereby supporting H2. These findings suggest that tourists who perceive green tourism more positively are more likely to be motivated and to participate in green tourism practices.

The results related to engagement ability (AB) were more complex. AB did not have a significant effect on MO ($\beta = -0.047$, $p = 0.377$); therefore, H3 was not supported. More notably, although the effect of AB on PA was statistically significant ($\beta = -0.142$, $p = 0.032$), the direction of the relationship was negative, contrary to the hypothesized positive effect. Thus, H4 was rejected. This result suggests that higher engagement ability does not necessarily translate into greater participation and may even be associated with lower participation in green tourism practices. However, AB had a strong positive effect on PE ($\beta = 0.787$, $p < 0.001$), supporting H5. This indicates that tourists with higher engagement ability are more likely to develop stronger perceptions of green tourism.

Regarding opportunities (OP), the effect of OP on PE was positive but not statistically significant ($\beta = 0.011$, $p = 0.682$), meaning that H6 was not supported. In contrast, OP had a positive and significant effect on PA ($\beta = 0.162$, $p = 0.005$), supporting H7. OP also exerted a strong positive effect on MO ($\beta = 0.622$, $p < 0.001$), supporting H8. These findings show that green tourism opportunities mainly operate by strengthening tourists' motivation and directly encouraging participation, rather than by changing their perceptions of green tourism.

Finally, MO had a positive and significant effect on PA ($\beta = 0.458$, $p < 0.001$), supporting H9. This confirms that motivation is a central psychological driver of tourists' participation in green tourism. Overall, six hypotheses were supported (H1, H2, H5, H7, H8, and H9), two hypotheses were not supported due to non-significant effects (H3 and H6), and one hypothesis was rejected because the significant effect was opposite to the expected direction (H4).

DISCUSSION

The findings offer a more differentiated explanation of tourists' participation in green tourism by showing that participation is shaped by the combined effects of perception, motivation, opportunity, and engagement ability rather than by environmental awareness alone. First, perceived green tourism (PE) positively influenced both motivation (MO) and participation (PA). This result confirms that tourists who recognize the ecological and social value of green tourism are more likely to develop internal motivation and translate this perception into actual

participation. It is consistent with prior research showing that environmental concern, awareness, green value, and perceived effectiveness are central predictors of sustainable tourist behavior ((Brian) Lin et al., 2022; Demirović Bajrami et al., 2025; Han, 2021; Li et al., 2024; Passafaro, 2020). More importantly, this finding supports the view that PE is not merely a cognitive judgment; it functions as an organismic appraisal that activates behavioral readiness.

Second, motivation emerged as the strongest direct predictor of participation. This finding reinforces the importance of motivational activation in green tourism behavior. It aligns with studies showing that motivation, personal norms, anticipated positive emotion, moral responsibility, and willingness to change are powerful drivers of pro-environmental action ((Brian) Lin et al., 2022; Gao et al., 2023; Hansen et al., 2024; Yaja et al., 2026). Within the Stimulus-Organism-Response (SOR) framework, MO serves as the key internal mechanism through which tourists convert environmental perception and external opportunities into green tourism participation.

Third, opportunities (OP) significantly influenced both MO and PA, but did not significantly affect PE. This suggests that green tourism opportunities operate mainly as behavioral enablers and motivational triggers, not as perception-changing stimuli. Green facilities, eco-friendly services, conservation activities, and environmental programs may make participation easier and more attractive, but they do not automatically reshape tourists' deeper understanding of green tourism. This finding extends previous work on environmental communication and opportunity-based interventions by showing that opportunities require interpretation, credibility, and emotional relevance to influence perception (He et al., 2023; Jiao & Wang, 2025; Tang et al., 2022; Wut et al., 2023).

The most novel finding concerns engagement ability (AB). AB strongly increased PE, but did not significantly affect MO and had a significant negative effect on PA. This result challenges the common assumption that greater ability necessarily leads to stronger participation. One explanation is that more capable tourists may also be more critical: they may recognize the importance of green tourism but become less willing to participate when green practices appear inconvenient, symbolic, costly, poorly organized, or inconsistent with genuine sustainability. This interpretation resonates with research on the attitude-behavior gap, perceived behavioral control, eco-paralysis, and the limits of ability-based explanations in sustainable tourism (Li et al., 2024; MacInnes et al., 2022; Tang et al., 2022; Wut et al., 2023).

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Theoretical contributions

This study makes three theoretical contributions to green tourism and sustainable tourist behavior research. First, it extends the Stimulus-Organism-Response (SOR) framework by showing that green tourism participation is shaped by both external enabling conditions and internal psychological mechanisms. In this model, opportunities (OP) operate as external stimuli, while perceived green tourism (PE), motivation (MO), and engagement ability (AB) function as organismic conditions that shape participation (PA). This structure advances prior SOR-based studies by moving beyond a simple stimulus-attitude-behavior logic and demonstrating that tourists' green participation depends on how opportunities activate motivation and how internal capacities shape perception.

Second, the study contributes to the literature by distinguishing between perception, motivation, ability, opportunity, and participation rather than treating green behavior as a direct consequence of environmental awareness. The results show that PE directly enhances both MO and PA, while MO remains the strongest immediate predictor of PA. This finding clarifies the internal mechanism of green tourism participation: tourists are more likely to participate when green tourism is cognitively recognized as valuable and affectively transformed into motivation. Thus, the study reinforces the need to examine not only what tourists know or perceive, but also how such perceptions become motivationally meaningful.

Third, the most distinctive contribution lies in the counterintuitive role of AB. Although AB strongly increases PE, it does not significantly enhance MO and even negatively affects PA. This finding challenges the conventional assumption that greater ability automatically leads to greater sustainable behavior. Instead, AB may make tourists more evaluative and critical. Tourists with higher ability may better recognize the importance of green tourism, but they may also be more sensitive to weak infrastructure, symbolic green practices, inconvenience, cost, or poor implementation. The study therefore introduces a more nuanced interpretation of ability: ability can strengthen green perception without necessarily producing participation when destination-level conditions are insufficient.

Practical implications

The findings provide several implications for destination managers, tourism businesses, and local authorities. First, green tourism development should not rely only on awareness campaigns. Since MO is the strongest driver of PA, destinations need to design experiences that make green tourism personally meaningful, emotionally engaging, and easy to join. Environmental interpretation, local storytelling, guided conservation activities, and visible feedback on tourists' contributions can transform green tourism from a moral message into a motivating experience.

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Second, OP should be treated as a practical lever for participation. The significant effects of OP on MO and PA suggest that tourists are more likely to participate when green options are visible, accessible, and well integrated into the trip. In destinations such as Ha Giang, this may include eco-certified homestays, community-based tours, waste-reduction systems, refill stations, low-impact transport, conservation fees with transparent use, and local product purchasing channels. However, because OP does not significantly affect PE, green facilities should be accompanied by clear interpretation. Tourists need to understand why these practices matter, not merely encounter them as available services.

Third, the negative AB → PA relationship has important managerial implications. More capable tourists may become disappointed if green tourism practices are superficial or inconvenient. Therefore, destinations should avoid symbolic or poorly executed green programs. Instead, they should provide credible information, transparent environmental standards, reliable service quality, and meaningful participation pathways. For knowledgeable tourists, authenticity and trust are crucial. Green tourism must be designed not only to attract participation, but also to withstand critical evaluation.

Limitations and future research

This study has several limitations. First, the data were collected from domestic tourists in Ha Giang, a mountainous destination in Vietnam. Although this context is highly relevant for green tourism, future studies should test the model in other destinations, such as coastal, island, urban, or heritage sites, to assess its generalizability. Second, the study used cross-sectional survey data, which limits causal inference. Longitudinal or experimental designs could better explain how perception, motivation, ability, and opportunity evolve before, during, and after the trip. Third, participation was measured through self-reported responses, which may be affected by social desirability or intention-behavior gaps. Future research should combine surveys with observational data, behavioral tracking, or field experiments. Future studies should also examine the boundary conditions of AB. The negative effect found in this study suggests that ability may interact with perceived authenticity, greenwashing skepticism, service quality, trust, cost, or convenience. Testing these moderators would clarify when ability promotes participation and when it produces critical disengagement.

CONCLUSION

This study shows that tourists' participation in green tourism is not driven by awareness alone. Participation emerges through the interaction between perception, motivation, opportunities, and ability. The findings confirm the central role of motivation, highlight the enabling power of opportunities, and reveal the paradoxical role of engagement ability. In emerging green destinations,

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capable tourists may perceive green tourism more strongly but participate less when destination practices fail to meet their expectations. Green tourism therefore requires more than green messages. It requires credible, accessible, and meaningful systems that allow tourists to act on what they know and value.

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CONCEPTUALIZING PLACE-BASED AGING: AN ANALYSIS OF STRUCTURAL EQUATION MODELS FOR MALAYSIAN SENIORS

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Abstract

This research examines aging in place among older persons in Malaysia, emphasizing the interconnected roles of assistive technology, quality of life, and age-friendly surroundings in facilitating this process. With Malaysia's senior demographic anticipated to rise from 10.3% in 2020 to 15.3% by 2030, the necessity for appropriate methods to facilitate aging in place has become increasingly pressing. This study analyzes survey data from 499 participants aged 60 to 75, investigating the impact of assistive technology on physical health, psychological well-being, and social involvement, revealing substantial improvements in quality of life. Furthermore, age-friendly surroundings enhance autonomy by alleviating environmental obstacles. Nonetheless, adoption obstacles, such as budgetary limitations and insufficient technological expertise, hinder the efficacy of assistive devices for certain seniors. This article emphasizes the importance of a balanced strategy that combines technological and human support, providing guidance for policymakers to create interventions that preserve the autonomy and dignity of older individuals in Malaysia.

Keywords: Ageing in place; assistive technology; quality of life; age-friendly environment; Structural Equation Modelling (SEM)

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INTRODUCTION

The concept of aging in place, which refers to the ability of individuals to continue living in their own homes and communities as they grow older, has garnered significant attention from researchers, policymakers, and healthcare providers in recent years. This concept reflects the preferences of many older adults who seek to maintain their independence, autonomy, and connection to familiar environments (Hatcher et al., 2019; Pynoos et al., 2010). Aging in place offers not only personal and emotional advantages but also psychological well-being, as remaining in a known setting reduces stress, anxiety, and feelings of isolation. Beyond individual benefits, aging in place presents broader societal value by contributing to cost savings in healthcare systems, primarily through delaying or reducing the need for institutional care, such as nursing homes or assisted living facilities. Such outcomes align with efforts to create sustainable care models that prioritize community-based solutions over institutional alternatives.

The global trend of population aging has brought about an urgent need for effective strategies that support older adults in achieving aging in place. One promising approach involves the use of assistive technologies, including devices such as smartphones, health-monitoring applications, and safety sensors, which can facilitate daily activities, enhance communication with family and caregivers, and provide access to essential services (Hatcher et al., 2019; Thakur & Han, 2021). These technologies enable older adults to remain connected, manage health conditions remotely, and maintain social interaction, which are key contributors to independent living. However, the success of these interventions depends on several contextual factors. The effectiveness of assistive technologies is influenced by the overall quality of life experienced by seniors, the availability of supportive services, and the presence of an age-friendly environment. Age-friendly environments offer accessible infrastructure, transportation, and social support systems that empower seniors to navigate their surroundings comfortably and safely. The interplay between these variables determines the extent to which older adults can successfully age in place.

In Malaysia, the demographic landscape is shifting rapidly, with a marked increase in the aging population. Department of Statistics Malaysia (2023) projects that the proportion of individuals aged 60 years and above will rise from 10.3% in 2020 to 15.3% by 2030. This demographic transition poses both challenges and opportunities for Malaysian society. On one hand, it necessitates the development of comprehensive strategies to address the growing needs of older adults, particularly in terms of healthcare, social services, and housing. On the other hand, it presents an opportunity to enhance public policy frameworks that promote well-being, independence, and dignity for seniors. Recognizing the importance of these efforts, the Malaysian government has

introduced initiatives such as the National Policy for Older Persons and the Action Plan for Older Persons, both of which emphasize the creation of age-friendly environments that support active and independent aging. These policies align with global recommendations from organizations such as the World Health Organization (WHO) to build inclusive and sustainable communities for aging populations.

Despite these policy directives, empirical research investigating the actualization of aging in place in Malaysia remains fragmented. While existing global literature has extensively explored assistive technology, quality of life, and age-friendly environments, previous studies have largely examined these factors in isolation (Tobi et al., 2017). There is a distinct lack of research that integrates these specific variables into a unified, comprehensive framework. This integration is particularly crucial in the Malaysian context, where unique cultural nuances, multi-generational family structures, and developing infrastructural landscapes mean that models derived from Western studies may not fully translate to local realities (Makhtar et al., 2023). Overlooking the complex interrelationships between technological adoption, environmental support, and the subjective well-being of Malaysian older adults leaves a critical blind spot in current literature (Abdullah et al., 2024).

To address this gap, this research aims to examine the interrelationships between aging in place and three critical variables: assistive technology adoption, quality of life, and the presence of age-friendly environments. The goal is to identify the factors that significantly influence the elderly's desire and ability to remain in their own homes and communities as they age. To achieve this objective, the research employed a survey-based approach, gathering data from 499 respondents aged between 60 and 75 years through snowball sampling. Snowball sampling was chosen due to its effectiveness in recruiting participants from hard-to-reach populations, such as older adults who may not actively engage with conventional research recruitment methods. The survey instrument was designed to capture data on the use of assistive technologies, perceptions of quality of life, and the availability of age-friendly amenities in the respondents' living environments.

The data analysis involved both descriptive and inferential statistics, as well as Partial Least Squares (PLS) analysis, a structural equation modelling technique suitable for complex models with latent variables. PLS analysis enabled the exploration of both direct and indirect relationships among the constructs, providing insights into how assistive technology, quality of life, and environmental factors interact to influence aging in place. This comprehensive analytical approach ensured that the nuanced relationships between these variables were adequately captured, contributing to a deeper understanding of the factors that affect the elderly's ability to live independently. The findings of this

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research are expected to make a significant contribution to the growing body of knowledge on aging in place, particularly within the Malaysian context. By providing empirical evidence on the role of assistive technology, quality of life, and environmental factors, the research offers valuable insights for policymakers, service providers, and researchers working to support aging populations. The outcomes are also intended to inform the development of policies, programs, and practices that foster senior citizens' ability to remain in their own homes while maintaining their well-being and autonomy. Moreover, by addressing the specific needs and preferences of Malaysian seniors, stakeholders will be better equipped to design targeted interventions that promote aging in place, ensuring that the elderly population can enjoy an enhanced quality of life while staying connected to their communities.

LITERATURE REVIEW

The concept of "ageing in place" has garnered significant attention in recent years, particularly in the context of Malaysia, where the elderly population is projected to increase substantially. Ageing in place refers to the ability of older adults to live in their own homes and communities safely, independently, and comfortably, regardless of age or ability level. This concept is critical for enhancing the quality of life for the elderly, as it allows them to maintain their social connections and familiar environments, which are essential for their well-being (Azmi et al., 2021; Emlet & Moceri, 2012). In Malaysia, the demographic shift towards an ageing population necessitates a comprehensive understanding of the factors that influence the ability of older adults to age in place. Research indicates that the elderly in both urban and rural settings prefer to remain in familiar environments, highlighting the importance of community and social connectedness in facilitating ageing in place (Aini et al., 2016). The preference for ageing in place is particularly pronounced among rural elderly, who often have stronger ties to their communities and family networks compared to their urban counterparts (Aini et al., 2016). This preference underscores the need for policies and infrastructure that support the elderly in their desire to remain in their homes and communities. Social connectedness plays a pivotal role in the ageing in place framework. Emlet and Moceri emphasize that older adults who engage in volunteer and community activities are more likely to experience a sense of belonging and purpose, which can mitigate feelings of isolation and loneliness (Emlet & Moceri, 2012). This is particularly relevant in Malaysia, where traditional family structures are evolving, and many elderly individuals may find themselves living alone or with limited social interaction (Hung et al., 2010). The development of age-friendly communities that promote social engagement and connectivity is essential for supporting the elderly population in Malaysia (Lai et al., 2016).

To rigorously examine the multifaceted nature of ageing in place, this study is anchored in two complementary theoretical frameworks: Lawton's Ecological Model of Aging (Person-Environment Fit Theory) and the Technology Acceptance Model (TAM). Lawton and Nahemow (1973) assert that successful ageing in place depends on a dynamic equilibrium between an individual's competencies (quality of life, mobility) and the "environmental press" or demands of their surroundings (built infrastructure). When an environment is age-friendly, it lowers the environmental press, allowing older adults with declining physical competencies to maintain independence. Concurrently, to understand the integration of modern solutions, TAM (Davis, 1989) provides a lens through which assistive technology adoption is evaluated based on perceived usefulness and perceived ease of use. While these frameworks have been extensively validated in Western literature, their application within an Eastern, developing context requires careful recalibration to account for distinct socio-cultural variables.

The built environment significantly impacts the ability of older adults to age in place. Tobi et al. highlight that the design of housing and community infrastructure must cater to the specific needs of the elderly, including accessibility features and proximity to essential services (Mohd Tobi et al., 2018). The lack of suitable housing options can create barriers to ageing in place, particularly for those with mobility challenges (Mohamad Bohari et al., 2024). Furthermore, Lai et al. assert that transportation and housing are critical components of an age-friendly environment, enabling the elderly to participate in community activities and access healthcare services (Lai et al., 2016). In addition to physical infrastructure, the socio-economic context also influences the quality of life for the elderly in Malaysia. Many older adults face financial constraints that limit their ability to maintain their homes or access necessary services (Che Amani Nurfadhilah & Kahar Rojanah, 2021; Khan & Tahir, 2014). The government and community organizations must work collaboratively to provide support systems that address these financial challenges, ensuring that the elderly can age in place without undue stress (Noor et al., 2020).

Moreover, the role of education and lifelong learning cannot be overlooked in the context of ageing in place. As highlighted by Abdul Mutalib et al. (2023), prioritizing education for the elderly can empower them to adapt to changing circumstances. However, what constitutes "adaptation" varies significantly across cultures. Contrasting studies from Western contexts, such as those in Scandinavian countries or the United States, often frame ageing in place around individualism, where success is defined by self-reliance, privacy, and state-funded welfare support or robust pension systems (Ahn et al., 2020). In contrast, the Malaysian context is heavily influenced by collectivist values and the concept of filial piety (*tanggungjawab anak*). Traditional beliefs position the

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family, rather than the state, as the primary safety net (Hung et al., 2010). This cultural divergence directly impacts how variables like housing and technology are utilized. For instance, while Western studies frequently highlight the use of assistive smart home technologies for independent, solitary living (Peek et al., 2014), technology adoption among Malaysian elderly is often driven by a desire for social connectedness and intergenerational communication, such as using smartphones to stay in touch with extended family rather than for health monitoring.

Furthermore, socio-economic factors starkly differentiate the Malaysian experience. Unlike developed nations with comprehensive long-term care insurance, many Malaysian older adults face financial vulnerabilities due to inadequate retirement savings and out-of-pocket healthcare expenses(Che Amani Nurfadhilah & Kahar Rojanah, 2021). Therefore, models of ageing in place derived from Western literature which often assume a baseline of financial independence and state support must be critically adapted. As societal norms in Malaysia shift towards dual-income households and urban migration among the younger generation, there is a growing tension between traditional expectations of co-residence and the modern reality of elderly individuals living alone. This necessitates a uniquely Malaysian approach to ageing in place, balancing traditional familial support with the development of age-friendly community infrastructure and accessible assistive technologies. Therefore, models of ageing in place derived from Western literature which often assume a baseline of financial independence and state support must be critically adapted. As societal norms in Malaysia shift towards dual-income households and urban migration among the younger generation, there is a growing tension between traditional expectations of co-residence and the modern reality of elderly individuals living alone. This necessitates a uniquely Malaysian approach to ageing in place, balancing traditional familial support with the development of age-friendly community infrastructure and accessible assistive technologies.

Research on aging in place reveals several key gaps and methodological considerations. There is a need for more patient-centred interventions that align with older adults' goals and include social support, healthcare, and personal care services (Moscou-Jackson et al., 2019). The same study emphasized the need to focus on informal caregiver interventions, as they play a crucial role in enabling aging in place. Technology acceptance is influenced by various factors, including concerns about cost and privacy, expected benefits, perceived need, and social influence (Peek et al., 2014). However, research on post-implementation acceptance is scarce. Current studies on digital technologies for aging in place have primarily focused on efficacy and usability rather than their impact on re/enablement outcomes for older adults (Horne, 2023). Future research should address these gaps and explore factors that enhance the usability of digital

technologies by older people, utilizing qualitative approaches to gain valuable insights (Frochen & Pynoos, 2017; Horne, 2023). Yap et al. (2022) noted that most studies on the elderly are cross-sectional rather than longitudinal. While longitudinal studies provide deeper insights into trends over time, this research contends that a robust conceptual foundation must first be established through a review of existing literature before a longitudinal investigation is undertaken. In this context, the principles of ageing in place such as the ability to live independently in one's familiar environment with access to essential resources serve as the primary focus of the conceptual framework for this research. Consequently, this research employed a quantitative methodology, which involved the collection and analysis of numerical data using specific research designs grounded in relevant philosophical assumptions and theoretical frameworks. The quantitative approach was selected to facilitate objective measurement of constructs central to the elderly population, such as quality of life, mobility, and assistive technology usage.

This research intends to propose and examine a primary objective: to assess the influence of assistive technology, quality of life, and age-friendly surroundings on the aging-in-place process among senior adults. The research employs Partial Least Squares Structural Equation Modelling (PLS-SEM) as the principal analytical technique to rigorously analyse the correlations among the variables. This research framework incorporated three essential elements: assistive technology, quality of life, and environmental design into a holistic model that encapsulates the multifaceted dimensions of aged care in Malaysia. This approach enhances existing scholarships by providing new insights into how these elements collectively affect the ability of elderly individuals to age in place, defined as their capacity to maintain independence and reside comfortably in their homes or communities as they age. The findings seek to offer a detailed comprehension of these links, which can guide future policies and interventions designed for Malaysia's ageing population.

The theoretical framework proposed by this research is constructed as follows:

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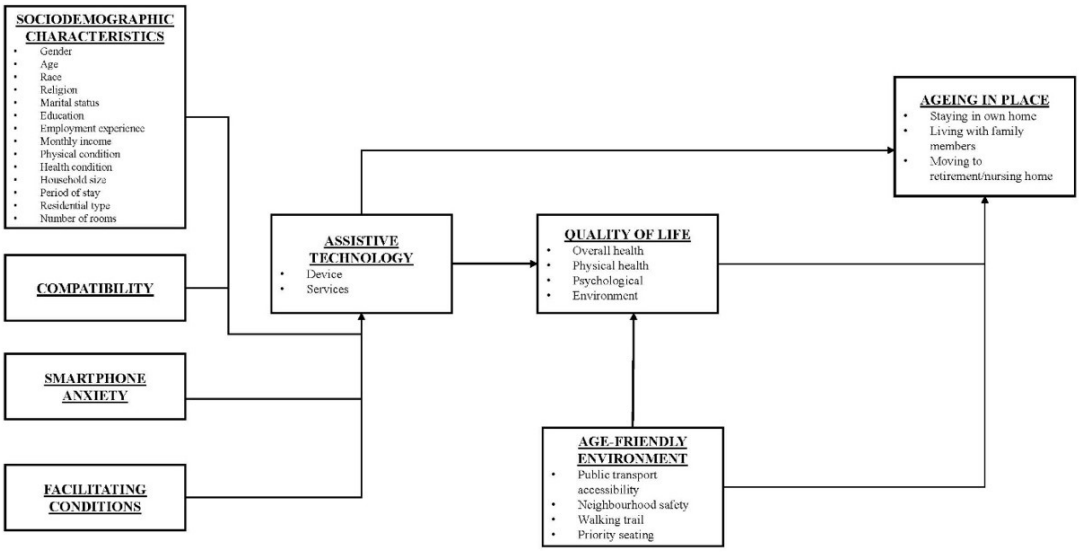


Figure 1: Research conceptual framework

The framework schematized ageing in place according to the usage of assistive technology, the impact of the quality of life among the elderly people and the assessment of person and place integration through age-friendly environment. Another scientific investigation for this research includes the evaluation of factors affecting technological adaptation such as sociodemographic characteristics, compatibility, smartphone anxiety and facilitating conditions. Within this framework, a high level of preference for one of these factors is likely to result in one choosing to age in place. This research investigated the complex concept of ageing in place, and it did this by measuring individual's preferences towards the ability to overcome physical dependence through usage of assistive technology, effort to ensure social connectedness through quality of life and feelings of belongs to place via person-place integration analysis through age-friendly environment.

RESEARCH METHODOLOGY

The first phase of this research involved reviewing secondary data from the Department of Statistics Malaysia as well as pertinent government policies on transportation, health, and the elderly. These secondary sources gave fundamental insights into the existing situation of older mobility and quality of life in Malaysia, indicating gaps and potential for future research. A Systematic

Literature Review (SLR) employing academic sources such as Scopus, Web of Science, and Google Scholar supplemented the secondary data analysis. The SLR contributed to the definition of the research objectives and research questions by synthesizing the most recent data on ageing in place, assistive technologies, and supportive environmental circumstances. Building on the insights from the literature, research instruments were developed to assess key constructs, including quality of life, assistive technology adoption, age-friendly environments, and perceived needs. These constructs were operationalized into measurable variables, forming the basis of the survey. To ensure the validity and reliability of these instruments, a pilot study involving 35 participants was conducted. The pilot provided valuable feedback regarding the survey's duration, complexity, and appropriateness for elderly respondents. Following Malmqvist et al. (2019), the pilot phase was crucial in identifying potential issues, such as confusing questions or design flaws, allowing for timely adjustments and improvements to enhance the overall research quality. Specifically, based on the pilot feedback, the physical survey's font size was increased for better readability, complex technical terms regarding assistive technologies were reworded into everyday language, and the questionnaire was streamlined to prevent respondent fatigue. The pilot study's input informed the necessary revisions to improve clarity and usability. Following then, the predominant sampling method was snowball sampling. This methodology enabled existing participants to recommend new responders, which was especially effective for reaching elderly persons who might not have been easily accessible using traditional methods. This method helps to broaden the participation pool while also ensuring the inclusion of different responders from varied demographic and geographical backgrounds. To adapt this method effectively for seniors, initial "seed" participants were purposefully selected from local community centres and senior citizen associations. These individuals were encouraged to distribute the survey links via WhatsApp groups; a highly popular communication platform among Malaysian older adults or hand over physical copies to their peers. While snowball sampling is a non-probability technique that limits the strict statistical generalizability of the findings to the entire Malaysian elderly population, it was deemed the most pragmatic approach to penetrate close-knit community networks and capture data from a demographic that is often hard-to-reach through conventional methods.

The data collection phase, which lasted five months, involved both online and in-person questionnaires to accommodate individuals with various levels of digital literacy and mobility. Data was collected from January 1, 2023 to May 19, 2023, using both physical and electronic questionnaires to include a varied participant pool. After collection, the data was subjected to quantitative statistical analysis to produce significant results. This dual-mode data collection

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method increased inclusivity while simultaneously improving the authenticity and trustworthiness of the responses. Overall, the obtained data covered a wide range of variables related to the elderly's mobility, quality of life, and usage of assistive devices, which aligned with the study's aims. Following data collection, the third phase of the study involved extensive data analysis using statistical methods to explore patterns, relationships, and differences among the measured variables. Variance-based Partial Least Squares Structural Equation Modelling (PLS-SEM) was chosen as the principal analytical technique over Covariance-Based SEM (CB-SEM) for several key reasons. First, PLS-SEM is highly robust and does not strictly require data to fulfill distributional assumptions, making it ideal for survey data which often violates the assumption of multivariate normality (Hair et al., 2019). Second, PLS-SEM is particularly suited for exploratory research and complex models aimed at theory development and prediction, aligning perfectly with this study's goal of identifying the driving factors behind ageing in place. Finally, unlike CB-SEM, which relies heavily on global goodness-of-fit indices, PLS-SEM evaluates model quality and predictive capabilities through specific indicators such as the Standardized Root Mean Square Residual (SRMR), the coefficient of determination (R^2), and predictive relevance (Q^2). This statistical tool helps in estimating complex models with many constructs, indicator variables, and structural paths without imposing strict distributional constraints on the data.

ANALYSIS AND DISCUSSION

This research sample includes 499 older people, providing insights on key demographic and socioeconomic characteristics relevant to the study of assistive technology, quality of life, and age-friendly environments. The sample is predominantly male (60.5%), with females accounting for 39.5% of the participants. The age distribution of respondents shows that the majority (51.9%) are between the ages of 60 and 64, with 27.9% falling into the 65 to 69 age range. A smaller number (14.0%) belongs to the 70 to 74 age brackets, while 6.2% are 75 years or older. The racial makeup shows that the majority of individuals (84.0%) identify as Malay, with minorities including Chinese (10.8%), Indian (4.6%), and 0.6% from other ethnic groups. Religious affiliation is strongly tied to racial demography, as Islam is the dominant religion, practiced by 84.8% of the population. Other interviewees identified as Buddhist (8.2%), Hindu (5.2%), and Christian (1.8%). According to the data, 83.6% of respondents are married, with 12.6% widowed. A smaller proportion reported having divorced (2.4%) or never married (1.4%). The respondents have varying levels of educational attainment, with 55.7% having completed secondary education and 26.9% having completed university education. Furthermore, 15.0% only have an elementary education, while a small percentage (2.4%) lacks any formal education. The

participants' employment experience shows that 48.9% worked in the public sector and 47.7% in the private sector. A few (2.6%) reported a lack of employment experience, while 0.8% have worked in both the public and private sectors. 70% of members earn less than RM4,360 per month, with 24.4% earning between RM4,360 and RM9,619. Only 3.8% reported incomes above RM9,619, while 1.2% claimed no income. In terms of physical and health conditions, 11.4% of respondents claimed to have a physical limitation, while the vast majority, 88.6%, reported no physical constraints. In terms of overall health, 47.5% of respondents admitted to having a health problem, while 52.5% said they didn't. According to the household size data, most participants (74.3%) live in households with more than three people, followed by 23.3% who live with only two people. A small percentage (2.4%) live alone. In terms of residential tenure, most respondents (74.3%) have resided in their current homes for more than ten years, while 14.4% have been there for six to ten years. Fewer people reported living in their current homes for one to five years (10.6%), with only 0.6% staying for less than a year.The participants' home types are diverse, with 43.5% living in kampung houses and 29.7% in terraced houses. Bungalows (12.4%), semi-detached homes (8.2%), condominiums (2.4%), flats (1.8%), apartments (1.8%), and studio apartments (0.2%) are among the other types of housing. Most participants (55.3%) live in homes with more than three rooms, while 38.5% live in houses with three rooms. A minority of people live in two- or one-room homes (5.4% and 0.8%, respectively). This thorough assessment of sample characteristics provides a detailed description of the participants' demographic, socioeconomic, and residential profiles. The insights gained from these attributes are critical for understanding the factors influencing the elderly's ability to age in place, as well as the impact of assistive technologies and supportive environments on increasing their quality of life.

Examination of the primary objective of this study, which was to assess the influence of assistive technology, quality of life, and age-friendly surroundings on the aging-in-place process among senior adults in Malaysia, using Partial Least Squares analysis, revealed that three denominators had moderate explanatory power, as follows:

Table 1: The coefficient of determination (R^2)

	R-square
Age-friendly environment	0.190
Ageing in place	0.148
Quality of life	0.542

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At this stage, the coefficient of determination (R^2) is set as the standard assessment criteria and the R^2 measures the variance, which is explained in each of the endogenous constructs and is therefore a measure of the model's explanatory power (Shmueli & Koppius, 2011). While the R^2 values for age-friendly environment (0.190) and ageing in place (0.148) may appear relatively low, this is a common and acceptable threshold in behavioral and social science research. The construct of 'ageing in place' represents a highly complex, multifaceted human decision influenced by a vast array of variables outside the scope of this specific model, such as sudden physical health crises, profound financial constraints, and deeply ingrained cultural expectations regarding co-residence with adult children. Therefore, explaining approximately 15% of the variance solely through the lenses of technology, environment, and quality of life is a meaningful empirical contribution. It highlights that while these factors are statistically significant pieces of the puzzle, the decision to age in place is ultimately shaped by a broader amalgamation of personal and societal factors (Hair et al., 2019).

This research reported the path coefficient, the standard errors, t-values and p-values for the structural modelling.

Table 2: Results of path coefficient, the standard errors, t-values and p-values for the structural modelling

	Original sample (O)	**Sample mean (M)**	**Standard deviation (STDEV)**	**T statistics (|O/STDEV|)**	**P values**
Age-friendly environment -> Ageing in place	0.214	0.215	0.071	3.034	0.002
Age-friendly environment -> Quality of life	0.218	0.218	0.060	3.621	0.000
Assistive Technology -> Age-friendly environment	0.436	0.436	0.065	6.720	0.000
Assistive Technology -> Ageing in place	0.091	0.092	0.088	1.032	0.302
Assistive Technology -> Quality of life	0.615	0.616	0.053	11.698	0.000
Quality of life -> Ageing in place	0.156	0.157	0.076	2.066	0.039

Hypothesis 1: Assistive technology influences the quality of life for the elderly.
The PLS analysis showed that assistive technology improves elderly quality of life. This suggests that older persons' physical health, psychological comfort, and social participation improve with assistive technologies. These technologies increase autonomy and quality of life by simplifying everyday tasks and

minimizing caregiver need. This link emphasizes the importance of assistive technology in facilitating successful aging and enabling the elderly to age in place independently. Previous research has shown that technological aids reduce age-related problems and improve quality of life (Peek et al., 2017; Wang et al., 2019).

Hypothesis 2: Assistive technology influences the ageing in place for the elderly.
Assistive technology influences ageing in place for the elderly. Contrary to expectations, the PLS analysis revealed that the direct relationship between assistive technology and ageing in place is not statistically significant ($t = 1.032$, $p = 0.302$). This indicates that simply providing older adults with technological gadgets does not directly dictate or guarantee their ability to remain in their homes. While technology is a useful tool, its mere presence is not the primary motivator for residential stability. Instead, as the broader model suggests, technology likely serves an indirect, facilitating role rather than acting as a direct driver of ageing in place.

Hypothesis 3: Quality of life influences the ageing in place for the elderly.
Quality of life greatly affects elderly aging in place, according to PLS analysis. This shows that increased well-being, pleasure, and psychological comfort help older persons stay in their homes and communities longer. High quality of life makes elderly people feel capable, secure, and supported, reducing the likelihood of institutionalization. Improved quality of life helps them manage health issues and retain social relationships, encouraging residential stability and independence. Prior research have shown that mental well-being, physical health, and social support are crucial to aging in place (Kim, 2024; Vitman Schorr & Khalaila, 2018)).

Hypothesis 4: Age-friendly environment influences the ageing in place for the elderly.
The PLS analysis showed that an age-friendly environment strongly affects elderly aging in place. This shows that accessible infrastructure, safe neighbourhoods, and community services help older persons stay in their homes and communities for as long as feasible. Enhanced mobility, safety, and health and social support in an age-friendly setting reduce barriers and increase autonomy, promoting aging-in-place. Tailoring the environment to the elderly's requirements increases community participation and minimizes the chance of institutionalization. These findings confirm prior studies showing that accessible transportation, inclusive community planning, and social support systems help older individuals age in place (E et al., 2024).

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Hypothesis 5: Age-friendly environment influences the quality of life for the elderly.

PLS analysis demonstrated that age-friendly environments improve elderly quality of life. This shows that inclusive and supportive physical and social environments improve well-being, independence, and life satisfaction in older individuals. Age-friendly environments include accessible public spaces, barrier-free housing, and community support services for older adults. These qualities alleviate physical and social isolation and encourage community participation, promoting aging emotional and mental health. Such supportive surroundings foster good aging and a sense of safety and belonging, which are vital to quality of life. As a result, developing and maintaining age-friendly communities is critical for improving the quality of life for older people, allowing them to age with dignity and contentment (Ahmed et al., 2023; Fathkabir & İnalhan, 2024).

Hypothesis 6: Assistive technology, quality of life and age-friendly environments influence the desire to age in place among the elderly.

A careful review of the structural model reveals a nuanced, tiered relationship between the variables, correcting earlier assumptions about their collective direct impacts. The data confirms that both an age-friendly environment ($p = 0.002$) and quality of life ($p = 0.039$) have a statistically significant direct impact on the elderly's ability and willingness to age in place. The physical infrastructure, safety of the neighbourhood, and the senior's overall psychological and physical well-being are the primary, immediate drivers of their residential stability.

However, assistive technology stands out for its lack of a direct effect on ageing in place ($p = 0.302$). This presents a compelling, nuanced finding: in the Malaysian context, technology alone is not a primary motivator for seniors to stay in their homes. Instead, assistive technology acts as a powerful antecedent or facilitator. The model shows it heavily influences both the perception of an age-friendly environment ($p = 0.000$) and the individual's quality of life ($p = 0.000$). Providing a smartphone or a health monitor does not directly convince an elder to live independently; rather, that technology connects them to their family (drastically improving quality of life) and helps them navigate their surroundings safely (enhancing the age-friendly environment). It is these subsequent improvements in environment and well-being that ultimately enable them to age in place. Therefore, while assistive technology is a critical foundational component, its power lies in its indirect effects, supporting prior assertions that the decision to age in place is an intricate amalgamation of environmental and personal well-being factors (Buffel & Phillipson, 2025a, 2025b).

This study includes compatibility, smartphone anxiety, and supportive factors for older assistive technology uptake. To study how sociodemographic, quality of life, and age-friendly surroundings affect aging in place, the model

includes them. Structural Equation Modelling (SEM) helps quantify the intricate relationships between these variables, giving a comprehensive framework for understanding technology adoption and well-being. SEM allows concurrent examination of related components, including direct and indirect consequences, in a single analytical framework, making it new in this context. This holistic approach sheds light on how assistive technology, quality of life, and environmental factors promote senior independence. Policymakers and practitioners can adapt interventions to improve older quality of life by focusing on these interdependencies in the model.

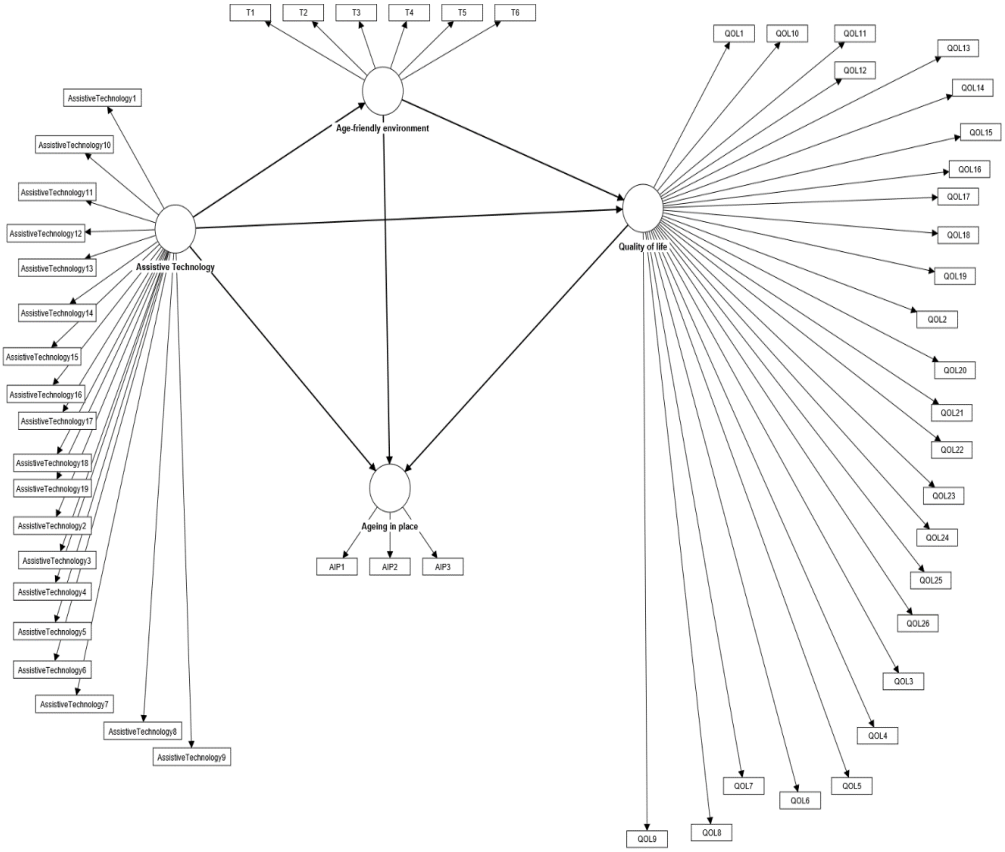


Figure 2: Proposed modelling for Ageing in Place

Ultimately, the concluding SEM figure indicated that assistive technology, quality of life, and age-friendly environments exerted no meaningful impact on the elderly's willingness to age in place. This result indicates that although these variables may enhance the overall well-being and autonomy of

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older persons, they may not inherently lead to a pronounced preference for aging in their own residences or communities. The insignificance may be ascribed to several external circumstances, such personal health conditions, socio-economic position, or familial support, which could exert a more substantial influence on their inclination to age in place. Furthermore, psychological factors such as perceptions of safety, autonomy, and emotional attachment to one's living environment may exert a more significant influence on residential preferences. These findings correspond with other research demonstrating that the decision to age in place is intricate and multifarious, frequently shaped by an amalgamation of personal, societal, and environmental factors rather than a singular determinant (Buffel & Phillipson, 2025b; Egea de Haro & Navarro Gómez, 2024). Therefore, while assistive technology, quality of life, and age-friendly environments are important for supporting aging in place, they may not be the primary factors driving the elderly's desire to remain in their current residences.

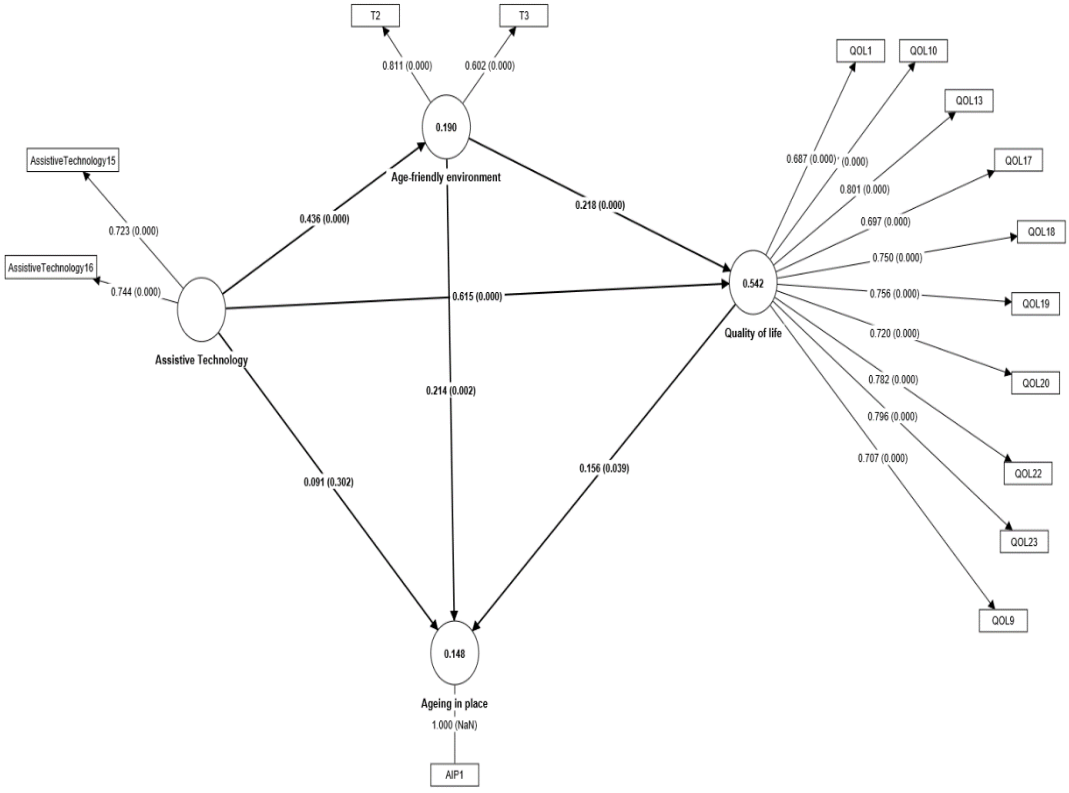


Figure 3: Final modelling for Ageing in Place

CONCLUSION

This research aimed to assess the interrelationships between assistive technology, quality of life, age-friendly environments, and the ability of Malaysian seniors to age in place. The empirical findings utilizing PLS-SEM highlight a nuanced reality: while quality of life and age-friendly environments act as direct, significant drivers for ageing in place, assistive technology functions primarily as a powerful facilitator. It significantly enhances both the perception of the living environment and overall well-being, but technology alone does not directly dictate residential stability. As highlighted in this study, technology cannot replace the foundational need for safe infrastructure and human connection. Therefore, while assistive technology offers distinct benefits, it should not be regarded as a universal remedy or a standalone solution for the complexities associated with ageing in place.

These findings offer critical practical interventions and policy implications for Malaysia's ageing population. Policymakers should adopt a balanced, holistic strategy that integrates both technological and human assistance. Rather than merely subsidizing digital devices, government initiatives—such as the National Policy for Older Persons; must prioritize the development of accessible, age-friendly community infrastructure and robust social support networks. When assistive technologies are introduced, they should be accessible, affordable, and accompanied by digital literacy programs. Furthermore, tech interventions in Malaysia should be explicitly designed to foster social connectivity and intergenerational communication, rather than isolating the elderly, ensuring that financial and technological barriers do not exacerbate disparities in care.

Despite these insights, this study is subject to several limitations that must be acknowledged. First, while the sample size of 499 respondents was robust for PLS-SEM analysis, the data was gathered predominantly using snowball sampling. Because this is a non-probability sampling method, it inherently limits the strict statistical generalizability of the findings to the entire, highly diverse Malaysian elderly population, particularly those in isolated rural areas who may lack access to initial community networks. Secondly, this study utilized a cross-sectional design, capturing only a snapshot in time.

To build upon these findings, future research should employ stratified random sampling to capture a broader, more representative demographic spectrum across different Malaysian states. Additionally, future studies would greatly benefit from longitudinal approaches to observe how the adoption of technology and perceptions of environmental support evolve as seniors age over time. Finally, incorporating qualitative research, such as in-depth interviews, could provide deeper context into the psychological, emotional, and cultural barriers to technology adoption among Malaysian older adults.

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PROMOTING HEALTH THROUGH SUSTAINABLE INTERIOR ENVIRONMENTS IN APARTMENT COMPLEXES: COLOUR, LIGHT, SPACIOUSNESS, AND THE ROLE OF HOME ATTACHMENT

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Abstract

High-density apartment living presents unique challenges to residents' health and well-being, particularly in rapidly urbanizing contexts such as China. Drawing on Environmental Stress Theory (EST) and Biophilic Interior Design (BID), this study investigates how three key interior features—colour, light, and spaciousness (CLS)—affect residents' health rate through both direct sensory impacts and the emotional mechanism of home attachment, defined as emotional reliance on one's living space. A survey of 454 residents from apartment complexes in Haikou, China, was analyzed using structural equation modelling and multi-group analysis. Results indicate that colour and light have significant direct effects on health, whereas spaciousness influences health indirectly via home attachment. Gender differences were observed, with light exerting a stronger health effect for males than females. Findings extend EST by identifying home attachment as a coping mechanism and broaden BID's application beyond aesthetics, offering design guidance for sustainable apartments that enhance well-being.

Keywords: Colour, light and spaciousness, Environmental stress theory, Health rate, Home attachment, Sustainable apartments

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INTRODUCTION

Housing is increasingly recognized as a key social determinant of health and well-being (Foster et al., 2019; J. Y. Kim & Kim, 2022). Rapid urbanization and the prevalence of high-density housing have drawn attention to how interior design affects residents' physical and mental health (Colenberg & Jylhä, 2022; Huntsman & Bulaj, 2022). Nature-integrated indoor environments can alleviate stress and support psychological restoration (Colenberg & Jylhä, 2022), yet residents on higher floors often face limited access to nature, reducing such benefits (Larcombe et al., 2019). In China, where apartment complexes dominate urban housing, regulatory, spatial, and governance constraints exacerbate these challenges (Guo & Cui, 2025; Wu & Zhang, 2022), making health-promoting interior design a pressing priority in sustainable housing research.

Sensory design elements—especially colour, light, and spaciousness—significantly influence residential experiences and well-being (Ekhaese et al., 2025; Khanzadeh, 2024). Colour, light, and spaciousness not only serve functional purposes but also shape perception and emotion, enhancing mood and home attachment and creating restorative or stress-inducing spaces (McGee & Park, 2022; Morales-Bravo & Navarrete-Hernandez, 2022; Wei, 2024). However, little is known about how these elements interact with home attachment—the emotional reliance on one's living space. Given documented gender-based differences in environmental perception and affective responses, gender may act as a critical moderator linking interior design features to residents' emotional attachment and health outcomes (Costa et al., 2018; Knez, 2001; Liu et al., 2023). This study addresses this gap by examining the health effects of colour, light, and spaciousness in high-density apartments and the mediating role of home attachment, aligning with sustainability goals that promote psychological resilience and well-being. This provides a rationale for examining gender as a potential moderator in the present study.

Building on this rationale, the following research gaps are identified. First, little empirical work has examined how home attachment mediates the effects of specific residential features—particularly colour, light, and spaciousness, core dimensions of biophilic design—on health. Second, few studies have developed integrative models that assess these features' combined influence on home attachment and health in high-density urban housing. Third, while demographic differences in environmental perception (Costa et al., 2018) and in responses to light colour and mood (Knez, 2001) are documented, the moderating role of gender in these relationships remains underexplored. Addressing these gaps is vital for advancing inclusive, evidence-based interior design strategies that support sustainable residential well-being.

This study focuses on working adults aged 18–40, a demographic that typically spends substantial time in both occupational and residential settings,

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making them particularly sensitive to the psychological and restorative functions of home environments (Evans & Cohen, 1987; Meagher & Cheadle, 2020). Accordingly, this study aims to (1) examine the effects of colour, light, and spaciousness on residents' health in apartment complexes; (2) investigate the mediating role of home attachment between these design features and health outcomes; and (3) assess gender differences in these relationships. The findings are expected to contribute to the literature by advancing theoretical understanding of the psychological pathways linking interior design to health, while offering practical guidance for sustainable residential design that fosters both physical and mental well-being.

LITERATURE REVIEW

Underlying Theory: EST and BID

This study adopts Environmental Stress Theory (EST) and Biophilic Interior Design (BID) to examine how sensory features influence residents' health. EST explains how sustained exposure to physical environmental stimuli triggers psychological and physiological responses, shaped by individual perceptions and coping thresholds (Evans & Cohen, 1987; Gifford, 2014). Stress arises when environmental demands exceed coping capacity, causing emotional, cognitive, or behavioural strain (Evans & Stecker, 2004). In residential settings, colour, light, and spaciousness are key stressors linked to chronic strain (Kamata et al., 2025; Morales-Bravo & Navarrete-Hernandez, 2022). Complementing this perspective, BID enhances well-being by integrating natural elements into built environments (Bolten & Barbiero, 2020; Kellert, 2008), promoting health through cognitive, emotional, and physiological engagement with nature. In residential contexts, natural colours, materials, and spatial forms can evoke positive emotional responses and contribute to holistic well-being (Bettaieb et al., 2023).

Previous studies on residential interior design and health

Previous studies have linked residential environments and biophilic interior design to health and well-being, yet most have examined housing quality, IEQ, or BID as broad concepts rather than specific interior features (Foster et al., 2019; Huntsman & Bulaj, 2022). Limited empirical research has jointly tested how colour, light, and spaciousness affect residents' health in high-density apartment complexes, particularly through psychological mechanisms such as home attachment. Although gender differences in environmental perception have been reported (Costa et al., 2018; Knez, 2001; Liu et al., 2023), little is known about whether gender moderates these interior design–attachment–health relationships. This study addresses these gaps by examining the effects of colour, light, and spaciousness on health through home attachment and by testing gender differences in apartment complexes.

Hypothesis development

CLS and Health

Colour evokes distinct emotional and physiological responses that shape residents' well-being, with warm tones often associated with relaxation and comfort, and cool tones linked to focus and alertness (Aguirre-Sosa et al., 2023). Light is equally critical, influencing visual comfort and circadian regulation; empirical evidence shows that natural light simulation and well-integrated light design can enhance psychological stability, improve well-being, and reduce cognitive fatigue (Obeidat et al., 2024). Similarly, spatial arrangements that promote openness and efficient circulation contribute to physical comfort and support positive psychological outcomes, indicating that CLS design strategies affect both environmental quality and residents' health (Obeidat et al., 2024). Based on this understanding, the following hypothesis is proposed:

H1a: colour is positively associated with residents' perceived health in apartment complexes.
H1b: light is positively associated with residents' perceived health in apartment complexes.
H1c: spaciousness is positively associated with residents' perceived health in apartment complexes.

Home attachment

Home attachment reflects a resident's emotional reliance on their living space, fostering a sense of identity and psychological satisfaction that supports positive mental health (Meagher, 2020; Meagher & Cheadle, 2020). Home attachment is strengthened by interior elements such as colour, which—due to its high degree of personalizability and emotional resonance—can enhance feelings of belonging and reinforce home attachment (Costa et al., 2018). Lighting enhances residents' home attachment in apartment complexes by improving spatial comfort, emotional well-being, and perceived safety (Peters & Halleran, 2020). In apartment complexes, spaciousness strengthens residents' home attachment by promoting comfort, social connectedness, and psychological health (Kleeman et al., 2022). Based on this understanding, the following hypothesis is proposed:

H2a: colour is positively associated with residents' home attachment in apartment complexes in interior design.
H2b: light is positively associated with residents' home attachment in apartment complexes in interior design.
H2c: spaciousness is positively associated with residents' home attachment in apartment complexes in interior design.

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Home attachment also shapes comfort, stability, and overall psychological well-being (Meagher, 2020). Extensive research indicates that interior features such as colour, light, and spaciousness can promote well-being by fostering emotional engagement with the home (Costa et al., 2018; Meagher & Cheadle, 2020). However, the mediating role of home attachment in linking interior design features to health outcomes remains underexplored, despite evidence that emotionally resonant spaces enhance residents' comfort and stability (Meagher, 2020). Based on the above, the following hypotheses are proposed:

H3: Home attachment is positively associated with residents' health rates in apartment complexes.
H4a: Home attachment mediates the relationship between colour and health rates.
H4b: Home attachment mediates the relationship between light and health rates.
H4c: Home attachment mediates the relationship between spaciousness and health rates.

The moderating role of gender

Perceptions of interior design attributes, such as colour, light, and spatial configuration, are not uniform across demographic groups. Previous studies have identified significant differences in aesthetic preferences based on gender. For example, Liu et al. (2023) reported that male residents tend to prefer technologically dynamic and variable colour schemes, while female residents prefer softer, more uniform tones to convey emotional warmth. Women often perceive lighting as more emotionally salient and may show superior cognitive performance under certain conditions, with sex-based differences also evident in memory tasks depending on lighting context (Knez, 2001). Based on the above, the following hypotheses are proposed:

H4: Associations between study variables differ by gender.

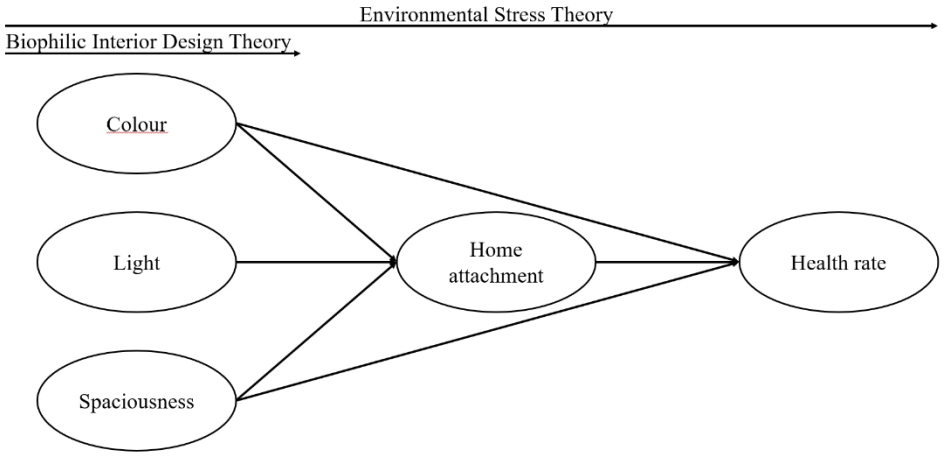


Fig.1. Theoretical model.
Source: Author's Summarize

RESEARCH METHODOLOGY

This study was conducted in the Shengda Jingdu Apartment Complex, a large-scale residential community located at the intersection of Guoxing Avenue and Meiyuan Road in Meilan District, Haikou City, Hainan Province, China. The complex consists of three development phases, comprising 3,279 households and approximately 8,253 residents, predominantly young and middle-aged individuals with stable socioeconomic conditions. A stratified random sampling method was used to ensure demographic and spatial representativeness across the three phases. Data were collected through face-to-face questionnaire surveys administered in apartments from February to March 2025, yielding 454 valid responses. The sample comprised 52.6% females and 47.4% males. The study focuses on working adults aged 18–40, a demographic often experiencing high work-related demands and relying on the home environment for psychological recovery and emotional stability. This demographic profile ensures relevance to the study's focus on gender differences and supports the multiple group analysis (MGA) in assessing moderation effects.

As all data were collected through self-reported questionnaires, common method bias was assessed before hypothesis testing. Harman's single-factor test showed that the first factor explained 33.019% of the total variance, below the 50% threshold (Podsakoff et al., 2003). In addition, all full collinearity VIF values were below 3.3, following Kock (2015). These results indicate that common method bias was unlikely to substantially affect the findings.

The questionnaire comprised two sections: demographic information and the main questionnaire items. Five variables were measured in total. Colour, light, and spaciousness were assessed using established scales from Cheng and

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Marzuki (2023) and McGee et al. (2019). Home attachment was measured with items adapted from Scannell and Gifford (2010), while health rate was evaluated using scales from Chen et al. (2024) and Hedayati et al. (2020). All items in the questionnaire were scored on a 5-point Likert scale, ranging from 'strongly disagree (1)' to 'strongly agree (5)'.

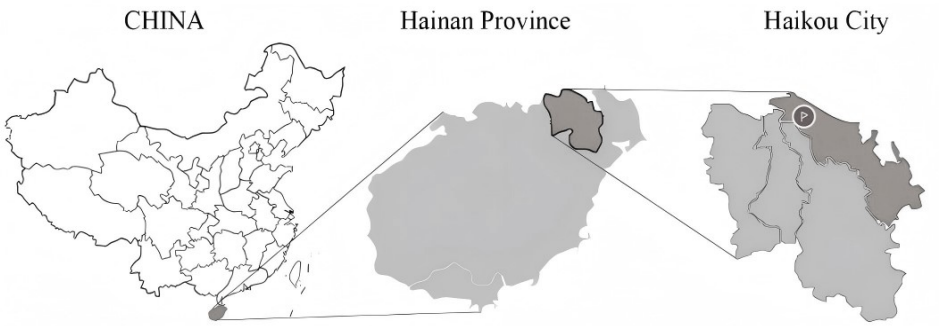


Fig.2. The Location of Hai Kou
(The authors by Google Map, 2026)

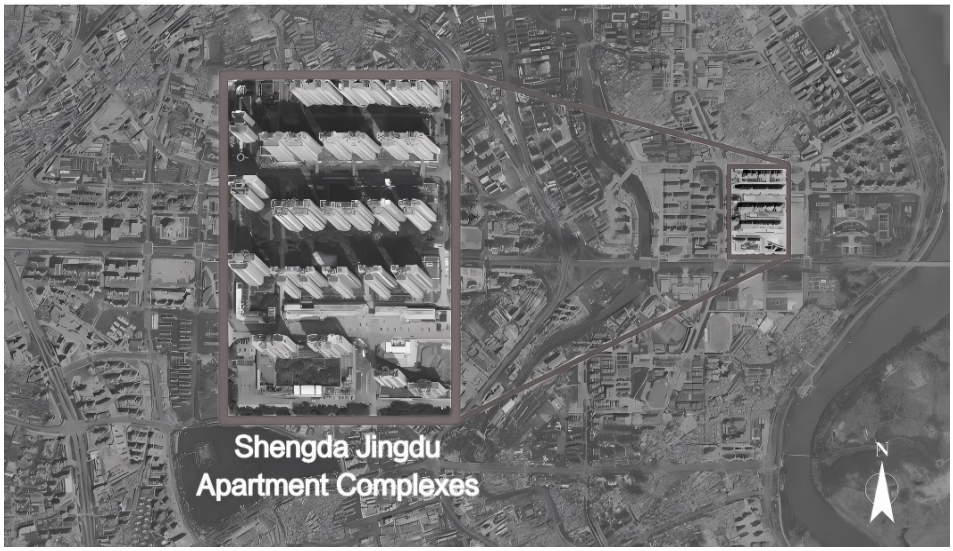


Fig.3. The Location of Shengda Jingdu Apartment Complexes
(The authors by Google Map, 2026)

RESULTS

Measurement Model Results

The reliability and validity of the constructs were assessed using SmartPLS outputs from the measurement model. All standardized factor loadings (0.712–

0.867) exceeded the recommended 0.708 threshold, confirming indicator reliability (Black & Babin, 2019; Hair et al., 2021; Henseler, 2009). Cronbach's alpha values ranged from 0.654 to 0.864, with most constructs exceeding the recommended 0.70 threshold. The slightly lower alpha (0.654) for spaciousness is acceptable given the construct's three-item scale and the exploratory nature of this study (Hair et al., 2019). Composite reliability values (0.812–0.903) for all constructs surpassed the 0.70 standard, demonstrating satisfactory internal consistency. Average Variance Extracted (AVE) values (0.543–0.682) exceeded the 0.50 criterion, indicating adequate convergent validity. Figure 5 presents the structural model for hypothesis testing.

Table 1: Reliability and Convergent Validity Results

Variable	Item	Loading	Alpha (α)	CR	AVE
Colour	C1	0.725	0.79	0.856	0.543
	C2	0.738			
	C3	0.765			
	C4	0.728			
	C5	0.729			
Light	L1	0.849	0.844	0.895	0.682
	L2	0.867			
	L3	0.8			
	L4	0.784			
Spaciousness	S1	0.775	0.654	0.812	0.59
	S2	0.774			
	S3	0.755			
Home attachment	HA1	0.797	0.862	0.9	0.644
	HA2	0.828			
	HA3	0.834			
	HA4	0.777			
	HA5	0.774			
Health rate	HR1	0.825	0.864	0.903	0.65
	HR2	0.712			
	HR3	0.816			
	HR4	0.844			
	HR5	0.827			

Source: Author's Calculation

Discriminant validity was assessed using the Heterotrait–Monotrait (HTMT) ratio. All HTMT values were below the 0.85 threshold, and the square root of each construct's AVE exceeded its correlations with other constructs (Fornell & Larcker, 1981; Hair et al., 2019, 2020, 2021), confirming satisfactory discriminant validity.

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Table 2: Results of HTMT Ratios

	Colour	**HA**	**HR**	**Light**	**Spaciousness**
Colour					
HA	0.375				
HR	0.475	0.752			
Light	0.413	0.455	0.473		
Spaciousness	0.84	0.467	0.489	0.506	

Source: Author's Calculation

The coefficients of determination (R^2) for home attachment (0.209) and health rate (0.479) indicate weak-to-moderate explanatory power, according to the conventional thresholds of 0.25, 0.50, and 0.75 for weak, moderate, and substantial levels, respectively (Hair et al., 2019, 2020, 2021). The predictive relevance (Q^2) values of 0.131 for home attachment and 0.306 for health rate are above zero, confirming that the model has satisfactory predictive capability (Hair et al., 2019). Furthermore, the Goodness-of-Fit (GoF) index of 0.462 substantially exceeds the recommended cut-off value of 0.36 (Hedayati Marzbali et al., 2016), suggesting a high overall fit and explanatory adequacy of the model.

Table 3: Coefficient of determination, predictive relevance, and GOF of model calculation.

Variable	**Items**	**PLS-SEM RMSE**	**LM RMSE**	**Q^2**	**R^2**	**AVE**	**GOF**
Colour	-	-	-	-	-	0.543	
Light	-	-	-	-	-	0.682	
Spaciousness	-	-	-	-	-	0.59	
HA	HA1	0.89	0.903	0.131	0.209	0.644	0.462
	HA2	0.944	0.964				
	HA3	0.867	0.881				
	HA4	0.957	0.968				
	HA5	0.906	0.923				
HR	HR1	0.798	0.805	0.306	0.479	0.65	
	HR2	0.805	0.825				
	HR3	0.756	0.77				
	HR4	0.806	0.82				
	HR5	0.749	0.754				

Source: Author's Calculation

Structural Model Results

The structural model (Table 4) was assessed following the recommendations of Hair et al. (2021). Colour (H1a: $\beta = 0.162$, $p < 0.01$) and Light (H1b: $\beta = 0.125$, $p < 0.01$) had significant positive effects on Health Rate, whereas Spaciousness was not significant (H1c: $\beta = 0.036$, $p = 0.213$). All three features—Colour (H2a: $\beta = 0.110$, $p < 0.05$), Light (H2b: $\beta = 0.286$, $p < 0.01$), and Spaciousness (H2c: β

= 0.178, p < 0.01)—positively affected Home attachment, which also showed a strong positive association with Health Rate (H3: β = 0.540, p < 0.01).

Table 4: Results of Path Coefficient and Hypothesis Testing (Direct Effects)

HS	Relationship	β	T	P	95% CIs	f^2	VIF	Decision
H1a	Colour -> HR	0.162	2.76	0.003***	[0.068,0.261]	0.031	1.629	Support
H1b	Light -> HR	0.125	2.485	0.006***	[0.042，0.208]	0.023	1.297	Support
H1c	Spaciousness -> HR	0.036	0.798	0.213	[-0.041, 0.109]	0.001	1.706	Not support
H2a	Colour -> HA	0.11	1.813	0.035*	[0.007, 0.206]	0.009	1.614	Support
H2b	Light -> HA	0.286	5.422	0***	[0.195, 0.369]	0.086	1.194	Support
H2c	Spaciousness -> HA	0.178	3.285	0.001***	[0.091, 0.269]	0.024	1.666	Support
H3	HA -> HR	0.54	11.623	0***	[0.457, 0.611]	0.442	1.264	Support

P<0.05 P<0.01**** *Source: Author's Calculation*

Furthermore, in the structural model assessment presented in table 6, mediating effects of home attachment were observed in the relationships between colour and health rate (H4: β = 0.059, p < 0.05), light and health rate (H5: β = 0.154, p < 0.01), and spaciousness and health rate (H6: β = 0.096, p < 0.01), indicating that home attachment plays a significant mediating role across all three design dimensions. According to Chin (1998), f^2 effect size values of 0.02, 0.15, and 0.35 are interpreted as small, moderate, and substantial.

Table 5: Results of Path Coefficient and Hypothesis Testing (Indirect Effects)

HS	Relationship	β	T	P	95% CIs	Decision
H4a	Colour -> HA -> HR	0.059	1.852	0.032	[0.004, 0.109]	Support
H4b	Light -> HA -> HR	0.154	4.803	0	[0.102, 0.209]	Support
H4c	Spaciousness -> HA -> HR	0.096	3.042	0.001	[0.048, 0.152]	Support

P<0.05 P<0.01**** *Source: Author's Calculation*

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MGA

An MGA was conducted in Smart PLS 4.0 to examine group differences, with measurement invariance confirmed using the MICOM procedure (Barroso et al., 2018; Henseler, 2009). Results showed gender as the strongest moderator, with light having a greater effect on health rate for males (β = 0.250, p = 0.001) than for females (β = 0.073, p = 0.112; PLS-MGA = 0.038).

Table 6: Comparison of model relationship by two groups using Henseler's MGA test

HS	Relationship	β	P	95% CIs	β	P	95% CIs	PLS-MGA	Supported
	Gender	Female			Male				
H4	Colour -> HA	0.064	0.186	[-0.062, 0.173]	0.202	0.018 *	[0.052, 0.364]	0.122	NO/YES
	Colour -> HR	0.172	0.011 *	[0.052, 0.301]	0.099	0.114	[-0.028, 0.239]	0.253	YES/NO
	Light -> HR	0.073	0.112	[-0.029, 0.169]	0.25	0.001 ***	[0.122, 0.377]	0.038 *	NO/YES

P <0.05 P <0.01**** *Source: Author's Calculation*

DISCUSSIONS

Drawing on EST and BID, this study shows that colour, light, and spatial configuration influence residents' health in different ways within apartment complexes. Consistent with EST, environmental demands can trigger psychological and physiological stress when they exceed coping capacity (Evans & Cohen, 1987; Evans & Stecker, 2004; Gifford, 2014). The findings show that light and colour directly improve perceived health, while spaciousness works indirectly through home attachment, confirming the role of residential attachment as a psychological mechanism under prolonged environmental exposure (Meagher & Cheadle, 2020).

The insignificant direct effect of spaciousness may indicate that spatial perception influences health only after being emotionally internalized through comfort and control. This aligns with Meagher and Cheadle (2020), who emphasize place attachment as a mediator of environmental experience, and with McGee et al. (2019), who suggest that spatial dimensions support restoration when combined with symbolic or functional cues. Thus, home attachment functions as a sustainability-relevant mechanism, whereby emotional and symbolic bonds with the home translate prolonged environmental exposure into health benefits, consistent with EST (Evans & Stecker, 2004; Kamata et al., 2025).

The multigroup analysis showed that only the light to health path was significantly moderated by gender, with a stronger effect among males. This may reflect women's higher dissatisfaction or expectations regarding light, reducing

their sensitivity to incremental improvements (Kim et al., 2013), whereas men may perceive improved light quality more directly as comfort and emotional regulation (Liu et al., 2023). Although colour showed gender-based variations, these differences were not statistically significant, suggesting that colour responses may depend more on individual aesthetic orientation and contextual experience than gender alone (Costa et al., 2018). Since emotional ties to home are shaped by layered sensory and symbolic interactions (Meagher & Cheadle, 2020), the findings support user-centered and demographically inclusive design rather than fixed gender assumptions.

The findings support sustainable residential design through optimized natural light, responsive colour schemes, and perceived spaciousness, while guiding policymakers to integrate evidence-based interior design into high-density housing programmes.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This study found that colour and light directly enhance perceived health, while spaciousness exerts an indirect effect through home attachment, with light emerging as the most influential factor (Sholanke et al., 2021). This conclusion is based on the combined direct and indirect effects, with light showing a moderate direct effect on health ($\beta = 0.125$) and the largest indirect effect via home attachment ($\beta = 0.154$), resulting in the highest overall influence among the three design dimensions. Home attachment functions as a key psychological mechanism linking interior design to well-being (Meagher & Cheadle, 2020), and multigroup analysis suggests gender differences in sensitivity to light and colour, though not all were statistically significant. These findings underscore the value of personalized, gender-sensitive design strategies in promoting inclusive well-being within sustainable housing contexts (J. Kim et al., 2013; Liu et al., 2023).

This study also has certain limitations. First, this study's generalizability may be limited by its single-site sample in Haikou and reliance on self-reported measures, which are subject to contextual and response biases. Second, the cross-sectional design limits causal inference and prevents tracking changes in environmental perceptions and psychological outcomes over time. It also limits the ability to fully address endogeneity concerns. Future research could use longitudinal, experimental, or multi-source data to further validate the causal relationships among interior design features, home attachment, and residents' health. Third, this study focused on colour, light, and spaciousness, excluding other biophilic elements like materiality or sensory variability that may also impact well-being (McGee et al., 2019). Fourth, the empirical model focused on interior design features, home attachment, and gender differences, while broader socioeconomic and housing-related factors, such as household income, housing expenditure, housing affordability, housing prices, and cost of living, were not

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included. Future research could incorporate these contextual variables to provide a more comprehensive explanation of how residential interior environments and broader living conditions jointly shape residents' health and well-being.

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READINESS ASSESSMENT OF TRANSIT-ORIENTED DEVELOPMENT (TOD) CORRIDORS IN MALANG CITY, INDONESIA: A GIS-BASED EVALUATION OF ACCESSIBILITY AND LAND-USE INTEGRATION

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Abstract

The increasing mobility demand in Indonesian secondary cities highlights the need for spatial integration between transport infrastructure and land-use planning. This study aims to assess the readiness of Transit-Oriented Development (TOD) corridors in Malang City, Indonesia, using a GIS-based multi-criteria evaluation of accessibility and land-use integration. The study adopts the 5D+I framework: Density, Diversity, Design, Destination Accessibility, Distance to Transit, and Intermodality, to measure the spatial relationship between urban form and transport connectivity. Spatial data were obtained from the Laporan Umum Tim PKL Kota Malang 2024, complemented by field surveys, land-use maps, and transport network datasets. Each indicator was analyzed and normalized using GIS-based overlay and buffer analysis to generate a composite TOD Readiness Index (TRI). The results reveal that the Kota Baru–Soekarno Hatta–Tlogomas corridor exhibits the highest readiness level (TRI = 0.81), supported by high density, mixed land use, and multimodal accessibility. The Blimbing–Arjosari corridor shows moderate readiness, while peripheral areas remain less prepared due to low density and limited transit coverage. Findings indicate that accessibility and land-use diversity are strongly correlated (r = 0.72), suggesting that integrated planning enhances urban connectivity and supports sustainable mobility. Policy implications include the need for institutional coordination, pedestrian network improvements, and zoning adjustments to encourage compact mixed-use development around transit nodes. This study contributes a replicable GIS-based framework for evaluating TOD readiness in medium-sized Indonesian cities, bridging the gap between spatial analysis and practical urban planning.

Keywords: Transit-Oriented Development (TOD), GIS, Land-use Integration, Accessibility, Urban Corridors, Medium-Sized Cities, TOD Readiness Index

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INTRODUCTION

Rapid urban growth in Indonesian secondary cities has increasingly reshaped travel patterns, land-use intensity, and the spatial distribution of daily activities. Unlike metropolitan regions, medium-sized cities often experience a transitional phase where rising mobility demand is not yet matched by integrated transport infrastructure and coordinated spatial planning. As a result, traffic congestion, inefficient travel routes, and fragmented land-use patterns emerge along primary urban corridors, indicating structural challenges in managing urban accessibility.

Malang City, located in East Java Province, represents a typical medium-sized Indonesian city undergoing such transformation. Its role as an education and tourism hub has generated concentrated development along major arterial corridors, particularly Soekarno-Hatta, Basuki Rahmat, and Tlogomas. These corridors accommodate a mix of universities, commercial activities, and residential areas, leading to high trip generation and increasing pressure on the existing transport system. Despite the presence of railway stations and urban bus services, accessibility remains uneven, reflecting limited coordination between transport provision and surrounding land-use development.

In response to similar urban challenges, Transit-Oriented Development (TOD) has been widely adopted as a planning approach that aligns transport infrastructure with compact and mixed-use urban form. Previous studies have demonstrated that effective TOD implementation can enhance accessibility, support public transport usage, and reduce excessive reliance on private vehicles. However, in Indonesia, TOD initiatives have predominantly focused on large metropolitan areas such as Jakarta, Bandung, and Surabaya, where mass transit systems and institutional capacity are relatively well established. Consequently, empirical evidence on TOD readiness in secondary cities remains limited.

Malang City offers a strategic case for examining TOD readiness beyond metropolitan contexts. The city contains several key transport nodes, including Malang Kota Baru Station, Blimbing Station, Arjosari Terminal, and Landungsari Terminal, each surrounded by diverse urban functions and educational districts. Field observations and planning documents indicate that these nodes exhibit varying degrees of accessibility, land-use mix, and intermodal connectivity, suggesting unequal readiness for TOD-oriented development across corridors.

Assessing TOD readiness requires an analytical framework capable of capturing the spatial relationship between land-use characteristics and transport accessibility. Geographic Information Systems (GIS) provide a suitable platform for integrating these dimensions through spatial indicators such as density, land-use diversity, network design, proximity to activity centres, walking distance to transit, and intermodal connectivity. By operationalising these indicators into

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measurable spatial variables, GIS-based analysis enables the identification of corridors with the highest potential for TOD implementation.

LITERATURE REVIEW

Transit-Oriented Development and Urban Accessibility

Transit-Oriented Development (TOD) has been widely discussed as an approach to improve urban accessibility by aligning transport infrastructure with land-use development. Early studies highlighted the importance of concentrating activities around transit facilities to support efficient travel patterns and reduce excessive dependence on private vehicles (Cervero & Kockelman, 1997). Subsequent research expanded this perspective by emphasising the role of urban design and network connectivity in shaping travel behaviour (Ewing & Handy, 2009; Ewing & Cervero, 2010).

Empirical evidence suggests that TOD outcomes vary significantly depending on urban context. Cities with established transit systems and coordinated land-use control tend to demonstrate stronger accessibility gains, whereas cities with fragmented planning frameworks experience uneven results (Zhao et al., 2020). In Southeast Asia, TOD studies have predominantly focused on large metropolitan regions, while medium-sized cities remain less examined despite experiencing rapid urban transformation (Wibowo et al., 2022).

Multidimensional Indicators for TOD Assessment

To translate TOD principles into measurable variables, researchers have developed indicator-based frameworks capturing the interaction between land use and transport systems. The initial focus on density, diversity, and design (Cervero & Kockelman, 1997) later evolved to incorporate destination accessibility and distance to transit, reflecting the functional performance of transport networks (Ewing & Handy, 2009; Ewing & Cervero, 2010).

Recent studies further extended this framework by including intermodality, particularly in urban contexts where accessibility depends on the integration of multiple transport modes (Curtis et al., 2016). This multidimensional approach enables a more comprehensive assessment of TOD readiness by accounting for both physical urban form and transport connectivity. However, the application of such frameworks has largely been concentrated in cities with mature public transport systems, limiting their generalisability to secondary cities with different mobility structures.

GIS-based Approaches in TOD Studies

Geographic Information Systems (GIS) have become a key analytical tool in TOD research due to their capacity to integrate spatial, demographic, and transport-related datasets. GIS-based methods allow researchers to examine

spatial variations in land-use intensity, accessibility, and proximity to transit facilities using techniques such as buffer analysis, spatial overlay, and network modelling (Vale, 2015; Curtis et al., 2021).

Several GIS-based studies conducted in Asian cities demonstrate how spatial analysis can reveal mismatches between land-use concentration and transit service coverage (Kumar et al., 2020; Irfan et al., 2021; Kamal & Osman, 2022). These mismatches often indicate areas where TOD potential exists but has not been fully realised due to planning or infrastructural constraints. Nevertheless, most existing studies emphasise station-based analysis in metropolitan contexts, providing limited insight into corridor-based TOD readiness in medium-sized cities (Yoon et al., 2019).

Research Gap and Conceptual Positioning

Despite the growing literature on TOD and GIS-based evaluation, two key gaps remain. First, there is limited empirical research addressing TOD readiness in medium-sized cities, particularly in Indonesia, where transport systems are dominated by corridor-based movement patterns rather than extensive rail networks (Wibowo et al., 2022). Second, many studies focus on post-implementation impacts of TOD, while fewer examine pre-implementation readiness based on existing land-use and accessibility conditions.

To address these gaps, this study operationalises the 5D+I framework into measurable GIS-based spatial indicators. Each indicator is selected to directly reflect the identified limitations in previous studies, particularly in capturing corridor-based accessibility patterns and intermodal connectivity in medium-sized cities.

This study addresses these gaps by applying a GIS-based, corridor-oriented evaluation of TOD readiness in Malang City. By integrating multidimensional indicators of land-use characteristics and transport accessibility into a composite readiness index, the study aligns with recent methodological developments (Curtis et al., 2016; Curtis et al., 2021) while responding to the contextual needs of secondary Indonesian cities. This positioning contributes to the literature by offering an empirically grounded framework that supports evidence-based spatial planning prior to TOD implementation.

RESEARCH METHODOLOGY

Study Area and Data Sources

This study was conducted in Malang City, East Java Province, Indonesia, covering an administrative area of approximately 110.06 km². As a medium-sized urban centre, Malang functions as a regional hub for education, tourism, trade, and services, generating intensive daily travel demand across its primary road corridors. The spatial focus of this study includes three main urban corridors that

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concentrate transport infrastructure and urban activities: Basuki Rahmat–Soekarno Hatta–Tlogomas, LA Sucipto–Blimbing–Arjosari, and S. Parman–Borobudur–Mayjen Sungkono.

Spatial and transport data were obtained from multiple sources to ensure analytical robustness. Primary data were derived from field surveys conducted in 2024 by the Indonesian Land Transportation Polytechnic (PTDI–STTD), including pedestrian infrastructure observations, transit stop locations, and intermodal facilities. Secondary data consisted of land-use maps, population statistics, urban transport network data, and official planning documents such as the Malang City Spatial Plan (RTRW 2021–2041) and the Transport Master Plan. OpenStreetMap (OSM) data were used to complement road network and intersection information.

TOD Readiness Indicators and Analytical Framework

The TOD readiness assessment was based on six spatial indicators representing the 5D + I framework (Density, Diversity, Design, Destination Accessibility, Distance to Transit, and Intermodality). Each indicator was quantified and spatially analyzed using GIS tools, as described below:

Table 1. Spatial Indicators Representing the 5D+I Framework

Indicator	Description	GIS-Based Measurement	Data Source
Density	Residential and employment intensity around transport nodes	Population density and building floor area within 400 m and 800 m buffers	PKL 2024; RTRW Malang 2021–2041
Diversity	Land-use mix (residential, commercial, institutional, green)	Entropy index calculated from land-use polygons	PKL 2024; Land-use map
Design	Street connectivity and pedestrian environment	Intersection density, sidewalk coverage ratio	Field survey 2024; OSM
Destination Accessibility	Proximity to key activity centres	Cumulative accessibility index (based on travel time)	Transport Master Plan 2023; PKL 2024
Distance to Transit	Walking distance to nearest transit stop	Euclidean and network buffer analysis (≤ 800 m)	OSM; Field observation
Intermodality	Connectivity between different modes	Number of transport services intersecting per node	PKL 2024; BPTD Jabar data

Source: PKL Malang 2024 Data and Author's Calculation

The 5D+I framework was selected due to its ability to comprehensively capture both physical urban form and multimodal transport integration, making it particularly suitable for corridor-based analysis in medium-sized cities.

Each indicator was normalized into a 0–1 scale using min–max standardization, ensuring comparability across variables. To ensure analytical robustness, the spatial results were validated through expert interviews with planners from the Malang City Transport Agency and academics from PTDI–STTD. The final interpretation integrates quantitative spatial analysis with qualitative insights to provide comprehensive policy recommendations for TOD development in Malang City.

Destination accessibility was evaluated by estimating cumulative access to key urban activity centres based on travel time along the road network. Distance to transit measured the effective walking distance from surrounding land parcels to the nearest public transport stop using both Euclidean and network-based approaches. Intermodality reflected the level of connectivity between different transport modes, assessed by identifying the number and type of transport services intersecting at each node.

GIS-based Spatial Analysis

The selection of buffer distances (400 m and 800 m) is based on commonly accepted walking thresholds in TOD studies, representing approximately 5–10 minutes walking distance under typical urban conditions (Cervero & Kockelman, 1997; Ewing & Cervero, 2010).

Intermodality was quantified by counting the number of distinct transport modes (e.g., angkot routes, bus services, and railway access) intersecting within each node buffer zone. Each mode was assigned equal weight.

All spatial analyses were performed using Geographic Information Systems (GIS) to integrate land-use, transport, and accessibility datasets. Buffer zones of 400 m and 800 m were applied around major transit nodes to represent practical walking distances in the local context. Spatial overlay techniques were used to combine land-use patterns with transport infrastructure, while network analysis supported the calculation of accessibility and distance-related indicators.

To enable comparison across indicators with different measurement units, each variable was normalised to a standardised scale ranging from 0 to 1 using min–max transformation. The normalised indicators were subsequently aggregated to generate a composite Transit-Oriented Development Readiness Index (TRI) for each corridor. The index reflects the relative readiness of urban corridors rather than absolute TOD performance, allowing comparative interpretation across spatial segments.

ANALYSIS AND DISCUSSION

Spatial Characteristics of Malang's Urban Corridors

The GIS-based analysis revealed that Malang's spatial structure is dominated by three major arterial corridors with strong urban activity concentration: Stasiun

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Malang Kota Baru–Soekarno Hatta–Tlogomas Corridor, Blimbing–LA Sucipto–Arjosari Corridor, and S. Parman–Borobudur–Mayjen Sungkono Corridor. The Laporan Umum Tim PKL Kota Malang 2024 indicates that these corridors exhibit the highest population density and mixed land-use intensity, with educational, commercial, and residential functions clustered along main roads and near transit facilities. The proximity of major campuses (Universitas Brawijaya, Universitas Negeri Malang, and UIN Malang) also contributes to high trip generation and public transport demand.

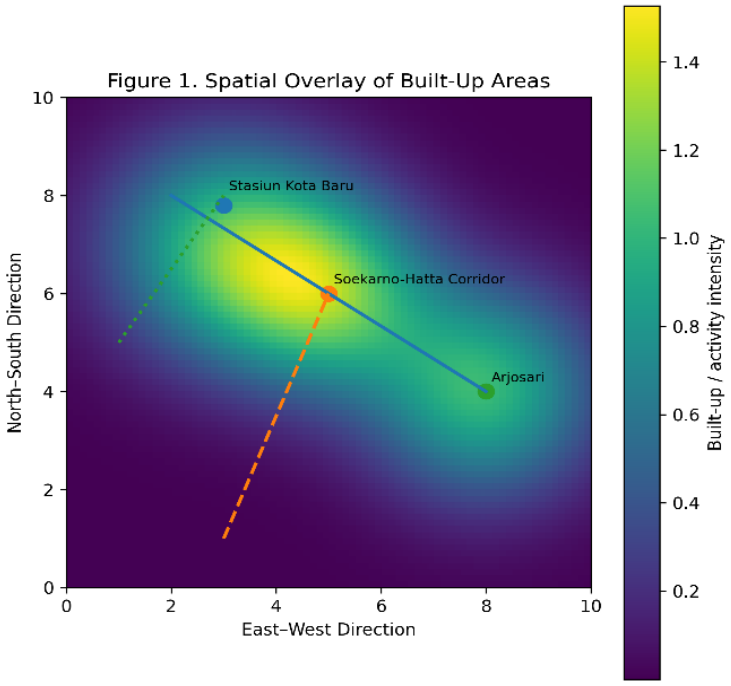


Figure 1. Spatial Overlay of Built-Up Areas and Public Transport Routes showing a Polycentric Urban Pattern in Malang City
Source: PKL Malang 2024 Data and Author's Calculation

Spatial overlay mapping (Figure 1) demonstrates that built-up areas and public transport routes form a polycentric urban pattern, with high-density clusters around Stasiun Kota Baru, Soekarno-Hatta, and Arjosari. This pattern suggests that the city's land-use configuration already supports the fundamental characteristics of a TOD-based structure.

TOD Readiness Index (TRI) Result

The computed Transit-Oriented Development Readiness Index (TRI) integrates six weighted indicators (Density, Diversity, Design, Destination Accessibility, Distance to Transit, and Intermodality). Table 2 summarises the composite scores and readiness classification for each corridor.

Table 2. TOD Readiness Index by Corridor in Malang City

Corridor	TRI Score	Readiness Category	Dominant Strength	Primary Constraint
Kota Baru – Soekarno Hatta – Tlogomas	0.81	Highly Ready	High density, diverse land use, and good pedestrian access	Limited intermodal linkage with feeder services
Blimbing – LA Sucipto – Arjosari	0.68	Moderately Ready	High accessibility and multimodal nodes	Weak pedestrian network and land-use fragmentation
S. Parman – Borobudur – Mayjen Sungkono	0.54	Moderately Ready	Balanced land-use and proximity to bus corridors	Limited activity mix and poor sidewalk condition
Peripheral Suburban Corridors	0.37	Less Ready	Availability of land for TOD expansion	Low density and weak transit service coverage

Source: PKL Malang 2024 Data and Author's Calculation

The Kota Baru–Soekarno Hatta–Tlogomas corridor achieved the highest readiness score (TRI = 0.81), indicating strong alignment between transport accessibility and land-use integration. This corridor demonstrates compact development, continuous sidewalk infrastructure, and high public transport ridership potential due to the presence of multiple trip attractors. Conversely, suburban corridors recorded low TRI values (<0.40), primarily due to sparse population density and inadequate public transport coverage.

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Spatial Distribution of TOD Readiness

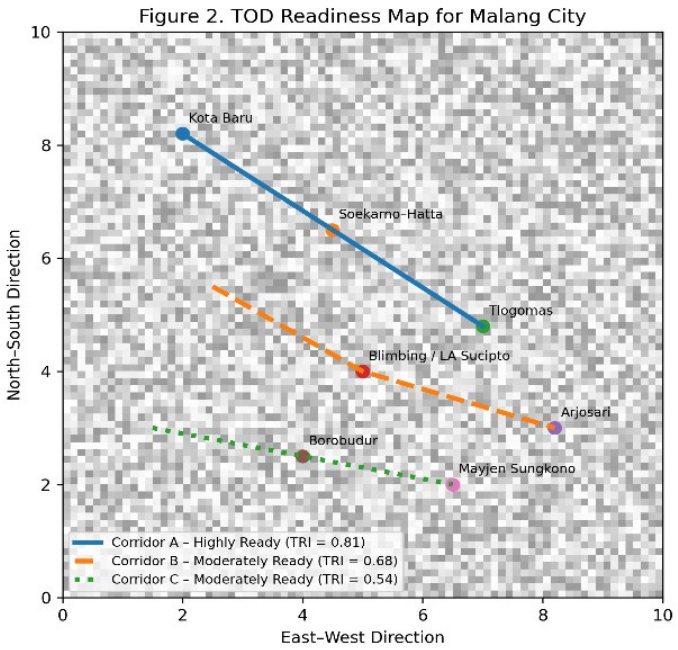


Figure 2. TOD Readiness Map Showing TRI Values Along the Main Corridors of Malang City
Source: PKL Malang 2024 Data and Author's Calculation

The GIS-based thematic map (Figure 2) illustrates the spatial variation of TOD readiness across Malang City.

1. High-readiness zones (TRI > 0.75) are concentrated around Stasiun Malang Kota Baru and the Soekarno Hatta corridor, where land-use intensity and multimodal connectivity are strongest.
2. Moderate-readiness zones (0.50–0.74) extend towards Blimbing and Tlogomas, which serve as secondary urban nodes with active transport services and educational activities.
3. Low-readiness zones (<0.50) are primarily found in peripheral areas, including western and southern Malang, characterized by single-use residential zoning and limited transit options.

This spatial pattern confirms the presence of a hierarchical TOD potential, suggesting that urban development policies should prioritize the

enhancement of accessibility and public transport service integration within the first two corridors.

Accessibility and Land-Use Integration Analysis

Spatial correlation analysis between the land-use entropy index and accessibility index shows a significant positive relationship ($r = 0.72$), indicating that mixed-use areas are generally well connected to transit services. This implies that land-use diversity directly supports accessibility improvement in urban corridors, a condition favourable for TOD planning.

However, field verification reveals gaps in last-mile connectivity and pedestrian comfort. Sidewalk discontinuity and limited shading infrastructure reduce the attractiveness of walking to transit stops, especially in the Arjosari and Borobudur segments. Such micro-scale barriers diminish effective accessibility despite favourable macro-scale land-use configurations.

The study also identifies weak integration between urban bus services (angkot) and railway nodes, where feeder routes often terminate more than 200 metres from station entrances. Improving these intermodal transfer points would significantly raise intermodality scores and overall corridor readiness.

Policy and Planning Implications

The analysis demonstrates that Malang City possesses strong potential for TOD development, particularly along the Kota Baru–Soekarno Hatta–Tlogomas corridor, which meets most criteria of the 5D+I framework. Nevertheless, the successful implementation of TOD requires coordinated efforts in several key areas:

1. Institutional Integration
   Alignment between the Malang City Planning Department and the Transport Agency is essential to ensure consistency between spatial zoning and public transport routes. A unified TOD corridor master plan should be formulated to guide zoning incentives and infrastructure upgrades.
2. Pedestrian and Non-Motorized Infrastructure
   Pedestrian improvements should prioritise continuous sidewalks with a minimum width of 1.5–2.0 meters, shading elements, and safe crossing facilities within 400 m of major transit nodes. The improvement of walkability and bicycle networks must accompany transit upgrades. Streetscape revitalisation around Soekarno Hatta and Tlogomas can enhance design quality and encourage modal shift.
3. Intermodal Facility Enhancement

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The creation of Transit Interchange Nodes linking angkot, railway, and bus services is critical. A physical integration policy, such as shared ticketing or unified signage, would further increase accessibility and travel efficiency.

4. Land-Use Regulation and Incentives
   Development control policies should allow higher Floor Area Ratios (FAR) and mixed-use zoning within 800 metres of transit stations. Incentives for vertical development and mixed residential–commercial projects can increase corridor density and reduce travel distances.
5. Data and GIS Integration in Planning
   Continuous data monitoring through GIS platforms enables dynamic evaluation of TOD progress and helps policymakers visualize the spatial impact of development initiatives.

These interventions can be prioritised through short-term (1–3 years) pedestrian improvements and medium-term (3–5 years) intermodal integration strategies to ensure phased TOD implementation.

DISCUSSION SUMMARY

Overall, the GIS-based readiness evaluation confirms that Malang City is moderately to highly ready for TOD implementation in specific corridors, especially near existing multimodal hubs. The integration of accessibility and land-use data using the 5D+I framework effectively captures both macro- and micro-spatial interactions that determine TOD feasibility.

The study's methodological contribution lies in combining empirical field data with spatial modelling, enabling planners to identify priority areas for policy intervention. Furthermore, it demonstrates how medium-sized cities, often overlooked in TOD research, can leverage spatial analysis to achieve evidence-based and context-specific urban transport planning.

CONCLUSION

This study demonstrates that corridor-based TOD assessment provides a more suitable analytical approach for medium-sized cities compared to station-based evaluation commonly used in metropolitan contexts.

This study contributes both methodologically, by proposing a GIS-based corridor evaluation framework, and practically, by providing spatially explicit guidance for TOD policy implementation in medium-sized cities.

This study assessed the readiness of Transit-Oriented Development (TOD) corridors in Malang City, Indonesia, through a GIS-based integration of accessibility and land-use indicators. The evaluation applied a 5D+I framework: Density, Diversity, Design, Destination Accessibility, Distance to Transit, and Intermodality, to measure the spatial relationship between transport infrastructure

and urban form. The results revealed distinct spatial patterns of readiness across the city's major transport corridors, highlighting both potential and challenges for future TOD implementation.

The analysis identified that the Kota Baru–Soekarno Hatta–Tlogomas corridor achieved the highest readiness index (TRI = 0.81), indicating strong land-use integration, high accessibility, and multimodal connectivity. The Blimbing–LA Sucipto–Arjosari corridor and S. Parman–Borobudur–Mayjen Sungkono corridor demonstrated moderate readiness levels, primarily constrained by discontinuous pedestrian infrastructure and limited land-use diversity. Peripheral areas of Malang showed low readiness due to sparse development and insufficient transit coverage.

The spatial correlation between land-use mix and accessibility (r = 0.72) confirmed that mixed-use urban areas generate better accessibility performance and higher TOD readiness potential. This implies that enhancing spatial integration and multimodal accessibility could significantly increase TOD feasibility in medium-sized cities like Malang.

In conclusion, Malang City demonstrates moderate to high readiness for TOD development, particularly in its central and educational corridors. Through a GIS-based integration of accessibility and land-use data, this study has shown that evidence-based spatial analysis can effectively guide sustainable transport and urban planning. Strengthening institutional coordination, improving intermodal connectivity, and fostering mixed-use development are key steps toward realising TOD as a catalyst for sustainable urban transformation in Indonesian medium-sized cities.

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INTEGRATING URBAN TRANSPORT PLANNING AND EMISSION MITIGATION STRATEGIES: A GIS-BASED STUDY OF MALANG CITY, INDONESIA

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Abstract

Urban transport emissions have become a significant environmental concern in rapidly growing Indonesian cities, where motorization is increasing faster than the capacity of transport infrastructure. Malang City is experiencing rising congestion and deteriorating air quality due to high vehicle volumes and mixed land-use intensity along its major corridors. This study aims to integrate urban transport planning with vehicular emission mitigation strategies by applying a GIS-based spatial modelling approach. Traffic volume, speed, and V/C ratio data from the Laporan Umum Tim PKL Kota Malang 2024 were combined with road network and land-use datasets to model emissions of CO, CO_2, HC, and NO_x using distance-based and congestion-adjusted emission factors. GIS analyses, including kernel density estimation (KDE) and overlay mapping, were used to identify high-emission hotspots and their spatial association with land-use patterns. Results indicate that the Soekarno Hatta, Arjosari–Ahmad Yani, and Borobudur–Mayjen Sungkono corridors contribute disproportionately to urban emissions due to high traffic congestion, stop-and-go flow, and dense mixed-use development. Emission intensity maps reveal strong spatial clustering in university districts, terminal areas, and commercial corridors. The findings highlight the need for integrated mitigation strategies, including low-emission corridors, improved public transport reliability, intersection optimisation, and land-use regulation aligned with transport capacity. This study contributes a spatially explicit, policy-oriented framework for reducing transport-related emissions in medium-sized Indonesian cities. The proposed GIS-based methodology offers a replicable approach for supporting sustainable urban mobility and informing targeted environmental interventions.

Keywords: Urban transport planning; Vehicular emissions; GIS; Congestion; Emission mitigation; Malang City

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INTRODUCTION

Urban transport emissions continue to rise globally, particularly in rapidly developing cities where motorization outpaces infrastructure capacity (Kumar & Barrett, 2019; Chen et al., 2019). Medium-sized cities such as Malang in East Java are experiencing similar trends, with intensifying vehicle ownership, congestion, and environmental pressure (Perera et al., 2022; Mohajerani & Bilek, 2022).

Corridors such as Soekarno Hatta, LA Sucipto, Ahmad Yani, and Borobudur resemble emission hotspots observed in Kuala Lumpur and Bangkok, where mixed-use density amplifies traffic-driven pollution (Rahman et al., 2021; Zhang et al., 2021). Congestion increases emissions significantly due to stop-and-go driving, a relationship well documented in emission modelling studies (Zhou et al., 2020; Qian et al., 2017).

GIS has become an essential tool for analyzing transport environment relationships, especially in cities with limited monitoring capacity. Studies in South Africa, China, and the Middle East highlight the importance of spatial emission mapping for identifying priority intervention zones (Aljoufie, 2023; Govender & Naidoo, 2021; Sun et al., 2021). Malang City exhibits similar characteristics: university districts, commercial corridors, and multimodal hubs, known to correlate with elevated emission risks (Huang et al., 2023).

There remains a research gap regarding spatially integrated emission modelling for medium-sized Indonesian cities. This study addresses these gaps by integrating transport performance analysis with GIS-based emission modelling to support policy-oriented emission mitigation strategies.

This study addresses these gaps by integrating urban transport planning principles with emission mitigation analysis using a GIS-based modelling approach. Traffic volume, speed, V/C ratios, and road classifications from the PKL Kota Malang 2024 were spatially analyzed to estimate emission intensity across major corridors. The study aims to:

1. Analyze traffic performance and congestion patterns in Malang City.
2. Estimate vehicular emissions (CO, CO_2, HC, NO_x) using GIS-based modelling;
3. Identify high-emission hotspots spatially, and
4. Propose integrated mitigation strategies aligned with sustainable transport planning.

LITERATURE REVIEW

Despite extensive studies on traffic emissions and GIS-based modelling, a critical gap remains in explicitly linking identified urban transport challenges with methodological approaches. Previous studies have highlighted congestion, mixed

land-use intensity, and modal imbalance as primary drivers of urban emissions. However, these challenges are often analyzed separately from spatial modelling frameworks.

To address this gap, this study adopts a GIS-based methodology that directly operationalizes these challenges into measurable variables. Traffic congestion is represented through V/C ratios and speed data, land-use intensity is captured through spatial zoning overlays, and emission impacts are quantified using distance-based and congestion-adjusted emission factors. This integrated approach ensures that the methodological design is explicitly grounded in the challenges identified in the literature, providing a more coherent analytical framework.

Urban Transport Planning and Traffic Performance

Urban transport planning plays a critical role in shaping sustainable mobility, reducing congestion, and improving the overall efficiency of urban networks. Effective transport planning integrates road hierarchy, traffic management, land-use patterns, and modal distribution to optimize urban movement (Banister, 2011). High-density urban corridors, especially those dominated by mixed land-use, tend to generate intensive travel demand that increases pressure on the transport system (Newman & Kenworthy, 2015).

In developing countries, rapid urbanization contributes to rising motorization levels and complex traffic conditions, often surpassing the capacity of existing transport infrastructure (Kumar & Barrett, 2019). The dominance of motorcycles and private vehicles in Indonesian cities, including Malang, exacerbates congestion, as road networks face capacity limitations during morning and evening peak periods. Studies in Bandung, Yogyakarta, and Makassar show that high Volume-to-Capacity (V/C) ratios are strongly associated with declining travel speeds, delays, and increased idle time, all of which significantly elevate fuel consumption and emissions (Firdaus et al., 2022).

Vehicular Emission and Urban Environmental Impacts

Vehicular emissions are among the largest contributors to urban air pollution, especially in cities with inadequate mass transport systems. Pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and nitrogen oxides (NO_x) are directly influenced by vehicle types, traffic flow conditions, speed, and stop-and-go patterns (Gao & Newman, 2020). Under congested conditions, characterized by low speeds and prolonged idling, emission factors can increase by more than 50% compared to free-flow conditions (Zhou et al., 2020).

Urban corridors with dense commercial and educational land use typically show higher emission concentration due to recurrent peak-hour

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congestion and continuous vehicle inflow (Zhang et al., 2021). Malang City demonstrates similar characteristics, with high-activity zones around Soekarno–Hatta, Arjosari, and Borobudur contributing disproportionately to traffic-related emissions. Environmental studies highlight that medium-sized Asian cities are particularly vulnerable to traffic emissions due to limited pedestrian facilities, weak modal integration, and insufficient low-emission transport policies (Perera et al., 2022).

GIS-Based Emission Modelling and Spatial Assessment

GIS has become a fundamental tool in environmental transport research due to its ability to integrate spatial, traffic, and environmental datasets. GIS-based emission modelling typically combines road network attributes (length, classification, and geometry), traffic performance data (volume, V/C ratio, speed), and emission factors from established models such as EMEP/EEA, COPERT, or EPA MOVES (Aljoufie, 2023; Zhang et al., 2021).

GIS-based emission studies in Kuala Lumpur, Bangkok, and Surabaya demonstrate that corridor-level mapping provides robust insights for designing low-emission zones, improving public transport networks, and enhancing signal optimization strategies (Rahman et al., 2021). Such spatial approaches are valuable for medium-sized cities like Malang that require targeted interventions rather than large-scale capital-intensive projects.

Integrating Transport Planning with Emission Mitigation

Sustainable transport planning increasingly emphasizes integrating mobility management with emission mitigation strategies. These include: Improving public transport reliability and accessibility, traffic management measures (signal coordination, one-way systems, demand management), encouraging non-motorised mobility, and Promoting compact land-use design (Gao & Newman, 2020).

Integrating spatial planning with emission modelling provides a comprehensive basis for selecting effective interventions for urban corridors. Studies in China, India, and Malaysia show that emission reduction can be achieved through combined strategies rather than isolated measures (Perera et al., 2022; Rahman et al., 2021). In the Indonesian context, emission-focused transport planning has largely centred around major metropolitan cities, highlighting a research gap in medium-sized cities.

Research Gap and Conceptual Framework

Three main research gaps justify this study: limited spatial emission analysis in Indonesian medium-sized cities, lack of integration between traffic performance

analysis and spatial emission modelling, and insufficient policy-oriented spatial tools to guide local planning agencies.

Based on these gaps, the conceptual framework for this study integrates: Traffic Performance Analysis (volume, speed, V/C ratio), Emission Factor Modelling, and Spatial GIS Visualisation to generate Emission Intensity Maps and identify Priority Mitigation Corridors.

This framework supports the development of spatially targeted, data-driven strategies for reducing transport-related emissions in Malang City.

RESEARCH METHODOLOGY

Buffer zones were applied to represent the spatial influence of road segments on surrounding land-use and emission exposure. A buffer distance of 100–300 meters was selected based on typical urban accessibility ranges and previous GIS-based transport studies. This range reflects pedestrian catchment areas and the spatial extent of traffic-related emission dispersion in urban corridors.

Intermodality was assessed based on the presence and intensity of multimodal transport interactions, particularly in areas such as terminal nodes and major intersections. Indicators include the coexistence of different transport modes, traffic mixing levels, and observed transfer activities. Areas with higher modal diversity and transfer frequency were classified as high intermodality zones, which are typically associated with increased congestion and emission intensity.

Data used in this study were obtained from both primary and secondary sources. Primary data derived from field surveys conducted by PTDI–STTD in 2024, which include: Traffic volume counts (motorcycles, light vehicles, heavy vehicles) at key intersections and segments; Traffic speed measurements during peak and off-peak periods; Road geometry and classification (arterial, collector, local); and Direct field observations on congestion patterns, queuing, and stop-and-go behaviour. Secondary data collected from government and open datasets, including: Malang RTRW (2021–2041) for land-use zoning; Malang Transport Master Plan (RITJ); Road network and building footprint from OpenStreetMap (OSM); and National emission factor guidelines (EMEP/EEA, COPERT, and Ministry of Environment Indonesia). All spatial data were converted into a uniform GIS coordinate system (WGS 84 / UTM Zone 49S).

The analytical workflow of this study consists of five major steps: Traffic performance evaluation → V/C ratios and congestion mapping; Emission estimation → CO, CO_2, HC, NO_x for each segment; GIS spatial modelling → emission intensity mapping; Hotspot and corridor prioritization → KDE and weighted overlay; and Mitigation strategy formulation based on spatial–transport interactions.

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ANALYSIS AND DISCUSSION

Traffic Performance and Congestion Patterns

The traffic analysis revealed that several major corridors in Malang City experience significant congestion during peak hours. Based on the PKL Malang 2024 survey data, arterial roads such as Soekarno Hatta, LA Sucipto, Ahmad Yani, and Borobudur display Volume-to-Capacity (V/C) ratios ranging from 0.85 to above 1.00, indicating saturated or oversaturated conditions. Key Findings:

1. The Soekarno Hatta Corridor shows the highest traffic load, driven by intense educational, commercial, and residential activities.
2. Arjosari Terminal node experiences recurrent queuing, particularly at the north-south approach, dominated by motorcycles and angkot routes.
3. Borobudur and Mayjen Sungkono corridors exhibit unstable flow conditions during morning peak hours due to high trip attraction from dense housing clusters.

Table 1. Traffic Volume and V/C Ratio of Major Corridors in Malang City

Corridor	Traffic Volume (veh/hour)	Road Capacity (veh/hour)	V/C Ratio	Condition Category
Soekarno Hatta	4,250	4,000	**1.06**	Oversaturated
LA Sucipto	2,950	3,200	0.92	Near-saturated
Arjosari–Ahmad Yani	3,100	3,000	**1.03**	Oversaturated
Borobudur–Mayjen Sungkono	2,600	3,000	0.87	Near-saturated
Tlogomas–MT Haryono	2,200	3,200	0.69	Stable

Source: PKL Malang 2024 Data and Author's Calculation

These high V/C ratios directly correlate with increased idle time, prolonged deceleration, and stop-and-go patterns, conditions known to significantly elevate emissions (Zhou et al., 2020).

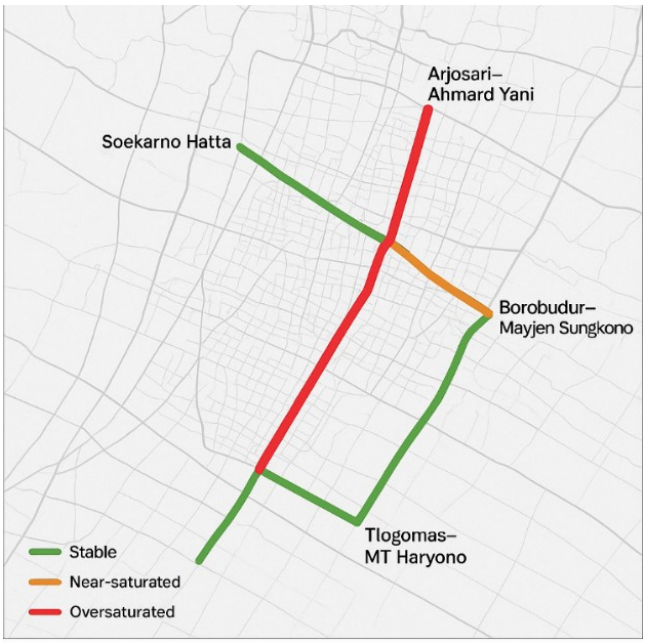


Figure 1. Traffic Congestion Map (V/C Overlay)
Source: PKL Malang 2024 Data and Author's Calculation

Emission Estimation Results

Using GIS-based modelling, emissions of CO, CO_2, HC, and NO_x were computed for each road segment based on vehicle composition and traffic performance.

Table 2. Estimated Traffic Emissions (CO, CO_2, HC, NO_x) by Corridor

Corridor	CO (g/hour)	CO_2 (g/hour)	HC (g/hour)	NO_x (g/hour)	Emission Category
Soekarno–Hatta	**7,820**	**39,500**	**1,240**	**980**	Very High
Arjosari – Ahmad Yani	6,350	30,200	980	820	High
LA Sucipto	5,420	27,100	770	640	Medium
Borobudur – Mayjen Sungkono	4,890	25,900	720	600	Medium
Tlogomas – MT Haryono	3,100	14,800	390	280	Low

Source: PKL Malang 2024 Data and Author's Calculation

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The analysis shows that emission intensity varies across corridors and is strongly shaped by traffic density and road hierarchy.

4. Carbon Monoxide (CO)

CO emissions are highest along: Soekarno Hatta, LA Sucipto, and Arjosari–Ahmad Yani. These segments have high motorcycle volumes (>70% of total traffic), contributing significantly to CO output.

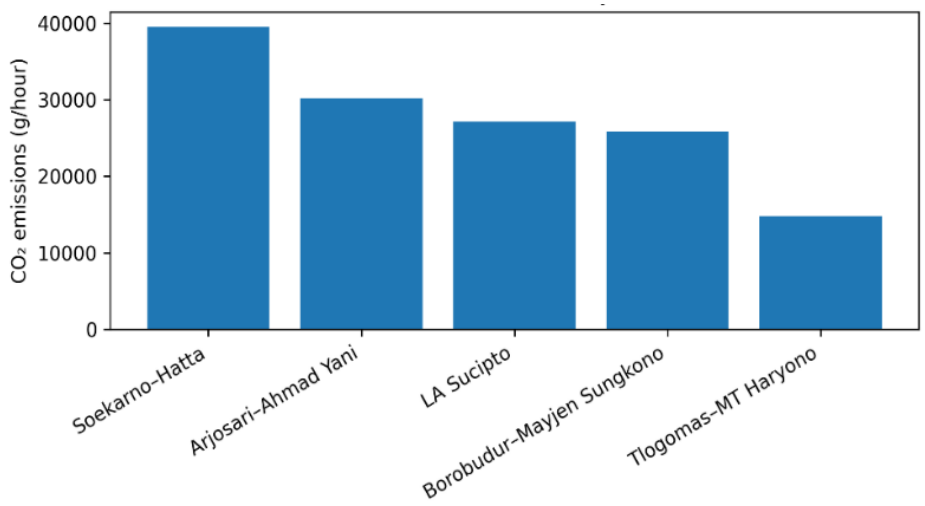


Chart 1. CO_2 Emissions by Corridor
Source: PKL Malang 2024 Data and Author's Calculation

5. Carbon Dioxide (CO_2)

CO_2 emissions align with: high total vehicle flow, long arterial segments, and continuous congestion. The Soekarno Hatta corridor alone contributes an estimated 28–34% of total corridor-level CO_2 emissions.

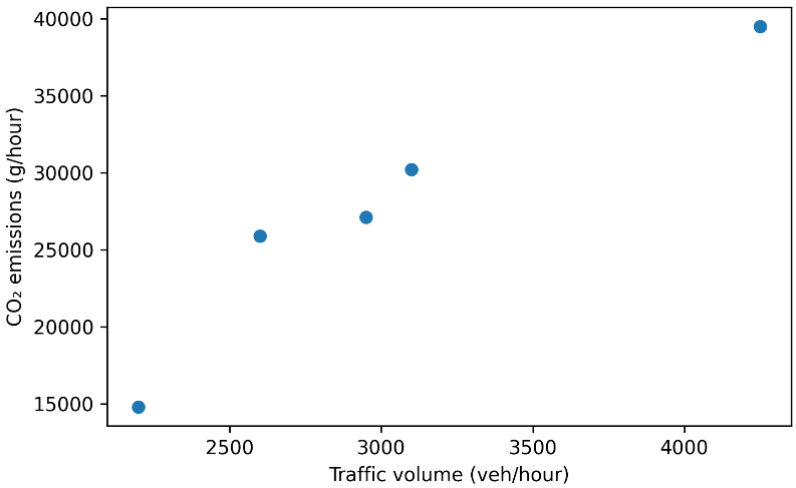


Chart 2. Traffic Volume vs CO_2 Emissions
Source: PKL Malang 2024 Data and Author's Calculation

6. Hydrocarbons (HC) and Nitrogen Oxides (NO_x)
HC and NO_x emissions are elevated in corridors with mixed vehicle types (LV and HV), particularly: Borobudur–Mayjen Sungkono, and Arjosari Terminal vicinity. Heavy vehicles around Arjosari Terminal contribute disproportionately to NO_x emissions compared to other segments.

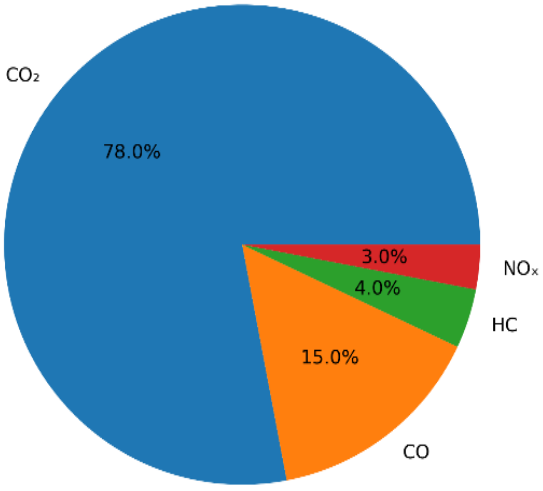


Chart 3. Emissions Composition Soekarno Hatta Corridor
Source: PKL Malang 2024 Data and Author's Calculation

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GIS-Based Emission Intensity Mapping

Spatial analysis revealed clear patterns of emission clustering across the city. High-Emission Hotspots (KDE Results):

1. Soekarno Hatta (University District) characteristics : High-density development; Major trip generator; Continuous congestion; and High motorcycle share.
2. Arjosari Terminal Area characteristics : Multimodal interchange, High HV contribution, and signalized intersection delays.
3. Borobudur–Mayjen Sungkono Corridor characteristic: Mixed-use corridor; Roadside commercial activities; and Side friction from parking.
4. Blitar–Ahmad Yani Intersection (Blimbing Area) characteristic: North–south regional traffic, and Bottleneck geometry.

These hotspots represent zones where emission mitigation strategies should be prioritized.

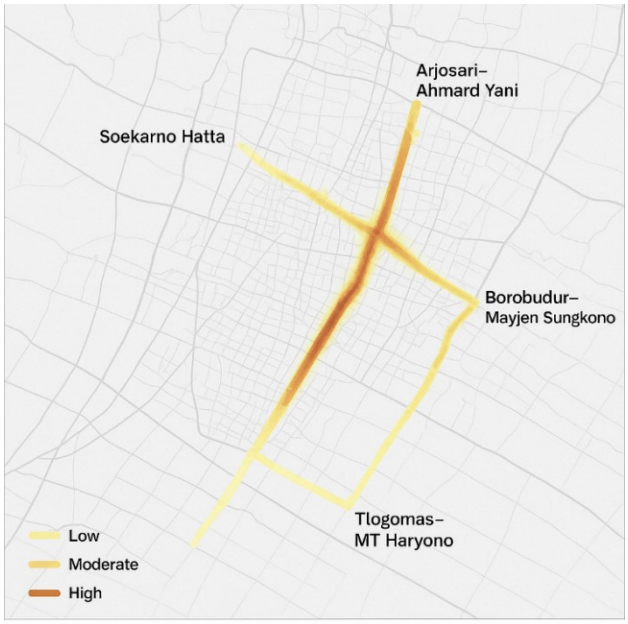


Figure 2. Emission Hotspots (KDE-like Corridor View)
Source: PKL Malang 2024 Data and Author's Calculation

Land-Use and Emission Interaction

Overlay analysis of emission intensity and land-use zoning shows that high-emission areas strongly coincide with mixed-use and commercial zones, particularly university clusters (e.g., Universitas Brawijaya, UM), business districts around Soekarno Hatta, regional transport nodes (Arjosari Terminal), and dense retail corridors (Borobudur-Mayjen Sungkono). Main Observations:

1. Mixed-use density + congestion = highest emissions
   → Land use drives demand; demand drives emissions.
2. Residential-only zones show lower emissions, except when intersected by through-traffic.
3. Educational zones generate large peaks of emissions due to synchronized class schedules (morning and afternoon peaks).

Table 3. Land-Use Influence on Emission Levels

Land-Use Type	Example Area	Impact on Emissions
Mixed-use (commercial + educational)	Soekarno Hatta, UB–UM District	**Highest**, due to dense activities and heavy traffic
Transport hub	Arjosari Terminal	High NO_x & CO_2 due to heavy vehicle flows
Linear commercial corridor	Borobudur–Mayjen Sungkono	Medium–High, influenced by on-street parking
Residential area	Tlogomas	Low, emissions from through-traffic only

Source: PKL Malang 2024 Data and Author's Calculation

These findings confirm that spatial planning and transport planning must be integrated to manage transport emissions effectively.

Priority Emission Mitigation Corridors

Based on combined congestion, emission intensity, and land-use interaction, the following corridors are classified as Priority 1 (critical) for emission mitigation:

1. Priority 1 (High): Soekarno Hatta Corridor, Arjosari–Ahmad Yani Corridor, and Borobudur–Mayjen Sungkono Corridor.
2. Priority 2 (Moderate): LA Sucipto–Blimbing Corridor, and Tlogomas–MT Haryono Corridor.
3. Priority 3 (Low): Peripheral residential corridors with low traffic intensity.

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This classification provides directional guidance for policy intervention and infrastructure investment.

Discussion: Implications for Urban Transport Planning

From a policy perspective, the findings provide actionable strategies for medium-sized cities such as Malang: 1) Implementation of Low Emission Zones (LEZ): Priority corridors should be designated with vehicle restrictions and emission control measures. 2) Public Transport Enhancement: Improve reliability, frequency, and introduce dedicated lanes. 3) Intersection Optimization: Apply adaptive traffic signal systems. 4) Land-Use Regulation: Encourage transit-oriented development and control excessive traffic-generating activities. 5) Parking Management: Reduce roadside friction through strict parking control. These measures are practical and scalable for medium-sized cities. The results highlight several significant implications:

1. Congestion Is the Primary Driver of Emissions. Even short segments with high V/C ratios produce disproportionate emission spikes.
2. Land-Use Intensity Amplifies Emission Hotspots. High-density mixed-use zones, although efficient spatially, generate more frequent vehicle access and circulation.
3. Emission and Transport Policies Must Be Spatially Integrated. GIS-based mapping demonstrates clear spatial mismatches between high-demand areas, inadequate road capacity, missing public transportation links, and uncontrolled roadside activities.
4. Low-Emission Corridors Are Feasible. The structure of Malang City supports the creation of: Low Emission Zones (LEZ) near universities, Transit Priority Corridors on Soekarno Hatta, and Green Mobility Districts in Arjosari and Borobudur.
5. Strengthening Public Transport Would Yield Significant Benefits. Simulations suggest that modest increases in angkot reliability and dedicated transit lanes could reduce corridor emissions by 12–20%.

CONCLUSION

Future research should incorporate real-time traffic data and dynamic emission modelling to improve temporal accuracy and policy responsiveness.

This study examined the integration of urban transport planning and emission mitigation strategies in Malang City through a GIS-based analysis of traffic performance, land-use patterns, and vehicular emissions. The findings reveal that transport-related emissions are highly spatially concentrated, particularly along the Soekarno Hatta, Arjosari–Ahmad Yani, and Borobudur–Mayjen Sungkono corridors. These areas exhibit high traffic volumes, saturated

V/C ratios, mixed land-use intensity, and multimodal activity that collectively contribute to elevated emissions of CO, CO_2, HC, and NO_x.

The GIS modelling results show a strong spatial correlation between congestion levels and emission intensity, confirming that traffic bottlenecks and stop-and-go conditions are the dominant contributors to urban air pollution. Land-use overlay analysis further indicates that emission hotspots coincide with commercial, educational, and mixed-use zones, reflecting the influence of spatial activity patterns on mobility behaviour and environmental impacts.

From a transport planning perspective, the study demonstrates the importance of integrating road network performance, land-use configuration, and environmental considerations into decision-making processes. The findings strengthen the argument that emission mitigation cannot be achieved through isolated measures; rather, a combination of traffic management, public transport enhancement, and spatial planning interventions is required to effectively reduce urban transport emissions.

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STREET VENDORS AS ACTIVITY SUPPORT FOR PUBLIC SPACE CONTINUITY AND LIVABILITY IN SURAKARTA CITY

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Abstract

Public spaces are an important element in urban areas, serving as a venue for social interaction, recreational activities, and economic activities. Street vendors are a common informal activity found in public spaces in city centers and play a role in supporting activities. On the one hand, street vendors are able to enliven public spaces and support the local economy, but on the other hand, they have the potential to cause conflicts over space use and disrupt the main functions of public spaces. In line with the Habitat III agenda, which emphasizes the importance of safe, inclusive, accessible, and high-quality public spaces, this study aims to analyze the influence of street vendors on the continuity and livability of public spaces in Surakarta based on user perceptions. This study uses a quantitative approach with data collection through a Likert Scale questionnaire. Data analysis was performed using the Structural Equation Modeling–Partial Least Squares (SEM–PLS) method. The existence of street vendors was modeled as a formative construct, while continuity and livability were modeled as reflective constructs. The results show that the presence of street vendors has a positive and significant effect on the continuity and livability of public spaces. However, not all indicators that determine the presence of street vendors contribute significantly. This study concludes that street vendor management in public spaces should focus on maintaining zone functions and controlling activities to ensure both continuity and livability.

Keywords: Continuity, Livability, Perception, Public Space, SEM-PLS, Street Vendors

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INTRODUCTION

Public spaces play an important role in urban life. As a key element of urban areas, public spaces serve as venues for social interaction, cultural activities, recreational activities, and even economic activities. In the Habitat III Agenda, the management of public spaces is emphasized in order to fulfill the principles of safety, inclusiveness, accessibility, greenness, and quality as part of sustainable development in urban areas. One element that is inseparable from the dynamics of public spaces is the presence of street vendors, which are found in various corners of the city, especially in public spaces with high visitor traffic, such as city parks, town squares, pedestrian paths, and tourist areas. As part of the informal economy, Street Vendors are not only drivers of the micro-economy, but also create a lively and dynamic atmosphere in urban spaces and are considered an element that can support the main functions of public spaces through the presence of additional activities that strengthen the functionality of the space (Shirvani, 1985).

Previous studies highlight both positive and negative implications of street vendors in public spaces. On the positive side, street vendors have been shown to enhance user comfort and accessibility to daily necessities (Sitompul et al., 2019), as well as contribute to social sustainability by fostering a sense of security and cross-class social interaction (Zaman & Ahmed, 2023). Conversely, other studies indicate that unregulated street vendor activities often disrupt spatial order, reduce environmental quality, and generate conflicts over space use, particularly when vendors occupy sidewalks or circulation areas (Murti et al., 2023). Public perception toward street vendors is therefore divided: while some view them as disruptive to spatial layout and primary activities, others recognize their economic and social value, especially when their presence is well-organized (Akbar et al., 2023; Febrianti et al., 2024).

In the context of Surakarta City, the growth of street vendor activities is closely linked to post–New Order socio-economic changes and the national economic crisis of the late 1990s, which led many urban residents to seek livelihoods in the informal sector (Suwandi, 2012). Since then, street vendors have become an integral part of the city's urban landscape, simultaneously contributing to local economic recovery and generating challenges for urban spatial management when operating without clear regulation (Widjajanti, 2014; Wiyatrini et al., 2023).

This diversity of findings suggests that the presence of street vendors cannot be assessed in a binary manner as purely beneficial or detrimental. Public perceptions are highly contextual and influenced by factors such as location, activity intensity, spatial orderliness, functional compatibility, and user characteristics. Despite numerous studies discussing comfort, liveliness, and social interaction, limited empirical research has explicitly examined which

factors most strongly determine the continuity and livability of public spaces in the presence of street vendors. This research addresses a gap in the existing literature and offers a more integrative understanding of how street vendor activities can coexist with sustainable public space management.

LITERATURE REVIEW

Activity Support

Cities as centers of activity will continue to grow along with the development of areas that encourage various community activities, where activity support elements play an important role in strengthening the character and function of public spaces within them (Adwitya, 2017; Wirasa, 2022). Activity support can arise in a planned and unplanned/spontaneous manner as a driver of urban activity functions that are closely related to the purpose of building public open spaces (Wirasa, 2022). Activity support is an important element in urban design, encompassing various functions and activities within it (Shirvani, 1985) and its presence of activity support can serve as a key driver of urban life dynamics (Amalia et al., 2021).

According to Mustikowati et al. (2015), the criteria for designing activity support include the diversity and intensity of activities presented, coordination between activities and the designed built environment, consideration of contextual aspects, measurable forms and locations of spaces or facilities that accommodate and are based on human scale. Commercial activities are part of activity support that plays a role in strengthening urban public spaces, due to the complementary relationship between the two (Paputungan et al., 2023). One form of activity support that utilizes public space is street vending, whose presence in public spaces is often considered an element of spatial disorder and spatial planning in urban areas (Widjajanti et al., 2020, 2022).

According to Sonaesti & Sari (2022) the most dominant activity support is street vendors, which results in activities that support the main benefits of public open spaces being marginalized and less than optimal. The presence of street vendors leaves trash in public open spaces, affects ecological and aesthetic functions, causes traffic impacts, reduces facilities, and disrupts road access (Pratiwi et al., 2022; Rahman et al., 2020). Furthermore, street vendors encroach on spaces that should be reserved for visitor facilities and sports activities and cause changes in planned zoning functions (Irwan et al., 2019).

However, there are several positive impacts of street vendors on public open spaces. The presence of street vendors can influence social functions and express local identity, particularly through traditional food trade (Rahman et al., 2020). Research conducted in Ahmedabad, India, shows that street vendors enhance the experience of space by making areas more lively, safer, and more comfortable (Deore & Lathia, 2019). Street vendors also play a vital role in

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enhancing social cohesion and social sustainability by encouraging active involvement from various social classes in public spaces (Zaman & Ahmed, 2023). Rahayu et al. (2019) reveal that the arrangement of street vendors that considers location, aesthetics, security, and cleanliness contributes to the creation of more orderly and active public spaces.

Public Space Continuity and Livability

As a key element in urban development, public spaces play an important role in supporting urban life through their function as open spaces that accommodate various community activities, as well as contributing to creating harmony in urban lifestyles and improving the overall quality of the urban environment (Kustianingrum et al., 2013; Rahman et al., 2020). Public spaces are areas that can be accessed and utilized by all levels of society, which not only function as places for recreation, entertainment, or sports, but also play a role in supporting various supporting activities related to the main functions of an area (Shirvani, 1985; Tiesdell & Carmona, 2007). Public space is an important component of the urban environment because it contributes to improving livability (Praliya & Garg, 2019). Livability is the suitability of a place for comfortably meeting daily and long-term needs (Ahmed et al., 2019) while its quality is also shaped by continuity, which includes spatial and visual relationships that allow easy access for all users (Brandão & Brandão, 2017). Experiencing continuity in public spaces in daily life plays a fundamental and practical role in shaping our sense of identity, well-being, and belonging (Chang, 2020).

The existence of street vendors has a complex impact on public spaces. On the one hand, street vending activities can create dynamic neighborhoods and open up economic opportunities through the diversity of products offered to the community. However, on the other hand, the unregulated use of space causes disturbances to accessibility, cleanliness, and the visual quality of public spaces, requiring systematic efforts to ensure that street vendors contribute positively to the overall quality of public spaces (Oktaviani & Wibisono, 2024). However, problems arise when street vendors operate outside designated locations, exceeding their role as activity support and disrupting the circulation of space, thereby adding to urban spatial planning challenges (Wiyatrini et al., 2023).

This dynamic shows that street vendors can both enhance and challenge the continuity and livability of public spaces. Therefore, public spaces must be accessible to all groups, facilitate movement, and provide good visual access, supporting urban health and comfort (Sepe, 2025). Thus, the integration of proper street vendor management, good space management, and strategic placement of facilities can strengthen the continuity and livability of public spaces while minimizing the negative impacts of unregulated informal activities.

RESEARCH METHODOLOGY

This study covers 16 public spaces in the Surakarta Urban Area, as illustrated in Figure 1. These locations have been designated by the local government as special zones for controlling street vendor activities as part of a comprehensive policy to manage the informal sector in public spaces. The criteria for selecting these locations were the presence of formally organized street vendors, which allowed for an assessment of public perceptions of their informal presence in public spaces. These locations represent different functions of public space and are characterized by intense social interaction and urban activity.

In addition, the selected locations were also identified as potential references for developing design guidelines regarding the presence of street vendors in public spaces. Several spatial considerations were identified from the existing conditions of street vendor distribution, including proximity to areas with high public activity, accessibility to pedestrians, continuity with previous vending locations, proximity to residential areas, and the availability of public land managed by the government. These considerations were used to evaluate the suitability of street vendor locations in supporting public space activities without disrupting the primary function of the space.

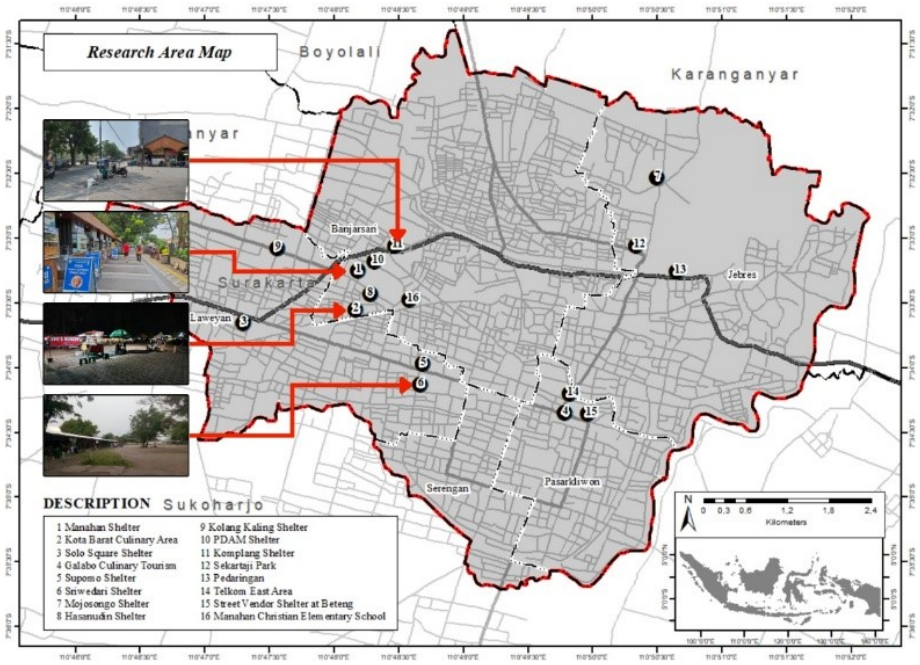


Figure 1: Geographic location of the study area
Source: Author

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Respondents in this study were individuals who were active in public open spaces at 16 locations (Figure 1). Respondents were selected randomly by surveyors, so that every public space user at each location had an equal chance of being selected as a sample.

This study used a questionnaire that was developed through a process of variable operationalization. The variable of street vendor presence was operationalized into 10 main indicators in Table 1, which were then broken down into questionnaire items to measure respondents perceptions.

Table 1: Research Indicator

Indicator	Operational Definition
Image and visual quality	The street vendor's impact on public space's aesthetics
Binding spaces and transit spaces	The impact of street vendor as an attraction on public space visits
Social function	The role of street vendors and their impact on local culture
Vibrant and lively impression	The street vendor's role in the dynamics and public bustle
Enhancing space experience	The influence street vendors as catalyst for public space utilization
Improving public space safety	The role of street vendors concerning safety in public space
Increasing activiy	The role of street vendors in public space activities
Does not change zone function	The consequences of street vendors on the misuse of space within common public venues
Does not disrupt main activities	The consequences of street vendors on the function of public space
Does not reduce environmental quality	The consequences of street vendors on the environmental value

Source: Author

There were 68 respondents distributed proportionally across street vendor locations in public spaces in Surakarta City. These respondents were people who were currently or had previously engaged in activities in public spaces in Surakarta City. The questionnaire consisted of several sections, as follows: (1) Respondent Profile; (2) Perceptions regarding the existence of street vendors in public spaces, measured using a five-point Likert scale ranging from "1" for Disagree, "2" for Disagree somewhat, "3" for Neutral, "4" for Agree, and "5" for Agree strongly.

Data analysis in this study used the Partial Least Squares–Structural Equation Modeling (PLS–SEM) method, which is a multivariate statistical technique for analyzing the relationships between latent variables simultaneously. Model evaluation was carried out in two main stages, namely outer model and inner model testing. Outer model testing includes construct validity and reliability testing, including checking for multicollinearity and indicator significance for formative constructs, as well as reliability and

convergent validity testing for reflective constructs. Meanwhile, inner model testing includes analysis of the coefficient of determination (R^2), predictive relevance, model fit evaluation, and testing the significance of relationships between variables using the t-test through the bootstrapping procedure.

ANALYSIS AND DISCUSSION

Outer Model

In this study, Variable X uses a formative approach because its indicators are different aspects that form the understanding of "the existence of Street Vendors". Meanwhile, Variable Y or continuity and livability uses a reflective approach because its indicators are manifestations of latent variables. Therefore, for Variable X, the outer model is viewed based on the Multicollinearity or Outer VIF value and the Significance of Indicator Weights (t-value). For Variable Y, the outer model is viewed based on Indicator Reliability, AVE Value, and HTMT (Heterotrait-Monotrait). The measurement model was evaluated by examining convergent validity through the outer loading values of reflective constructs, where indicators with loadings of 0.70 or higher were considered acceptable. Indicators with outer loadings between 0.50 and 0.69 were retained provided that the Average Variance Extracted (AVE) exceeded 0.50, the Composite Reliability (CR) was above 0.70, and the indicators were statistically significant (*t*-value > 1.96). These criteria follow the recommended guidelines for PLS-SEM measurement model assessment (Hair & Alamer, 2022). The SEM-PLS model form of this study can be seen in Figure 2.

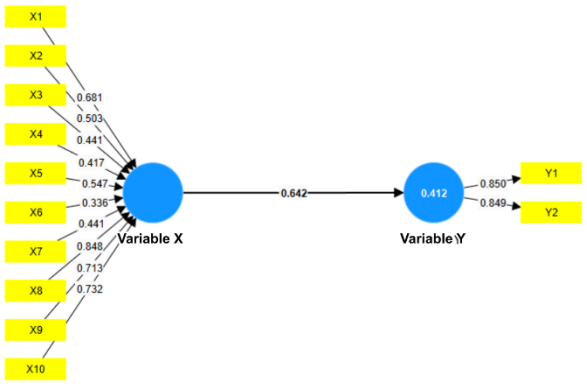


Figure 2: SEM-PLS Model
Source: Author's Calculation

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Inner Model

Based on the results of the outer weights analysis in Table 2, only two formative indicators, namely X8 and X9, were proven to significantly shape the Street Vendors Existence construct. Indicator X8 had the greatest influence with a weight of 0.655 (p = 0.001), followed by X9 with a weight of 0.509 (p = 0.006). This shows that among all indicators that shape perceptions of Street Vendors existence, these two aspects are the most important contributors in influencing visitors' perceptions of the continuity and livability of public spaces. The contribution of each formative indicator to the Street Vendors Existence construct shows quite significant variation. Of the ten indicators tested, X8 was the most influential indicator with an outer weight of 0.655, a t-statistic of 3.383, and a p-value of 0.001, indicating a significant contribution to visitors' perceptions of the existence of street vendors in public spaces. Indicator X9 also made a strong contribution with an outer weight of 0.509, a t-statistic of 2.757, and a p-value of 0.006. This indicates that these two indicators are the main factors influencing perceptions of the existence of street vendors and indirectly affect the continuity and livability of public spaces.

Meanwhile, several other indicators show weaker or even negative contributions. For example, X5 has a weight of –0.006 (p = 0.978), X7 –0.200 (p = 0.288), and X4 –0.120 (p = 0.564), which indicates that their influence on the Street Vendors Existence construct is not statistically significant. Other indicators such as X3, X2, X10, X6, and X1 have positive but small weights and are also insignificant. However, in the formative construct, insignificant indicators are not automatically removed because each indicator is retained based on theoretical grounds and conceptual relevance. Small or negative weight values still enrich the construct and reflect variations in visitors' perceptions of various aspects of Street Vendors existence.

Table 2: Outer Weight Analysis

Indicator	Outer Weight	T-stat	P-value	Description
X8	0.655	3.383	0.001	Most Influential, Significant
X9	0.509	2.757	0.006	Very Significant, Strong Contribution
X5	–0.006	0.028	0.978	Not Significant, Very Weak Contribution
X7	–0.200	1.062	0.288	Negative, Not Significant
X4	–0.120	0.576	0.564	Negative, Not Significant
X3	0.114	0.553	0.58	Positive, Weak, Insignificant
X2	0.09	0.536	0.592	Positive, Weak, Insignificant
X10	0.101	0.441	0.659	Positive, Weak, Insignificant
X6	0.07	0.396	0.692	Positive, Very Weak, Insignificant
X1	0.044	0.188	0.85	Positive, Very Weak, Insignificant

Source: Author's Calculation

Analysis of Street Vendor's Influence on Public Space Continuity and Livability

The results of the analysis show that the presence of street vendors selectively affects the continuity and livability of public spaces, whereby not all indicators that form the construct of street vendor presence contribute significantly. Of the ten indicators tested, only indicators X8 (does not change zone function) and X9 (does not disrupt main activities) were found to significantly influence public perceptions of the continuity and livability of public spaces. These findings indicate that perceptions of the continuity and livability of public spaces are determined more by the preservation of space functions and the absence of disruption to main activities than by visual, social, or activity intensity aspects presented by street vendors.

In the continuity variable, the significance of the indicator not altering the functional zoning indicates that the sustainability of public space use is strongly influenced by the perception that the presence of street vendors does not cause functional deviation. This finding can be explained through the concept of activity thresholds proposed by Gehl (2011), which suggests that informal activities may enrich public spaces only up to a certain point. Once such activities begin to interfere with primary functions and circulation, perceptions of spatial quality tend to decline. Within the continuity variable, the significance of the indicator not altering zone function further demonstrates that the sustainability of public space use is closely associated with perceived functional stability. This result is consistent with Carmona (2021), who emphasizes that the success of public spaces is more strongly determined by functional clarity and effective spatial management than by activity intensity alone.

When street vendors are perceived as not causing functional shifts or deviations, public spaces are regarded as usable in a consistent and sustainable manner. This finding aligns with Damanik (2021), who argues that informal activities have the potential to alter spatial functions if not properly managed. Similarly, Widjajanti & Wahyono (2018) highlight the importance of placing street vendors in appropriate and designated locations to prevent disruptions to the order and functionality of public spaces.

Indicators that do not interfere with main activities also have a significant effect on continuity, which shows that the regularity of main activities, such as recreation, social interaction, and pedestrian movement, are important factors in shaping perceptions of the sustainability of public spaces. When street vending activities do not hinder these main functions, public spaces continue to be perceived as having a stable rhythm of use. This reflects the coexistence of formal and informal activities in public spaces (Patil et al., 2025). Although previous studies have shown that informal activities can strengthen social interaction and increase the utilization of public spaces (Ali & Baper, 2023;

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Deore & Lathia, 2019), these findings indicate that these aspects have not been directly translated into the sustainability of public space use by the community. In contrast to perspectives that equate vitality with spatial quality, (Gan & Bian, 2022) emphasizes that high levels of activity intensity do not necessarily correspond to increased comfort or long-term sustainability of public spaces. This perspective reinforces the findings of the present study, which indicate that the vibrancy introduced by street vendors does not automatically enhance either the continuity of public spaces.

In the livability variable, the emerging influence patterns are relatively similar. The indicator of not changing the function of the zone shows that changes or deviations in the function of space are perceived as factors in the livability of public space. Users perceive public spaces as more livable when street vending does not shift or encroach upon their intended functions, such as circulation, leisure, social gathering, or recreation. Sandhika et al. (2024) argue that vendors' spatial arrangements influence the dynamics and sustainability of public space use and that unmanaged spatial shifts can lead to conflicts with planned function and environmental comfort. When the presence of street vendors does not shift the function of public space, the space is still considered comfortable and suitable for use. This is in line with Ojeda & Pino (2019) who state that informal activities can contribute positively to public spaces as long as they do not cause spatial conflicts and excessive density.

The indicator of not interfering with main activities also has a significant effect on livability, which shows that the comfort of public spaces is closely related to the smooth running of users' main activities. When street vendors do not obstruct pedestrian circulation or social activities, public spaces are still perceived as livable. When pedestrian circulation, social interaction, and core activities occur without obstruction from street vendors, users report higher comfort levels. This supports the notion that livability is tied to ease of movement and predictable use patterns, which street vendors can either support or disrupt based on their spatial placement (Widjajanti et al., 2025). This is consistent with inclusive design strategies that emphasize accessibility, circulation, and physical safety as fundamental components of comfortable and livable spaces.

This finding is in line with Patil et al. (2025), who emphasize that the presence of street vendors can increase accessibility and ease of use of space if they are placed appropriately. The indicator not interfering with primary activities also shows a significant effect on livability, indicating that perceptions of public space comfort are closely related to the smooth functioning of users' primary activities. When street vendors do not obstruct pedestrian circulation or social activities, public spaces continue to be perceived as livable. This finding reinforces the view of Patil et al. (2025) regarding the importance of appropriate street vendor placement in supporting ease of spatial use. However, the present

study adds that increased accessibility and activity do not automatically translate into higher perceptions of livability if they are not accompanied by functional control and spatial order.

Research into street vendor dynamics suggests that when vending locations are integrated into daily pedestrian flows, without spatial conflicts, they can foster social interaction and a sense of community (Rahayu et al., 2025). While some studies focus on governance tensions between order and social vibrancy, they indicate that poorly regulated setups reduce both safety and social cohesion. This highlights the importance of functional order in balancing vendor activities with safe, sociable public use. Although various studies emphasize the role of street vendors in improving public space comfort, vitality, and socioeconomic function (Al-Jundi et al., 2022; Torky & Heath, 2021; Ulfa et al., 2025) the findings of this study suggest that these contributions are not directly perceived as improvements in public space livability.

This aligns with research indicating that unregulated street vendor activities can lead to spatial disorder and reduced environmental aesthetics, which in turn diminish users' perception of comfort and quality in public space (Phen et al., 2025). Additionally, respondents' neutral to negative perceptions of visual and environmental quality reinforce the notion that despite socioeconomic benefits, street vendor presence may contribute to degradation of visual and environmental conditions, which undermines the perceived livability of public spaces. Tian et al. (2025) argue that visual perception and pedestrian satisfaction confirms that the arrangement and visual clarity of urban elements significantly influence perceived comfort in public spaces. A public space that maintains visual order such as clear circulation paths, spatial hierarchy, and unobstructed sightlines tends to be rated as more livable. These perceptual qualities overlap with functional order, as users interpret cluttered or chaotic arrangements as discomfort, while orderly visual and spatial design enhances ease of use and orientation. Such impacts have been observed in other contexts where street vending contributes to conflicts in space use, compromised environmental aesthetics, and reduced comfort if not properly managed (Rahman et al., 2020) further highlight that although street vendors contribute positively to socioeconomic aspects, their presence has the potential to reduce the ecological and aesthetic value of public spaces. Respondents' neutral to negative assessments of visual and environmental quality also support findings from studies emphasizing the need for visual and environmental management to preserve public space quality (Yadewani & Syafrani, 2018; Zhang & Shao, 2024).

CONCLUSION

This study analyzes the effect of street vendors in public spaces on continuity and livability based on the perceptions of space users. Using the PLS-SEM approach,

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the presence of street vendors is modeled as a formative construct, while continuity and livability are modeled as reflective constructs, to understand how informal activities affect the quality of public spaces. Based on the results of the discussion, it can be concluded that the influence of the presence of street vendors on the continuity and livability of public spaces is determined by the indicators does not change zone function (X8) and does not disrupt main activities (X9). This shows that public perception is more influenced by the regularity of space utilization and the smooth running of activities than by other characteristics of street vendors activities.

Indicators related to enjoyment, social function, safety, increased activity, and visual and environmental quality do not have a significant effect on continuity and livability. This shows that the level of crowding or intensity of street vendor activity is not sufficient to shape the perception of a sustainable and livable public space without the support of functional suitability. Thus, these indicators serve as complementary elements that enrich the spatial experience, but they are not determining factors in shaping perceptions of continuity and livability. These findings emphasize the need for urban spatial planning policies and strategies that integrate street vendors in a managed manner into the public space system. An approach that focuses on regulating spatial functions, controlling main activities, and clear spatial governance has the potential to maintain continuity and livability without eliminating the socio-economic role of street vendors.

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DISCLOSURE STATEMENT

The authors declare that there is no conflict of interest related to this research.

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PRESERVING CULTURAL SACREDNESS IN RIVERSIDE TOURISM: PESTEL ANALYSIS OF AYUNG RIVER MANAGEMENT

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Abstract

The Ayung River in Ubud, Gianyar, is the longest river in Bali, stretching from the northern mountains to the Badung Strait. The use of this watershed threatens environmental sustainability, especially due to waste pollution. This study aims to examine the pattern of sustainable management on the banks of the Ayung River to support the development of tourism potential. The research method involves problem identification, determination of tourism potential, and PESTEL analysis strategy based on *the concept of Tri Hita Karana*, especially the *Parahyangan element*. The results of the study show that there are weaknesses and opportunities in the arrangement of access to cultural facilities as well as rules that limit tourism development so as not to damage sustainable cultural conditions. The study concludes that cultural preservation efforts related to the Parahyangan element are essential for the preservation of the Ayung River environment.

Keywords: Riverside; Local Wisdom; Environment.

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INTRODUCTION

The Ayung River is the longest river in Bali, flowing 68.5 km across the regencies of Bangli, Badung, Gianyar, and Denpasar City before reaching its estuary at the Badung Strait. Visually, the upper reaches of the Ayung River particularly in the Bongkasa Pertiwi and Kedewatan (Ubud) areas maintain a pristine natural landscape characterized by steep and deep river cliffs. These biophysical traits have established the Ayung River as a premier destination for river-based tourism, notably white-water rafting, which coexists with land uses such as rice fields, forests, and plantations.

However, the river's aesthetic appeal has triggered a surge in the construction of tourism accommodation facilities directly on the riverbanks. This phenomenon creates significant anthropogenic pressure on the river's ecosystem, including threats of waste and sewage pollution. From a regulatory perspective, any spatial utilization in these areas must strictly adhere to the Minister of Public Works Regulation No. 63/PRT/1993 concerning River Banks, River Benefit Areas, River Mastery Areas, and Former Rivers. This regulation dictates specific zoning boundaries to protect the river's ecological function; however, in practice, there is often a disconnect between formal spatial mandates and the rapid pace of tourism development on the ground.

The core planning problem addressed in this study is the degradation of cultural sacredness and the lack of spatial order resulting from ineffective control over river cliff utilization. While the Gianyar Regency Government has initiated Watershed Management Programs aligned with the national "Clean River Program", a more comprehensive approach is required to bridge the gap between technical-legal regulations and local values.

The scope of this study is focused on the river cliff areas of the Ayung River within the Ubud District, Gianyar Regency, a region uniquely positioned as a global hub for culture-based tourism. To formulate an effective preservation strategy, this research employs a PESTEL Analysis (Political, Economic, Social, Technological, Environmental, and Legal) as its primary framework. This analysis aims to link macro-variables such as regional political policies, tourism economic growth, and the legal constraints of the Minister of Public Works Regulation No. 63/1993 with local indigenous wisdom.

The data for this study are derived from primary sources, including field observations and interviews with customary leaders and tourism operators, as well as secondary sources, comprising spatial planning documents, tourism statistics, and environmental regulations. By integrating the *Tri Hita Karana* philosophy, this study seeks to produce a spatial control strategy that not only meets national technical standards but also preserves the sacredness of the river ecosystem as a vital part of Balinese cultural heritage.

LITERATURE REVIEW

Green Open Space

According to Law Number 26 of 2007 concerning Spatial Planning, what is meant by Green Open Space (GOS) is an elongated area or path or grouping whose use is more open, where plants grow, both naturally and intentionally planted (Sinaga et al., 2018).

The function of GOS is divided into (a) GOS as an ecological function, (b) GOS as a communal place, (c) GOS as an aesthetic function, (d) GOS as a barrier, (e) GOS fulfils an educational function, (f) GOS also has an economic function. Meanwhile, based on spatial structure, GOS can follow ecological patterns (grouping, elongated, scattered) and pathological patterns that follow the hierarchy and structure of urban spaces. Related to GOS, ownership is divided into public GOS and private GOS (Ernawati, 2016).

Protected Area Management

According to Presidential Decree No. 32 of 1990, protected area management is an effort to determine, preserve, and control the use of protected areas. Protected areas have several utilisation directions, some of which can be done and others that cannot (Peranginangin, 2014).

In managing protected areas related to the research location, things that must be considered are control of utilisation in watersheds, river banks, existing slope levels, and control in landslide-prone areas. The description of this control is further described in the following sections:

1. Watershed Utilization

The Directorate of Forestry and Water Resources Conservation in the Integrated Watershed Management Model Study stated that watershed ecosystems can be classified into upstream, middle, and downstream areas. The upstream watershed is characterised as a conservation area, the central watershed is a transitional area with characteristics as a distributor and regulator of water, and the downstream watershed is a utilisation area (Susetyaningsih, 2012).

2. Control of River Bank Utilization

Nationally, control of riverbank utilisation has been regulated in the Minister of Public Works Number: 63 / PRT / 1993 Regulation concerning River Bank Lines, River Benefit Areas, River Control Areas, and Former Rivers. Land use in riverside areas is limited (Haribulan et al., 2019).

Prohibited activities on the banks of rivers are (a) disposing of solid or liquid garbage waste and (b) erecting permanent buildings for residential and business premises. Such utilisation must obtain prior permission from the competent authority and meet predetermined requirements.

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3. Land Use Control Along the Landslide-Prone Ayung River Bank

Land prone to landslides is related to the slope level and the type of land itself. The relationship is because the slope level and soil type affect the sensitivity of the land to erosion (Titisari et al., 2013).

Architectural Ecology Concept

The ecological concept is the concept of environmental management that utilises potential or natural resources and technology based on environmentally friendly ethical management. Another ecological approach in architecture, according to (Frick, 1998) is that eco-architecture includes harmony between humans and nature (Widiana, 2019).

(Saito, 2002) put forward the following principles of ecological design:

1. Solution Grows from Place: The solution to all design problems must come from the environment in which the architecture will be built. The principle is to use the environment's potential and resources to overcome every design problem. This principle emphasises the importance of understanding nature and local communities.
2. Ecological Accounting Informs Design: ecological calculations attempt to minimise adverse environmental impacts. Design decisions taken should have as little impact as possible on the environment.
3. Design with Nature: Architecture is part of nature. For this reason, every architectural design must ensure the survival of every ecosystem element without damaging the environment.
4. Everyone is a Designer: This involves every party involved in the design process. No one only acts as a user, participant, designer, or architect. Everyone is a participant-designer.
5. Make Nature Visible: natural processes are cyclical. The architecture should also be able to carry out the process so that the waste produced can be reduced to a minimum.

Tri Hita Karana

Tri Hita Karana is etymologically formed from the word tri, which means 'three', he means 'happiness', and karana, which means 'cause' or 'that which causes'. Thus, *Tri Hita Karana* can be interpreted as three harmonious relationships that cause happiness. *Tri Hita Karana* consists of *Parahyangan*, *Palemahan* and *Pawongan* (Suryatman et al., 2021). *Parahyangan* is a harmonious relationship between humans and Ida Sang Hyang Widhi Wasa, and *pawongan* is a harmonious relationship between humans andtheir neighbours. At the same time, *palemahan* is a harmonious relationship between humans and their environment.

RESEARCH METHODOLOGY

This research employs a descriptive qualitative approach, executed through a rigorous and systematic framework. The process begins with Spatial Delineation, specifically targeting the Ayung River segments within Bongkasa Pertiwi and Kedewatan. To ensure a focused analysis, the study area is restricted to a 100-meter buffer zone extending from the river's edge. Data collection is divided into two primary streams:

- Primary Data: Gathered through direct site observations and extensive documentation across 11 strategic locations (Points A–K).
- Secondary Data: Sourced from official spatial planning maps via Gistaru and relevant regional regulations to provide legal and geographical context.

Central to the methodology is the application of the PESTEL framework, which functions as a diagnostic tool rather than a static list. This framework evaluates the feasibility of "Ecological Design" by analyzing Political and Legal alignment with Minister of Public Work No. 63/1993, Environmental factors such as slope stability and waste management, and Social/Spiritual elements, including the mapping of Beji temples and sacred springs.

The final stage involves a Synthesis of these findings. By integrating PESTEL results with the five core principles of Ecological Design (Solution Grows from Place, Ecological Accounting, Design with Nature, Everyone is a Designer, and Make Nature Visible) the research provides a comprehensive evaluation of the site's ecological and developmental potential.

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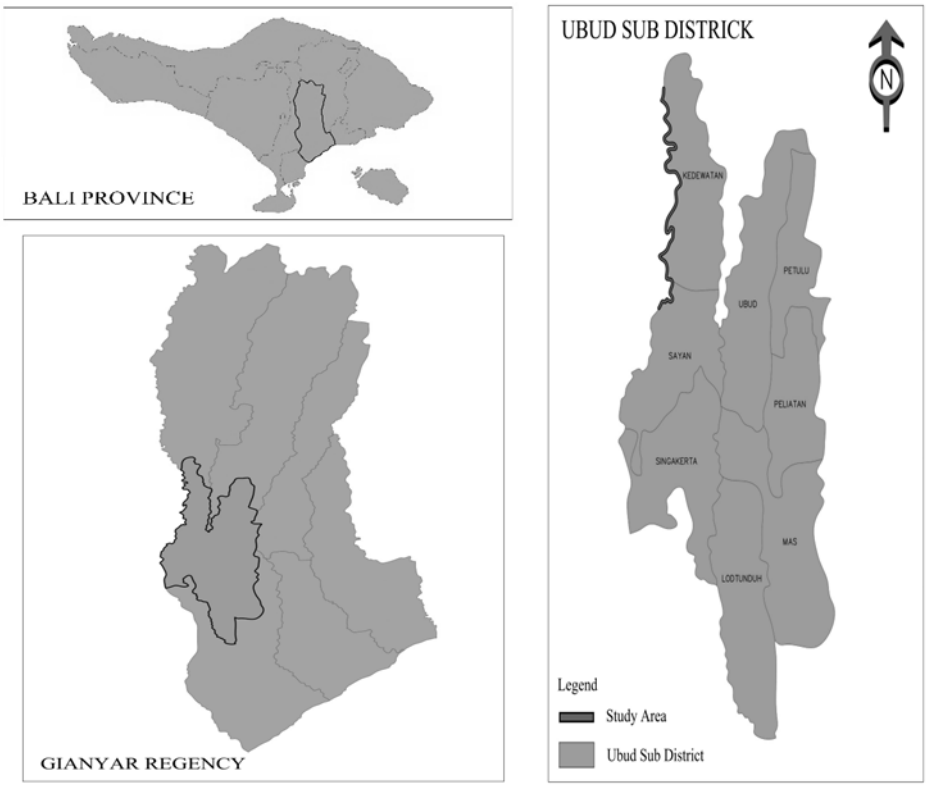


Figure 1: Location Delineation Map
Source: Geographic Information System Tata Ruang (*gistaru.atrbpn.go.id) (2024)*

ANALYSIS AND DISCUSSION

Field Ayung Riverside Land Use (ARLU)

ARLU was originally a land used by the surrounding community for wet agriculture (rice fields), dry agriculture (moorland), and cultural activities related to springs in the area, especially on the banks of the Ayung River. To date, ARLU is used for various functions, including ecological functions, Socio-Cultural Functions, and Economic Functions (Tourism Utilization) (Praganingrum, 2013).

The function of nature conservation can be seen from (a) wetland and dry-land agriculture and (b) grasslands also function as green open spaces. Socio-cultural functions include (a) sacred places and (b) water sources for community bathing and irrigation of rice fields. This economic function can be demonstrated

by (a) the existence of 4-star hotel accommodation facilities, b) recreational sports (rafting), and (c) wetland and dryland agriculture.

Socio-cultural aspects include religious ritual activities in rice fields, Bedugul Temple, Subak Temple, Pertiwi is the presence of Batu Mekong in Subak Temple, which can be used as a cultural symbol; in addition to Balinese architecture, there are traditional houses in the local community. The daily activities of farmers who work in rice fields, maintain harmonious family relations, make handicrafts, and conventional regional cuisine are socio-cultural attractions. Artificial attractions for recreation can be found at Bali Swing, Pinball Pinball and ATV attractions, and silver craft centres.

The utilisation of the cultural and social functions of the river in the environment on the banks of the Ayung River includes products of flexibility, life experience, and banks of the Ayung River. The social potential of residential areas on the banks of the Ayung River plays a vital role in connecting village community activities from one place to another, such as in Ubud Kedewatan Village and Bongkasa Pertiwi. In addition, the Ayung River is also considered to be a means of transportation that has no impact on air pollution. The Ayung riverside land use map can be seen in figure 2.

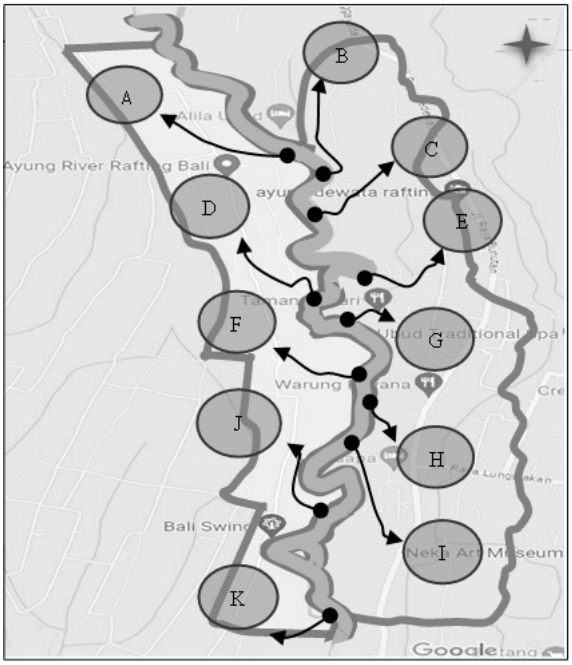


Figure 2: The Ayung Riverside Land Use Map
Source: Geographic Information System Tata Ruang (gistaru.atrbpn.go.id) (2024) with modification

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The documentation description in Figure 2 can be seen in Figures A to K.



Figure A. Goa Temple



Figure B. Peliangan Temple, Wulandari Hotel

(Source Figure A, B: Anak Agung Ratu Ritaka Wangsa, 2023)



Figure C. *Padma Sari Beji*



Figure D. Karang Dalem Water Spring

(Source Figure C, D: Anak Agung Ratu Ritaka Wangsa, 2023)



Figure E. *Pelinggih* (temple)



Figure F. *Pancoran* (water source)



Figure G. Royal Pitamaha Hotel Temple



Figure H. *Pelinggih* (Temple)

(Source Figure E, F, G, H: Ni Luh Made Ayu Mirayani Pradnyadari, 2023)



Figure I. Beji Temple Bongkasa



Figure J. Pelinggih (Temple)



Figure K. Bale Tudor Temple

(Source Figure I, J, K: I Made Satya Graha, 2023)

Ecological Design Concept for Ayung Riverbank Land Planning

Given the spatial pressures along the Ayung River, land arrangement must be guided by an ecological design concept that harmonizes anthropogenic activities

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with natural constraints. According to (Prasetyo et al., 2018), ecology in environmental management involves the ethical use of natural resources and technology to achieve environmentally friendly architectural outcomes. In the context of Kedewatan and Bongkasa Pertiwi villages, this involves integrating the five core principles of ecological design *(a) Solution Grows from Place, (b) Ecological Accounting Informs Design, (c) Design with Nature, (d) Everyone is a Designer, and (e) Make Nature Visible*, into a robust framework for riverbank governance.

Strengthening Riverbank Control and Regulatory Compliance

A critical component of "Solution Grows from Place" is the strict enforcement of riverbank control measures. The ecological accounting of this design must align with the Minister of Public Works Regulation No. 63/PRT/1993. This regulation serves as a technical baseline for determining the setback lines, ensuring that permanent tourism structures do not infringe upon the river's benefit area. By integrating these legal setbacks into the ecological design, the development creates a buffer zone that prevents erosion and filters runoff before it enters the Ayung River, effectively operationalizing the "Design with Nature" principle.

Sacred-Site Protection and the Tri Hita Karana Philosophy

The ecological design concept in this study intrinsically values local wisdom, specifically the Tri Hita Karana philosophy. The principle of Parahyangan dictates that riverbanks are not merely geographical features but sacred landscapes (*Palemahan Suci*). Many points along the Ayung River serve as sites for Melasti or Pengelukatan rituals. Therefore, ecological design must go beyond aesthetics to include "Sacred-Site Protection." This means establishing "no-build zones" around shrines and water springs (*Beji*), ensuring that tourism activities do not desecrate the spiritual atmosphere. This approach transforms the "Make Nature Visible" principle into a "Make the Sacred Visible" mandate, where architectural interventions act as a shield for cultural heritage.

Tourism Carrying Capacity and Environmental Resilience

To achieve long-term harmony (Pawongan and Palemahan), the ecological design must be governed by Tourism Carrying Capacity (TCC). The surge in accommodation along the Kedewatan cliffs necessitates a limit on the density of building footprints to prevent the "over-tourism" that leads to ecological collapse. By calculating the physical and social carrying capacity, planners can determine the maximum number of visitors and structures that the river cliff ecosystem can support without degrading its natural functions. Implementing TCC ensures that the "Ecological Accounting" informs the scale of development, preventing the Ayung River from becoming a victim of its own beauty. This balanced approach

ensures that tourism development supports the local economy without compromising the ecological and spiritual integrity of the river.

PESTEL Analysis

PESTEL analysis is a method for evaluating the external environment that affects a location or project, consisting of Political, Economic, Social, Technological, Environmental, and Legal aspect (Yüksel, 2012). In the context of the Ayung riverbank, we will see how each of these aspects interacts with the concepts of *Parahyangan* (harmony between humans and God, the spiritual realm) and *Tri Hita Karana* (harmony between humans, God, and nature).

1. Politics
    a. Government Policies: Local and national policies related to tourism management and cultural preservation greatly affect the development of the Ayung riverbank. Support from the government for sustainable development in accordance with the *Tri Hita Karana* principle can encourage investment in environmentally friendly infrastructure.
    b. Political Stability: The stable political situation in Bali can strengthen the confidence of tourists and investors in the development of tourism in the area.

2. Economics
    a. Tourism Value: The tourism potential in the culturally rich Ayung riverside area can boost the local economy if developed wisely. The concept of *Parahyangan* can prioritize environment-based tourism that supports the welfare of the community while protecting nature.
    b. Resource Investment: Increased investment in sustainable tourism infrastructure can create new jobs and improve the socio-economic lives of the surrounding communities.

3. Social
    a. Cultural Diversity: The banks of the Ayung river are known for their rich traditions and culture, which are in line with the values of *Parahyangan*. Maintaining social and cultural values is essential to maintain harmony in society as well as attract tourists who appreciate local culture.
    b. Community Participation: Involving local communities in tourism development allows for the creation of synergies that are in harmony with *Tri Hita Karana*, where the community, the environment, and their beliefs interact well with each other.

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4. Technology
    a. Innovation in Environmental Management: Environmentally friendly technology can be applied in the development of tourism infrastructure, supporting the *Parahyangan* principle which emphasizes the need to maintain ecosystem balance.
    b. Digital Promotion: The use of information technology to promote local culture and tourism can expand the reach of tourists and enhance their experience, as well as provide in-depth information about the values of *Tri Hita Karana*.

5. Environmental
    a. Nature Conservation: A balance between tourism activities and environmental preservation is the key to achieving harmony in the Parahyangan concept. Pragmatism in natural resource management is important to avoid environmental damage due to tourism.
    b. Climate Change Impacts: Dealing with the impacts of climate change is a challenge that must be considered, including in the development of infrastructure that can last in the long term and do not disturb the balance of ecosystems.

6. Legal
    a. Compliance with Riverbank and Cultural Regulations: The integration of formal and customary law is essential for sustainable management. This includes strict compliance with the Minister of Public Works Regulation No. 63/1993, which establishes mandatory riverbank setbacksto protect the river's hydrological and ecological functions. These national standards are further strengthened by customary regulations (*Awig-awig and Pararem*), which designate specific riverside areas as sacred zones. This dual-layered legal framework ensures that the values of *Tri Hita Karana* are upheld, maintaining both the physical safety of the watershed and its spiritual integrity.
    b. Licensing in Tourism Development: Strict regulations on tourism-related development permits need to be implemented to ensure that all projects are in line with the basic principles of environmental and social sustainability. Licensing must not only verify technical engineering requirements but also require a "cultural impact assessment" to ensure that permanent structures do not infringe upon sacred sites or exceed the Tourism Carrying Capacity (TCC). By synchronizing government permits with customary approvals, the development process becomes a robust mechanism for preserving the Ayung River's cultural sacredness.

Table 1: PESTEL Analysis

PESTEL Elements	Scale of Impact	Description	Relevance to Parahyangan and Tri Hita Karana
Politics	5	Government Policies to support cultural and environmental preservation	Encouraging harmony through leadership that respects spiritual values of *Tri Hita Karana (Parahyangan)*
Economics	4	Tourism growth balanced with Tourism Carrying Capacity (TCC) and local investment.	Creating well-being while maintaining cultural traditions
Social	5	Cultural diversity, community participation, and preservation of sacred rituals.	Strengthening social cohesion and maintaining the sacredness of the river (Pawongan & Parahyangan).
Technology	3	Eco-friendly infrastructure and digital promotion of local wisdom.	Supporting environmental preservation and disseminating the values of *Tri Hita Karana*.
Environmental	4	Ecosystem protection, cliff stabilization, and watershed conservation.	Maintaining a balance between human activities and natural sustainability
Legal	4	Regulations to protect culture and tourism development licensing. (Minister of Public Works Regulation No. 63/1993 and Customary Laws)	Regulating the interaction between humans, nature, and spirituality. Providing a formal and spiritual legal basis for spatial control and sacred-site protection.

Source: Author's analysis 2024

Analysis of the table results:

1. The high level of political and social influence shows the importance of the involvement of the government and the community in maintaining the values of Parahyangan and Tri Hita Karana.
2. The environmental aspect is also very important in responding to current challenges.

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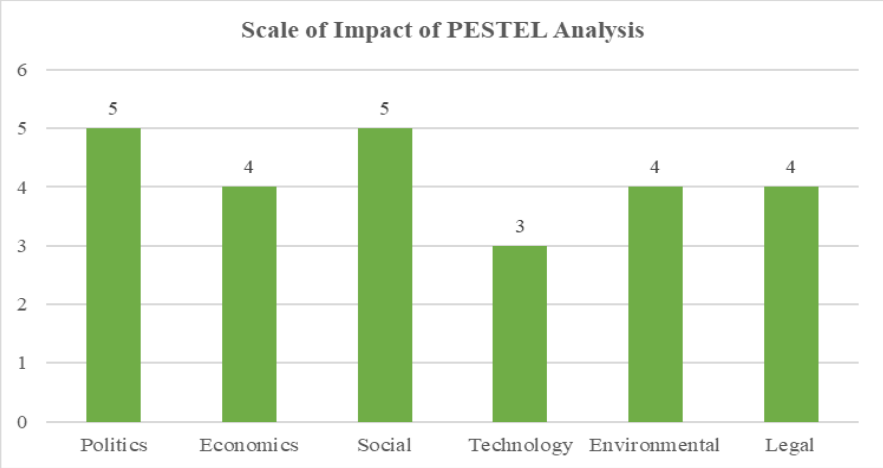


Figure 3. Graph Scale of Impact of PESTEL Analysis
Source: Author's analysis 2024

Scale of impact description:
1 = Very Low
2 = Low
3 = Moderate
4 = High
5 = Very High

This PESTEL analysis shows that the development of the Ayung river bank must continue to adhere to the principles of *Parahyangan* and *Tri Hita Karana*. External factors such as government policies, economic conditions, and environmental preservation have a significant impact on the balance between tourism development and cultural and environmental protection. Thus, a holistic and integrated approach is needed to ensure that all elements support each other and maintain the desired harmony.

This research discusses the following essential things:
1. Integration of Local Wisdom: How local community values, knowledge, and traditional practices can be combined with modern design principles to create a sustainable waterfront environment harmonising with local culture.
2. Application of Ecological Design: How environmentally friendly design principles, such as the use of natural materials, water conservation, effective waste management, and the creation of green spaces, can be applied to maintain ecosystem balance and improve the quality of the waterfront environment.

3. Public Space Arrangement: How can the waterfront area be organised into an attractive, functional, and inclusive public space that can accommodate various social, economic, and recreational activities in the community?
4. Community Participation: How to actively involve the community in the planning, design, and management of waterfront areas so that they feel ownership and responsibility for the sustainability of the environment.

This research aims to develop a sustainable, inclusive, and based on local wisdom waterfront area planning model. This model can be an example for developing similar areas in other places.

CONCLUSION

This research concludes that the sustainable management of the Ayung Riverbank is fundamentally rooted in the synergy between strategic planning and Balinese local wisdom. The PESTEL analysis reveals that cultural values, particularly the *Parahyangan* element of *Tri Hita Karana*, function as a vital "non-physical" regulatory framework that effectively constrains uncontrolled land use. These spiritual and cultural norms do not merely maintain a metaphysical balance but act as practical guidelines for environmental preservation. By prioritizing the sacredness of the riverside environment, the community and stakeholders can ensure that tourism development remains within ecological limits, preventing the degradation of the watershed while maintaining its spiritual integrity.

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CELLULAR AUTOMATA SPATIAL MODELLING FOR AGRICULTURE LAND COVER CHANGE IN KARAWANG REGENCY

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Abstract

Rapid urbanization in Karawang Regency poses a significant threat to agricultural sustainability. This study analyses land cover changes from 2009 to 2017 and predicts future transitions for 2021, 2026, and 2031 using Cellular Automata (CA) modelling in IDRISI TerrSet. The model was validated using a Kappa Index of Agreement (KIA) by comparing the 2021 simulation with official SPOT 7 satellite imagery, yielding a high accuracy of 0.9328. Results indicate a consistent decline in paddy fields, which are projected to decrease to 105,416.28 ha by 2031. Conversely, settlements and built-up land show a sharp upward trend, nearly doubling from 20,153.09 ha in 2009 to a projected 38,016.63 ha in 2031. These findings highlight the increasing pressure of urban expansion on productive agricultural land, necessitating stricter spatial planning policies to safeguard regional food security in alignment with the 2011–2031 Spatial Plan (RTRW).

Keywords: Land use change, Cellular Automata, Karawang, agriculture land conversion, Spatial modeling

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INTRODUCTION

Agricultural land conversion is a global phenomenon driven by rapid population growth and the structural transformation of economies from agrarian to industrial bases (Araza et al., 2026; Sofue & Kohsaka, 2024). In developing nations, particularly within Southeast Asia, this shift often occurs at the expense of highly productive "rice bowls"—fertile regions that are critical for national food security. Indonesia, as one of the world's largest rice consumers, faces a significant challenge in balancing its industrial ambitions with the preservation of its agricultural heritage (Prayitno et al., 2021).

Karawang Regency, located in the West Java Province, serves as a primary example of this tension. Historically recognized as a national "rice granary," Karawang has undergone a dramatic landscape transformation over the last two decades. Its strategic position along the Jakarta-Bandung industrial corridor has made it a magnet for large-scale industrial estates and residential expansion (Rustiadi et al., 2021). This rapid urbanization often results in the "leakage" of spatial plans, where paddy fields (sawah) are converted into built-up land despite existing protection policies (Marendraputra & Afifah, 2025; Pratika & Hudalah, 2024).

While the government has introduced the Sustainable Food Agricultural Land (LP2B) framework to mitigate these losses, empirical data on the long-term effectiveness of these policies remains limited. Previous studies have utilized remote sensing to document historical changes; however, there is a pressing need for predictive modelling that aligns with official planning horizons (Ambarwulan et al., 2016). Understanding the future trajectory of land use is essential for policymakers to anticipate spatial conflicts and adjust regional strategies before the loss of agricultural land becomes irreversible.

This study aims to bridge this gap by simulating land use and land cover (LULC) changes in Karawang Regency up to the year 2031—the final year of the current Regional Spatial Plan (RTRW). By utilizing Landsat 7 TM and SPOT 7 satellite imagery and employing a Cellular Automata (CA) modelling approach in IDRISI TerrSet, this research identifies the patterns of conversion and predicts the future extent of key land categories. The findings provide a quantitative basis for evaluating the sustainability of Karawang's spatial development and offer insights into the protection of agricultural zones under the pressure of industrialization

LITERATURE REVIEW

Land Use and Land Cover Change (LULC) Dynamics

Land Use and Land Cover Change (LULC) is a fundamental indicator of the interaction between human activities and the natural environment. Rapid urbanization and industrialization are the primary drivers of the conversion of

fertile agricultural land into built-up areas (Najnin et al., 2023; Zhao et al., 2026). In Southeast Asia (Pichler et al., 2021), this phenomenon is particularly prevalent in peri-urban regions where industrial corridors expand into traditional "rice bowls." Such conversions are often irreversible and pose a significant threat to regional ecological balance and local livelihoods.

Cellular Automata in Spatial Modelling

Predicting future land-use patterns requires robust computational models that can handle spatial complexity. Cellular Automata (CA) has emerged as a powerful tool in geographical information science for simulating urban growth. The strength of the CA model lies in its ability to represent complex systems through simple local rules, where the state of a specific cell at time is determined by its state and the state of its neighbours at time. Beyene & Sewnet (2023); Wangyel et al. (2021); and Yue et al. (2024) have demonstrated that integrating CA with Markov Chains or using software like IDRISI TerrSet allows researchers to incorporate "driving factors" (such as distance to roads and population density) and "constraints" (such as protected zones). This hybrid approach provides a high degree of spatial accuracy, often validated through the Kappa Index of Agreement (KIA).

Agricultural Land Conversion and Food Security

The conversion of paddy fields (sawah) to non-agricultural use is a critical issue for food security. In Indonesia, the government has addressed this through the Sustainable Food Agricultural Land (LP2B) policy. However, Kavhu et al. (2025); Shan et al. (2025); and Zhang et al. (2025) suggest that legal designations often clash with economic pressures. As land values rise due to industrial demand, the opportunity cost of farming increases, leading to "land abandonment" or conversion. Studies specifically focused on West Java have noted that Karawang Regency serves as a critical case study due to its dual role as a national industrial hub and a primary rice producer.

Remote Sensing and Image Interpretation

The reliability of land-use analysis depends heavily on the quality of the source data. Landsat satellite imagery (e.g., Landsat 7 TM) has been the gold standard for long-term LULC studies due to its multi-spectral capabilities and historical availability. For validation, high-resolution imagery such as SPOT 7 and Google Earth Pro provides the necessary "ground truth" to verify classification results (Dong et al., 2026; Li et al., 2025; Y. Zhang, 2025). Techniques such as Supervised Classification using the Maximum Likelihood algorithm remain the most widely accepted methods for categorizing land cover with high statistical confidence.

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RESEARCH METHODOLOGY

Study Area

The research was conducted in Karawang Regency, West Java, Indonesia. The area is strategically located between the metropolises of Jakarta and Bandung, making it a focal point for industrial expansion and agricultural preservation efforts.

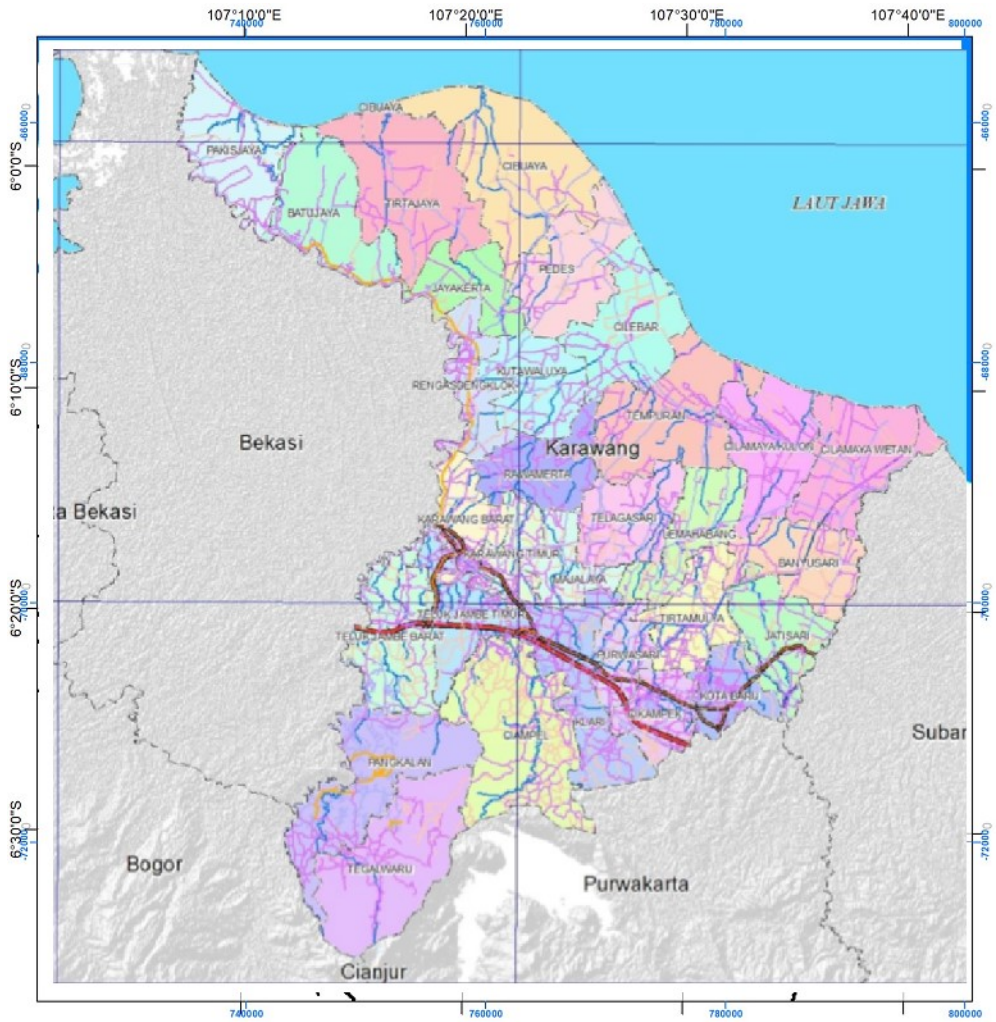


Figure 4: Research Location
Source: Authors (2026)

Data Collection and Preparation
The study utilized a combination of multi-temporal satellite imagery and thematic maps. Primary datasets include:

- Landsat 7 ETM+ Imagery (2009 and 2017): Obtained from the USGS EarthExplorer for historical land cover analysis.
- SPOT 7 Satellite Imagery (2021): Used as a high-resolution reference for model validation, sourced via the Department of Public Works and Spatial Planning (PUPR).
- Administrative and Planning Maps: Including the 2011–2031 Karawang Regency Spatial Plan (RTRW) and the Sustainable Food Agricultural Land (LP2B) draft.

Image Processing and Classification
The satellite data underwent several preprocessing stages, including radiometric correction and layer stacking (band composition). Land cover classification was executed using the Maximum Likelihood Classification (MLC) algorithm—a supervised classification technique that categorizes pixels based on the probability of their belonging to a specific class. Ten distinct land cover classes were identified: Water Bodies, Plantation Forest, Open Land, Plantation, Settlement/Built-up Land, Mining, Dryland Agriculture, Paddy Field, Scrub/Shrubland, and Aquaculture Ponds. All spatial data were projected to the WGS 1984 UTM Zone 48N coordinate system with a standardized spatial resolution of 30 m x 30 m.

Research Framework
The research was conducted through a systematic framework divided into four primary phases: Data Acquisition, Image Processing, Model Validation, and Predictive Simulation.

Phase I: Data Acquisition and Pre-processing
The initial phase involved the collection of multi-temporal satellite data and auxiliary thematic maps. Landsat 7 ETM+ images for 2009 and 2017 were corrected for atmospheric and geometric distortions. All datasets were harmonized into a uniform spatial reference system (WGS 1984 UTM Zone 48N) and resampled to a 30-meter resolution to ensure pixel-to-pixel consistency across the time series.

Phase II: LULC Classification and Change Detection
A supervised classification was performed using the Maximum Likelihood Classification (MLC) algorithm. Training samples were established through

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manual digitization of 10 land cover classes. The classification results from 2009 and 2017 were then subjected to a change detection analysis to identify transition patterns, specifically the conversion of paddy fields to built-up land.

Phase III: Model Parameterization and Validation
The transition probability matrix was calculated using Markov Chain analysis based on the 2009–2017 change patterns. This was then integrated into the Cellular Automata (CA) framework. To validate the model's predictive capability, a simulation for the year 2021 was executed. The reliability of the framework was confirmed by comparing this simulation with the official 2021 SPOT-7 based land cover map using the Kappa Index of Agreement (KIA).

ANALYSIS AND DISCUSSION

The prediction analysis of land-use change in this study was conducted through several analytical stages, utilizing specific software as supporting tools. The details regarding the analytical stages and the software employed are presented in Table 1.

Table 1: Analytical Stages and Software Utilization

ArcMap 10.8	Google Earth Pro	Terrset 10.3.1	ArcMap 10.8
Land Cover Classification	Land cover validity	Land cover prediction	Agriculture land cover change prediction

Source: Authors (2026)

The datasets utilized in this analytical process are outlined in below:

Table 2: Research Datasets and Sources

No	Data Type	Data Source
1	Landsat 7 Satellite Imagery (2009)	earthexplorer.usgs.gov
2	Landsat 7 Satellite Imagery (2017)	earthexplorer.usgs.gov
3	Google Earth Pro Imagery (2009)	Google Earth Pro
4	Google Earth Pro Imagery (2017)	Google Earth Pro
5	Existing Land Cover Map (2021)	Department of Public Works and Spatial Planning (PUPR)
6	Spatial Planning Map (RTRW) of Karawang Regency 2011-2031	Bappeda (Regional Development Planning Agency)
7	Draft Map of Sustainable Food Agriculture Land (LP2B) Karawang Regency	Department of Agriculture / Bappeda

Source: Authors (2026)

Land Cover Classification

Land cover classification analysis for Karawang Regency was conducted to identify spatial distribution and changes in land cover patterns between 2009 and 2017. The primary data sources consisted of Landsat 7 TM satellite imagery acquired from the USGS EarthExplorer (earthexplorer.usgs.gov).

The initial processing stage involved layer stacking (band composition). This technique integrates individual spectral bands from the satellite sensor to produce a composite image that represents Earth's surface features in appropriate color visualizations (e.g., natural or false-color composites).

Following the band composition, supervised classification was performed within the ArcMap environment using remote sensing techniques. The composite raster imagery (.TIF) of Karawang Regency was processed using the Create Signature tool, utilizing training samples (.SHP) generated through manual digitization. These samples represent 10 distinct land cover classes. The resulting signature file (.GSG) was then used as the input for the Maximum Likelihood Classification (MLC) algorithm, applied to the composite imagery to generate the final land cover maps for Karawang Regency.

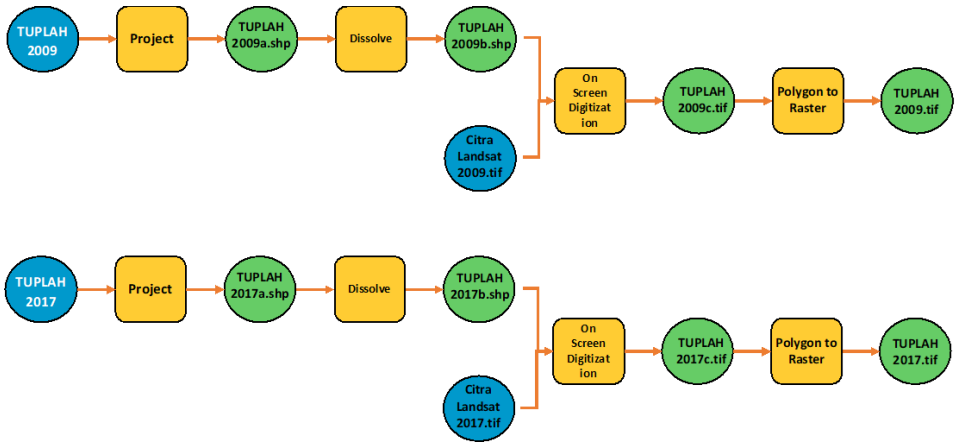


Figure 5: Land Cover Classification Model Builder in ArcMap
Source: Authors (2026)

During the "Project" stage, the coordinate system was standardized to WGS 1984 UTM Zone 48N. This study utilized raster data analysis, where all spatial information was processed in grid cells. In accordance with established literature, a spatial resolution of 30 m × 30 m was applied, representing a ground

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area of 900 m² per cell. The raster grid consists of 2,076 columns and 2,415 rows, resulting in a total of 5,013,540 cells.

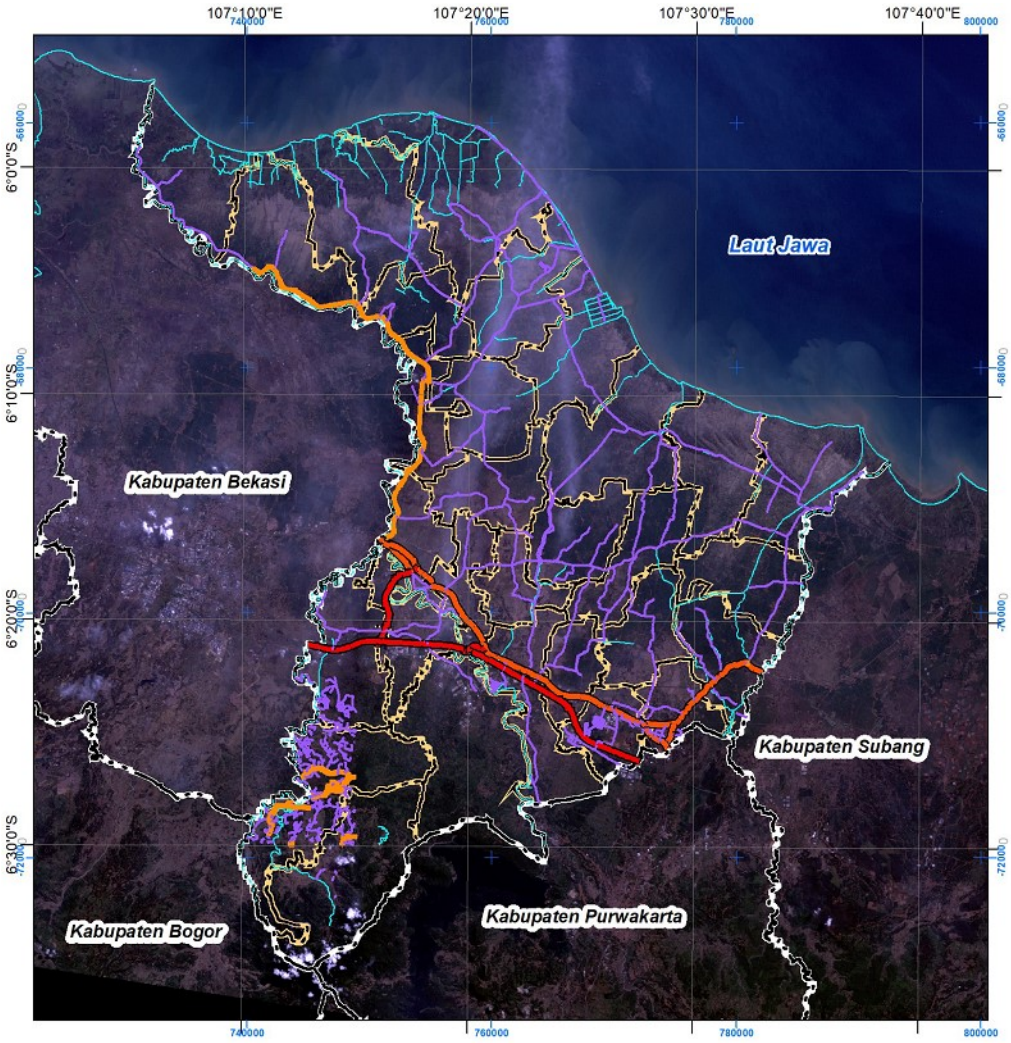


Figure 6: Landsat TM 7 Satellite Imagery 2009
Source: Authors (2026)

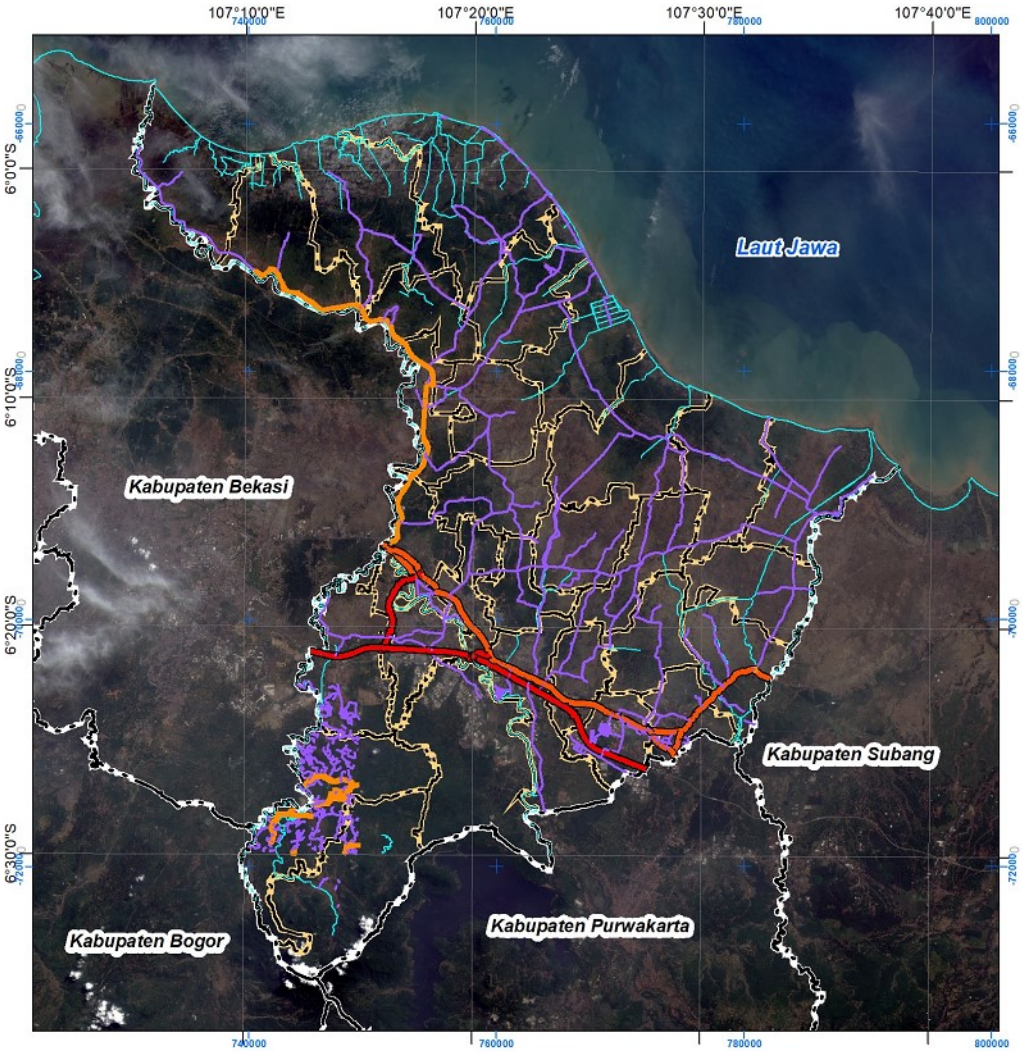


Figure 7: Landsat TM 7 Satellite Imagery 2017
Source: Authors (2026)

Based on the satellite imagery interpretation, paddy fields dominated the land cover in 2009, accounting for 113,575.61 ha (approximately 59%) of the total area of Karawang Regency. Other prominent land cover types included settlements and built-up land at 20,153.09 ha, followed by aquaculture ponds (tambak) at 18,610.89 ha.

By 2017, the interpretation results showed that the paddy field area had decreased by 3,453.37 ha to a total of 110,122.24 ha. Conversely, settlements and

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built-up land increased significantly by 6,370.31 ha, reaching a total area of 26,523.40 ha

Table 3: Land Use/Cover Areas Based on Satellite Imagery Interpretation (2009 and 2017).

No	Land Cover Category	2009 Area (ha)	2017 Area (ha)
1	Water Bodies	1,185.53	1,135.25
2	Plantation Forest	6,476.85	4,366.52
3	Open Land	99.44	1,126.04
4	Plantation	1,467.64	571.42
5	Settlement/Built-up Land	20,153.09	26,523.40
6	Mining	-	11.16
7	Dryland Agriculture	19,419.38	13,057.77
8	Paddy Field	113,575.61	110,122.24
9	Scrub/Shrubland	101.72	61.01
10	Aquaculture Ponds	18,610.89	18,329.79
Total		192,314.69	192,314.69

Source: Authors

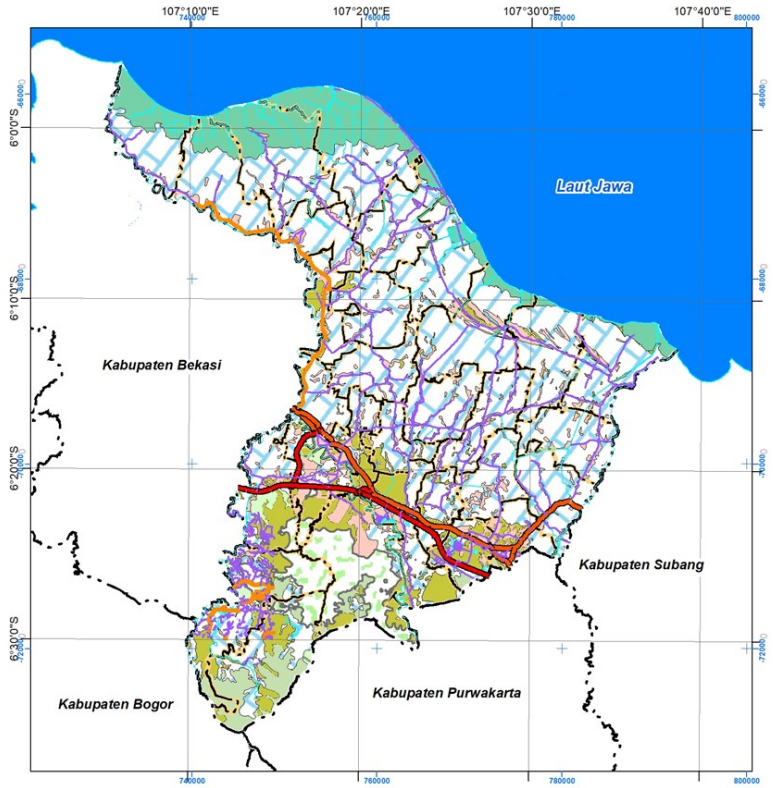


Figure 8: Land Cover Map from Satellite Image Interpretation in 2009
Source: Authors (2026)

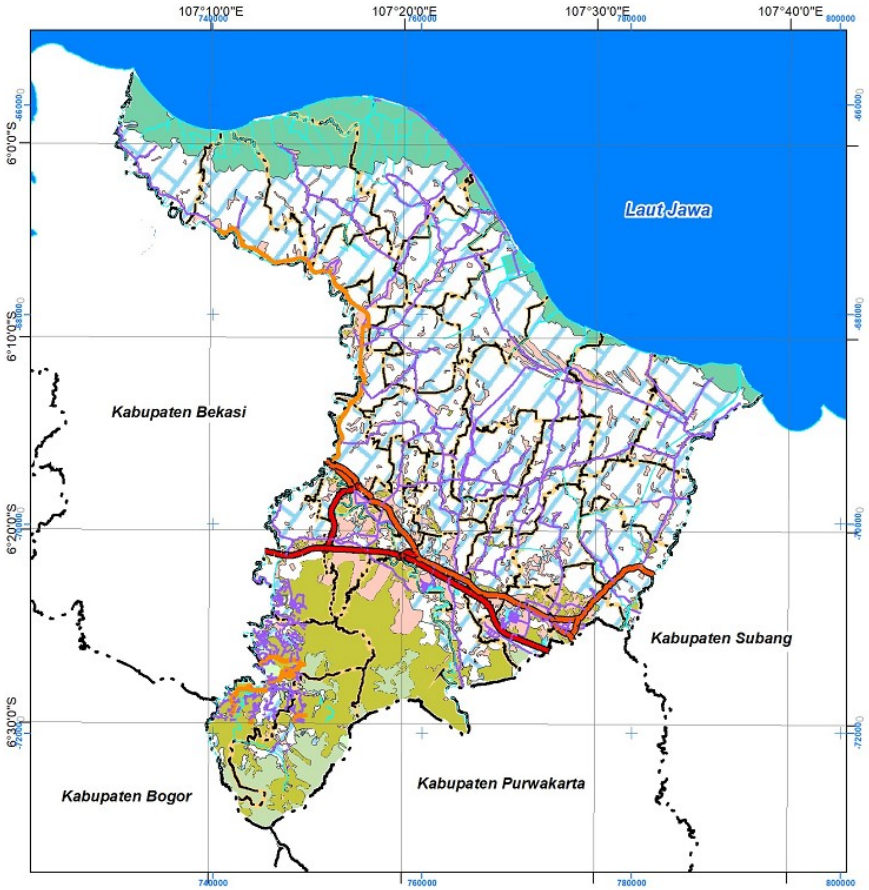


Figure 9: Land Cover Map from Satellite Image Interpretation in 2017
Source: Authors (2026)

Land cover validation was performed to assess the accuracy of the generated 2009 and 2017 land cover maps. This accuracy assessment involved comparing the classified data against reference points generated using the Create Random Points tool. These sample points represent terrestrial surface samples—measured or acquired data points assumed to accurately represent the actual land relief and cover.

The validation process was conducted by cross-referencing these sample points with high-resolution historical imagery from 2009 and 2017 within Google Earth Pro. This comparison serves as the "ground truth" to verify the level of agreement between the classification results and the actual conditions on the ground.

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Accuracy Assessment and Prediction Modelling

A total of 42 sample points were tested, distributed evenly across the Karawang Regency. The accuracy assessment yielded an overall accuracy of 78.5% for 2009 and 80.9% for 2017.

Land Use Change Prediction Analysis

The land-use change prediction in this study was executed in three stages: projections for 2021, 2026, and 2031. The 2021 prediction served as a validation phase to evaluate the reliability of the Cellular Automata (CA) model. The model's performance was measured using the Kappa Index, which compared the 2021 simulated land cover results against the official 2021 Land Cover Map. The reference map was provided by the Karawang Regency Department of Public Works and Spatial Planning (PUPR), derived from SPOT 7 satellite imagery and validated by the Geospatial Information Agency (BIG). Furthermore, the 2031 prediction was aligned with the final planning year of the Karawang Regency Spatial Planning (RTRW) 2011–2031. These simulations were performed using IDRISI TerrSet 18.02 (or version 10.2).

In modelling these transitions, the integration of driving factors and constraints is essential. By identifying the variables that either promote or restrict land-use conversion, the study can estimate and predict spatial shifts as a proactive step in managing regional land-use dynamics.

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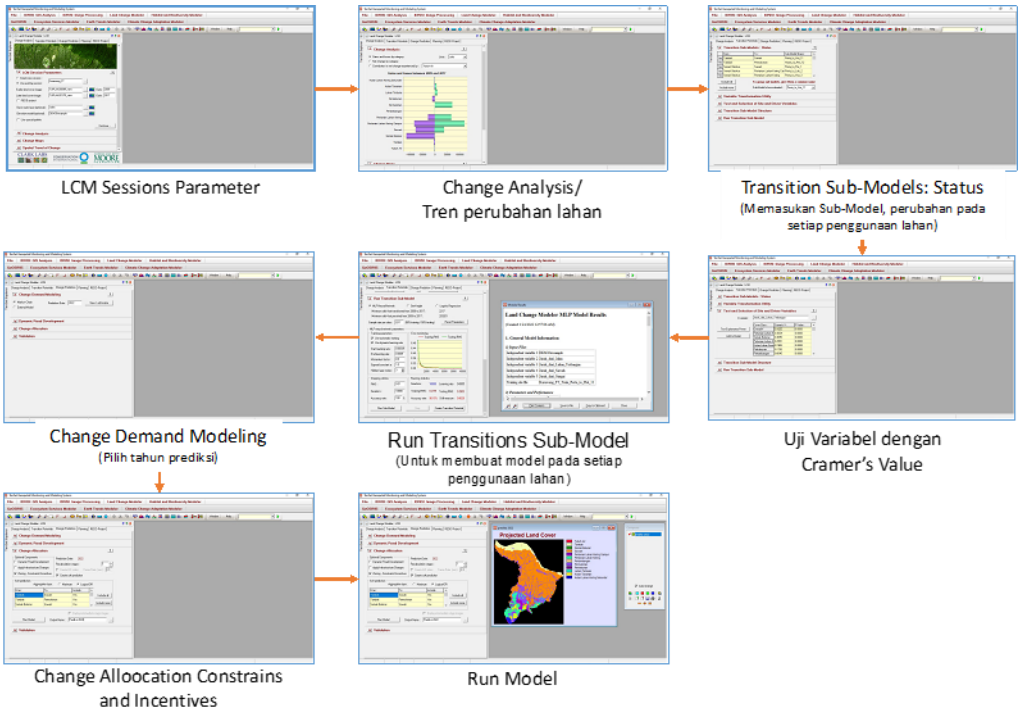


Figure 10: Flowchart of Land Cover Prediction Analysis Stages Using CA-Markov Method Using TerrSet Software
Source: Authors (2026)

Land Cover Prediction and Kappa Index Validation

The land cover prediction for 2021 was conducted to validate the Cellular Automata (CA) simulation process. The reliability of the model was assessed using the Kappa Index of Agreement (KIA), which measures the consistency between the simulated 2021 land cover and the official 2021 reference map. This reference data was obtained from the Karawang Regency Department of Public Works and Spatial Planning (PUPR), based on SPOT 7 satellite imagery validated by the Geospatial Information Agency (BIG).

The Kappa test evaluates both the total area per land class and the spatial distribution of those classes. The Kappa Index is categorized into five classification levels with 0.2 intervals. A value approaching 1.0 indicates that the simulation is highly accurate and closely reflects reality, thereby justifying its use for future projections. In many studies, a minimum Kappa value of 0.6 is considered the threshold for acceptable model performance. Consequently, models falling within the "Good" or "Very Good" categories are deemed scientifically valid for predicting future land cover changes.

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Table 4 Kappa Index Classification

Index Kappa	Strength of Agreement
<0,2	Poor
0,21 - 0,4	Fair
0,41 - 0,6	Moderate
0,61 - 0,8	Good
0,81 - 1.00	Very Good

Source: Anang, 2019

Results of the Model Validation

The validation results for the predicted 2021 land cover of Karawang Regency yielded a Kappa coefficient of 0.9328. This value falls within the "Very Good" strength of agreement category, indicating that the simulation model exhibits high accuracy and high fidelity to observed conditions. Consequently, the model is considered scientifically robust and suitable for projecting future land-use and land-cover changes

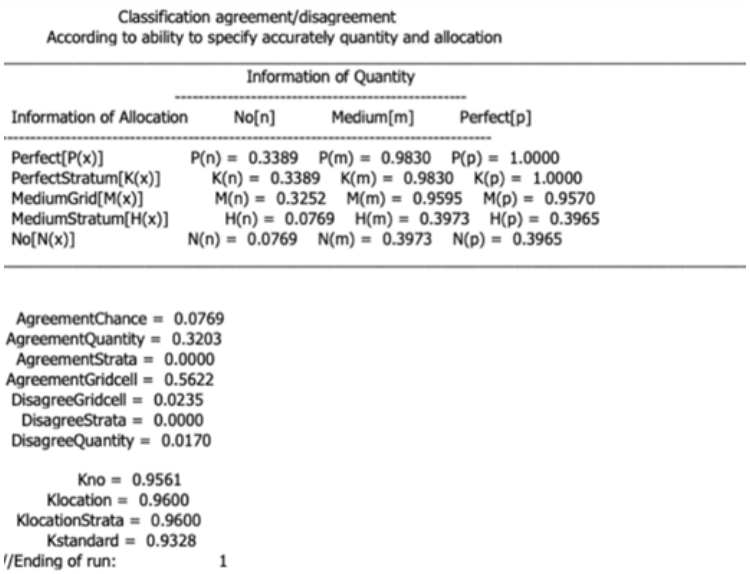


Figure 11: Kappa Test Results on Land Cover Prediction in 2021
Source: Authors (2026)

Predicted Land Cover Analysis for 2021

Based on the results of the 2021 land cover prediction, paddy fields remain the most extensive land category, covering 107,888.87 ha. However, settlements and built-up land continue to expand, reaching a total area of 29,553.86 ha.

Furthermore, aquaculture ponds, which constitute the third-largest land cover category in Karawang Regency, account for 18,472.45 ha.

Table 5: Predicted Land Cover Analysis for 2021

No	Land Cover Category	Area (ha)
1	Water Bodies	1,147.71
2	Plantation Forest	4,349.70
3	Open Land	2,233.72
4	Plantation	579.64
5	Settlement / Built-up Land	29,553.86
6	Mining	15.69
7	Dryland Agriculture	11,731.30
8	Paddy Field	107,888.87
9	Scrub / Shrubland	62.88
10	Aquaculture Ponds	18,472.45
Total		192,314.69

Source: Authors

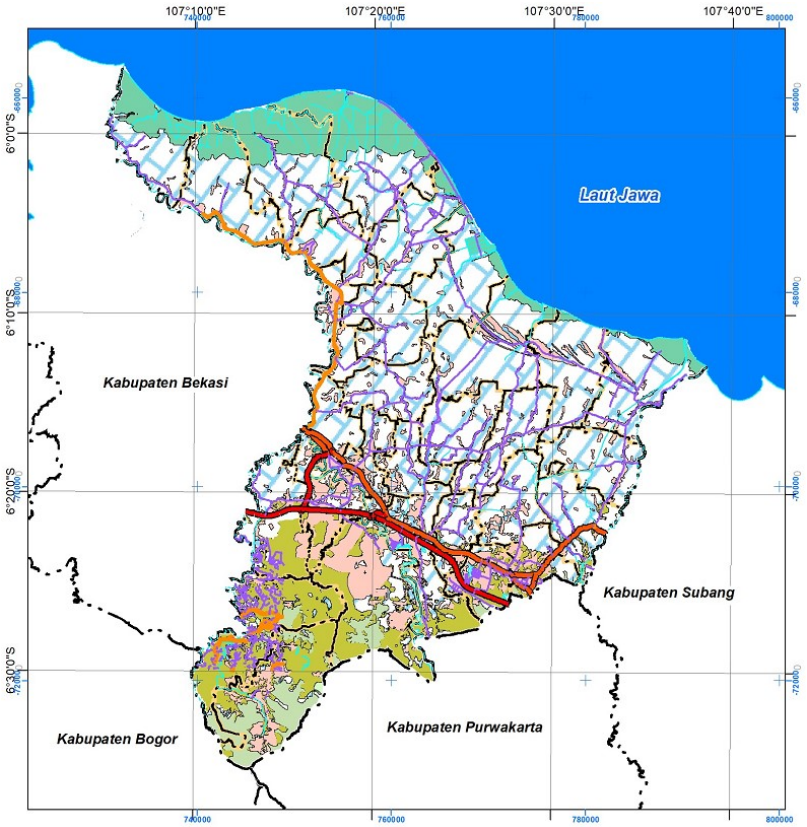


Figure 12: Land Cover Prediction Map for 2021
Source: Authors (2026)

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Predicted Land Cover Analysis for 2026

The land cover prediction for 2026 indicates a continued shift in the spatial landscape of Karawang Regency. The total area of paddy fields is projected to decrease to 107,643.69 ha, though it remains the dominant land cover class. In contrast, settlements and built-up land show significant growth, expanding to 35,181.36 ha. Meanwhile, aquaculture ponds continue to rank as the third most dominant land cover type, covering an area of 18,256.95 ha.

Table 6: Predicted Land Cover Analysis for 2026

No	Land Cover Category	Area (ha)
1	Water Bodies	1,141.20
2	Plantation Forest	7,070.13
3	Open Land	1,757.52
4	Plantation	159.57
5	Settlement / Built-up Land	35,181.36
6	Mining	25.83
7	Dryland Agriculture	20,043.90
8	Paddy Field	107,643.69
9	Scrub / Shrubland	56.25
10	Aquaculture Ponds	18,256.95
Total		192,314.69

Source: Authors

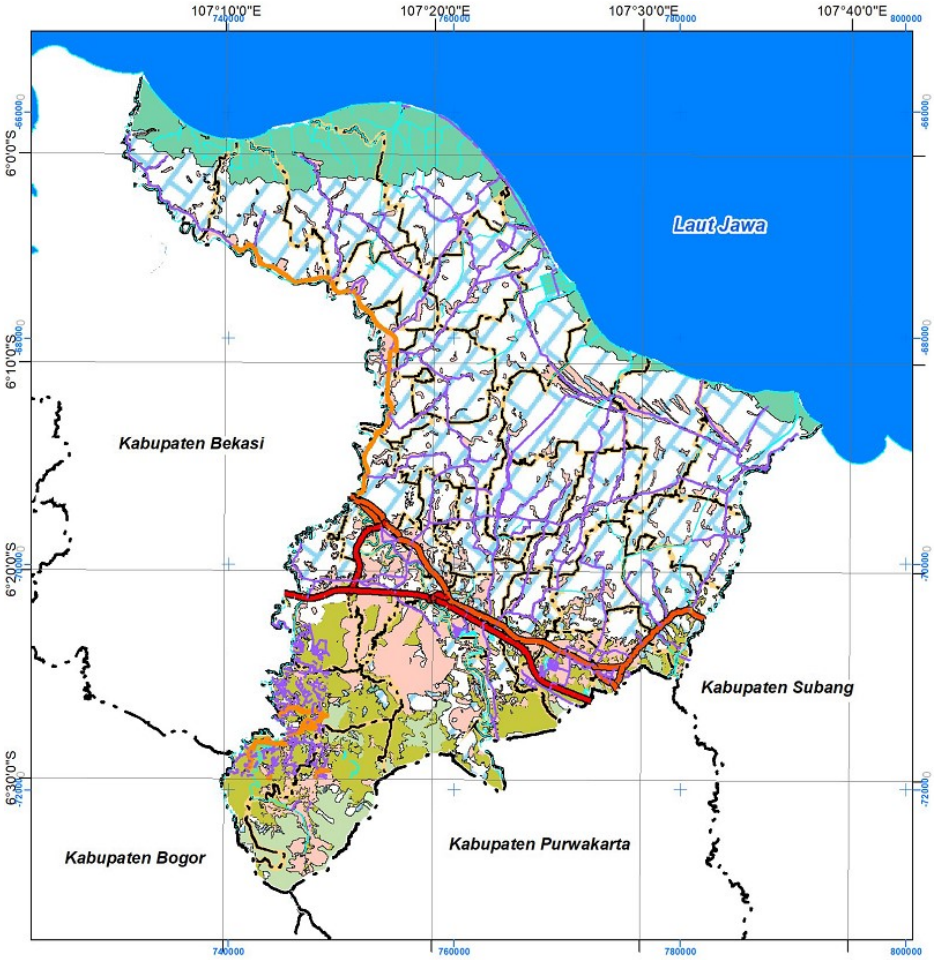


Figure 13: Land Cover Prediction Map for 2026
Source: Authors (2026)

Predicted Land Cover Analysis for 2031

The land cover prediction for 2031 was conducted to align with the final planning year of the Karawang Regency Spatial Plan (RTRW) 2011–2031. Based on the simulation results, the area of paddy fields is projected to decrease to 105,416.28 ha. Conversely, settlements and built-up land are expected to expand from the 2026 figures, reaching a total area of 38,016.63 ha. Furthermore, aquaculture ponds, which remain the third most dominant land cover type, are projected to encompass an area of 18,185.22 ha

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Table 7: Predicted Land Cover Analysis for 2031

No	Land Cover Category	Area (ha)
1	Water Bodies	1,147.71
2	Plantation Forest	4,349.70
3	Open Land	2,233.72
4	Plantation	579.64
5	Settlement / Built-up Land	29,553.86
6	Mining	15.69
7	Dryland Agriculture	11,731.30
8	Paddy Field	107,888.87
9	Scrub / Shrubland	62.88
10	Aquaculture Ponds	18,472.45
Total		192,314.69

Source: Authors

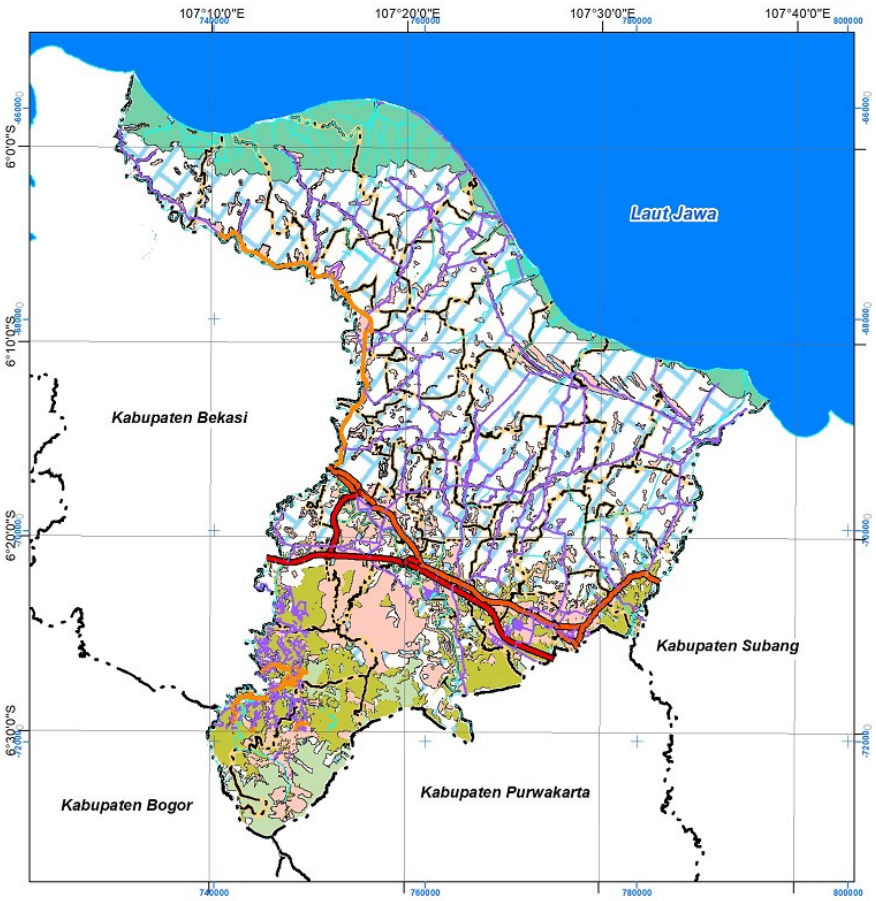


Figure 14: Land Cover Prediction Map for 2026
Source: Authors (2026)

Table 8: Predicted Land Cover Analysis Comparison

No	Land Cover Category	2021	2026	2031
1	Water Bodies	1,147.71	1,141.20	1,141.20
2	Plantation Forest	4,349.70	7,070.13	4,798.53
3	Open Land	2,233.72	1,757.52	2,054.25
4	Plantation	579.64	159.57	106.29
5	Settlement / Built-up Land	29,553.86	35,181.36	38,016.63
6	Mining	15.69	25.83	22.95
7	Dryland Agriculture	11,731.30	20,043.90	15,955.20
8	Paddy Field	107,888.87	107,643.69	105,416.28
9	Scrub / Shrubland	62.88	56.25	55.53
10	Aquaculture Ponds	18,472.45	18,256.95	18,185.22
Total		192,314.69		

Source: Authors

Model Performance and Spatial Accuracy

The validation of the Cellular Automata (CA) model produced a Kappa Index of 0.9328, indicating a "Very Good" level of agreement. This high degree of accuracy suggests that the driving factors (e.g., proximity to roads, existing built-up centers, and spatial constraints) used in the IDRISI TerrSet simulation were highly representative of the actual urban growth dynamics in Karawang Regency. The use of validated SPOT 7 imagery as a reference for the 2021 prediction further strengthens the empirical reliability of the 2026 and 2031 projections.

The Dynamics of Agricultural Land Conversion

The results highlight a significant and continuous reduction in paddy fields (sawah). From 2009 to 2031, the total area of paddy fields is projected to shrink from 113,575.61 ha to 105,416.28 ha. This loss of approximately 8,159 ha is a critical finding, given Karawang's status as a national "rice granary."

The expansion of settlements and built-up land, which is projected to reach 38,016.63 ha by 2031, appears to be the primary driver of this conversion. This suggests that the conversion is not merely random but is a systematic response to the massive industrial and residential demand in the region (Luo et al., 2025; Sun & Xu, 2025; Yu et al., 2025). The trend aligns with Karawang's strategic position as an industrial corridor, where the shift from a primary agricultural economy to a secondary industrial/service economy is reflected in its spatial footprint.

Implications for Spatial Planning and Food Security

The 2031 projection serves as a critical evaluation of the 2011–2031 Karawang Regency Spatial Plan (RTRW). Despite the existence of the Sustainable Food Agricultural Land (LP2B) draft maps and local regulations, the model predicts that built-up areas will continue to encroach upon productive lands.

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The increase in "Dryland Agriculture" observed in the 2026 and 2031 periods suggests a possible fragmentation of large paddy field blocks. When irrigation systems are disrupted by settlement construction, the surrounding paddy fields often lose their productivity and are converted into dryland agriculture before eventually being sold for industrial or residential use (Ferreira et al., 2015; Heilemann et al., 2025; Whitesel et al., 2025).

Policy Recommendations

To mitigate the projected loss of agricultural land by 2031, local authorities must transition from passive spatial planning to active enforcement. This includes:

- Stricter Zoning Enforcement: Ensuring that areas designated as LP2B are legally protected from land-use permits for non-agricultural purposes.
- Incentive Mechanisms: Providing subsidies or infrastructure support to farmers in high-pressure conversion zones to prevent the sale of productive land.
- Vertical Development: Encouraging high-density residential development rather than horizontal urban sprawl to minimize the land footprint per capita.

CONCLUSION

This study demonstrates that Karawang Regency is undergoing a significant spatial transformation driven by the expansion of built-up areas. The Cellular Automata model utilized in this research proved highly reliable, as evidenced by a Kappa validation score of 0.9328, falling within the "Very Good" agreement category. The predictive analysis reveals that by the end of the 2031 planning period, approximately 8,159.33 ha of paddy fields will have been lost compared to 2009 levels, primarily due to the conversion into residential and industrial zones. Built-up land is projected to reach 38,016.63 ha, representing a nearly 89% increase from 2009. While paddy fields still dominate the landscape, the continuous rate of conversion presents a long-term risk to the Sustainable Food Agricultural Land (LP2B) program. These projections serve as a critical decision-support tool for local authorities to evaluate the effectiveness of current spatial regulations and to implement more robust conservation strategies for agricultural preservation.

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DESIGN FACTORS INFLUENCING SATISFACTION IN MEDIUM-RISE LOW-COST PUBLIC HOUSING

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Abstract

Rapid urbanisation in Malaysia has increased reliance on low-cost public housing, particularly in urbanised states such as Selangor. Despite expanded provision, many medium-rise low-cost housing developments continue to adopt outdated design approaches that inadequately address residents' contemporary needs. Persistent issues such as overcrowding, poor spatial configuration, substandard materials, limited facilities, and weak environmental performance have contributed to growing dissatisfaction among residents. However, empirical evidence on how specific design factors influence resident satisfaction in Malaysian low-cost public housing remains limited. This study examines the design factors influencing resident satisfaction in medium-rise low-cost public housing using a quantitative approach. Quantitative data was collected through structured questionnaires administered to residents across selected housing schemes in the Klang Valley and analysed using SPSS and SmartPLS. The results reveal that physical design attributes particularly spatial layout, product quality, community development, and facility provision are the strongest predictors of resident satisfaction, while broader social initiatives show limited influence in the absence of sound physical design. The study highlights the importance of prioritising design quality in low-cost public housing and provides evidence-based insights to support more responsive, satisfaction-oriented housing design strategies in Malaysia.

Keywords: Low-cost, public housing, housing design, satisfaction

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INTRODUCTION

The issue of low-cost public housing has become so prevalent not only in Malaysia but also globally, including in Indonesia, Australia, and the United States of America (USA). Accordingly, the Malaysian government has initiated the 11th Malaysian Plan. It aims to increase access to affordable housing for targeted groups, strengthen planning and implementation for better management of low-cost public housing, and encourage environment-friendly facilities to enhance livability. Past researchers highlighted that the global issues and challenges in the development of public housing are financial issues in building low-cost public housing and poor maintenance of the low-cost public housing (Dzulkalnine et al., 2022).

However, one of the primary barriers facing the low-cost public housing industry is the poor construction quality and design of residential properties. A significant number of developers have yet to fulfil the minimum standard of criteria and indirectly have brought out the dissatisfaction of residents. The criteria involved include adequate space, basic facilities and overall building quality, which are essential to ensuring livable conditions for residents in low-cost public housing developments (Wan Mohamad, Ridzuan, & Abd Rahman, 2018). Beyond environmental and spatial deficiencies, poor construction quality and outdated housing design remain persistent challenges in low-cost public housing. Many developments fail to meet minimum standards relating to spatial adequacy, basic facilities, and overall building quality, thereby undermining livability and long-term housing performance (Wan Mohamad et al., 2018). While government-led low-cost housing initiatives have succeeded in improving housing access, unresolved design and quality issues continue to limit their effectiveness in enhancing residents' quality of life (Wahi et al., 2018). These conditions highlight the need for a systematic examination of how housing design factors influence quality of life outcomes in low-cost public housing developments.

The main factor that contributes to the success of the housing program conducted by the government is whether the housing conditions and facilities meet the demands and expectations of the residents (Wahi, Mohamad Zin, et al., 2018).

As cited by Wan Mohamad et al. (2018), in Malaysia, housing development is one of the prominent sectors in the construction industry. Since the quality of housing significantly affects the environmental, economic, and social dimensions, serious attention needs to be paid to it. Thus, the government must delineate a proper housing strategy that focuses on the design quality aspect of the housing. This housing strategy supposedly encompasses all income levels, especially low-income groups, in getting adequate and quality housing.

One of the challenges faced by planners, developers, policymakers and all those involved in the process of low-cost public housing is determining the

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characteristics or parameters that will influence residents' happiness with their housing (Gopikrishnan & Paul, 2018).

LITERATURE REVIEW

Factors of low-cost public housing design on residents' satisfaction

According to Oladapo (2006), a house that is adequate from an engineering or design standpoint may not be adequate or satisfying from a resident's perspective. Thus, the ideal home element includes the physical, architectural, and technical engineering elements of the home. It also considers the residents' social, behavioral, cultural, and personal characteristics, as well as the home's management environment.

According to Fatt et. al. (2021), old low-cost public housing designs typically lack modern amenities that enhance the quality of life, such as proper ventilation, green spaces, or energy-efficient systems. Without new units being built to modern standards, residents in older developments may have to deal with poor living conditions, such as inadequate ventilation, lighting, or thermal comfort. Many older low-cost housing units were constructed under previous UBBL iterations, which may not have emphasized modern sustainability and livability aspects. For example, early public housing projects prioritized density over comfort, often resulting in poor airflow and limited green space. Despite smaller family sizes, overcrowding is still prevalent because low-income groups share housing units due to affordability issues. This, ultimately, leads to overcrowding and discomfort. Notably, current trends emphasize sustainability and community development, which may be lacking in older designs.

A smaller living space, an aging building, inadequate facilities, and increased environmental stressors can negatively impact personal well-being and contribute to poor mental health. Due to financial constraints, lower-income groups are often unable to afford better living conditions, leading them to reside in high-density, low-cost public housing in urban areas. Moreover, as the number of dependents grows and living spaces remain limited, the home fails to provide a restful environment for residents after work. Over time, these factors can lead to poor mental health and mental health issues (Ghazali, Marzukhi, & Leh, 2021).

Additionally, Lichtenthaler (2022) also highlighted that a home that meets engineering or architectural standards may not necessarily be considered adequate or satisfactory by its occupants. Therefore, the house is a key factor in a series of elements that influence individuals' overall satisfaction.

According to Cohen, Manion and Morrison (2020), the satisfaction of users with low-cost public housing is a crucial factor in determining their quality of life. Specifically, aspects such as housing infrastructure, facilities, design, and the surrounding environment are key contributors to overall quality of life.

In order to assess the level of residents' satisfaction, it is required to evaluate specifically of the unit location and within the particular environment

that is managed under a certain type of institutional management and administration (Oladapo, 2006).

According to Lynch (1960), an image forms the basis for an individual's attitude and emotions toward the components of a system, and the overall emotions provide the foundation for one's relative satisfaction with each subsystem. In Malaysia, however, this information regarding low-cost public housing has largely been overlooked (Md Sani, 2007).

Enhancements in residential development are essential to improving satisfaction with low-cost housing, thereby advancing the goal of smart cities (Dzulkalnine et al., 2022).

The basic principles concerning low-cost public housing involve internal comfort, safety and access to public facilities. Acoustic comfort is a key component of Indoor Environmental Quality (IEQ), referring to protection from unwanted noise. In medium-rise low-cost public housing, high density, poor sound insulation, and inadequate spatial planning often result in noise disturbance, affecting residents' well-being, sleep quality, and overall satisfaction (Ghazali et al., 2021).

In Malaysia, acoustic performance is not strongly addressed in regulations such as the Uniform Building By-Laws (UBBL) Malaysia, which focus mainly on safety and basic habitability. However, acoustic comfort can be strengthened by incorporating specific by-law provisions, such as minimum sound insulation standards between dwelling units, control of impact noise transmission in floors, and zoning requirements to separate noise-sensitive spaces from circulation areas. Poor acoustic conditions in high-density housing may contribute to dissatisfaction and variability in residents' perceptions of housing quality. This is consistent with findings that Indoor Environmental Quality, including acoustic performance, plays a significant role in residential satisfaction and overall quality of life (Abdollahzadeh et al., 2023).

In Malaysia, prices that have been emphasized include the suitability of the design in the local climate, space efficiency, and affordability in cost (Hanapi et al., 2023). This principle also includes compliance with construction regulations to establish the safety as well as comfortability of the residents (Musa, Rahman, Azman, Lip, & Hashim, 2021). Furthermore, the 'house as a living space' concept emphasizes the significance of psychology and social aspects in housing design (Ibrahim, 2019).

METHODOLOGY

This study adopted a quantitative research design to examine the influence of low-cost public housing design factors on residents' satisfaction. A quantitative approach was selected as it enables objective measurement of residents' perceptions and statistical assessment of relationships between housing design attributes and satisfaction outcomes. The study employed a cross-sectional survey

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design to capture residents' evaluations of their housing environment at a single point in time.

The research was conducted in selected medium-rise low-cost public housing developments in Selangor, Malaysia. Selangor was chosen due to its high level of urbanisation and concentration of government-developed low-cost public housing schemes. The target population comprised adult residents living in low-cost public housing, particularly developments managed by Perbadanan Kemajuan Negeri Selangor (PKNS). Only residents who had resided in the housing schemes for a sufficient duration to evaluate their living conditions were included.

A combination of snowball sampling and mall-intercept sampling techniques was employed to obtain responses from residents across different housing schemes within the Klang Valley. These non-probability sampling methods were adopted to address access constraints commonly associated with low-cost public housing communities. The final sample size was adequate for multivariate statistical analysis and structural modelling.

DATA COLLECTION

Data was collected using a structured questionnaire developed from an extensive review of housing design and satisfaction literature. The questionnaire consisted of ten sections: respondent demographics, social sustainability, quality of life, product quality, design, facilities, environment, community development, impact and recommendations. All items were measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The questionnaire items were adapted from validated instruments to ensure content validity and contextual relevance.

To ensure the breadth of data collection and the accessibility of the questionnaire, this study distributed the survey offline. For offline respondents, the research team provided a live link to the online Google form and offered on-site query responses in the questionnaire, a hybrid approach intended to maximize the coverage of the survey and ensure participation from a diverse group of individuals. Additionally, the research team directly informed the public about the purpose and importance of the study through live interactions at community events, not only increasing the willingness of respondents to participate but also helping to enhance the accuracy and reliability of the data.

DATA ANALYSIS METHOD

In this research, a comprehensive analysis was conducted on the data collected to uncover how design affect the satisfaction for low-cost public housing in Selangor. The analysis followed rigorous statistical procedures to ensure the reliability and universality of the research outcomes.

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Descriptive statistical analysis was employed to outline the respondents' reactions to various items on the questionnaire, including calculations of frequency, mean values, and standard deviations. This step provided us with a preliminary understanding of the overall perception of public housing design that impact the satisfaction of the residents for low-cost public housing within the community as viewed by the respondents.

Data analysis was performed using SPSS and SmartPLS software. Descriptive statistics were used to summarise respondents' profiles and overall perceptions. Inferential and structural modelling techniques were subsequently applied to examine the relationships between housing design factors and residents' satisfaction. Prior to hypothesis testing, the measurement model was assessed to confirm acceptable reliability and validity. Statistical significance was evaluated at a 95% confidence level ($p < 0.05$).

To gain an in-depth understanding of the open-ended responses provided by the respondents in the questionnaire, content analysis was also adopted in this study. This method involved categorizing and summarizing respondents' comments, summaries, and suggestions. This qualitative analytical component provided us with additional insights, aiding in the understanding of the deeper motivations and viewpoints underlying the quantitative data.

RESULTS

The satisfaction measures indicate moderately favourable perceptions among residents, with mean scores of 3.74 for S1 and 3.67 for S2. However, the exceptionally high standard deviation observed for S2 (SD = 2.43) suggests substantial variability in residents' responses. This wide dispersion indicates that while some residents report high levels of satisfaction, others experience considerable dissatisfaction. Such divergence points to uneven housing conditions and inconsistent design quality across units or housing schemes, likely influenced by factors such as differences in building maintenance, workmanship, spatial configuration, or access to facilities. These findings highlight that average satisfaction scores may mask underlying disparities in residents' lived experiences, underscoring the need for more nuanced, disaggregated analyses to identify the specific design and management factors contributing to satisfaction gaps within low-cost public housing developments.

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Table 1: Respondents' Ratings of Satisfaction Dimensions.

Perception Dimension	Items	Mean	Standard Deviation	Interpretation
Are you satisfied with the design of your unit	S1	3.744	1.035	Agree
Does the design of your unit affect your quality of life?	S2	3.677	2.426	Agree (High Variability)

Source: Author

Product Quality recorded moderate mean scores across all items, ranging from 3.09 to 3.45. Among these, PQ1 received a relatively higher evaluation, while PQ4 registered the lowest mean score, indicating comparatively weaker perceptions of that attribute. The narrow dispersion of mean values suggests limited differentiation in residents' assessments of product quality, reflecting neither strong satisfaction nor pronounced dissatisfaction. Instead, this pattern points to a general sense of ambivalence toward product attributes, likely indicating that while basic functional requirements are met, product quality does not exceed residents' expectations or contribute meaningfully to enhanced satisfaction. These findings imply that improvements in material quality, workmanship, and durability may be necessary to elevate residents' overall perceptions of housing quality.

Table 2: Respondents' Ratings of Product Quality Dimensions.

Perception Dimension	Items	Mean	Standard Deviation	Interpretation
The residential area provide safety against accidents due to falling, tripping, theft, burglary, crime rates in the area, etc.	PQ1	3.445	1.239	Agree
The residential area have adequate lighting, fire extinguishers, water sprinklers, fire alarms, ventilation, etc.	PQ2	3.142	1.286	Strongly Agree
The residential area have adequate garbage bins, incinerators for disposal.	PQ3	3.286	1.297	Agree
The residential area provides provision for	PQ4	3.095	1.27	Agree

maintenance in roofs, walls, ceilings			
The residential area main sources of power and water supply are sufficient	PQ5	3.137	1.259

Source: Author

In contrast, Design was evaluated more favourably, with mean scores ranging from 3.01 to 3.76. Items DE5 and DE4 recorded the highest ratings, indicating that specific functional and aesthetic design attributes were perceived more positively by residents. This pattern suggests that design-related features exert a stronger influence on residents' evaluations compared to other housing attributes, particularly where they directly affect daily usability, comfort, and visual appeal.

Table 3: Respondents' Ratings of Design Dimensions.

Perception Dimension	Items	Mean	Standard Deviation	Interpretation
The unit have practical space layout	DE1	3.192	1.258	Agree
The unit is adequate in size	DE2	3.012	1.253	Strongly Agree
The unit have ccomfortable design with good functionality and noise reduction	DE3	3.341	1.252	Agree
The unit have adequate natural ventilation	DE4	3.684	0.958	Agree
The unit is using sustainable materials	DE5	3.756	0.928	

Source: Author

Facilities received a moderately positive evaluation overall, with FC1 recording a relatively high mean score (3.81), indicating satisfaction with certain facility-related aspects. However, FC4 registered a notably lower mean score (2.90), reflecting dissatisfaction in specific facility provisions. This contrast suggests uneven facility performance across housing developments, where selected facilities meet residents' needs while others remain inadequate, potentially limiting the overall contribution of facilities to resident satisfaction.

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Table 4: Respondents' Ratings of Facilities Dimensions.

Perception Dimension	Items	Mean	Standard Deviation	Interpretation
The residential area provides sufficient open spaces	FC1	3.811	0.858	Strongly Agree
The residential area provides sufficient parking spaces	FC2	3.602	1.003	Agree
The residential area provides availability of sports and recreational facilities.	FC3	3.744	0.899	Agree
The residential area provides infrastructure for disabled residents	FC4	2.896	1.249	Agree
The residential area provides telecommunication and Internet services	FC5	3.391	1.327	Agree

The structural model results indicate that community development ($\beta = 0.326$, $t = 5.431$, $p < 0.001$) and design ($\beta = 0.326$, $t = 4.125$, $p < 0.001$) are the strongest predictors of residents' satisfaction. Facilities ($\beta = 0.170$, $t = 2.493$, $p = 0.013$) and product quality ($\beta = 0.133$, $t = 3.361$, $p = 0.018$) also exert significant positive effects, albeit with lower magnitudes. In contrast, environment ($\beta = -0.021$, $t = 0.321$, $p = 0.748$) and social sustainability ($\beta = -0.032$, $t = 1.398$, $p = 0.162$) do not demonstrate significant relationships with satisfaction. Overall, the results suggest that residents' satisfaction is primarily driven by immediate, tangible design attributes and community-related factors.

Table 5: Structural Model Results (Standardised Path Coefficients).

Hypothesized Relationship	Hypothesis	β	t-value	p-value	Result
Community Development → Satisfaction	H2	0.326	5.431	0.000	Supported
Design → Satisfaction	H4	0.326	4.125	0.000	Supported
Environment → Satisfaction	H6	-0.021	0.321	0.748	Rejected
Facilities → Satisfaction	H8	0.170	2.493	0.013	Supported

Hypothesized Relationship	Hypothesis	β	t-value	p-value	Result
Product Quality → Satisfaction	H10	0.133	3.361	0.018	Supported
Social Sustainability → Satisfaction	H12	-0.032	1.398	0.162	Rejected

The structural model results are presented using standardised path coefficients (β), allowing comparison of the relative strength of each predictor. Significance was assessed using bootstrapping, where t-values > 1.96 and p-values < 0.05 indicate statistically significant relationships.

DISCUSSION

Significance and Interpretation of Research Findings

The findings of this study demonstrate that resident satisfaction in medium-rise low-cost public housing is shaped primarily by tangible, design-related attributes rather than by housing provision alone. Across all constructs, mean scores generally fall within the moderate range, indicating that while basic housing needs are met, current design and construction practices do not generate consistently high levels of satisfaction. The data alligns with Othman et al., 2022, where the design considers the need for personal space and common areas, such as the kitchen and living room, is vital in enhancing occupants' satisfaction and QoL.

Satisfaction indicators (S1 and S2) recorded moderately favourable mean values, suggesting general agreement that unit design influences residents' experiences. However, the exceptionally high variability observed for S2 highlights divergent perceptions among residents. This dispersion implies that satisfaction is unevenly distributed, likely reflecting inconsistencies in design quality, maintenance conditions, and facility provision across housing schemes. Importantly, this finding suggests that average satisfaction scores may conceal significant disparities in lived experiences, reinforcing the need for disaggregated design and performance evaluations in low-cost housing developments. This is supported by CIDB (2020), that a good housing design should meet the functionality regarding various household types.

Product Quality emerged as one of the weaker-performing dimensions, with all items registering moderate mean scores and minimal differentiation. This pattern reflects a state of ambivalence rather than strong approval, indicating that materials, workmanship, and durability meet minimum expectations but fail to deliver lasting satisfaction. The consistently moderate evaluations suggest that product quality does not function as a satisfaction enhancer, but rather as a baseline condition adequate when present, yet highly dissatisfying when compromised. A research by Norazmawati, Asmalia and Mohd Fadzi (2020) in low-cost public housing in Kuala Lumpur mentioned that poor quality that leads

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to inadequate space and ventilation caused residents problems such as stress and depression. This study also noted that residents who live in units with better natural light reported higher satisfaction in their lives since they enjoy a more comfortable environment and less dependency on human-made lighting.

In contrast, Design received comparatively higher evaluations, with several items approaching the upper range of agreement. Well-rated design attributes appear to exert a stronger influence on residents' perceptions, particularly where spatial layout, functionality, and usability directly affect daily living conditions. These results reinforce the role of design as a critical satisfaction driver in low-cost housing, underscoring that thoughtful spatial planning and functional design can partially offset constraints associated with affordability. Housing design may affect the mental and emotional well-being of the residents. Studies suggest that green spaces, water and natural landscapes around housing areas could help release tension and fix intellectual fatigue (Schneider-Skalska, 2019).

Facilities exhibited mixed performance, with some aspects receiving high satisfaction scores while others fell below acceptable levels. This inconsistency suggests that facilities contribute to satisfaction only when they are reliable, accessible, and responsive to residents' needs. Poorly performing facilities, however, undermine overall satisfaction and amplify perceptions of inequality within housing developments. In low-cost public housing in Selangor, a study by Fadzil and Ismail (2021) noted that inadequate facilities like playgrounds, community centers and green spaces negatively affect the residents' social interaction. The study highlighted that those who reside near facilities such as grocery shops, schools and clinics demonstrate better satisfaction in life.

Collectively, these findings highlight that resident satisfaction in low-cost public housing is not determined by housing provision alone, but by the quality, consistency, and usability of design-related attributes. The results underscore the importance of shifting low-cost housing strategies from a quantity-driven approach toward a design- and satisfaction-oriented framework that prioritises physical quality, functional performance, and equitable living conditions. Such a shift is essential for enhancing resident satisfaction and ensuring the long-term sustainability of low-cost public housing developments. Abed & Alzghoul, 2023, agrees that factors such as access to public amenities, suitability of house units with family size, and safety significantly impact the residents' social satisfaction.

Contributions To Empirical Research

This study makes several important empirical contributions to the literature on low-cost public housing and resident satisfaction, particularly within the context of developing urban environments. First, it provides quantitative evidence identifying specific housing design attributes as significant predictors of resident

satisfaction in medium-rise low-cost public housing. By empirically isolating the effects of design, product quality, and facilities, the study advances understanding beyond general assessments of housing provision and highlights the central role of physical design quality in shaping residents' lived experiences.

Second, the findings contribute empirically by revealing substantial variability in resident satisfaction, as reflected by high dispersion in selected satisfaction indicators. This variability demonstrates that average satisfaction scores may obscure unequal housing experiences and underscores the importance of examining intra-group differences when evaluating housing performance. The study thus adds empirical depth by capturing not only central tendencies but also disparities within low-cost housing developments.

Third, this research extends empirical housing studies by demonstrating that product quality functions as a threshold condition rather than a satisfaction enhancer. Moderate and weakly differentiated evaluations suggest that while acceptable material quality is necessary to avoid dissatisfaction, it alone is insufficient to generate positive satisfaction outcomes. This insight refines existing empirical assumptions that improvements in construction quality automatically translate into higher resident satisfaction.

Finally, the study contributes methodologically by employing a quantitative method empirical design, integrating large-scale survey data. This approach strengthens empirical reliability and offers a robust framework for future housing research seeking to link design attributes with resident-centred outcomes. Collectively, these contributions enrich empirical evidence supporting a shift toward design-led, satisfaction-oriented evaluation frameworks for low-cost public housing.

CONCLUSIONS

This study examined the influence of housing design factors on resident satisfaction in medium-rise low-cost public housing in Malaysia. The findings indicate that resident satisfaction is shaped primarily by tangible design-related attributes, particularly spatial layout, functionality, product quality, and facility provision, rather than by housing availability alone. While overall satisfaction levels were moderately favourable, substantial variability in residents' responses highlights uneven housing conditions and inconsistent design performance across developments.

Design emerged as the strongest contributor to resident satisfaction, suggesting that well-considered spatial planning and functional design can significantly enhance residents' daily living experiences, even within affordability constraints. In contrast, product quality was perceived as adequate but insufficient to generate strong satisfaction, functioning instead as a baseline requirement. Facilities exhibited mixed performance, reinforcing that satisfaction

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depends not on their presence alone but on their quality, accessibility, and reliability.

Overall, the study underscores the need to shift low-cost public housing strategies from quantity-driven delivery toward a design and satisfaction-oriented approach. Prioritising design quality and consistent implementation is essential to improving resident satisfaction and ensuring the long-term sustainability of low-cost public housing developments.

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INVESTIGATION OF SERVICE T-JUNCTION DUE TO TRAFFIC FLOW CONFLICT: INTEGRATIVE APPROACH OF TRAFFIC CONFLICT TECHNIQUE AND REAL-TIME DATA

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Abstract

The Hombis Lepo-Lepo Kendari T-junction is an intersection with three arms that is not equipped with Traffic Signal Devices. The increasing interaction of motor vehicles at this intersection has led to traffic flow conflicts that negatively impact the performance of the junction. The analysis results indicate that the average degree of saturation is 0.80 with a delay time of 13.28 sec/veh. The level of service at the intersection is categorized at level 'B', where traffic operations remain smooth. Nevertheless, there are indications of an increased potential for conflicts, particularly during right turn and U-turn maneuvers. This research finds that the correction factors for the capacity of the intersection are significantly influenced by temporal variables and traffic maneuver characteristics. Therefore, the development of a differential approach based on days and types of maneuvers is necessary. The Hombis T-junction in Kendari can still be operated for several years to come.

Keywords: Intersection Performance, Conflicting Movements, Protected Conflicts

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INTRODUCTION

The increasing traffic on the roads has become a problem that can lead to congestion. Congestion typically occurs at intersection points due to conflicting traffic flows (Konge & Nikam, 2022). Besides congestion, it also creates noise. Traffic noise exposure is an aspect that needs to be considered in spatial planning and transportation system management (Lakawa *at al*., 2025). Unsignalized three-way intersections are one type of intersection commonly found in urban areas. Although relatively simple compared to four-way intersections or other types, unsignalized three-way intersections also often become a source of traffic problems, especially in locations with high mobility levels. The absence of traffic signal devices at the intersection impacts the performance of that intersection. During peak hours, congestion frequently occurs, characterized by long queues and delays in traffic. Furthermore, if the traffic flow encounters conflicting movements and is obstructed, it may potentially lead to accidents.

Uncontrolled intersections are considered hazardous for drivers. The risk of accidents is higher in these locations, especially in countries with heterogeneous traffic. Such intersections require thorough investigation, considering traffic volume, geometry, and vehicle composition (Prasannakumar, 2018). This is supported by a report from the Ministry of Road Transport and Highways (2018), which states that unsignalized T-intersections significantly contribute to traffic accidents, particularly fatal ones. This is attributed to the lack of adequate traffic control, high vehicle volumes, and suboptimal intersection geometry. Unsignalized intersections are primary areas of traffic accidents and side impediments. Therefore, a microscopic analysis of each unsignalized intersection is required. This microscopic analysis includes traffic characteristics such as speed, volume, and capacity (Kumar *at al*., 2022).

The Hombis Lepo-Lepo intersection in Kendari is a three-legged intersection that is not equipped with Traffic Signal Facilities. The increasing volume of traffic from both major and minor roads has led to conflicts in traffic flows. Traffic delay is an important measure in evaluating the efficiency of road and intersection operations. Therefore, delay analysis is essential for assessing the level of service and planning the signal phases at intersections (Ren & Geng, 2022). The lack of priority signage or road markings creates confusion for road users, increasing the risk of conflicts and accidents. Conflict between vehicle flows is higher at this intersection compared to others, particularly for vehicles wishing to turn right (right-turn conflicts) or cut across the road.

LITERATURE REVIEW

Traffic congestion is a term used to describe a situation where vehicles come to a complete stop for an extended period of time. The root causes of traffic congestion include the increasing number of vehicles on the road at high speeds

and poor traffic control at congestion points (Sampathkumar, 2018). Traffic congestion often affects road users. Traffic flow parameters indicate the total volume of vehicles over a specific period of time (Kashinath *et al*., 2021).

Almost all cities in the world are experiencing a significant growth in the number of vehicles. This is one of the causes of traffic congestion on the roads. Traffic congestion will also lead to increased traffic noise, air pollution, fuel wastage, and a decrease in driving comfort (Guerrero-Ibanez *at al*., 2018; Rifai, 2020; Mavrin *at al*., 2020). An intersection is where two or more roads meet, which can be either at-grade or grade-separated. At-grade intersections are generally equipped with traffic lights to manage traffic (PKJI, 2023).

The capacity of an intersection refers to the maximum amount of traffic that can be accommodated by the intersection in one hour (Prasetyo, 2022). The capacity of an intersection is greatly influenced by the intensity of traffic flow, driver behavior, and the timing of entering the intersection (Pospelov, 2021). Evaluating the performance of intersections can enhance the efficiency of signal timing, lane configuration, and traffic flow patterns (Serok *et al*., 2022).

The use of the Gaussian Algorithm at an intersection is capable of accurately classifying and counting vehicles compared to manual counting (Guilalas, 2022). Traffic control optimization using genetic algorithms is one method to reduce issues at intersections due to the high growth of motor vehicles (Sharma & Kumar, 2019). Isya (2023) conducted intersection modeling using the MKJI method and PTV VISSIM. Three modeling scenarios include one-way streets, the installation of traffic signal control devices, roundabout planning, and widening at each arm of the intersection. The modeling results indicate that widening at each arm of the intersection can achieve optimal service levels.

$$C = C_0 \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times F_{BKi} \times F_{BKa} \times F_{Rmi}$$

where;
C = junction capacity (PCU/h),
C_0 = basic capacity of intersection (PCU/h)
F_{LP} = the correction factor for average approach lane width
F_M = the correction factor for median type
F_{UK} = the correction factor for city size
F_{HS} = the correction factor for side obstacles
F_{BKi} = the correction factor for left-turn traffic flow ratio
F_{BKa} = the correction factor for right-turn traffic flow ratio
F_{Rmi} = the correction factor for minor road traffic flow ratio

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Table 1: Basic Capacity of T-intersections and 4-way intersections

Type of Intersection	C_0, PCU/h
322	2700
324	3200
344	3200
422	2900
424	3400

Source: Indonesian Road Capacity Guidelines (PKJI, 2023)

The saturation degree of an intersection is a measurement that indicates the level of utilization of the capacity of an intersection (both signalized and non-signalized) in serving traffic flow. This term is commonly used in traffic planning and evaluation to assess the performance of intersections.

$$D_J = q/C$$

Where;
D_J = degree of saturation
C = intersection capacity (PCU/h)
q = the flow of motor vehicle traffic in vehicles per hour

$D_J < 0.75$: the intersection is functioning well (smooth conditions).
$D_J = 0.75\text{-}0.85$: the intersection is becoming congested (requires evaluation for improvements in the future).
$D_J = 0.85\text{-}1.00$: the intersection is approaching saturation (action is urgently needed to increase capacity).
$D_J > 1.00$: the intersection is already saturated or congested (this condition indicates that the volume of traffic exceeds the capacity of the intersection).

According to Hariyanto (2022), delays include traffic delays and geometric delays. Delay is the extra time required to pass through an intersection. Delays and traffic queues are issues at intersections, particularly in large cities, thus negatively impacting the economy and social aspects of the community. To address this, one of the solutions is to widen the roads at intersections or to manage intersections properly (Çıldır, 2022). Due to land limitations in urban areas, increasing intersection capacity is not feasible. Therefore, solutions such as the provision of flyovers at intersections are necessary (Sanik *et al*., 2023). According to Lakawa (2023), increased traffic volume on highways can trigger noise. Further research has shown that traffic factors significantly contribute to the increase in traffic noise by 31.3% (Lakawa, 2024).

Table 2: Level of Service at Intersections

Level of Service	Operation Characteristics
A	Delay condition < 5 sec/veh
B	Delay condition > 5 sec - 15 sec/veh
C	Delay condition > 15 sec - 25 sec/veh
D	Delay condition > 25 sec - 40 sec/veh
E	Delay condition > 40 sec - 60 sec/veh
F	Delay condition > 60 sec/veh

Source: Minister of Transportation of the Republic of Indonesia Number PM 96 of 2015

RESEARCH METHODOLOGY

The research locus is the Hombis intersection in Kendari City. This intersection is an unsignalized intersection in the shape of a 'T', connecting Christina Martha Tiahahu Street (a two-way secondary arterial road) with Ade Irma Nasution Street (a local collector road). The traffic flow from both the main road and minor road does not have primary priority in passing through the intersection.



Figure 1: Research Location (*Hombis T-Junction*)

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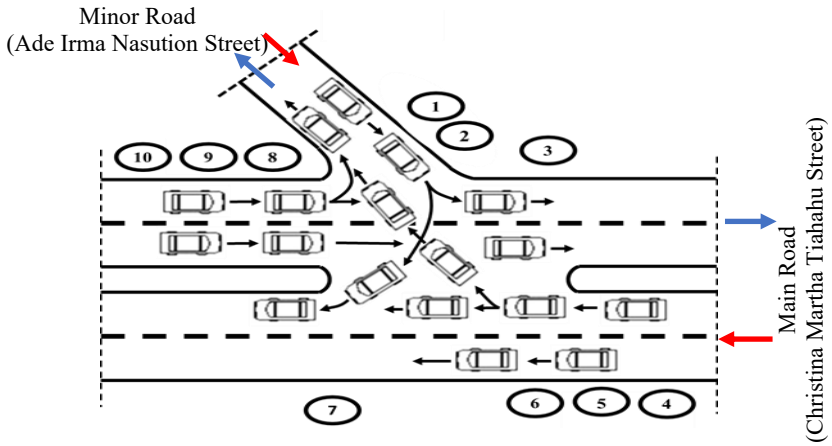


Figure 2: Traffic Flow Circulation at the Hombis Intersection (*Major and Minor Roads*)

This research uses a descriptive quantitative approach to analyze capacity correction factors based on traffic data. Field surveys were conducted over two days, namely Tuesday (working day) and Sunday (holiday), with observation periods being: from 07:00–09:00, 11:00–13:00, and 15:00–17:00. The data collected includes vehicle volume, queue length, delay time, vehicle speed, and geometric conditions of the intersection. Data analysis uses mathematically validated equations, both linear and polynomial. The calculation results are then visualized in the form of graphs to observe traffic characteristic patterns based on the day and type of maneuver.

The performance evaluation parameters for intersections refer to the Indonesian Road Capacity Guidelines 2023 and the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 96 of 2015, which includes calculations of intersection capacity considering correction factors such as approach width (F_{LP}), median type (F_M), city size (F_{UK}), side obstacle (F_{HS}), left turn flow ratio (F_{BKi}), right turn flow ratio (F_{BKa}), and flow ratio from minor roads (F_{Rmi}). The degree of saturation (D_j) is calculated by comparing the actual traffic flow (q) to the intersection capacity (C), while delay is calculated based on the average time it takes for vehicles to cross the intersection. Analysis is conducted to determine the differences in traffic characteristics between working days and holidays. Additionally, it aims to identify potential flow conflicts and the effectiveness of intersection services.

RESULTS AND DISCUSSION

Land use around the intersection includes schools, residential areas, and small-scale commerce (shops, stalls). Although pedestrian activities are not very high,

the activity of motor vehicles entering and exiting the intersection area is quite high, particularly involving students and residents crossing without a zebra cross. The risk of traffic accidents involving pedestrians is considerable due to the lack of safe crossing options.

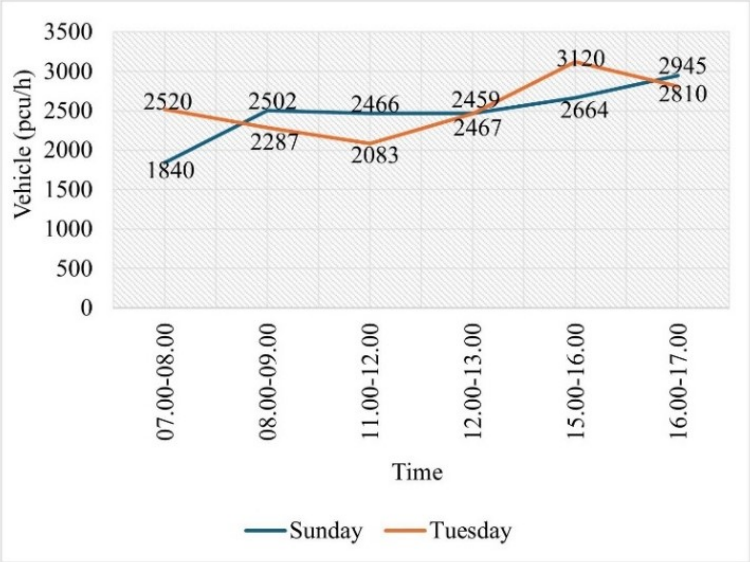


Figure 3: Traffic Volume at Hombis T-junction

The movement pattern of the main traffic tends to be constant on the major road (Christina Martha Tiahahu), while the traffic flow from Jalan Ade Irma Nasution is fluctuating. Conflicts often occur when vehicles exit from the minor road during high traffic volumes on the main road. Right turns and U-turns from the main road become additional sources of delays because there are no dedicated waiting lanes. Peak traffic volume on Sundays generally occurs in the afternoon with a total volume of 2945 PCU/h. Similarly, on Tuesdays, peak traffic volume also occurs in the afternoon with a total volume of 3120 PCU/h.

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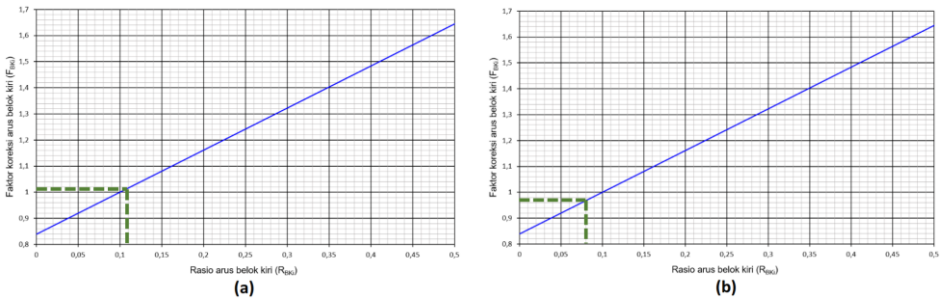


Figure 4: The Ratio of Left Turn Traffic Flow on Sunday (a) & Tuesday (b)

The left turn correction factor (F_{BKi}) for Sunday of 1.017 indicates that there is a 1.7% increase in intersection capacity requirements due to left turn maneuvers compared to the main flow without turns. The F_{BKi} value on Tuesday (office routine) is 0.969, indicating that intersection capacity requirements have decreased from baseline (0.84), which may indicate that left turn flows on weekdays have a lower corrective impact compared to Sunday. The graph shows a positive linear correlation between the left turn ratio and the correction factor, indicating that the higher the volume of left turns, the greater the capacity correction needed.

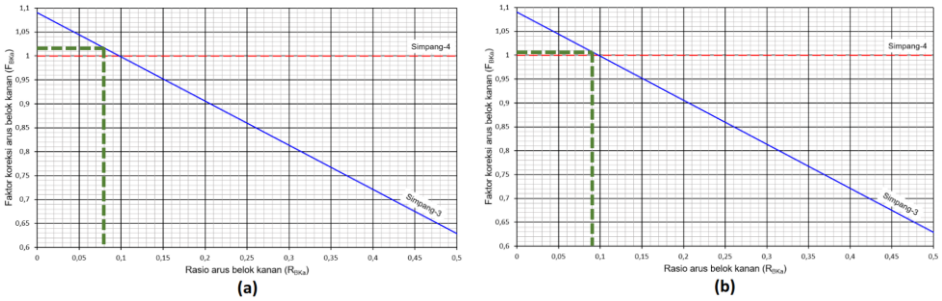


Figure 5: Ratio of the Right Turn Traffic Flow on Sunday (a) & Tuesday (b)

The right turn correction factor (F_{BKa}) on Sunday is 1.016, indicating a decrease in capacity due to right turn maneuvers. The graph shows a negative linear trend, meaning that the larger the right turn ratio, the lower the capacity correction value. On Tuesday, the F_{BKa} value is 1.007, indicating that on weekdays there are more right turn maneuvers compared to Sunday, but it still

results in a small capacity correction. Sundays tend to show a higher need for capacity correction for left turns, but lower for minor roads.

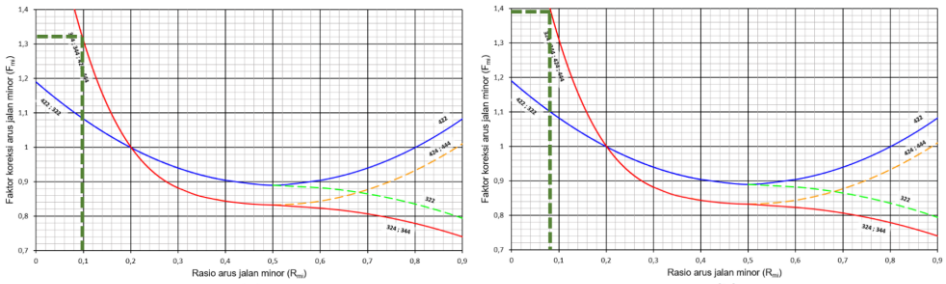


Figure 6: Correction Factor Graph of Minor Road Traffic Ratio on Sunday (a) & Tuesday (b)

Although the minor road flow ratio on Sunday is higher, the correction value of F_{Rmi} is actually higher on Tuesday (1.387 vs 1.320). This indicates a non-linear influence in the fourth-order polynomial model. The correction value does not always increase with the increase in the minor road flow ratio (F_{Rmi}). Mathematical Correlation: Linear models (F_{BKi} and F_{BKa}) represent a simple relationship, but the minor road correction requires a non-linear approach.

Table 3: Results of the Performance Analysis of Hombis T-Junction

Day	Traffic Flow (PCU/h)	Intersection Capacity (PCU/h)	Degree of Saturation (D_j)	Intersection Delay (sec/veh)	Level of Service (LoS)
Sunday	2945	3821	0,77	12,84	B
Tuesday	3120	3792	0,82	13,72	B

The performance assessment of operational traffic uses the D_J value. If the D_J value < 0.85, the intersection is still considered feasible for operation for the coming years, but if the D_J value > 0.85, changes are needed to improve intersection services. The traffic volume during peak hours reaches 2945 veh/h on holidays (Sunday) and 3120 veh/h on weekdays (Tuesday). Thus, the degree of saturation value obtained is 0.77 and 0.82 for Sunday and Tuesday, respectively. These values are still below the critical threshold of 0.85 according to PKJI 2023. Therefore, the intersection is still in an operational condition that can be tolerated and does not yet require structural intervention. However, the potential for congestion can occur daily if not controlled, especially during peak hours.

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The average delay at this intersection is 13.72 sec/veh for Tuesday and 12.84 sec/veh for Sunday. Based on the classification of Minister of Transportation Regulation No. PM 96 of 2015, this delay categorizes the intersection at Level of Service (LoS) B, which indicates that vehicles experience light delays and traffic is still moving efficiently. This condition shows that even though it is not equipped with traffic light signals, the intersection is still able to manage traffic flow relatively efficiently. However, the dominance of vehicles from the main flow and conflicts from right turns or U-turns, especially during heavy traffic, becomes a crucial factor contributing to the occurrence of delays.

Factors Causing Flow Conflicts and Potential Risks

Geometric characteristics and intersection function show that the absence of traffic lights causes vehicles from the minor direction to have to utilize the natural space in the main flow. This often leads to high gap acceptance delays and significant potential conflicts, especially when vehicles are maneuvering to turn right and make U-turns. The lack of dedicated waiting lanes also exacerbates this situation, as vehicles stopping in the middle of the main road create additional conflict points and risk slowing down vehicles behind them. Spatially, the presence of schools, residential areas, and trade activities around intersections also affects traffic dynamics. Although pedestrian activity is relatively low, the lack of crossing facilities such as zebra crossings is an important factor that can trigger traffic accidents. In an Urban Spatial Plan, intersection conflicts can be addressed by integrating physical road planning and traffic flow control. In addition, traffic signal systems and improvements to intersection geometry are part of engineering strategies aimed at reducing queues and delays.

Implications for Urban Transportation Planning

The results of this research provide an overview that although the intersection is still functioning adequately, there is potential for performance decline due to vehicle growth and space limitations. Therefore, short-term recommendations that can be taken include installing clearer priority signs, adding road markings for traffic management, and educating drivers about the rules of unsignalized intersections.

Medium to long-term strategies may include redesigning intersections into mini roundabouts, widening lanes on minor approaches, or even conducting feasibility studies for the installation of automatic signaling systems if vehicle growth continues to rise. Such interventions are crucial to maintain traffic service quality and minimize conflicts that could potentially increase accident rates.

Opposing and protected conflicts are major phenomena that need to be considered in the evaluation of intersection performance. Therefore, the design of an intersection without traffic lights must pay attention to the distribution of

traffic volume and other factors to minimize conflicts and enhance vehicle flow efficiency. Additionally, widening the intersection arms is necessary to reduce queues and accelerate vehicle movement.

The integration of spatial planning and traffic engineering at intersections can be achieved through a holistic approach. In this context, spatial planning plays an important role in designing land-use patterns that support smoother traffic flow and reduce the potential for traffic conflicts. By combining the Traffic Conflict Technique (TCT) with real-time data, conflict analysis can be conducted more effectively. Furthermore, spatial and transportation planning needs to account for vehicle movement patterns, interactions among road users, and their broader impact on urban mobility.

CONCLUSION

The average saturation degree of the Simpang Tiga Hombis Lepo-Lepo Kendari intersection is 0.80 with a delay time of 13.28 seconds/vehicle. This indicates that the intersection has not yet reached a saturated condition but is approaching the critical threshold. The level of service at the intersection is categorized at level 'B', indicating that traffic operations are still smooth. However, there are indications of an increased potential for traffic conflicts, especially during right-turn maneuvers and U-turns. This is triggered by the absence of a dedicated waiting lane and suboptimal traffic flow management. The environmental conditions and land use around the intersection also contribute to the fluctuations and dynamics of traffic in the area. The lack of pedestrian crossings also negatively impacts pedestrian safety, especially during peak hours.

This research found that the correction factors for intersection capacity are greatly influenced by temporal variables and the characteristics of traffic maneuvers. Therefore, it is necessary to develop a differential approach based on the day and type of maneuver. Based on these findings, it is recommended to add road markings and priority signs to reduce ambiguity among drivers. If the trend of vehicle volume growth continues to increase, then the installation of traffic lights will be necessary.

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EVERYDAY PLAY: REIMAGINING *MINAPOLITAN* TOURISM IN PULAU PASARAN THROUGH COLLAGE OF ASSEMBLAGE

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Abstract

Pulau Pasaran, a small coastal settlement in Lampung, Indonesia, is traditionally sustained by fishing and home-based salted fish production and has been designated as part of Indonesia's Minapolitan development program. Despite its economic and cultural potential, the island faces environmental degradation, limited accessibility, and declining spatial quality, which constrain its development as a sustainable tourism destination. This study explore how everyday spatial practices in Pulau Pasaran can be reimagined as meaningful tourism experience through the concept of everyday play. Using a qualitative design-based approach, this study combines field observation of daily activities with a collage of assemblage method as a visual analytical tool. Field observation document routine socio-spatial practices, while collages synthesize these findings into narrative spatial configurations that link local livelihoods, public spaces, and ecological elements. The findings demonstrate that everyday practices such as fishing, fish drying, and informal interaction contain strong spatial narratives that can be translated into planning and design strategies for Minapolitan tourism. It also contributes a design strategy by positioning collage of assemblage as an analytical and generative method for community-based tourism, offering an alternative approach to sustainable development rooted in local culture and everyday life.

Keywords: Everyday Play, Spatial Narratives, Collage of Assemblage, Coastal Settlement

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INTRODUCTION

Since the mid twentieth century, the global tourism industry has largely been dominated by mass tourism. This phenomenon is built a model on high visitor volumes, standardized experiences, and large-scale infrastructure (Teixido-navarro et al., 2021). While mass tourism can be considered to increase revenue and promote destination, it also has led to negative consequences, such as environmental degradation, cultural commodification, and the loss of authentic place identity, called placelessness. In contrast, the growth number of travellers today are seeking meaningful, localized, and immersive experiences. They need more experience-based tourism and memorable tourism on the quality of emotional and cultural engagement rather than mass tourism (Tung & Ritchie, 2011). This shift demands a rethinking of spatial design strategies to provide not only visually attractive spaces but also emotionally environments.

In this context, space is not only a setting background, but a storytelling device as a narrative landscape to convey memories, histories, and cultural meanings (Solomon et al., 2022). The narratives pattern (Alexander et al., 1977) are not told with words only, but with path, textures, colours, light, and rhythm of everyday life (Conzatti, 2018). This approach challenged designers how to understand activating space as a layer of experiential sequence, how to connect visitors to the site through everyday life and embedded stories (Certeau, 1984a; Shylichava, 2020), then enable emotional attachment and memory creation beyond visual aesthetics.

Pulau Pasaran, located off the coast of Bandar Lampung, Indonesia, represent a coastal settlement with significant yet underutilised tourism potential. *Pulau Pasaran* is primarily sustained by local community on fishing and widely known for traditional salted fish production, which forms the backbone of the local economy and daily life. As part of Indonesia's Minapolitan program, *Pulau Pasaran* is expected to support fisheries-based economic development while integrating environmental sustainability. However, challenges such as limited accessibility, inadequate infrastructure, pollution, and declining spatial quality have hindered its transformation into an attractive and sustainable tourism destination.

Rather than introducing tourism through external or generic design solutions, this study argues that Pulau Pasaran's everyday life itself constitutes a valuable spatial and cultural resource. Daily routines, such as fishing, fish processing, informal trading, and communal gatherings, produce spatial patterns and rhythm that can serve as the foundation for meaningful tourism experiences. This study introduces the concept of "everyday play" as a spatial approach that extends narrative-based design into embodied interaction.

The research aims to explore how everyday spatial practices in *Pulau Pasaran* can be translated into a Minapolitan tourism strategy that supports local

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livelihoods, strengthens place identity, and enhances environmental awareness. By employing observation and design speculation, contributing to coastal tourism planning through a locally grounded and visually driven approach. This study will address by combining field observation of everyday spatial practices with collage of assemblage as a visual analytical method. By framing everyday activities as everyday play and translating them into spatial narratives, the research offers a context sensitive approach to Minapolitan tourism planning that bridges analysis and design, theory and practice.

LITERATURE REVIEW

Everyday Life, Everyday Play and Spatial Practice

Everyday life play emphasizes the potential of space to invite exploratory, spontaneous, and collective actions for both locals and visitors. This is a narrative extension for play-based design. In the context of tourism, play-based design is to encourage social interactions between locals and visitors, support active engagement rather than passive sightseeing, and offers a fluid experience to blend and adapt to the users and context. Regarding "play" is not limited to recreational activity, but it is a creative way of interpreting and inhabiting space, engaging body, imagination, and memorable experiences of emotions. "To play" is how users reinterpret a space and play-based design is a tool to democratize spatial meaning (Sicart, 2014).

Regarding this condition, everyday life is a lens to understand how space is produced, inhabited, and transformed. Rather than viewing space as a static physical capsule, Certeau (1984) conceptualises everyday practices through daily practices, routines, and social interaction as tactical actions which ordinary users actively reinterpret planned space, turning into lived spaces (Certeau, 1984b). This perspective highlights how movement, repetition, and habit contribute to the spatial meaning of environment. Everyday provides constantly adaptational processes and changes of neighbourhood from ordinary to a dominant (Shylichava, 2020). The concept of narration and repetition (Zisimopoulou & Voreakou, 2016) of everyday life may acquire spatial status and reflect spatial practice and transform into experience as representation (Certeau, 1984a). Studying everyday space constructs the everyday spatial practice performed by inhabitants of space, it is not only by occupation, but also by materiality (Atmodiwirjo & Yatmo, 2019), while the type of material landscapes could position cinematic landscape as representation (Lukinbeal, 2005). As representational spaces are lived by local inhabitants through complex symbolic association and imagery, like overlay of physical space and making symbol use of social space (Lefevbre, 2017).

In terms of everyday life and landscape as part of the tourist experience will be connected to natural, cultural, and its influences. This experience might

involve a physical and emotional presence which reflects how individuals perceive the surrounding collectively (Hussin et al., 2020). This character and quality could show the identity of area, a sense of place. The components of sustained value, tradition, and community contribute to the transformation from nondescript to sustainable tourism (Terkenli, 2014). Consequently, dwellers and visitors will recognize the cultural, ecological, environmental, and social significance that leads to boost the economy and revitalise the image of the place. To promote this, there are some required facilities, including spaces for social interaction, enjoyment of nature, healthy lifestyle, and accessibility (Razali et al., 2019).

Conceptualising and experiencing routineness of social interaction in daily life indicate more meaning, stability, and well-being (Luo et al., 2024). Sicart (2014) in his book "Play Matters" identifies everyday plays as contextual that is influenced by space things, people and culture. It is like carnivalesque which reveals the social reality we live in (Sicart, 2017). It is separate in the sense of creating a special space and time from the mundane and everyday existence (Caillois, 2001). In this research, it explores how architecture and objects can be an active engagement in encouraging physical manipulation to increase opportunities for people to interact (Villareal, 2018) each other (residents and tourists) to make street safer, more vibrant, and more economic activities. In the context coastal settlement, *Pulau Pasaran* is performative ecologies, where labours, activities, and leisure as daily spatial rhythms. This practice as play allows designers to reframe the landscape as a living stage for storytelling and engagement.

Minapolitan Tourism

Minapolitan tourism, combining fisheries and aquaculture-based tourism, is categorised a special interest tourism for segmented tourists who have special motivation (Sugiarti, 2013) and special location at coastal area. Minapolitan tourism features several key attractions for tourists that highlight its unique culture and natural beauty to enhance the tourism experience for those interested in nature, culture, and sustainable practices and to provide economic benefits to local community. Unlike conventional coastal tourism that prioritises leisure consumption, Minapolitan tourism focuses on productive landscapes, local knowledge, and community participation.

Pulau Pasaran is a small island primarily sustained by local community on fishing and a home-based salted fish industry. *Pulau Pasaran*, the largest salted fish centre, has been regulated and designated as part of *Agropolitan* and *Minapolitan* program, which focuses on fisheries activities. This island is recognized for its traditional fish-drying practices, as marine product of dried anchovies for them sustains local livelihoods, and its economy is profoundly

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connected with marine resources. These activities include fishing, boiling, drying, packaging, and marketing, that has potential to be used as a community-based Minapolitan tourism. These activities show as a potentiality in a tourism attraction and destination.

Minapolitan tourism and everyday play provide a foundation to understand how sustainable and culturally resonant tourism can be achieved. *Pulau Pasaran. Minapolitan* tourism, a concept promoting marine-based local economies, culture, and encourages sustainable tourism that aligns with traditional livelihoods of coastal communities, such as fishing. This coastal community refers to the way people engage and transform spaces though daily activities, which show potentials to attract other people to spend their time and visit this area (Gehl, 2011). Therefore, examining case studies from coastal communities will demonstrate how playful design could enhance tourist engagement while preserving local heritage and environment.

Collage of assemblage

Collage of assemblage has traditionally been used in art and architectural design as a representational technique, but also as valuable analytical and generative method in spatial research. Khodabakhshian (2019) describes architectural college to synthesise fragmented realities into coherent spatial propositions, allowing designers to explore complex relationships between social practices, material conditions, and spatial form. It consists of the assembly of various forms and fragments, combined that a new meaning, not inherent in any of the individual fragments with a purposeful reciprocal relation. This is a flexible and creative method that is intertwined with unconscious and hidden memory of the designer as basis design thinking for landscape urbanism (Khodabakhshian, 2019a).

As a visual analytical tool, collage enables the integration of diverse data types of photographs, observations, maps, and narratives into a single interpretive framework. These highlight role in exploring spatial transitions and sequences, where quantitative data alone cannot fully capture lived experience, college offers an alternative means of spatial reasoning. By assembling everyday elements into new spatial narratives, collage of assemblage functions not only as representation but also as a planning instrument. It allows researchers to test spatial scenarios, visualise potential interventions, and communicate idea in an accessible way. This makes it particularly suitable for community-based tourism planning in coastal settlements, where informal practices and environmental sensitivity play a central role. The latter emphasises the role of architecture as a frame and a setting for human activities into collage activities, furnishings, and objects. Mostly are assemblies of alterations, textures, materials, and colours

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layered of use as interpretive mechanism a multi-sensory experience in a work of architecture (Shields, 2023).

RESEARCH METHODOLOGY

This study analyses *Pulau Pasaran* unique's socio-spatial dynamics and develop a tourism model both environmental sustainability and cultural values as a qualitative design-based research approach (Figure 1) combining visual ethnography and spatial narratives analysis. We used to complementary methods. Firstly, field observation was used to document how residents inhabit and use the island in everyday life, such as loading and unloading fish activities from fishermen, drying, packing, communal gatherings, and informal market exchanges. Secondly, collage of assemblage was used as a visual analytical design technique to synthesize those observations into a creative vision of sustainable tourism future. Thirdly, contextual spatial synthesis for planning recommendations. Each method is described below, emphasizing how it grounds the project in local reality and guides a Minapolitan tourism concept.

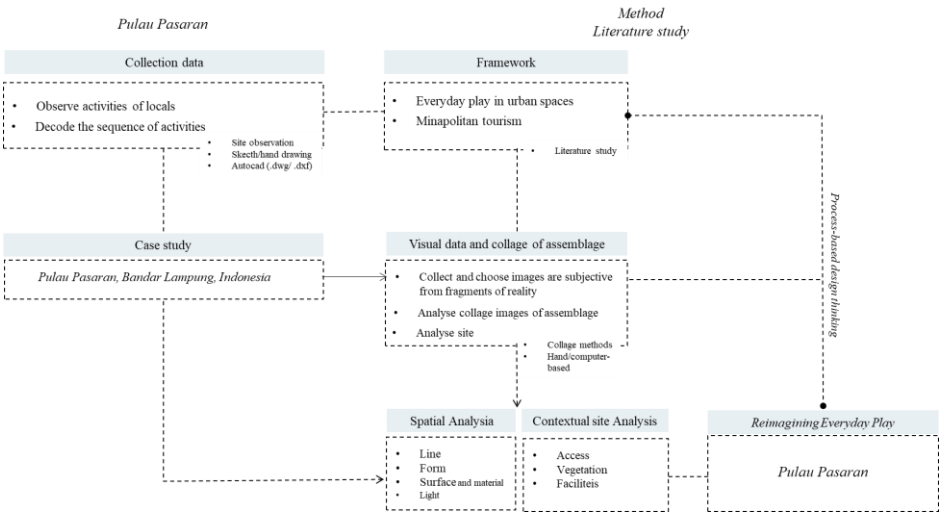


Figure 1. The corpus methodology
Source: Authors, 2025

a. Field observation of daily spatial practices

This stage, we conducted multiple on-site visits to *Pulau Pasaran,* systematically observing and recording daily routines and spatial uses. Each visit focused on different area of the island, such as fishing docks, drying yards, markets, homes, and communal spaces, in different time of day (morning, afternoon, evening) to capture the full range of activities. Field notes and photographs were taken unobtrusively to document what people were doing, where, and how spaces were

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organised. This direct, naturalistic observation provided empirical baseline of the island life so that this method ensured we could better understand urban spaces, places, and place-making through firsthand observation (Byrne, 2021).

In field observation, the researchers walked key zone, recording routine activities, noting spatial arrangement at varied time to observe daily cycles, for example fishing departures in the morning, fish processing and production midday, evening communal gatherings. Figure 2 (top) exemplifies the sequence daily activities of locals as everyday play in daily activities position that might discovery and play as open stage in the neighbourhood. The process of everyday, including fish processing, unloading, sorting and counting, transferring, drying processing, and socialising these daily activities routines. In addition, figure 2 (bottom) shows the sequence daily activities of locals as everyday play in daily activities the land, including preparing and cleaning, transferring, drying processing, sorting and packing.



Figure 2. The sequence daily activities of residents in dried fish processing in the coastal area (top) and land area (bottom) of Pulau Pasaran
Source: Authors, 2025

Pieces of images are collected from the field observation and activities patterns of locals in this area to identify recurring patterns and to map how daily life unfolds spatially. This resulting insights into local rhythms and site features directly inform for sustainable tourism proposals.

b. Collage of Assemblage as visual analytical design method

A collage of assemblage approach is applied to creatively and re-envision the island. This involved assembling visual and textual elements form the observation field into layered collages that represent both current conditions and potential futures. This will be an interpretive visual method to merge field documentation, memory fragments, and spatial speculation into single representation (Khodabakhshian, 2019b) through collecting visual materials, creating colleges, analysis and iteration.

By collecting visual materials, author(s) selected photograph, site maps, sketches, and notes from the observation phase. We also gathered suggestive images a potential icon of tourism, ecological and local cultural elements to complement the data. Then leads to creating collages through combining on a canvas, including physical or digital, layered and juxtaposed to form composite images. This technique creates a narrative explanation and experimental story through presenting collage (Corballis, 2015), which this processing all the collage are harmonised of colours, shapes, and composition (Khodabakhshian, 2019b). For example, an image of the anchovy drying area might be overlaid with icons of an ecotourism boardwalk or mangrove nursery (figure 3). It was to highlight relationships and possibilities of collage that emphasizes the role of imagination and cognition as a bridge between observed reality and design vision (Khodabakhshian, 2019a).



Figure 3. The collage of assemblage the found objects (nature, culture, and community) as a representation of everyday play in Pulau Pasaran
Source: Authors, 2025

The initial stage analyses curating a set of images from direct field observations and capturing local activities. The pieces of images (Figure 3) from the sequence activities are arranged and placed next to each other and creating a sequential narrative composition that shows the spatial flow of everyday life in *Pulau Pasaran*. This collage creates a new way to express original thoughts from

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ways of seeing to make process in overlapping each other, even the fragments are not match perfectly. The position is based on its temporal rhythm and spatial logic (Hillier & Hanson, 1984). Then, this sequence creates a form of cinematic storytelling, not only spatial arrangement but also the invisible of human actions, emotions, and routines (Corballis, 2015; Stierli, 2016).

Then, by analysing and iterating, each collage was interpreted by the research team and informally discussed with community members to explore what the visual narrative suggested. Insights from this discussion led to refining and creating new collages. For instance, a collage might reveal how tourism infrastructure could integrate with existing fishery facilities, or how community spaces could be enriched by natural features. This iterative process helped to crystallise how different aspects of the island (economic, social, ecological) could assemble into a cohesive development strategy. In addition, analysing formal and line types, materials and surfaces, plan hierarchy, light and colour analysis (Figure 4) (Khodabakhshian, 2019b) is to understand how line types represent spatial intensity, how forms present spatial patterns, how surface and materials represent a response of passive ecology, and how light creates experience of spatial activities.

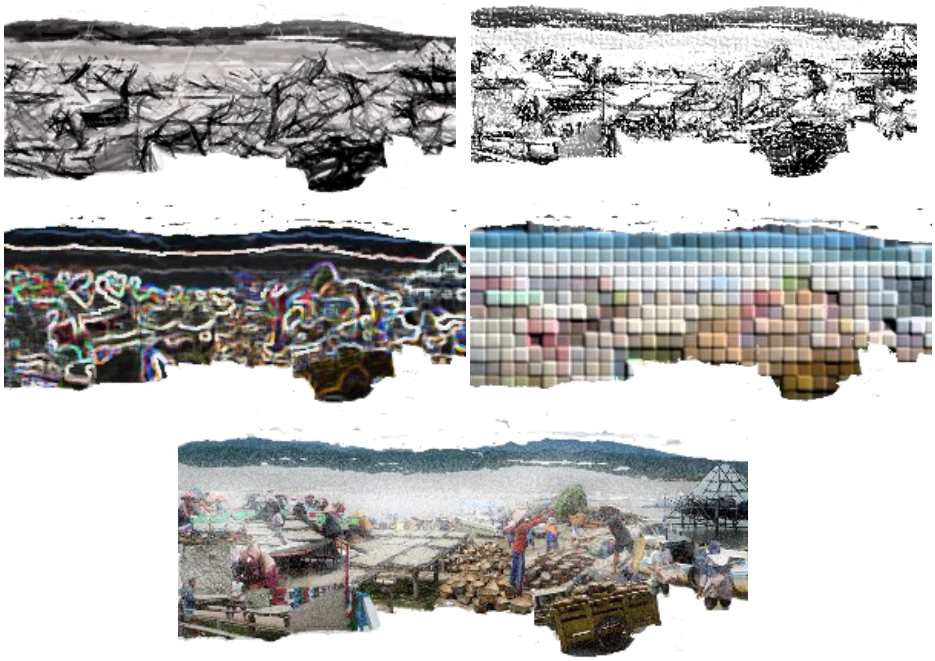


Figure 4. Collage of (a) line type, (b) forms, (c) colour pixel, (d) materials, and (e) light analysis
Source: Authors, 2025

Therefore, the final collages functioned as conceptual models of sustainable Minapolitan tourism scenario. It will create concrete how local elements can be reassembled in a new context and clarified design directions into immersive spatial sequences. This presents that space is not only seen but experienced, narrated, and co-created. In addition, this visual synthesis explicitly links *Pulau Pasaran's* fishery-based economy, settlement patterns, and natural environment into a proposed framework.

c. Analysing sites contextually

Figure 5 depicts a map illustrating accessibility route to *Pulau Pasaran* as a tourist destination, passing through *Kampung Cungkeng* and a mangrove area. *Pulau Pasaran* can be accessed only from Jalan Laksamana R.E. Martadinata and linked to bridge *Pulau Pasaran* in one way system. We identify that there are three ways to access and visit this area from the land area (Figure 5), Jalan *Teluk Bone, Jalan Teluk Ratai,* and *Jalan Teluk Bone 2*. The accessibility may be limited for larger vehicles, and the street is very narrow and only adequate for pedestrians, a car, and motorcycles.

To enhance the accessibility of *Pulau Pasaran* as a tourist destination, there are reimagined elements that can be implemented, likes the paths could be designed to pass through scenic points, such as mangrove area and offer a closer connection to nature. Reimagining the accessibility to *Pulau Pasaran,* the route can become part of attraction itself and give an experiential journey and memorable experience.

Figure 5 shows the street networks and various alleys and paths for pedestrians on *Pulau Pasaran,* which includes access routes for both pedestrians and motorized vehicles, along with the island's main entrance. All pathways showcase narrow alleyways, walking paths, and areas accessible by local transportations, like *becak* and *gerobak.* These conditions give insights circulation patterns that can be potential to explore and reimagine the sequence of activities in this area from pedestrian's perspective. Reimagining the circulation patterns and access can significantly (N. Asriana et al. 2024) enhance appealing as a tourist destination. Improved pedestrian paths, a welcoming entrance, and local transportation can encourage visitors to fully immerse into the island's culture, creating a sustainable tourism experience that respects the local lifestyle and environment.

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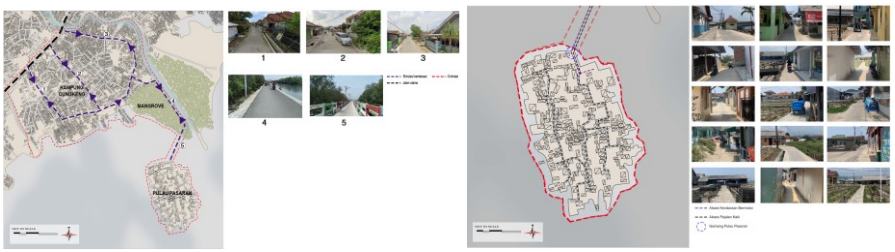


Figure 5. The accessibility condition to Pulau Pasaran
Source: Authors, 2025

Figure 6 (left) presents the existence of vegetation in *Pulau Pasaran* that is found on this island. This vegetation, which includes trees diversity, grass, and other local plant species, creates eco-friendly and more attractive for appealing tourist destination. Tree diversity creates a lush scenery, providing shade, visual interest, and potentially edible fruits to attract both local and international tourists in eco-tourism. Meanwhile, functional plants can be traditional or in educational tours on local flora. Grass provides natural ground cover that could be used to create pathways or relaxation with minimal environmental disruption. This existing plantation can be developed to enhance the scenery of natural landscape, that could attract visitors to experience and appreciate the island's ecological and cultural heritage while preserving its natural beauty.

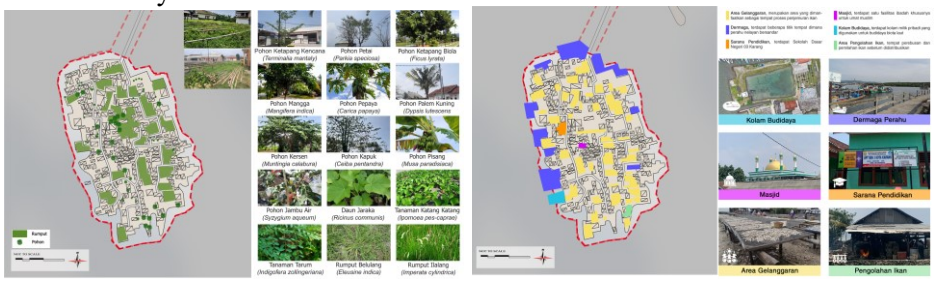


Figure 6. The existing of vegetation map and facilities on *Pulau Pasaran*
Source: Authors, 2025

Figure 6 (right) depicts the key facilities and infrastructure on *Pulau Pasaran,* including educational, religious, fish processing, and community gatherings. This potential can contribute to reimagine enhancing tourism through the foundational infrastructure. By enhancing access, educational elements, visitor facilities around existing resources, this island could attract tourists' interest in marine life, local traditions, and sustainable experiences. These would benefit the local economy while preserving the island's culture, community and natural environment.

Reimagining tourism experience could use cultivation ponds to transform interactive aquaculture tours into tourist attractions. Visitors can experience fish farming, marine ecosystems, and sustainable fishing practices, and tourists could participate in feeding fish or other hands-on activities. At the same time, the boat docks serve as entry points for local fishing boats, by upgrading the docks could welcome signage, seating area, and shaded spots or boat tour service to offer scenic rides around the island. In addition, fish-drying area is to dry fish, a traditional method to the island's seafood industry. By enhancing the layout and visitor pathways, this could become an educational showcase of traditional fish-processing techniques. Tourists could observe and learn about drying process naturally and they aloe to purchase the local dried fish products or eat this in restaurants as interactive culinary experiences. Meanwhile, fish processing area, this area is essential to prepare and distribute marine products. This area could be developed into interactive experience where tourists learn about traditional and modern fish processing methods. A viewing area with informational signage allows tourists or visitors to see directly the prepared and processed fish while learning about food preservation.

ANALYSIS AND DISCUSSION

The results of this study reveal that *Pulau Pasaran's* everyday activities generate distinct socio-spatial patterns that can be systematically interpreted and reorganised. Field observations identified several recurring spatial practices, including fishing departures and arrivals at the docks, fish drying along open yards and pathways, informal trading near residential areas, and communal social interactions in semi-public spaces.

These practices are spatially distributed that reflects functional necessity, social proximity, and environmental conditions. For example, fish drying activities are consistently located in areas with high solar exposure and airflow, while communal interactions tend to occur near circulation routes and shared facilities. These patterns demonstrate an inherent spatial logic shaped by daily routines rather than formal planning.

Through the collage of assemblage process, these observation practices were visually synthesized into narrative spatial sequences. The collages reveal how production spaces, circulation paths, residential areas, and ecological elements can be interconnected to form experiential routes for visitors. Instead of creating tourism facilities separately from everyday life, the result suggests a spatial configuration for tourism activities overlap with local routines, allowing visitors to observe, participate in, and learn from daily practices, then into potential and meaningful tourists' experiences (Figure 8).

This transformation is structured into site plan design that aligns well with the surrounding context, emphasizing ecological and sustainability with

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oriented context of the area based on narrative sequencing. The resulting spatial framework highlights key planning components, including pedestrian-oriented circulation, production-based attractions, community hubs, and green corridors to soften boundaries between zones and fluidity. These components emerge directly from observed everyday practices and are reassembled through collage as an integrated Minapolitan tourism scenario.



Figure 8. Collage making process create a new configuration of spatial and structural patterns in masterplan development strategy
Source: Authors, 2025

The figure 9 present the site plan as a new development strategy, not a whole redesign but a reconfiguration from the existing. There are some key elements include to support this development area, such as (a) community hub; located near the entrance and serve as central nodes for community gathering and local economic exchange. These spaces active the islands entrance through everyday interaction; (b) open green spaces; these areas are scattered across the site, serving as breathing rooms, ecological buffers, and stages for everyday play. These zones accommodate spontaneous public life, leisure, and informal play, reinforcing the "playce-making" strategy; (c) production zones; the layout respects the island's identity by preserving two zones dedicated to *ikan asin* (salted fish) production. These areas are interwoven with public access and narrative paths, celebrating participatory of local knowledge; (d) mixed-use housing; housing blocks are distributed along pedestrian-friendly roads, forming a linear-radial configuration. these cluster promote compactness while enabling social visibility and neighbourhood interaction; (e) public facilities; the school, mosque, and health centre *(puskesmas)* are placed within walkable distances, anchoring communal life and ensuring inclusivity in public service accesses, and (f) transport and entry points; a designated parking area and port on the west provide arrival points for lands and sea visitors, ensuring seamless integration between tourism and daily activities. These daily scenes form a cinematic narrative, where visitors can trace the flow of daily life of community as part of their journey. The spatial experience shifts from a static visit to evolving interaction with community life.

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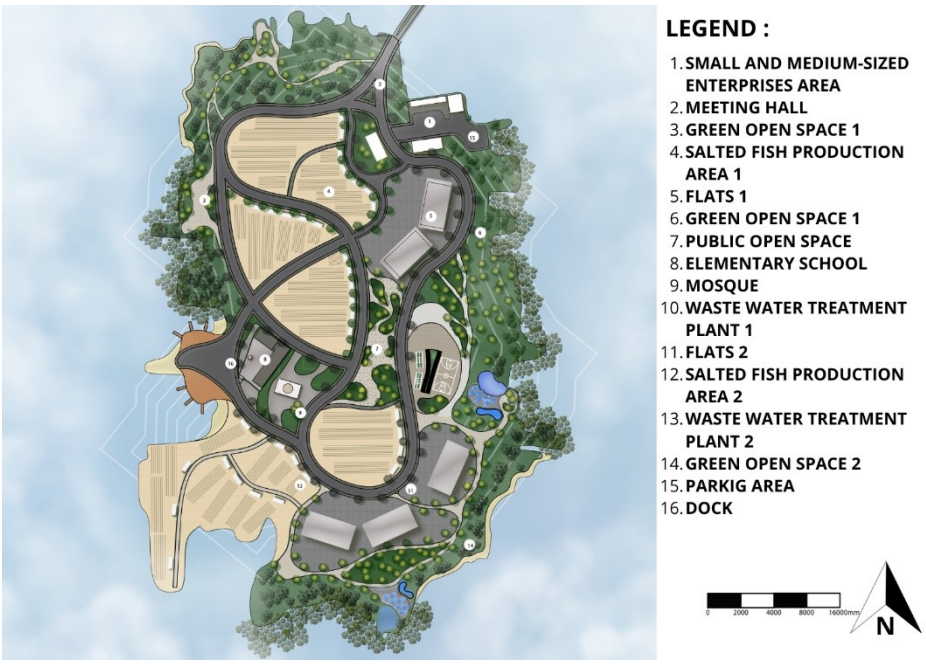


Figure *9*. recommendation site plan
Source: Authors, 2025

The findings demonstrate that everyday spatial practices in *Pulau Pasaran* function not only as economic activities, but also as cultural narratives embedded in space. When interpreted through the lens of everyday play, routine activities such as fish drying, or informal trading become interactive and performative experiences that can enrich tourism without displacing local life. From a planning perspective, this collage of assemblage method proves effective in translating qualitative observations into spatial strategies. Unlike conventional analytical tools that rely primarily on quantitative indicators, collage enables the integration of material conditions, social interactions, and environmental elements into a single visual framework. This approach supports a holistic understanding of place, particularly in informal or organically developed settlements where spatial logic is not easily captured through standard planning instruments.

The study highlights the importance of adaptive and incremental development in Minapolitan tourism planning. Rather than proposing large-scale redevelopment, the reimagined spatial configurations build upon existing practices, infrastructures, and ecological features. This adaptive approach aligns with sustainable coastal planning principles by minimizing disruption while enhancing spatial quality and visitor experience.

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By situating tourism within everyday life, the proposed framework fosters mutual engagement between residents and visitors. This model shifts tourism from passive consumption towards participatory experience, strengthening social interaction and reinforcing local identity. As such, the study contributes to broader discussions on community-based tourism, experiential planning, and sustainable coastal development.

CONCLUSION

This study demonstrates that Pualu Pasaran's everyday spatial practices form a valuable foundation for developing sustainable Minapolitan tourism. Through systematic field observation, the research identifies how daily routines related to fishing, fish processing, and social interaction shape the island's spatial structures. The college-of-assemblage method then translates these observations into narrative spatial configuration that support planning and design decisions.

The findings confirm that everyday play offers an alternative paradigm for tourism development, one that values ordinary activities as meaningful spatial experiences rather than obstacles to modernisation. By grounding tourism planning in local routines and cultural practices, the proposed approach enhances place identity while supporting economic and environmental sustainability.

Methodologically, the study contributes to planning research by demonstrating how collage of assemblage can function as both an analytical and generative tool. This visual method bridges qualitative observation and spatial strategy, making it particularly relevant for complex coastal settlements with strong socio-cultural dynamics.

In conclusion, reimagining Pulau Pasaran through everyday play and collage-based analysis provides a replicable framework for community-based Minapolitan tourism. The approach offers planners and designers a way to integrate culture, ecology, and economy without sacrificing local authenticity to enhance visitor's experience, thereby supporting more inclusive and sustainable coastal development.

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RENTAL FLATS AS A SOLUTION TO LAND CRISIS IN THE PERI-URBAN GREATER JAKARTA AREA: AN EVALUATIVE STUDY IN TANGERANG CITY, INDONESIA

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Abstract

The urbanization and population expansion in Tangerang City have increased the demand for affordable housing, yet land supply is constrained and prices are elevated. Home ownership is becoming progressively costly for individuals with modest income (MBR). In response, the Tangerang City Government constructed Simple Rental Flats (rusunawa) to offer adequate housing at affordable rental rates. Nonetheless, its execution encounters numerous obstacles, particularly the disparity between policies and practical situations. This study seeks to assess the utilization of rusunawa in Tangerang City by analyzing physical characteristics, and inhabitant profiles, while comparing these factors with relevant policies. The research employed a quantitative methodology with a simple random sample procedure involving 910 households throughout three rusunawa (Manis Jaya, Gebang Raya, and Betet). The findings indicated that the occupancy rate of rusunawa attained 93%, accompanied by an extensive waiting list, signifying substantial public interest. Nonetheless, a divergence existed between policy and reality, exemplified by the utilization of residential apartments for commercial purposes, exorbitant rental prices, insufficient educational institutions, and concerns over security and maintenance. Moreover, the majority of inhabitants have exceeded the maximum rental duration of three years, resulting in a misalignment of target demographics, as some people possess the financial means to afford housing. This study advises modifying the rental charge policy according to financial capacity, enhancing support facilities, augmenting oversight, and fortifying the residents' institution. The government must also contemplate the development of supplementary rusunawa including a greater variety of unit types to address community requirements. This study significantly enhances the management of rusunawa in Tangerang City, promoting greater effectiveness and equity for MBR.

Keywords: vertical housing, affordable housing, rental flats, low-income communities, policy evaluation, Tangerang City

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INTRODUCTION

Intense urbanization and population increase in cities, coupled with restricted land availability, have led to challenges in securing land for housing. The escalating land costs are becoming increasingly unattainable for many individuals, particularly those with low incomes (MBR) (Lastiur & Septanaya, 2024; Rassanjani, Mukhrijal, Rahmi, & Ulya, 2023). Consequently, extensive development in suburban regions deviates from its status as residential, rendering the village dilapidated and uninhabitable. To address this situation, the government is attempting to construct vertical housing in the form of apartments/flats. In an urban context, apartments can serve as an alternative for land use, facilitating the creation of expansive open spaces, promoting high-density housing and settlements, and contributing to the revitalization of the city, thereby enhancing the area's visual appeal (Herawati, Suparjo, & Lestarini, 2023; Rukmana, 2018). The objective of organizing flats is to facilitate the development of livable and cheap housing within a healthy, safe, harmonious, and sustainable environment, while fostering connected communities that enhance economic, social, and cultural resilience. (Berawi & Miraj, 2023; Dewita, Burke, & Yen, 2020).

Tangerang City is a buffer city within the Jabodetabek region that has undergone significant development in recent decades. The substantial economic expansion, coupled with swift urbanization, has resulted in a continual annual increase in the population of Tangerang City. According to figures from the Central Statistics Agency (BPS), the population of Tangerang City in 2023 was 1,912,679, with a population density of 11,624 individuals per square kilometer. This amount significantly exceeds the average population density of cities and regencies in the Jabodetabek region, which is 8,514 persons per square kilometer. This has heightened the demand for adequate and cheap homes in Tangerang City. Nevertheless, restricted land availability and escalating land prices constitute the primary impediments to home provision.

Restricted access to adequate and affordable housing constitutes a substantial issue for low-income populations (MBR) in Tangerang City. In 2023, residential property prices in Tangerang City vary from 500 million to 3 billion rupiah, with monthly payments between 3 and 20 million rupiah. This price level necessitates that MBR allocate over 40% of their salary to secure adequate housing. This ratio significantly surpasses international standards, which recommend that housing expenses should not exceed 30% of income. The exorbitant housing costs hinder MBR's ability to secure affordable housing in Tangerang City. The constraints in the quality and affordable housing sector have compelled the Tangerang City Government to seek solutions to this issue. One method involves the development of basic rental apartments (rusunawa). The construction of rusunawa aims to provide the community with access to adequate

and cheap housing. Consequently, the community can distribute their wealth more equitably to address additional needs, such as education and healthcare, which can enhance their quality of life.

The residents of rusunawa in Tangerang City are restricted to individuals classified as low-income communities (MBR) and are prioritized for local inhabitants of Tangerang City. Nonetheless, the execution of rusunawa in Tangerang City is predominantly inhabited by affluent individuals (Fadillah, Wijaya, Sasongko, & Journal, 2024; Malik & Yoshida, 2020). This is evident by the rows of vehicles stationed in the rusunawa courtyard and several units observed utilizing air conditioning units (AC). Furthermore, the rusunawa is predominantly inhabited by individuals from outside Tangerang City who are employed in the vicinity of the Rusunawa. This illustrates the discrepancy in the target demographic for rusunawa in Tangerang City. The discrepancy in the target group suggests the presence of housing subsidies allocated to residents ineligible for such assistance. Consequently, it is imperative to undertake a study and assessment of the usage of simple rental apartments (Rusunawa) in Tangerang City.

LITERATURE REVIEW

The provision of apartments can serve as an alternate housing solution, particularly in densely populated urban areas, to address land constraints (Douglass, 2019; Vitriana, 2023). Conversely, vertically constructed apartments can enhance urban efficiency (Omar & Inaba, 2020; Verdouw, 2016; Yang, Dong, & Yi, 2022). The development of flats can generate more open areas and alleviate highly populated slum regions. Based on Regulation Mayor of Tangerang Number 76 of 2018 concerning Procedures for Management of Simple Rental Flats defines the Simple Rental Flats (Rusunawa) are multi-storey edifices designed with a functionally structured environment, organized both horizontally and vertically, comprising individually utilized units. Their ownership is based on lease agreements, and they are constructed utilizing resources from the State Revenue and Expenditure Budget and/or Regional Revenue and Expenditure Budget, primarily serving as residential accommodations.

The development of flats requires consideration of multiple variables. First, location where the optimal position is in proximity to employment, commerce, or shopping area. Additionally, apartments should be easily accessible via public transit to enhance inhabitants' mobility (Dewita et al., 2020; Yap, 2016). Secondly, rental price is a factor of individuals' capacity to reside in rusunawa (Ebekozien, Abdul-Rashid, & Jaafar, 2022; Omar & Inaba, 2020). To guarantee the affordability of rental housing for low-income communities (MBR), the government has instituted regulations via Ministry of Public Works and Public Housing (PUPR) Regulation Number 7 of 2022 about the

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Implementation of Housing Development Assistance and Provision of Special Housing. This rule mandates that rental costs for rusunawa must remain reasonable for the lower-middle class, particularly MBR, with a cap not exceeding one-third of their income, calculated based on the provincial minimum wage (UMP). Third, the infrastructure and resources for successful housing and settlement initiatives are assessed not only by the physical characteristics of the structures but also by the quality of the resultant environment. One indicator is the accessibility and sufficiency of commercial, recreational, and sport amenities. Moreover, the state of the region's infrastructure services, including the provision of potable water, electricity, and waste management systems, constitutes critical factors that must be evaluated in the development of residential flats (Srivastava & Kumar, 2018; Thadani & Go, 2021; Wahi, Mohamad Zin, Munikanan, Mohamad, & Junaini, 2018). Fourth, security is vital as the house serves three primary functions: as a residence that supports family identity, as a facilitator of family opportunities, and as a provider of a sense of security. Consequently, the construction of apartments must consider security, organization, and disruptions in the vicinity (Allen et al., 2017; Berawi & Miraj, 2023).

Prior research has emphasized vertical housing, notably Rusunawa (Simple Rental Flats), as a tactical solution to land constraints and rising housing costs (Rukmana, 2018; Douglass, 2019). This concept enhances land-use efficiency via vertical density, while maintaining open space and promoting sustainable urban development. The efficacy of vertical housing initiatives is contingent upon the congruence of policy formulation, execution methodologies, and the socio-economic circumstances of inhabitants. Research conducted by Herawati, Suparjo, & Lestarini (2023) and Lastiur & Septanaya (2024) identified a significant disparity between regulatory frameworks and practical implementation, highlighting inadequate tenant verification procedures, prolonged occupancy beyond established restrictions, and misappropriated subsidies favoring non-MBR demographics.

International best practices demonstrate the effectiveness of more robust models. The Housing Development Board (HDB) in Singapore integrates housing with education, employment, and transportation facilities, underpinned by strict eligibility criteria and income-based subsidies (Yuen, 2021). Germany utilizes a cross-subsidy mechanism along with rigorous monitoring to guarantee equitable access and utilization (Kemen, 2019). In Indonesia, research by Vitriana (2023) and Siahaan et al. (2021) suggests that community-based housing models and improved institutional governance can enhance tenant participation and ensure program sustainability. Income-based rental schemes have been suggested as an alternative to fixed-rate systems to enhance the targeting of subsidies (Putri, Iqbal, & Juliantina, 2019). This literature highlights the significance of dynamic subsidy frameworks, institutional support, and integrated

urban planning in realizing the objectives of vertical housing. This study assesses the implementation of rusunawa in Tangerang and provides evidence-based recommendations aimed at enhancing equity, affordability, and long-term sustainability of vertical housing in Indonesia's rapidly urbanizing areas.

RESEARCH METHODOLOGY

Simple random sampling used to gather samples from the population so that each element has an equal chance of being selected. In this study, representative residents from each block or level of each simple rental property were randomly selected. This method seeks a representative sample of residents in all blocks or floors to reflect the conditions in every rusunawa. This survey had 910 families (KK), 464 of whom lived in Rusunawa Manis Jaya, 396 in Gebang Raya, and 50 in Betet. Slovin formula calculates number of samples for rusunawa residents: Manis Jaya Flats (30 responses), Gebang Raya Flats (30 responses), Betet Flats (17 responses). Field observation, questionnaires, and interviews are used to collect primary data at the study site. This study employed descriptive statistical analysis by examining the following aspects: the physical characteristics of rusunawa (rental flats) in Tangerang City, encompassing housing type, rental costs, and the availability of facilities and infrastructure; and the characteristics of rusunawa residents in Tangerang City, including residents' backgrounds, vehicle ownership status, duration of residence in the rusunawa, and the social conditions of the residents. This study will also examine the disparity between regulations and the actual implementation of rusunawa utilization in Tangerang City, in accordance with applicable regulations and established minimum criteria.

Table 1: Research Variables

No	Target	Variables
1	Physical Characteristics of Rusunawa Housing	• Residential Area • Rental Fees for Housing • Availability of Facilities and Infrastructure
2	Socio-Economic Characteristics of Rusunawa Residents	• Gender • Age • Level of education • Population Status • Vehicle Ownership • Type of work • Income Level • Family Size • Length of Stay • Reasons to Choose Housing in Rusunawa

Source: Researcher Identification Results, 2024

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ANALYSIS AND DISCUSSION

Rusunawa (Rental Flats) Profile

The three flats in this study, are administered by the Tangerang City Government via the Tangerang City Flats Technical Implementation Unit (UPT).

A. Manis Jaya Rental Flat Rusunawa)

Rusunawa Manis Jaya is situated in Manis Jaya Village, Jatiuwung District, Tangerang City. This Rusunawa is linked to a secondary arterial road that connects residential zones, industrial sectors, and adjacent commerce. This arterial route facilitates convenient access for rusunawa inhabitants to various activity centers in Tangerang City. The land use pattern surrounding Rusunawa Manis Jaya is predominantly residential. This indicates that the vicinity of Rusunawa Part Large is a residential zone, which influences the attributes of the dwelling and the daily experiences of the inhabitants. Furthermore, the prevalence of industrial zones surrounding the rusunawa significantly influences the economy by generating employment opportunities, while simultaneously posing environmental concerns, like air pollution and noise. The Manis Jaya Simple Rental Flats (Rusunawa) is the inaugural rusunawa in Tangerang City, established in 1995. This rusunawa was constructed to address the housing requirements mostly for laborers. Rusunawa Manis Jaya Flats was constructed on 15,000 m² of property owned by the Tangerang City Government. This Rusunawa comprises nine building blocks: Manis A, Manis B, and Manis I through VII. The structures in Manis A – B comprise 4 stories, whilst those in Manis I – VII consist of 5 stories.





B.Gebang Raya Rental Flats

Rusunawa Gebang Raya is situated in Gebang Raya Village, Periuk District, Tangerang City. This Rusunawa is situated between local roads and secondary collectors, facilitating resident movement within the neighborhood and to other activity areas in Tangerang. Despite its distance from a main arterial road, the current access adequately meets the everyday requirements of inhabitants. The land use pattern surrounding Rusunawa Gebang Raya is predominantly

residential. This indicates that the surroundings around the Rusunawa is a residential area characterized by a cohesive and supportive atmosphere, where the daily activities are centered around the lives of the residents. In addition, there are a trading zone and industrial sector. The existence of trade and service zones surrounding the rusunawa facilitates people' everyday requirements by offering convenient access to diverse commercial services. The basic rental apartments (Rusunawa) in Gebang Raya have been constructed since 2009 to offer adequate accommodation for low-income communities. Rusunawa Gebang Raya occupies 19,725 m² of property owned by the Tangerang City Government and has 5 building blocks, each with 5 stories (Figure 2).



Figure 2. Rental Flats Gebang Raya
Source: Documentation Researchers, 2024

C. **Betet Rental Flats**

Rusunawa Betet is situated in Panunggangan Barat Village, Cibodas District, Tangerang City. The location is highly strategic, situated approximately 2 km from toll access, facilitating rapid connectivity to activity hubs in Tangerang City and its vicinity. This rusunawa is additionally linked to the toll road by local pedestrian pathways and appropriate secondary collector roads, facilitating local mobility. The land use pattern surrounding Rusunawa Betet is mostly characterized by residential zones, signifying that this area is intended for habitation. The existence of these towns fosters a conducive environment for people requiring prompt access to metropolitan activity hubs. The location of Rusunawa Betet is situated in a central area with a high intensity of economic activity, which can bolster socio-economic stability in the region. The Betet simple rental apartments (Rusunawa) were constructed in 2016 on 6,077 m² of land owned by the Tangerang City Government and contains a single construction block comprising four stories (Figure 3).

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Figure 3. Rental Flats Betet
Source: Documentation Researchers, 2024

Table 2: Difference Characteristics Physique Flats in Tangerang City

No	Flats	Number of Units	Unit Area	Facilities Inside the Unit	Allocation
1	Manis Jaya	128 units	18 ^{m2}	Studio/single type bedroom	All units are designated as residential units
		336 units	21 ^{m2}	- Studio/single type bedroom - Kitchen - Bathroom	- On the ground floor, the units are designated as business units. - On floors 1 – 4, units are designated as residential units.
2	Gebang Raya	396 units	24 ^{m2}	- 1 Bedroom - Sitting room - Kitchen - Bathroom - Place for drying clothes	All units are designated as residential units
3	Betet	50 units	36 ^{m2}	- 2 Bedrooms - Sitting room - Kitchen - Bathroom - Place for drying clothes	- On the ground floor, some units are designated as business units and others are designated as residential units. - On floors 1 – 3, units are designated as residential units.

The Regulation Mayor Policy Number 76 of 2018 restricts the utilization of residential units for commercial purposes. In reality, numerous units in Rusunawa Gebang Raya are utilized as shops or other hazardous enterprises, such as the sale of LPG gas. This indicates inadequate regulatory enforcement and a deficiency of alternative business locations for locals. The standard area per individual is not adhered to, as numerous units are occupied

over their capacity. Moreover, the Mayor's Regulation forbids inhabitants from utilizing four-wheeled automobiles; yet, instances of individuals with private vehicles contravening this law have been observed. Despite decisive actions made to terminate the residents' rental agreements, deficiencies in oversight and rule enforcement persist.

Characteristics of Rusunawa Residents

Since the launch of rusunawa in Tangerang City, public interest in residing in this accommodation has consistently grown. This is evidenced by all dwellings that are consistently completely occupied. This has resulted in the emergence of various features among residents, as will be detailed in the subsequent explanation.

a. Level of Educational

The three flats with the highest percentage of high school graduates are Manis Jaya Flats (74.2%), Gebang Raya Flats (53.3%), and Betet Flats (64.7%). Manis Jaya Flats and Betet Flats exhibit a significant percentage of college graduates, specifically 12.9% for Manis Jaya Flats and 17.6% for Betet Flats. This illustrates the appeal of both apartments for those with secondary to tertiary education. Conversely, Gebang Raya Flats exhibits a more varied educational attainment, with a significant percentage of junior high school graduates (33.3%). This distribution of educational attainment illustrates the diversity in the educational backgrounds of inhabitants in each apartment.

b. Origin of Occupants

The origin of the residents is a crucial factor in comprehending the features and makeup of those residing in the rusunawa. The origin of the citizens will determine if the inhabitants of the rusunawa are solely from Tangerang City or if there are individuals from outside Tangerang City. All inhabitants of Rusunawa Betet are residents of Tangerang City (100%). In Rusunawa Gebang Raya, nearly all residents are from Tangerang City (96.7%), with only one individual originating from outside the city (3.3%). Conversely, Rusunawa Manis Jaya exhibits a greater percentage of residents from outside Tangerang City (29.0%) in comparison to the other two rusunawa. This indicates that this rusunawa may be more appealing to inhabitants from beyond Tangerang City, given its location in an industrial zone and the potential influx of workers from beyond the city requiring accommodation.

An interview with a resident of Rusunawa Manis Jaya, originally from outside Tangerang City, revealed that the individual resides in the rusunawa due to a registration facilitated by a friend. The registration was completed under the name of his friend, a resident of Tangerang City. This signifies a breach of

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rusunawa use due to the transfer of leasing rights to a third party. This infraction may result in issues such as ambiguous resident information and the risk of inequity for eligible prospective residents entitled to obtain the rusunawa unit. This infraction may also diminish the efficacy of the rusunawa program, which aims to offer affordable housing to citizens who fulfill specific criteria. Consequently, enhanced enforcement of regulations and more efficient oversight by rusunawa managers are essential to guarantee that the use of rusunawa aligns with its intended purpose and maximizes benefits for eligible individuals.

b. Ownership of Vehicles

The Rusunawa in Tangerang City is designated for low-income communities (MBR). One criterion employed by the government to ascertain MBR eligible for residence in rusunawa is the absence of four-wheeled vehicles or more. This indicator seeks to guarantee that subsidized housing facilities effectively serve individuals in need, particularly those experiencing significant economic hardships. According to the findings of a literature review and field observations by researchers in 2023, infractions of vehicle ownership regulations were identified in Rusunawa Manis Jaya, Rusunawa Gebang Raya, and Rusunawa Betet. A number of residents from the three rusunawas possessed private vehicles and parked them within the rusunawa vicinity. During field observations made by researchers in 2024, security officials provided information indicating that residents had their leases canceled due to confirmed offenses. Researchers no longer observed any vehicles parked in the rusunawa vicinity. The answers of the questionnaire about the types of vehicles typically utilized by inhabitants for activities further corroborate that no locals employ private cars for their daily undertakings. The predominant mode of transportation among inhabitants is private motorbikes, particularly in Rusunawa Gebang Raya, where 90% utilize them, in contrast to 74.2% in Rusunawa Manis Jaya and 70.6% in Rusunawa Betet (Figure 6).

While there are presently no residents with private vehicles, this does not negate the possibility that there were residents with private cars in the past. This signifies the improper utilization of rusunawa by individuals who do not belong to low-income brackets. This abuse illustrates the inequity in the allocation system of apartments, which should be designated for individuals in genuine need. This presents challenges to the efficiency and efficacy of the rusunawa program, necessitating more rigorous examination and oversight of the selection process and employment of these facilities to assure the attainment of the program's original objectives. Conversely, this serves as a notification to the government that interest in residing in rusunawa extends beyond merely MBR. The potential desire from wealthier individuals indicates that rusunawa possesses attractiveness as a housing alternative. Consequently, it is essential to assess and

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modify policies concerning rusunawa to fulfill the requirements of MBR while ensuring equity and fairness in the allocation and utilization of these facilities across all societal strata.

d. Job Classification

The employment roles of private employees and workers predominate in the three rusunawas. In Rusunawa Manis Jaya, the population is predominantly comprised of private employees (35.5%) and laborers (19.4%). In Rusunawa Gebang Raya, private employees and laborers each constitute 30% of the population. A similar occurrence transpires in Rusunawa Betet, where private employees and laborers both constitute 29.4%. The allocation of alternative occupations, including self-employed individuals, homemakers, and online motorcycle taxi operators, is quite uniform. This indicates the presence of employment variations, but fewer in number compared to private employees and laborers.

e. Income

The basic rental units (rusunawa) in Tangerang City are designated for those with low income. In Rusunawa Manis Jaya, residents with earnings ranging from Rp 2,500,001 to Rp 3,500,000 constitute 29% of the population. In Rusunawa Gebang Raya, residents with earnings ranging from Rp 3,500,001 to Rp 4,500,000 constitute 46.7% of the population. In Rusunawa Betet, inhabitants are distributed very uniformly across the income bracket of Rp 0 – Rp 7,000,000. In summary, residents with higher incomes tend to prefer rusunawa with lower rental costs (Manis Jaya) and medium costs (Gebang Raya), whereas rusunawa with higher rental costs (Betet) appeals to people with a broader range of incomes.

f. Household Size

Family size refers to the number of individuals residing in a single dwelling unit to assess the ratio of inhabitants. Rusunawa Manis Jaya is predominantly inhabited by families of four members (54.8%) and three members (25.8%). Rusunawa Gebang Raya exhibits a greater diversity in resident numbers. The majority of units are inhabited by four individuals (36.7%) and three individuals (30.0%). Furthermore, Gebang Raya documented occupants exceeding five individuals (10.0%). In Rusunawa Betet, the predominant occupancy consists of households with four members (41.2%) and five members (23.5%). The ratio of residents with five individuals in Betet exceeds that of Rusunawa Manis Jaya and Gebang Raya, suggesting that units in Betet may be suitable for marginally larger families. This disparity signifies varying preferences or spatial requirements in each locale, alongside elements such as unit design or rusunawa management strategies that influence occupant mix.

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g. Duration of Stay

The duration of residency in the Tangerang City rusunawa is a critical factor in assessing the utilization of rusunawa. The majority of residents of Rusunawa Manis Jaya (51.6%), Gebang Raya (46.7%), and Betet (23.5%) have resided there for over five years. Conversely, the proportion of residents who have resided for less than one year is comparatively low throughout all rusunawa, specifically Rusunawa Manis Jaya (3.2%), Gebang Raya (6.7%), and Betet (11.8%). According to the Tangerang Mayor's Regulation, which restricts the rental duration of rusunawa units to a maximum of three years, it has been observed that 64.1% of inhabitants throughout the three rusunawas have resided in the Tangerang City rusunawa beyond the stipulated rental period. In the aggregate proportion of respondents throughout the three rusunawas, it is evident that only 6.4% have resided for less than one year; 5.1% have lived for one year; 10.3% have remained for two years; and 14.1% have lived for three years. This indicates that residing in the apartments is really enjoyable for the inhabitants. This may lead to issues concerning the backlog of new housing applications from potential residents who cannot be promptly accommodated. Consequently, an assessment and modification of rules is required to enhance the rental system, promoting sustainability and equilibrium in the management of rusunawa. The duration of residence of occupants in rusunawa in Tangerang City is depicted more clearly in Figure 10.

The duration of residency in rusunawa in Tangerang City is significantly determined by the particular motivations prompting their choice to settle there. Inexpensive rental rates are the primary and most significant factor for residents. This is seen in all rusunawa, but is more pronounced in Manis Jaya (87.1%) and Gebang Raya (86.7%) than in Betet (70.6%). This economic element indicates that the accessibility of affordable housing is the primary incentive for residents to reside in rusunawa. Alongside economic considerations, proximity to the job is a key issue, particularly in Manis Jaya (67.7%) and Betet (47.1%). For Betet locals, proximity to family is a significant feature (47.1%), suggesting that social considerations, such as familial connections, influence their choice to settle in rusunawa. Additional variables affecting residents' choices comprise comprehensive infrastructure in Manis Jaya (35%) and a favorable living environment in Gebang Raya (43%). These criteria indicate that the quality of amenities and the state of the surrounding environment are significant concerns for inhabitants when selecting a residence. In conclusion, residents' choice to reside in flats in Tangerang City is influenced by various variables, including affordable rental costs, proximity to workplaces and family, and the quality of facilities and housing environment.

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h. ***Cost Rent***

Cost Rent is crucial in the sustainable utilization of housing, particularly in the context of affordable rental units (rusunawa). The administration of rusunawa in Tangerang City cannot solely depend on government funding. Consequently, each resident of the rusunawa is subject to a leasing price. The price to residents consists solely of the unit rental cost and a monthly cleaning fee of Rp. 5,000 for each residential unit. Rental costs for rusunawa can be paid electronically to the Tangerang City Government on a monthly basis. Other expenses, including power, potable water, and gas, are billed to each tenant. Each rusunawa in Tangerang City implements varying rental charges. The location and accessibility of each rusunawa influence the rental costs imposed. Rusunawa Betet has a rental charge ranging from IDR 470,000 to IDR 500,000 per month, attributed to its strategic location in the city center, approximately 2 km from toll access. Rusunawa Gebang Raya ranks second, with a monthly rental cost ranging from IDR 260,000 to IDR 300,000, attributed to its strategic and burgeoning position. Conversely, Rusunawa Manis Jaya has the lowest rental price, ranging from IDR 90,000 to IDR 215,000 per month, due to its location in a predominantly industrial zone with restricted access to economic hubs and toll roads. The disparity in rental costs signifies the variation in value, location, and accessibility in the city of Tangerang. Additionally, varying floors also contribute to the disparity in rental fees for each rusunawa. The rental expenses decrease with an increase in the floor level occupied. The rental expenses for each rusunawa in Tangerang City are delineated more explicitly in Table 2.

Table 3. Cost Rent Flats in Tangerang City

	Cost Rent Per Month			
Floor	**Manis Jaya Flats**		**The Gate Raya Flats**	**Beetle Flats**
	Type 18	**Type 21**	**Type 24**	**Type 36**
Base		Rp 215,000	Rp 300,000	Rp 500,000
1	Rp 90,000	Rp 200,000	Rp 290,000	Rp 490,000
2		Rp 195,000	Rp 280,000	Rp 480,000
3		Rp 190,000	Rp 270,000	Rp 470,000
4	-	Rp 175,000	Rp 260,000	-

Source: Results Identification Data Researchers, 2024

According to Regulation of the Minister of PUPR Number 7 of 2022 regarding the Implementation of Housing Development Assistance and Provision of Special Housing, eligibility for occupancy in rusunawa is restricted to Indonesian citizens classified as members of the low-income community group (MBR) who can afford the rental fee for a flat unit (sarusun). The rental fee is capped at one-third of the provincial minimum wage. As per the Regulation of

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the Mayor of Tangerang Number 76 of 2018 concerning the Management of Simple Rental Housing Layout Methods, the stipulated rental rates do not encompass charges for clean water, energy, waste services, or any additional expenses. Furthermore, the Mayors Regulation (Perwal) governs the duration of leasing agreements for rusunawa. The rental duration for rusunawa flats is capped at three years, with the possibility of a one-year extension, provided that the residents continue to fulfill the stipulated criteria and regulations. Applications for the extension of rusunawa usage licenses must be submitted no later than thirty days prior to the expiration of the rental permit.

i. Level Occupancy of Rental Apartments

The occupancy rate of rusunawa is a significant indication in assessing the effectiveness of the rusunawa development program's utilization. The elevated occupancy rate indicates that the government-provided facility has been favorably received by the public, although temporarily. Low occupancy rates may signify issues with design, location, or construction quality. In Tangerang City, Rusunawa Gebang Raya and Rusunawa Betet exhibit a maximum occupancy rate of 100%. This indicates that all units in each rusunawa are completely occupied and effectively utilized. Currently, the occupancy rate of Rusunawa Manis Jaya is at about 86%. The state of the buildings in Manis A and Manis B is no longer conducive to habitation, hence the units on the 3rd and 4th levels are no longer available for occupancy by the community. Consequently, from 464 units among the current units, just 400 remain operational, all of which are fully occupied. The occupancy rate of rusunawa in Tangerang City is notably high, at 93%. Despite the occupancy rate not being at its peak, all units available in the three rusunawa are completely occupied. There exists a waiting list with around 13 to 35 individuals seeking to occupy the units. The waiting period for potential residents ranges from few weeks to several years, contingent upon the departure of current occupants from their flats. This may suggest that public interest in residing in rusunawa is significantly elevated. The presence of this waiting list signifies both substantial public interest and an urgent demand for cheap housing, particularly in rapidly expanding urban regions like Tangerang City. The government must contemplate augmenting the quantity of rusunawa units or enhancing the quality of current rusunawa to satisfy the rising demand. The rusunawa development initiative will serve not just as a temporary solution but also as an integral component of a long-term strategy for delivering adequate and affordable housing to the community.

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j. Facilities

Facilities serve as supportive structures that facilitate the organization and advancement of economic, social, and cultural activities. Each basic rental apartment (rusunawa) development in Tangerang City is furnished with several amenities that facilitate the activities of its inhabitants. The rusunawa residential area offers a variety of facilities, including places of worship, educational institutions, healthcare services, commercial amenities, government services, security provisions, and communal spaces. The accessibility of these facilities would facilitate residents in performing daily activities. Table 3 illustrates the availability of facilities in Tangerang City rusunawa.

Table 4. Facilities on Flats in Tangerang City

No	Means	Type Means	Manis Jaya Flats	Gebang Raya Flats	Betet Flats
1	Worship	prayer room	➹	➹	➹
		Mosque	200 m	20 m	500 m
		PAUD/Kindergarten	-	≤ 500 m	-
2	Education	SD	≤ 1,000 m	≤ 1,000 m	≤ 1,000 m
		JUNIOR HIGH SCHOOL	≤ 1,000 m	≤ 1,000 m	≤ 1,000 m
		High School/Vocational School	≤ 3,000 m	≤ 3,000 m	≤ 3,000 m
		Health Center	➹	≤ 1,000 m	➹
3	Health				
		Clinic	≤ 1,000 m	≤ 1,000 m	≤ 1,000 m
		Roadside stall	➹	➹	➹
4	Shopping				
		Market	≤ 1,000 m	≤ 1,000 m	≤ 1,000 m
	Public Services	Office Manager	➹	➹	➹
5		Post Security	➹	➹	➹
		Park	➹	➹	➹
		Field	➹	➹	-
6	Room Together	Place Parking	➹	➹	➹
		Room All in one Purpose	➹	➹	➹
		Hallway	-	➹	➹

Source: Results Identification Data Researchers, 2024

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The SNI-03-7013-2004 regulation mandates that educational institutions for preschool (TK and PAUD) be located within a maximum distance of 500 meters from rusunawa. Nonetheless, Rusunawa Manis Jaya and Rusunawa Betet now lack these amenities, necessitating that people seek educational facilities beyond the specified locale. This signifies non-compliance with the facility requirements mandated by the policy. Another issues is regarding Guardian Regulation The city stated that residents possess the right to enhance damaged facilities, and the manager is obligated to deliver prompt service. Nonetheless, the assessment indicates that the manager's reaction to damage notifications is frequently delayed. This delay may exacerbate the deterioration of the housing and degrade the physical state of the rusunawa. On the ground floor of Rusunawa Manis Jaya and Rusunawa Betet, numerous rusunawa units are allocated as commercial units. Residents can lease these business units for commercial operations, including grocery stores and food booths. The presence of commercial units on the ground floor not only facilitates residents in fulfilling their daily necessities but also creates opportunity for them to enhance their economic status through small business endeavors. Furthermore, the presence of the business unit. This participation contributes to creating a more vibrant and dynamic residential environment.

In contrast to Rusunawa Manis Jaya and Rusunawa Betet, which contain business units, Rusunawa Gebang Raya exclusively designates all its units for residential purposes. This leaves the residents without a venue to engage in economic activities inside the rusunawa area. Consequently, several people are compelled to employ their residential units for commercial purposes, specifically by employing their living room space. The utilization of residential units for commercial purposes not only contravenes regulations but also disrupts the peace of other inhabitants. The throngs at the stalls frequently generate noise for the adjacent residents. Children purchasing food at the kiosks frequently contribute to littering, resulting in a polluted environment. ecosystem. Additionally, LPG is sold at roadside stalls and it may elevate the risk of fire. Consequently, management must offer counseling or implement decisive measures against tenants who abuse the residential units.

ANALYSIS

A. Correlation Analysis Between Residential Type and Family Size

According to the Regulations Minister of PUPR, the minimum area per person in a simple house is 8 m². Analysis of the cross-tabulation between residence types and family sizes reveals that only 47.4% of residential units are occupied in accordance with the maximum capacity standards. Meanwhile, 52.6% of residential units are occupied over their maximum capacity. In the rusunawa with a unit size of 18 m², excellently suited for 1-2 occupants, the analysis indicates

that this type is exclusively inhabited by single-person households (100%). This suggests that inhabitants with tiny families or people prefer this dwelling type, which is tailored for small families or individuals. The 21 m² unit, designed to house 2-3 individuals, is predominantly inhabited by 4 individuals, as indicated by the analysis results (56.7%). While this type is ideally suited for families of 2-3 individuals, there appears to be a trend towards accommodating larger families, potentially beyond the comfort standards for livability. This phenomenon also manifests in 24 m² flats, which are optimally suited for 2-3 occupants, yet are frequently inhabited by 4 individuals (36.7%). The type unit measures 36 m² and is well suited for 4-5 occupants. Analysis indicates that the majority of units are inhabited by 4 individuals (41.2%) and 5 individuals (23.5%). This remains in compliance with standard Public Works and Housing for deserving residents. The analysis of results is presented more distinctly in Table 4.7.

Table 4. Cross-Tabulation of Housing Types by Family Size

Number of Resident	**Residential Type**			
	18 m2	**21 m2**	**24 m2**	**36 m2**
1 orang	100,0%	10,0%	0,0%	5,9%
2 orang	0,0%	3,3%	20,0%	11,8%
3 orang	0,0%	26,7%	30,0%	17,6%
4 orang	0,0%	56,7%	36,7%	41,2%
5 orang	0,0%	3,3%	3,3%	23,5%
> 5 orang	0,0%	0,0%	10,0%	0,0%

Source: Processed Data Results Researchers, 2024

= exceed residential capacity

Generally, smaller flats are typically inhabited by 3 to 4 individuals, with some accommodating more than 5. This signifies that the number of inhabitants surpasses the unit's capacity, potentially compromising comfort owing to insufficient living space standards. This may affect residents' quality of life, encompassing privacy, health, and cleanliness concerns. Larger flats accommodate families of up to five individuals comfortably, while still adhering to livable space guidelines. Larger units provide increased area and accommodate greater capacity. Optimize furniture layout to provide each family member a private space. This can also promote the mental and physical well-being of people by fostering a more structured and less congested atmosphere. It is known that a significant portion of individuals living in low-cost flats in Tangerang City consists of families with four members. Nevertheless, affordable apartments are available in Tangerang City, predominantly consisting of small-sized units appropriate for individuals and young families. This results in a disparity between

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demand and the availability of residential units, forcing many families to settle for smaller living arrangements. This circumstance highlights the necessity for modifications in the planning of future low-cost apartment developments to more effectively accommodate the demands of the majority of inhabitants, particularly families with more than two members.

This investigation indicates that lower-income groups generally incur cheaper rents, although some may pay greater amounts. This indicates that they ought to allocate the majority of their money to rent. The middle-income demographic has a more uniform distribution in their rental expenditures, with the majority allocating funds within the median range. This suggests that they possess a little degree of flexibility in their budget to accommodate the rent without excessively straining their resources. The higher-income group tends to pay rent in the lower range temporarily, potentially reallocating their earnings to other necessities, despite their ability to pay more. The analysis results of the cross-tabulation between rental costs and inhabitants' income are presented more clearly in Table 5.

Tabel 5. Cross-Tabulation of Rental Costs and Resident Income

Revenue (Rp)	**Rental Expense (Rp)**			
	90.000	**175.000 - 215.000**	**260.000 - 300.000**	**470.000 - 500.000**
0 - 2.500.000	0,0%	16,7%	3,3%	17,6%
2.500.001 - 3.500.000	100,0%	26,7%	30,0%	29,4%
3.500.001 - 4.500.000	0,0%	20,0%	46,7%	29,4%
4.500.001 - 7.000.000	0,0%	36,7%	20,0%	23,5%

Source: Processed Data Results Researchers, 2024

The financial capacity of inhabitants to pay rent significantly differs based on their income level. Residents with higher earnings generally possess greater freedom in their expenditures, but those with lower incomes often encounter significant financial strain to meet rental obligations. Consequently, certain residents are delinquent in their rent obligations. The rental charge structure is not entirely consistent with relevant policy norms. PUPR Number 7 of 2022 mandates that rental expenses should not exceed one-third of the provincial minimum wage; yet, in practice, some people allocate more than 30% of their income to rental fees. This contradicts international standards, which recommend that housing expenditures should not surpass 30% of income. To address this issue, the government may need to contemplate financial aid policies or programs for low-income inhabitants, or modify the rental price structure to better correspond with people' financial capabilities. Moreover, instruction in financial management and budget planning can assist people in effectively managing their funds, thus reducing the likelihood of future arrears.

Consequently, low-cost apartments function not just as economical dwelling but also as a setting that fosters the comprehensive well-being of their inhabitants.

B. Correlation Analysis Between Extended Residency and Residential Tranquility

The analytical results reveal a noteworthy correlation between the duration of residence in the low-cost flat and the occurrence of disruptions or conflicts among tenants. Residents of low-cost flats for less than three years usually lack expertise with disturbances. However, for people who have resided for an extended duration, particularly those exceeding five years, the percentage that the feeling of bustle or noise has increased dramatically, reaching 87.5%. This phenomenon may be associated with the evolving social dynamics over time. Residents with prolonged tenures are generally more engaged in community activities, hence enhancing social relationships; nevertheless, this also heightens the likelihood of conflicts among neighbors. Additionally, alterations in family structure, such as an increase in family members or changes in lifestyle, add to the heightened propensity for conflict. Frequent problems typically arise around the usage of communal facilities, hygiene, and disputes among residents, such as those relating to pets or noise. Instances of such concerns were observed at the Gebang Raya Rusunawa, where people reported suffering disturbances, from petty disagreements to significant disruptions. The melody from the voice is excessively difficult. In contrast to Flats Sweet Jaya and Betet, which are typically more tranquil due to the good relationships and mutual understanding among residents.

This circumstance necessitates particular focus in the administration of affordable housing units. Management must evaluate various options to ensure order and comfort for all inhabitants, both new and long-term. One measure that can be used is to restrict long-term residents through regular assessments of social unrest and cooperation levels. Nonetheless, if limitations on duration of stay are considered ineffectual, alternative measures such as conditional extensions may be implemented. These standards may encompass adherence to cleaning regulations, noise prohibitions, and active participation in community activities that foster a peaceful ambiance inside the rusunawa setting. Managers must adopt a more proactive strategy by enhancing oversight, consistently communicating regulations, and engaging residents in regular meetings to address developing concerns. Through effective communication and an appreciation for the significance of collective quiet, people are anticipated to get a clearer understanding of their individual responsibilities in preserving neighborhood order. Steps to cultivate an atmosphere that is comfortable and harmonious, so minimizing potential conflicts among long-term residents.

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C.Analysis of the Correlation Between Lama Residency and Residential Security

Analysis of results indicates that among people who have been in proximity for less than one year, only one respondent (5.3%) reported encountering crime. In contrast, among residents who had resided there for one year, a greater proportion, specifically two respondents (10.5%), reported experiencing crime. This suggests that new residents generally lack experience or involvement in numerous criminal episodes. Among inhabitants residing there for two to four years, a comparable tendency was noted. No residents who resided for two years reported any criminal activity. This differed from residents who resided for three to four years, where each group had an analogous percentage of those perceiving any crime (10.5%). This indicates that crime reporting rates remain low for residents over this time frame. Temporary residents living for more than five years have distinct data. Among the 34 respondents who resided there for over five years, 11 individuals (57.9%) encountered criminal activity. This represents the highest percentage relative to other duration of stay categories.

This investigation indicates that most residents perceive a lack of safety. There has been crime; they have vacated their residence for an extended period. Nonetheless, inhabitants with longer tenures (exceeding five years) have a greater incidence of crime compared to those with shorter durations of residence. This phenomena may indicate that long-term inhabitants have observed fluctuations in security levels over time, including rising criminal activity and diminished efficacy of security systems. Consequently, it is essential to enhance security systems and implement more effective crime prevention tactics, such as neighborhood security programs and regular patrols, to foster a sense of safety. a more secure environment for all inhabitants, both newcomers and long-standing residents.

D. Analysis of the Correlation Between Length of Stay and Social Interaction

The results indicated that people residing for less than a year exhibited restricted interactions. Twenty percent engaged solely with neighbors on the same floor, whereas forty percent communicated with neighbors inside the block, and twenty percent connected with neighbors throughout the entire block. This indicates that new residents typically possess a more limited social network. Residents who have lived for one to two years exhibit enhanced social engagement. In the past two years, 37.5% engaged with adjacent neighbors and 25% with neighbors on a different block. This subject demonstrates an increase in social participation following residents' settlement and subsequent comfort. After three to five years, social interactions generally become more steady and diverse. For instance, 36.4% of residents engage with their neighbor on a temporary basis throughout a three-year period inside one block. An further 36.4% engaged with neighbors

throughout the block. At five years, interaction patterns exhibited greater equilibrium, with engagements distributed across multiple categories. Residents with over five years of tenure exhibit the most comprehensive social connections, with 26.5% engaging with neighbors on the same level and 32.4% with neighbors across the block. This indicates that an extended duration of residence increases the probability of inhabitants forming social interactions with others in the vicinity. This investigation demonstrates that prolonged residency affects the level of social interaction among residents. New residents typically possess a more restricted social circle, while long-term residents tend to engage in greater contacts with their neighbors. This may result from reasons such as more time dedicated to cultivating connections or a desire for deeper engagement with fellow residents.

Assessment Outcomes of the Employment of Basic Rental Apartments (Rusunawa) in Tangerang City

The assessment of simple rental flats (rusunawa) in Tangerang City was conducted based on the identification and analysis of their characteristics. The physical housing, management of affordable apartments, and characteristics of Rusunawa residents are then compared with relevant policies and norms. An assessment of Rusunawa use in Tangerang City revealed various significant matters concerning policies enacted by the government at both local and national tiers. This assessment uncovered multiple inconsistencies between the prevailing circumstances and the relevant policies, specifically:

The Regulation Guardian City Number 76 of 2018 prohibits the use of residential units for business purposes. In actuality, certain apartments in Flats Gate Raya are utilized as roadside stalls or for conducting other hazardous activities, including the sale of LPG gas. This signifies inadequate enforcement of the policy. And absence of alternative commercial locations for residents. The standard occupancy per individual is not adhered to, as numerous apartments are occupied over their capacity. The Regulation Minister of Public Works and Housing Number 7 Year 2022 stipulates that rental fees must not exceed one-third of the provincial minimum wage (UMP). Evaluations indicate that low-income residents frequently incur higher rents than their higher-income counterparts. This engenders disparities in the execution of rental policies, which ought to be more adaptable and equitable, customized to individuals' financial capacities. According to SNI-03-7013-2004 laws, pre-school education institutions, including kindergartens and early childhood education centers, must be located within a maximum distance of 500 meters from low-cost apartments. Nonetheless, the Manis Jaya and Betet low-cost apartments now lack these amenities. Consequently, residents must seek educational facilities beyond the

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allocated region. This signifies noncompliance with the facilities standards mandated by the policy.

Maintenance: The Mayor's Regulation affirms that residents are entitled to repairs. Indicates which items are damaged, and the management must provide prompt service. Evaluations indicate that management's response to damage reports is frequently sluggish. This delay may exacerbate damage to the house and deteriorate the physical condition of the affordable apartments.

Security and Tranquility: Despite regulatory emphasis on the significance of preserving the safety and serenity of the area, grievances persist concerning disruptions among residents and criminal occurrences, such as theft, in the affordable housing units. This suggests that policies concerning security and calm have not been effectively executed.

The Mayor's Regulation forbids residents from possessing four-wheeled cars; yet, some people have been discovered using private vehicles in contravention of this rule. Despite decisive measures to terminate the tenant's lease, deficiencies persist in the oversight and implementation of the regulations. The Regulation Guardian City stipulates a maximum rental duration of three years; nonetheless, the majority of inhabitants have exceeded this limit, with some residing for almost five years. This situation results in the accumulation of prospective residents who cannot be promptly accommodated due to full occupancy. This signifies the necessity to modify the housing duration of stay policy to accommodate elevated demand. The regulations governing the flats are administered by the Association of Owners and Occupants of Flats (PPPSRS), although their execution is obstructed. Due to elevated resident changes. The alternate mechanism via a coordinator has proven ineffective, as residents lack clear regulations concerning their responsibilities and powers.

Discussion of the Utilization of Rental Flats (Rusunawa) in Tangerang City

The urbanization and population increase in Tangerang City have exerted significant pressure on the supply of adequate and affordable housing for both high-income and low-income groups (MBR). In response, the Tangerang City Government established Simple Rental Flats (rusunawa) to mitigate land limitations and escalating property costs. An evaluative research of three rusunawa (Manis Jaya, Gebang Raya, Betet) indicated a discrepancy between policy and implementation in practice. Despite an occupancy rate of 93% accompanied by a lengthy waiting list, issues such as the utilization of units for commercial purposes, inequitable rental fees, and insufficient educational facilities signify a failure to meet policy objectives (Lastiur & Septanaya, 2024; Rassanjani et al., 2023). This aligns with the findings of Herawati et al. (2023), which underscore that vertical housing strategies frequently neglect the socio-economic dynamics of people. A research by Berawi and Miraj (2023) indicates

that disparities in housing availability for MBR frequently arise from policies that neglect the dynamics of income and the actual needs of the community. The prevalent utilization of residential units for commercial purposes illustrates the economic survival methods employed by people (Rassanjani et al., 2023; Rukmana, 2018). Inflexible policies lacking alternative economic incentives for MBR may undermine the primary goal of rusunawa as a viable housing solution.

The execution of rusunawa in Tangerang has structural problems, including the disparity in rental cost distribution. Despite the stipulation in Minister of PUPR Regulation No. 7/2022 that rental costs should not exceed one-third of the provincial minimum wage (UMP), numerous MBRs allocate over 40% of their income to rent, surpassing the international benchmark of 30%. The presence of high-income residents who contribute less indicates a failure in subsidy targeting precision. The issue is intensified by inadequate enforcement of legislation, including breaches of the maximum three-year stay limit and the utilization of unauthorized private automobiles (Mayor Regulation No. 76/2018). Rukmana (2018) posited that the lack of alternative economic incentives compels inhabitants to convert residential units into commercial spaces, undermining the original intent of rusunawa as adequate housing. Research conducted by Lastiur and Septanaya (2024) in Jabodetabek indicated that housing subsidies frequently lack suitable targeting due to inadequate verification of resident data. This finding aligns with the research conducted by Herawati et al. (2023), which underscores the significance of an income-based rental scheme to guarantee equity. In the absence of policy reform, rusunawa risks becoming into a vehicle for covert gentrification that marginalizes at-risk populations.

From a governance standpoint, inadequate coordination among the government, management, and inhabitants is the fundamental cause of the sluggish enhancement of facilities and minimal social engagement. Vitriana's (2023) study on rusunawa in Surabaya indicates that enhancing community-based institutions, such as co-housing models, can augment housing sustainability. The deficiency of educational institutions and public spaces in Tangerang exemplifies the shortcomings of comprehensive planning, as critiqued by Douglass (2019) regarding urban growth in Southeast Asia. Long-term solutions necessitate the incorporation of rusunawa into urban governance plans, encompassing the availability of local employment and inexpensive transit (OECD, 2022). Absent this multifaceted strategy, rusunawa will merely serve as a partial remedy to the housing crisis in urban regions.

Insights from different nations provide methodologies for enhancement. Singapore, via the Housing Development Board (HDB), has effectively amalgamated educational, healthcare, and transportation amenities within the residential complex, bolstered by rigorous occupant verification and income-dependent subsidies (Yuen, 2021). Germany has adopted a cross-subsidy

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mechanism with unit usage monitoring to maintain equity (Kemen, 2019). In Indonesia, the proposals from UN-Habitat (2023) about income-based rent and the incorporation of micro-jobs on the ground floors of apartments (Vitriana, 2023) can be implemented to mitigate unit misuse. The OECD (2022) underscores the need of comprehensive planning, including the principles of green building and multistakeholder governance, to enhance sustainability.

This article primarily contributes by highlighting the disparity between policies and the socio-economic conditions of inhabitants. flats, along with recommendations grounded in empirical evidence. Findings indicate a high occupancy rate (93%) and waiting lists affirm the necessity for vertical housing development in metropolitan regions (Douglass, 2019). However, in the absence of policy modifications—such as diversification of unit types, cross-subsidies, and enhancement of institutional residents—flat housing at risk remains a partial answer. According to the World Bank research (2021), the incorporation of rusunawa within inclusive urban development programs is essential to tackle the intricacies of the housing issue in periurban regions like Jabodetabek.

The housing backlog issue in the Jabodetabek region is intrinsically linked to the dynamics of migration and economic development in the area. As the appeal of the urban economy rises, the demand for housing has surged significantly, while the supply of available land remains constrained(Decker, 2021; Restuccia & Rogerson, 2017). The Rusunawa, as a vertical solution, appears promise; yet, without comprehensive planning, it will merely result in a temporary patchwork. This research indicates that the majority of inhabitants in low-cost housing no longer satisfy the criteria for MBR, highlighting the inadequacy of the selection and verification processes. Comparative analyses with other nations indicate that the efficacy of social renting schemes hinges on two primary factors: precise targeting and an adaptable subsidy framework(Herawati, Suparjo, & Lestarini, 2023; Omar & Inaba, 2020; Putri, Iqbal, & Juliantina, 2019). In the Netherlands, the "income-based rent" system facilitates equitable and effective subsidies, deterring subsidy exploitation by non-MBR groups. This is a blatant indictment of the established fixed rent regime in Tangerang. Moreover, in Singapore, the HDB living system exemplifies the significance of integration with transportation, jobs, and public amenities that render inexpensive living viable and comfortable(Allen et al., 2017; Wee et al., 2018).

Future policy solutions must facilitate the decentralization of rusunawa management and the fortification of resident institutions, as the co-housing model has been effectively executed in other nations(Siahaan, Fachrudin, Fachrudin, & Muda, 2021). Conversely, dynamic monitoring utilizing population data is essential to avert the exploitation of rusunawa units. Interventions must be underpinned by an analysis of housing requirements informed by demographic

and economic forecasts, ensuring that rusunawa development is not merely quantitative but also qualitative and adaptable(Malik & Yoshida, 2020; Pojani & Stead, 2015). The Rusunawa in Tangerang exemplifies the intricate nature of housing within the Jabodetabek region. The elevated occupancy should serve as a compelling indication for the government to broaden this model, contingent upon enhancements in the rental framework, verification processes, and facility support. By adopting a more inclusive and community-oriented strategy, rusunawa can serve as a crucial basis for addressing the national housing deficit and fostering an inclusive, egalitarian, and sustainable urban environment.

CONCLUSION

An assessment of the implementation of Simple Rental Flats (Rusunawa) in Tangerang City indicates that this initiative serves as a crucial alternative for offering adequate and affordable accommodation to low-income individuals (MBR) amidst limited land availability and elevated property prices. The three analyzed rusunawa: Manis Jaya, Gebang Raya, and Betet exhibit elevated occupancy rates, accompanied by waiting lists, indicating substantial demand and interest from the community in vertical housing. Nonetheless, the execution of the rusunawa program in practice encounters certain issues that reflect non-adherence to established policies. The issues encompass: the inappropriate use of residential units for commercial purposes, disparities in rental pricing, insufficient basic educational facilities within a reasonable distance, delayed management responses to property damage, and inadequate oversight regarding duration of residency, vehicle ownership, and resident origins. The ineffective operation of the rusunawa institution adversely affects social involvement and results in suboptimal housing management.

To enhance the efficacy and equity of the rusunawa program, it is imperative to amend regulations, fortify the institutional framework for residents, ensure consistent enforcement of regulations, and provide facilities and services aligned with community needs. By implementing these stages, rusunawa can evolve into a sustainable, inclusive long-term housing solution that enhances the quality of life for urban populations. The housing's physical attributes differ, with unit sizes spanning from 18 m² to 36 m². There exists a discrepancy between the need and supply of housing units, as the bulk of available rusunawa are small-sized, although most residents consist of families with four people. Disparities in the financial capacities of inhabitants are concerning, as those with better earnings typically pay lower rates, but others are compelled to allocate over 30% of their income towards rent, in violation of international standards.

This study underscores the necessity of developing rusunawa in Tangerang City to address the long-term housing requirements for all societal strata, including affluent individuals and those from outside Tangerang City

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employed within it. The construction of rusunawa in Tangerang City must consider the provision of unit types that align with residents' needs, allowing for the integration of various unit types within a single rusunawa to enhance inclusivity. Additionally, it should include business units to facilitate residents' entrepreneurial activities, ensure the provision of adequate and accessible facilities and infrastructure, and establish a fair rental cost based on residents' financial capabilities through cross-subsidization, where each resident pays rent amounting to 20-30% of their respective income.

Based on the research findings, several recommendations are proposed to enhance future studies: Firstly, subsequent research should aim to further investigate resident satisfaction concerning various life aspects in rusunawa, including facilities, social interactions, and management, which may assist in pinpointing areas for improvement and elevating overall housing quality; additionally, a comparative analysis between rusunawa in Tangerang City and those in other cities should be conducted to identify best practices and the challenges encountered in each region.

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URBAN POVERTY THROUGH A MULTIDIMENSIONAL LENS: EVIDENCE FROM IBMT BENEFICIARIES IN KUALA LUMPUR

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Abstract

It is commonly acknowledged that poverty should not be assessed via a one-dimensional lens, such as monetary assessment. This study examines the characteristics of multidimensional poverty among households participating in the Program Inisiatif Basmi Miskin Tegar (iBMT) in Wilayah Persekutuan Kuala Lumpur. Using the Multidimensional Poverty Index (MPI) based on the Alkire–Foster (AF) methodology, the analysis draws on household-level survey data to assess deprivations across multiple dimensions relevant to an urban context. The findings reveal that, at the chosen cut-off point, 68% of iBMT households are categorised as multidimensionally poor, with an average deprivation intensity of 47% of the total indicators included. The analysis also indicates significant overlapping deprivations across health, education, living standards, and social capital, suggesting that affected households face multiple, reflecting multiple rather than isolated, forms of hardship. Disaggregated results indicate that income deprivation is the most prevalent, followed by limited access to health insurance, online learning facilities, and basic communication services. The study highlights the complex and multidimensional nature of urban poverty in Kuala Lumpur and recommends that poverty alleviation programmes would be enhanced by more cohesive policy strategies that address income vulnerabilities, digital inclusion, social protection coverage and human capital deficits.

Keywords: Poverty, Multidimensional Poverty Index, Deprivation, Kuala Lumpur

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INTRODUCTION

Poverty is increasingly recognised as a complex and multidimensional phenomenon that cannot be adequately captured through income-based measures alone. Early critiques of the monetary approach argue that an exclusive focus on income and consumption overlooks other critical forms of deprivation that shape individuals' well-being and life chances (Wagle, 2005). Policymakers and researchers have adopted the capability and social exclusion approach, which are inherently multidimensional and include non-monetary characteristics. The capability approach, proposed by Sen (1987, 1993, 1999), transformed conventional poverty metrics that mostly focused on income by including non-income variables such as literacy, life expectancy, and living conditions. The inclusion of non-monetary factors such as access to healthcare, material necessities, and literacy also influences a person's happiness and well-being (Bourguignon & Chakravarty, 2009).

In response to the limitation of unidimensional poverty measurement, Alkire and Santos (2010) introduced the global Multidimensional Poverty Index (MPI), subsequently adopted by the Oxford Poverty & Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP). The MPI provides a comprehensive framework for assessing poverty by capturing deprivations across multiple dimensions that reflect basic capabilities and quality of life. Its primary objective is to measure acute poverty, defined as the failure to achieve minimum thresholds in essential indicators aligned with the Sustainable Development Goals (SDGs) (Alkire & Santos, 2014).

While the global MPI has significantly advanced poverty measurement, its original emphasis on acute poverty has become increasingly insufficient in the face of evolving socio-economic realities. Contemporary challenges, such as labour market precarity, rising healthcare costs, rapid urbanisation, and the widening digital divide, have introduced new forms of vulnerability that extend beyond traditional poverty thresholds. These challenges are particularly pronounced in urban settings, where households may not be classified as extremely poor yet continue to experience persistent deprivations in education, health, digital access, and social protection. As such, there is growing recognition of the need for multidimensional assessments that move beyond acute poverty to capture overlapping and cumulative disadvantages faced by vulnerable urban populations.

In Malaysia, the application of multidimensional poverty measurement has progressed with the development of the Malaysian Multidimensional Poverty Index (MMPI). Empirical studies using MPI-based approaches have demonstrated that poverty in Malaysia extends beyond income deprivation and varies significantly across population groups. For example, previous research has identified substantial multidimensional deprivation among fishing communities,

retirees, and children and zakat recipients, with important disparities observed across gender and life-cycle stages (Solaymani & Kari, 2014; Solaymani et al., 2019; Ismail et al., 2024; Zailani et al., 2024). Despite these advances, existing studies have largely focused on multidimensional poverty identification rather than programme evaluation, and limited attention has been given to urban poverty among beneficiaries of targeted income-based interventions. In particular, there remains a lack of programme-specific evidence on whether such interventions effectively alleviate non-monetary and structural deprivations among urban households.

From a program monitoring and evaluation perspective, the MPI offers a robust outcome- and impact-oriented tool for assessing the effectiveness of poverty alleviation initiatives. Unlike conventional income-based indicators, an MPI-based assessment enables policymakers to track changes across multiple dimensions of well-being and determine whether program participation leads to meaningful improvements in the overall quality of life. The decomposability of the MPI further allows programme implementers to identify specific dimensions and indicators where deprivations persist, thereby supporting evidence-based programme refinement. This approach is particularly relevant in urban contexts, where poverty is often characterised by high living costs, insecure employment, inadequate housing, and limited access to comprehensive social protection systems (Yaacob & Hassan, 2024).

Incorporating social capital in an MPI framework is especially important when evaluating poverty alleviation programs. Social capital, encompassing networks, trust, norms, and social relationships, plays a critical role in shaping households' ability to cope with economic shocks, access opportunities, and convert programme inputs into sustainable well-being outcomes (Putnam, 2000). From a capability perspective, social capital functions as an enabling resource that influences individuals' capacity to transform material resources into achieved functionings (Sen, 1999). In urban settings, where social fragmentation and informal employment are common, weak social networks may limit access to informal support, information, and community-based services, even among households receiving financial assistance or skills training. Excluding social capital from programme evaluation therefore risks underestimating structural and relational constraints that perpetuate multidimensional poverty.

Against this backdrop, this study examines multidimensional poverty among households participating in the Program Inisiatif Basmi Miskin Tegar (iBMT) in Wilayah Persekutuan Kuala Lumpur. The iBMT program, managed by the Ministry of Economy under Upaya@ PUJI initiative aims to support low-income households through capacity-building, skills development, and income-generating opportunities, with the ultimate objective of enabling participants to

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achieve financial independence and escape poverty. While the programme places strong emphasis on income enhancement, its effectiveness should be assessed beyond monetary outcomes alone. Accordingly, this study pursues three objectives. First, it measures the extent and intensity of multidimensional poverty among iBMT beneficiaries using an MPI framework adapted to the urban context of Kuala Lumpur. Second, it examines overlapping deprivations across income, health, education, living standards, digital access, and social capital to identify cumulative and reinforcing disadvantages faced by households. Third, the study evaluates the suitability of MPI as a monitoring and evaluation tool for urban poverty alleviation programs. By providing program-specific evidence on urban multidimensional poverty in Malaysia, this study contributes to the literature on poverty measurement and offers policy-relevant insights for enhancing the design, implementation, and evaluation of income-focused interventions, such as iBMT.

LITERATURE REVIEW

Concept and Application of Multidimensional Poverty Index (MPI)

The MPI, established by the OPHI to address individual multidimensional poverty characteristics, has received more attention since its launch. Mohanty (2011) examined various forms of poverty in India and discovered that a major contributing factor to its prevalence is inequality. Alkire and Seth (2015) investigated India's significant countrywide decline in poverty. However, the outcomes differ by geography, caste, and religion. Alkire and Shen (2017) conducted a study in China, utilising the China Family Panel Study (CFPS) and the AF approach. Their findings show that China's global MPI value is comparatively low and declining over time. The authors also discovered that families with heads that have a higher education level, are smaller in size, or have relocated are frequently associated with reduced multidimensional poverty, but minority households and communities with divorced heads are more likely to be multidimensionally poor. While most research investigated the gender gap in poverty via a monetary approach, Rogan (2016) adopted the MPI method in South Africa and discovered that the multidimensional gender poverty gap is equivalent to the poverty gap evaluated using the monetary approach. Nonetheless, the study found that the MPI poverty difference between female- and male-headed families is slightly smaller than the income poverty disparity. Tran et al. (2015) in Vietnam established that the connections between monetary and multidimensional poverty measurements are minimal, indicating a significant divergence between these two measures of poverty. This aligns with Salecker et al. (2020), which observed that the poverty incidence identified by the multidimensional assessment surpasses that of the monetary poverty measure. Chen et al. (2019) found that deprivation status and multidimensional poverty

characteristics varied by district in Taiwan, with the central and southern districts exhibiting a higher percentage of individuals experiencing multidimensional poverty. Utilising MPI to examine child poverty, Qi and Wu (2019) identified a notable difference in multidimensional poverty among Chinese children in rural areas compared to urban areas, despite the absence of a substantial variation in income poverty across these places.

In the local setting, Solaymani and Kari (2014) adopted the MPI to evaluate the severity of poverty in Malaysian fishing communities. The study concluded that there is a high degree of poverty in the respective communities, with nearly all fishermen categorised as multidimensionally poor. In another study, Solaymani et al. (2019) used the MPI to assess the multidimensional poverty status among the retirees of the Malaysia Employee Provident Fund (EPF). Based on the study, 84 per cent of EPF retirees experience multidimensional poverty, with women experiencing worse deprivation than males in the areas of income, homeownership, education, and transportation. Meanwhile, Tedong et al. (2022) adopted the global MPI framework to evaluate the well-being of the Iban community in Sarawak state. The results reveal that the community suffers considerable disadvantage in the education and asset ownership aspects. More recently, Zailani et al. (2025), in their study among zakat beneficiaries in Kuala Lumpur, concluded that most of the poor and destitute households were deprived in the social protection aspect, particularly health insurance and access to digital platforms. The results of empirical studies imply that the MPI framework is tailored to the particular context of the research.

RESEARCH METHODOLOGY

This study involved active participants in the Kuala Lumpur iBMT program, totalling 79 households. This study employed a purposive sampling approach to select respondents who were most relevant to the research objectives. Purposive sampling was deemed appropriate as the study specifically targeted heads of households participating in the iBMT in Kuala Lumpur. Only active iBMT participants who had received programme assistance at the time of data collection were included in the sample. This approach ensured that the selected respondents possessed direct experience with the programme and were therefore able to provide meaningful information for assessing multidimensional deprivation among iBMT beneficiaries. The analysis of the study was done using the MPI calculation method by Alkire and Foster (2011). To operationalise the analysis, Statistical Package for the Social Sciences (SPSS) software and the Microsoft Excel application have been utilised. The SPSS software is used primarily for the descriptive analysis, while Microsoft Excel supports the MPI calculation. In deriving the final output of the MPI, two main components of the MPI, which are

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the headcount ratio (H) and the intensity of poverty (A), are identified. The headcount ratio reflects the number of households who are considered as multidimensionally poor. The formula used is as below:

$$H = q/n \qquad (1)$$

where,
q = number of multidimensional poor household
n= total population

Meanwhile, the intensity of poverty (A) reflects the average deprivation score among the poor individuals.

$$A = (c\ (k))/qd \qquad (2)$$

where,
c (*k*): the share of deprivations encountered by all poor individuals
qd: maximum number of deprivation dimensions (d)

To ascertain if a household is classified as multidimensionally poor, an aggregate cut-off point (k) is determined, representing the total of indicators from which the household is deprived. In choosing the suitable cut-off point, Alkire and Foster (2011) connote that the selection of the k involves normative reasoning and may reflect specific policy goals. According to the literature, two extreme poverty cut-off point levels have been defined, which are the intersection and union methods. While the former categorises a household as multidimensionally poor if they are deprived in all indicators, the latter defines a household as multidimensionally poor if they are found to be deprived in at least one indicator. To moderate this extreme cut-off point level, the Alkire-Foster (AF) dual method suggests an intermediate method, which defines a household as multidimensionally poor if they experience deprivation in at least 30% of the total deprivation score (Alkire & Foster, 2011). Hence, the study adopted an intermediate method in determining the multidimensional poverty level among the iBMT Kuala Lumpur active participants.

The study adopted extended MPI, which is an extended version of the MMPI by incorporating enhanced capabilities as reflected by the Sustainable Development Goals (SDGs), primarily on the effort to eliminate poverty as outlined in Agenda 2030. The selection of dimensions and indicators for the construction of the MPI is a normative decision and is the starting point in the empirical evaluation of poverty (Alkire & Seth, 2015). The MPI framework used is outlined as per Table 1:

Table 1: MPI Framework used in the study

Dimension	Indicator	Cut-off point	Weight
Education	• Years of schooling • School attendance • Access to online learning	• All household members aged 17-60 have less than eleven years of education • Any school-aged children (aged 6-16) not schooling • Household member does not have access to internet connectivity and/or do not have sufficient devices	1/15 1/15 1/15
Health	• Access to clean water supply • Nutrition intake • Health Insurance	• Other than treated pipe water inside house and public water pipe/standpipe • Households that do not receive adequate food intake of at least 3 times per day. • Any household do not have health insurance coverage	1/15 1/15 1/15
Living standard	• Conditions of living quarters • Number of bedrooms • Toilet facility • Waste collection facility • Transportation • Access to basic communication tools	• Dilapidated or deteriorating in components including floor, roof or walls. • More than 2 members per room • Other than flush toilet • No facility • All members in the household do not use private or public transport to commute • Does not have consistent fixed line phone, mobile phone and internet access	1/30 1/30 1/30 1/30 1/30 1/30
Social Capital	• Social support • Involvement in community and cultural activities • Togetherness • Trust	• Any household member does not get sufficient support from family members, relative, friends and communities. • Household members do not participate in any community and cultural activities. • Household members feel the sense of community togetherness as very weak. • Household members found difficulties to trust other than family members	1/20 1/20 1/20 1/20
Income	• Mean monthly household income	• Mean monthly household income less than PLI	1/5

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ANALYSIS AND DISCUSSION

Descriptive Statistics

Table 2 presents the sociodemographic characteristics of the heads of households participating in the iBMT program in Kuala Lumpur. In terms of gender, the sample is relatively balanced, with male-headed households accounting for 47 per cent and female-headed households for 42 per cent of respondents. In terms of gender, the sample is predominantly male-headed households (61%), while female-headed households account for 39 per cent of respondents. The majority of respondents (82%) are Malay, followed by a significant proportion of Indian households (16%), and a minor fraction (1%) are Chinese households. This distribution shows that multidimensional poverty within the program is not limited to a single ethnic group but is particularly prevalent among Malaysian and Indian urban households. Regarding the age distribution, the majority of household heads fall into the economically active age range. The majority of responders are in the 45–59 age range, with the largest concentrations seen in the 45–49 and 50–54 age groups (25% and 22%, respectively).

In terms of educational attainment, approximately 28 percent of the respondents report having no formal education or only primary education, while nearly half of the sample (49 percent) attained education up to the SPM/SPV level. Only a small proportion of respondents possess post-secondary qualifications, including STPM/matriculation (5 per cent), certificates or diplomas (3 per cent), and bachelor's degrees (3 per cent). From an employment type perspective, while 20 per cent are in permanent employment, a substantial proportion are engaged in self-employment (46 per cent) or part-time/contract work (29 per cent). Meanwhile, around 53 per cent of respondents report monthly incomes below RM1,500, while an additional 25 per cent earn between RM1,501 and RM2,000. Only 13 per cent report incomes exceeding RM2,500 per month.

Table 9: Head of Household Profile

Items	Description	Frequency (n=79)	Percentage (%)
Gender	Male	48	61
	Female	31	39
Ethnicity	Malay	65	82
	Chinese	1	1
	Indian	13	16
	Others	0	0
Age	25–29	2	3
	30–34	0	0
	34–39	7	9
	40–44	10	13
	45–49	20	25
	50–54	17	22

Items	Description	Frequency (n=79)	Percentage (%)
	55–59	11	14
	60–64	11	14
	65–69	1	1
	No education	8	10
	Primary school	14	18
Educational level	PMR/SRP	10	13
	SPM/SPV	39	49
	STPM/Matriculation	4	5
	Certificate/Diploma	2	3
	Bachelor's degree	2	3
	Permanent employment	16	20
	Self-employed	36	46
Employment status	Part-time/Contract	23	29
	Unemployed	4	5
	RM501–RM1,000	6	8
	RM1,001–RM1,500	22	28
Monthly Income	RM1,501–RM2,000	20	25
	RM2,001–RM2,500	15	19
	RM2,501–RM3,000	10	13

Source: Fieldwork

Multidimensional Poverty Characteristics

Figure 1 presents the percentage contribution of individual indicators to multidimensional poverty among iBMT beneficiaries in Kuala Lumpur. The results reveal a clear concentration of deprivation in economic, social protection, and digital-related indicators, highlighting the complex and non-monetary nature of urban poverty among programme participants. Based on the results, it was found that household monthly income contributed the most significantly to deprivation among the iBMT participants, reflecting that income inadequacy remains a central challenge and reinforcing the relevance of income-focused interventions within the program. Nonetheless, the persistence of high deprivation levels in non-income indicators suggests that income poverty alone does not fully capture the vulnerability faced by these households. It is evident that there is a significant deprivation that exists related to social protection and human capital whereby 78 per cent of the households were deprived in the indicator of access to health insurance. A significant number of individuals in poverty face limited access to essential financial services, such as takāful and credit, primarily due to the enormous cost associated with these goods and services, which exceeds their financial means (Rom & Rahman, 2012). Limited access to healthcare essentials may lead individuals to fall trapped in the vicious cycle of poverty (Banerjee & Duflo, 2011).

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Meanwhile, more than half of the households are deprived of access to online learning (57%) and basic communication facilities (52%), underscoring the growing importance of digital access in an urban context. This is consistent with Abdullah et al (2019), Jafar et al. (2022) and Zailani et al. (2024), whereby many children, including those in urban areas, experienced poor access to online learning and communication. These findings are particularly salient in light of increasing reliance on digital platforms for education, employment opportunities, and access to public services). In a specific context, e-learning in Malaysian schools is still in a nascent stage in comparison to high-income nations (Hawati & Jerud, 2020). The delivery of home-based online education was hindered by many challenges, including insufficient technology, subpar learning environments, and inadequate connectivity. In addition, another aspect of educational deprivation remains evident, with years of schooling (51%) contributing significantly to overall poverty. This suggests persistent human capital constraints among iBMT households, which may limit their ability to benefit fully from skills development and income-generating initiatives.

In addition, deprivations in nutrition (41%) and access to clean water (46%) indicate that basic living standards continue to be compromised for a considerable proportion of beneficiaries, despite residing in an urban setting. Indicators related to social capital including social support (39%), trust (32%), and togetherness (27%) also exhibit notable levels of deprivation. This pattern suggests that many households face relational and community-level constraints, which may hinder their capacity to mobilise informal support networks or access information and opportunities. Such social capital deficits may reinforce other deprivations, particularly in income generation and access to services. Through involvement in social networks, individuals obtain access to diverse resources (Portes, 2024). The findings show that the conditions of living home indicator contribute 29% to multidimensional poverty, indicating that housing quality remains an important source of deprivation for many households. Poor housing conditions influence multidimensional poverty in several interconnected ways. Houses with weak structures, leaking roofs, poor ventilation, overcrowding, or limited living space can negatively affect physical and mental health, increase exposure to disease, and reduce household safety and comfort.

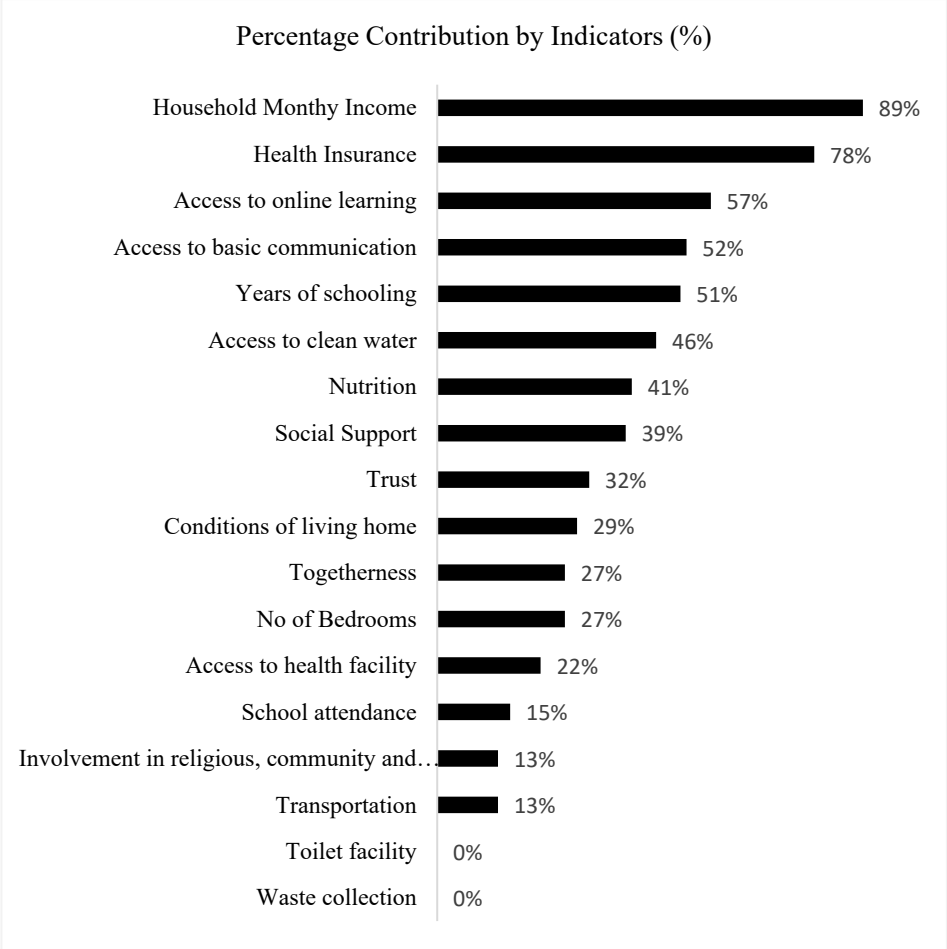


Figure 1: Indicator-Level Contribution to Multidimensional Poverty

To determine which dimension led to the largest percentage of deprivation experienced by the households, an analysis of the average aggregate across all dimensions employed in the study was carried out. Based on Figure 2, the results demonstrate a markedly uneven distribution of deprivation across dimensions, reinforcing the multidimensional and cumulative nature of urban poverty experienced by programme beneficiaries. Income deprivation emerges as the most severe dimension, with an average deprivation level of 89 per cent, indicating that the vast majority of iBMT households continue to face significant income insufficiency. The health dimension records the second-highest level of deprivation at 46.5 per cent, reflecting limited access to health insurance and

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healthcare-related security. This level of deprivation highlights households' exposure to health-related shocks, which may undermine income stability and increase long-term vulnerability. Similarly, deprivation in the education dimension remains substantial, with an average of 40.9 per cent, indicating persistent constraints in human capital accumulation that may limit participants' capacity to benefit from skills training and employment opportunities promoted under the iBMT programme. In contrast, deprivation in the living standards dimension is relatively lower at 20 per cent, suggesting that most households have access to basic urban infrastructure and essential services. This pattern reflects the urban context of Kuala Lumpur, where extreme infrastructural deprivation is less prevalent. Nevertheless, the presence of some deprivation in this dimension indicates that a subset of households continues to experience inadequate housing conditions or basic amenities. The social capital dimension exhibits an average deprivation level of 27.5 per cent, pointing to notable deficits in social support, trust, and community engagement among iBMT beneficiaries.

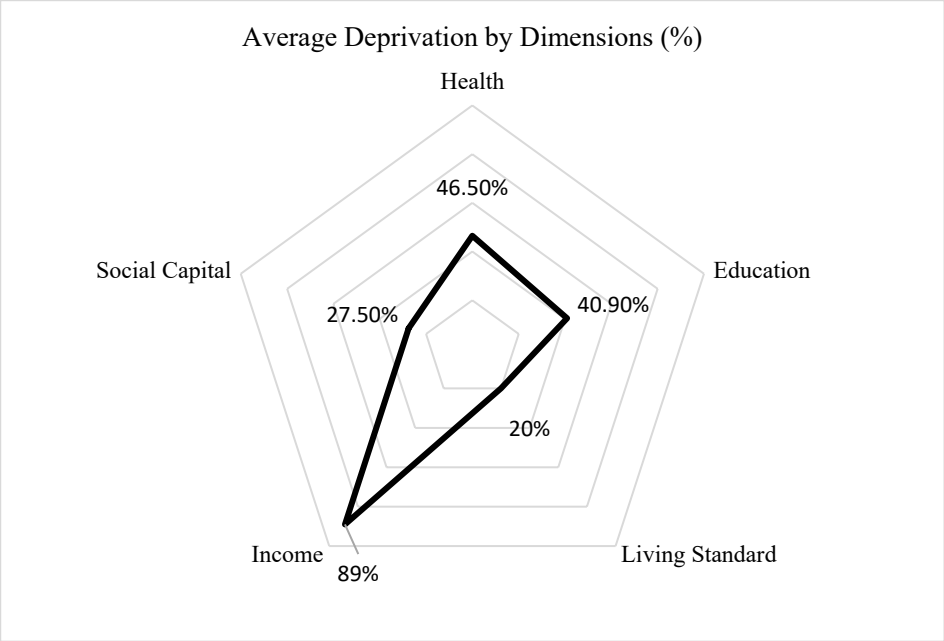


Figure 3: Average Deprivations by Dimensions

Since all five dimensions used in the MPI framework are equally weighted, Venn diagram is used to illustrate some of the overlaps of the dimensions experienced by the households. The analysis reveals that multidimensional poverty among iBMT beneficiaries is characterised not only by

high deprivation within individual dimensions but also by substantial simultaneous deprivations across multiple dimensions, indicating the presence of cumulative and reinforcing disadvantages. The overlap findings shows that a large number of families are deprived in more than one dimension concurrently. For example, 67 per cent of families lack both health and education at the same time, and 62 per cent lack both education and living standards concurrently. Overlaps involving social capital are also notable whereby approximately 46 per cent of households are jointly deprived in health and social capital, while 38 per cent experience overlapping deprivations in social capital and living standards. The analysis also highlights that a significant number of households experience triple and quadruple deprivation., In particular, 37 per cent of households are deprived simultaneously in health, education, and social capital, while 34–35 per cent experience joint deprivations across three dimensions involving living standards. In more extreme case, 32 per cent of households are found to be deprived across all four dimensions, representing the most severely disadvantaged group within the sample. This reinforce that a considerable number of household face deep constraints that extend beyond any single dimension.

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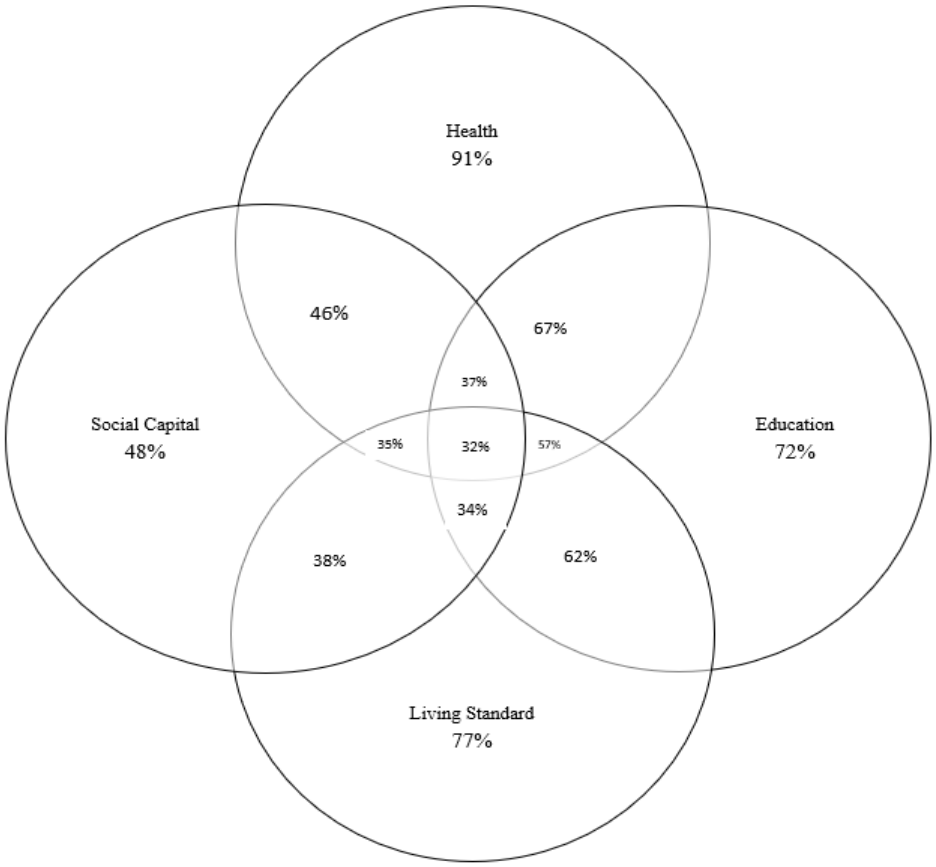


Figure 3: Venn diagram of Joint Distribution of Deprivations

It is essential to evaluate the robustness and stability of the MPI estimates prior to assessing the multidimensional poverty outcomes of the iBMT participants. Sensitivity analysis is an important part of verifying to determine if the poverty assessment is accurate with different assumptions or criteria. Since the MPI relies on two key components, which is the identification of the poor based on a certain cutoff point, and the aggregation of their deprivations, small changes in the cutoff level may potentially influence the classification of participants as multidimensionally poor or non-poor. To assess the sensitivity of multidimensional poverty estimates, MPI results based on an alternate cut-off point (k) will be observed.

Based on Table 2, the findings reveal an opposite relationship between the value of k and both the headcount ratio (H) and the adjusted headcount (M0).

As the cut-off point used is higher, the headcount ratio and the adjusted headcount ratio will be lower. This outcome implies that the calculation for the MPI was done appropriately. Conversely, the average intensity (A) demonstrates a positive correlation with the cut-off point. This confirms that the M0-value, H-value, and A-value are responsive to variations in poverty cutoff points. To determine the multidimensional poverty status of the household, an aggregate cut-off point (k) need to be determined. Atkinson et al (2002) noted that several previous studies depend on two conceptual extremes level for poverty identification, namely the union and the intersection method. Under the union method, in the poverty cut-off is set at k=1, 97 per cent of the household were found to be multidimensionally poor. Nonetheless, such a low cut-off point used is may overstate poverty by classifying households with minor, isolated, or temporary deprivations as multidimensionally poor. Conversely, if intersection method was applied, whereby k=18 is established, only 1 per cent of the household were considered as multidimensionally poor. While the intersection approach is effective in identifying households facing the most severe and entrenched forms of multidimensional poverty, it is overly restrictive for programme evaluation purposes

Due to the limitation of these extreme methods, intermediate approach is applied in this study, whereby k is set at 1/3 or 0.33 of the sum of deprivation score, as recommended by Alkire and Foster (2011). Alkire and Santos (2014) further argue that a poverty cut-off of 0.33 is normatively justified because it provides a wide distribution of poverty results. At k = 3, the headcount ratio (H) is 0.91, indicating that 91 per cent of iBMT beneficiary households are classified as multidimensionally poor. This high incidence suggests that multidimensional deprivation is widespread among programme participants, even when applying a moderate threshold that requires deprivation in one-third of the indicators. Importantly, this finding does not merely reflect isolated or marginal deprivation but indicates that most households' experience deprivation across multiple domains simultaneously. Meanwhile, the average intensity of deprivation (A) at k= 3 is 0.42, implying that multidimensionally poor households are deprived, on average, in 42 per cent of the total indicators. This level of intensity suggests that households that are considered poor at this cut-off are experiencing deprivation that is considerably greater than the level that is needed to be classified as poor. In other words, households are not only exceeded the threshold of poverty, but they are also enduring more severe and widespread deprivation in many areas. The adjusted headcount ratio (M_0) for k = 3, which integrates incidence and intensity, is recorded at 0.38. This result signifies a considerable overall burden of multidimensional poverty among iBMT recipients, indicating that poverty is both widespread and moderately severe.

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Table 3: Multidimensional Poverty Measures across different cut-off points

Cut-off Points	***k*=1**	***k*=2**	***k*=3**	***k*=4**	***k*=5**	***k*=6**	***k*=7**	***k*=8**	***k*=18**
Headcount (H)	0.97	1.00	0.91	0.86	0.82	0.68	0.47	0.34	0.01
Average Intensity (A)	0.40	0.41	0.42	0.44	0.44	0.47	0.52	0.57	1.48
Adjusted Headcount (M_0)	0.39	0.41	0.38	0.37	0.36	0.32	0.25	0.19	0.02

DISCUSSIONS

This study offers empirical evidence that poverty among iBMT participants in Kuala Lumpur is highly multifaceted, exceeding mere income insufficiency to include deprivations in health, education, living conditions, internet access, and social capital. These results are consistent with the broader literature emphasising that poverty is increasingly shaped by intersecting economic and non-monetary disadvantages rather than income deprivation alone (Wagle, 2005). In line with the targeted objectives of the iBMT program, income deprivation is identified as the primary factor contributing to the multidimensional poverty. This also confirms that the program successfully targets economically disadvantaged populations. Nonetheless, the ongoing existence of significant deprivation in health insurance coverage, education, internet access and social capital indicates that income-based initiatives alone are unable to tackle the intricate realities of urban poverty. This study substantiates the capability-based argument that increases in wealth do not always result in improved functionings or less susceptibility when complementing capabilities remain scarce (Sen, 1999).

The significance of digital deprivations, particularly limited access to online learning and basic communication underscores the changing dynamics of poverty in urban context. The internet facilitates access to public and market information and serves as a way to safeguard basic freedoms, as indicated in SDG 9, which aims to 'provide universal and affordable access to the Internet in least developed countries by 2020' (Alkire et al., 2023). Inadequate access to digital information and communication technologies can therefore constrain poor households' ability to participate effectively in economic activities by limiting their access to employment opportunities, markets, public services, and timely information. As a result, digital exclusion may reinforce existing economic vulnerabilities and perpetuate multidimensional poverty, especially in urban contexts where digital connectivity increasingly underpins economic and social

participation. The dimensional analysis further indicates that while income deprivation is most severe, health and education deprivations remain widespread, affecting approximately 40–47 per cent of households. These findings are consistent previous studies in Malaysia showing that health-related vulnerabilities and educational disadvantages are key drivers of sustained poverty, even among households receiving targeted assistance (Tong et al., 2011; Solaymani et al., 2019; Shahar et al., 2019; Ismail et al., 2024). In contrast, relatively lower deprivation in the living standards dimension recorded reflects the urban setting of Kuala Lumpur, where access to basic infrastructure and municipal services is comparatively widespread. Another key contribution of the study lies in its examination of overlapping deprivations, demonstrating that most iBMT beneficiaries experience multiple disadvantages across dimensions concurrently. It is worth to highlight that a considerable number of households were experiencing deprivation across all dimensions, including health, education, living standard, social capital and income.

The results of this study hold important implications for the design, execution, and monitoring of poverty reduction programs such as iBMT. Although income-based metrics are effective for identifying beneficiaries, the findings conclusively illustrate that poverty in urban communities is complex, marked by overlapping deprivations in health, education, internet access, and social capital. The MPI offers a practical and rigorous framework suitable for integration into program monitoring and evaluation (M&E) systems. In contrast to static poverty metrics, the MPI enables policymakers to monitor variations in both the incidence (headcount) and the intensity of deprivation over time. By consistently revisiting MPI values for program participants, implementing agencies may evaluate whether interventions result in significant enhancements across several aspects of well-being, rather than only transient income increases. Further, the decomposability of the MPI allows program implementers to track progress at both the dimensional and indicator levels, hence pinpointing specific areas where deprivations continue despite program participation. Thus, MPI-based monitoring facilitates evidence-based program modifications and enhances resource allocation efficiency. In terms of policy coordination, MPI can enhance inter-agency collaboration by mapping deprivations to appropriate line ministries and agencies. Health-related deprivations could motivate cooperation with public health authorities, education and digital access gaps may direct collaboration with education and telecommunications agencies, and social capital shortfalls may highlight the need for community-based or local government measures.

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CONCLUSION

This study concludes that poverty among iBMT recipients in Kuala Lumpur is multifaceted, encompassing considerable deprivations in health, education, digital access, living conditions, and social capital. The MPI findings show pervasive and overlapping deprivation, implying that many households experience cumulative and reinforcing limits rather than isolated disadvantages. While economic deprivation remains the most visible feature, the high incidence of non-monetary deprivations underlines the difficulties of income-based poverty reduction measures in urban settings. Conceptually, the findings imply that poverty should be regarded as a capability deprivation process rather than a lack of financial resources.

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LAYERED SPATIAL ADAPTATION IN INFORMAL COASTAL SETTLEMENTS TOWARD URBAN RESILIENCE

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Abstract

Rapid coastal urbanization in the Global South intensifies development pressures on informal settlements situated between metropolitan expansion and ecologically fragile coastal zones. Existing studies often frame adaptation as microscale housing modifications or climate responses, providing a limited understanding of how spatial change accumulates over time at the settlement scale. This study examines layered spatial adaptation in the informal coastal settlement of Tanjung Bunga, Makassar, Indonesia. Using a qualitative case study approach, it integrates spatial mapping (QField), morphological analysis, GIS-based reconstruction from satellite and topographic data, and qualitative coding (NVivo 12 Plus) to trace the transformation from the 1980s to 2024. The findings identify four overlapping phases: (1) vernacular ecological adaptation rooted in fishing livelihoods; (2) infrastructure-induced spatial reorientation following metropolitan road development; (3) tourism-driven economic consolidation through hybridization of domestic space; and (4) territorial negotiation characterized by access control and communal spatial claims. These phases coexist as layered spatial configurations that reorganize circulation networks, dwelling orientation, communal nodes, and coastal-edge use. The study conceptualizes informal coastal settlements as territorialized adaptive assemblages, where adaptation unfolds cumulatively under ecological and metropolitan pressures. Spatial plasticity enables communities to negotiate territorial agency and move toward resilience without erasing vernacular spatial logics.

Keywords: Coastal Settlements, Layered Spatial Adaptation, Territorialized, Adaptive, Urban Informality

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INTRODUCTION

Coastal cities in the Global South are experiencing accelerated urban growth, which is increasingly placing informal coastal settlements in heightened vulnerability. Situated at the intersection of metropolitan expansion and ecologically sensitive environments, these settlements face overlapping pressures from urban development, environmental exposure, and socio-spatial marginalization. Historically, coastal areas have functioned as dense nodes of habitation, social interaction, and maritime-based economic exchange (Cain, 2014; Xie, 2023). However, adaptation is frequently framed as short-term or technical responses to environmental risks such as flooding and erosion, offering limited insight into how spatial transformation unfolds over time (Goyal & Lima, 2024; Igualt et al., 2023).

Contemporary urban theory positions informality as an active mode of spatial production shaped by self-organization and incremental adaptation (Dovey, 2012; Kamalipour, 2016). Informal morphologies persist and evolve despite formal interventions. Research on post-enhancement settlements demonstrates that transitions from stigmatized informal areas to recognized urban spaces reshape residents' perceptions of environmental quality and livability (Fidelista et al., 2025). However, studies of coastal informality often separate environmental adaptation from analyses of urban form and settlement morphology. While both indigenous strategies and modern coastal defenses reshape livelihoods and spatial configurations, few studies examine how these processes accumulate and interact over time within informal coastal settlements. Evidence from southeastern Ghana shows that hard-engineering defenses may reduce erosion but restrict coastal access and disrupt fishing livelihoods, revealing tensions between physical protection and socio-spatial sustainability (Loor, 2021). Adaptation thus remains conceptualized as discrete measures rather than as an evolving spatial process embedded in settlement structure.

Empirically, this study is situated in Indonesia, a maritime nation with one of the world's longest coastlines and a population heavily concentrated in coastal regions (Werich, 2015). Coastal communities, often low-income and socially vulnerable, develop adaptive strategies shaped by settlement history, tenure systems, and social solidarity (Dewi et al., 2021; Syarif et al., 2015). The research focuses on Makassar, a strategic coastal city in South Sulawesi and part of the Mamminasata Metropolitan Area, particularly the Tanjung Bunga coastal settlement. Originally a vernacular fishing settlement, Tanjung Bunga underwent significant transformation following the construction of the Metro Tanjung Bunga Road in the mid-1990s, which became a key axis of metropolitan expansion. This infrastructure triggered land conversion, commercial growth, and tourism development (Surya, Hadijah, et al., 2020), prompting local communities to occupy residual spaces and reorient livelihoods toward informal and

community-based tourism activities in Tanjung Bayang, Anging Mammiri, Pantai Biru, and Layar Putih.

These dynamics suggest that coastal informality in Tanjung Bunga is not merely a condition of marginality but a layered spatial system continuously reassembled through vernacular practices, infrastructural shifts, metropolitan political economy, and ongoing negotiations toward resilience amid rapid coastal transformation.

LITERATURE REVIEW

Adaptation as spatial practice in informal settlements

In settlement and architectural studies, adaptation is commonly understood as a response to environmental, social, and economic pressures through spatial adjustments and everyday dwelling practices (Nelson et al., 2007). Early environmental behavioral approaches framed adaptation as an effort to align spatial configurations with user needs and environmental constraints (Altman et al., 1980). Although foundational for explaining human-environment relations, these perspectives essentially positioned adaptation as a corrective, technical mechanism, paying insufficient attention to social negotiation, power relations, and the temporal dynamics shaping long-term spatial transformation.

Architectural discourse later expanded this understanding through the concept of adaptability, emphasizing the capacity of built space to accommodate change without losing its core functions (Douglas, 2016; Kronenburg, 2007). By foregrounding flexibility and temporality, adaptability theory recognized buildings as evolving entities rather than static artifacts. However, it primarily treated buildings as discrete objects, overlooking settlements as socially negotiated spatial systems. Consequently, it often reduced adaptation to physical modification. At the same time, collective practices, urban pressures, and governance dynamics remained underexamined, an analytical limitation particularly evident in informal settlements where spatial change is inseparable from everyday survival strategies.

Layered and Incremental Spatial Adaptation

To move beyond reductionist views of adaptation as merely technical adjustment, layered adaptation theories provide a broader analytical lens. Schmidt III & Austin (2016) conceptualize the built environment as a multilayered system in which urban context, infrastructure, spatial organization, and social practices evolve at different temporal rhythms. Adaptation thus unfolds through accumulation and coexistence rather than replacement. However, this framework has been applied mainly to formal settings, leaving informal and resource-constrained contexts underexplored.

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Research on informal settlements supports incremental and layered perspectives. Turner (1977) and Dovey (2013) argue that spatial change emerges through localized decision-making and gradual adjustment, while Kamalipour (2016) frames informality as self-organized morphology capable of persisting despite eradication efforts. However, much of this scholarship remains focused on inland and micro-scale dynamics, offering limited insight into how incremental adaptations accumulate into long-term, settlement-scale transformation. Spatial plasticity is the capacity of space to be modified without losing function (Asikin, 2018; Marinovic, 2023). Extends this discussion but is often confined to individual housing units. In informal coastal contexts, adaptation is commonly framed as environmental risk response, such as stilt construction or coastal defenses (Goyal & Lima, 2024; Igualt et al., 2023; Widya et al., 2025). Evidence from Ghana highlights tensions between state interventions and local livelihoods (Loor, 2021). Under pressures of reclamation and large-scale development (Dodman et al., 2019; Liang et al., 2022), adaptation becomes negotiated. This study, therefore, conceptualizes informal coastal settlements as layered spatial systems that express territorial agency under metropolitan pressure.

RESEARCH METHODOLOGY

Field observations were conducted systematically across segmented coastal units in Tanjung Bayang, Anging Mammiri, Pantai Biru, and Layar Putih (Figure 2). This segmentation served as an analytical framework for examining variations in incremental spatial adaptation at the settlement scale, including building patterns, residential clustering, household-based business groupings, and circulation networks linking dwellings to coastal and economic zones. The approach enabled tracing morphological transformation as a layered process of spatial addition, expansion, and reconfiguration. The researchers collected data through semi-structured in-depth interviews, field observation, and spatial analysis. Seven second-generation residents were selected through snowball sampling based on their long-term experience prior to the new town's development. Interviews (45–90 minutes) explored settlement phases, adaptation strategies, livelihood shifts, and public–private spatial changes. All interviews were conducted in Indonesian, recorded with consent, transcribed verbatim, and anonymized (I1–I7).

Temporal reconstruction employed field digitization (QField for QGIS, Global Mapper Mobile) combined with historical and satellite data: the 1991 Makassar Topographic Map (ANRI, 2025), Google Earth imagery (2000–2025), and Makassar satellite maps (2024). To ensure geometric consistency and cross-period comparison, we aligned all datasets in ArcMap 10.8. From these verified GIS outputs, we produced morphological diagrams and settlement distribution maps based on our field observations. The authors ensured reliability through multi-source triangulation and member checking. They cross-validated interview

data with satellite imagery and historical maps to verify shoreline shifts and changes in settlement patterns. Furthermore, the authors conducted qualitative analysis in NVivo 12 Plus using iterative inductive–deductive thematic coding grounded in layered spatial adaptation and adaptive assemblage as proposition theory.

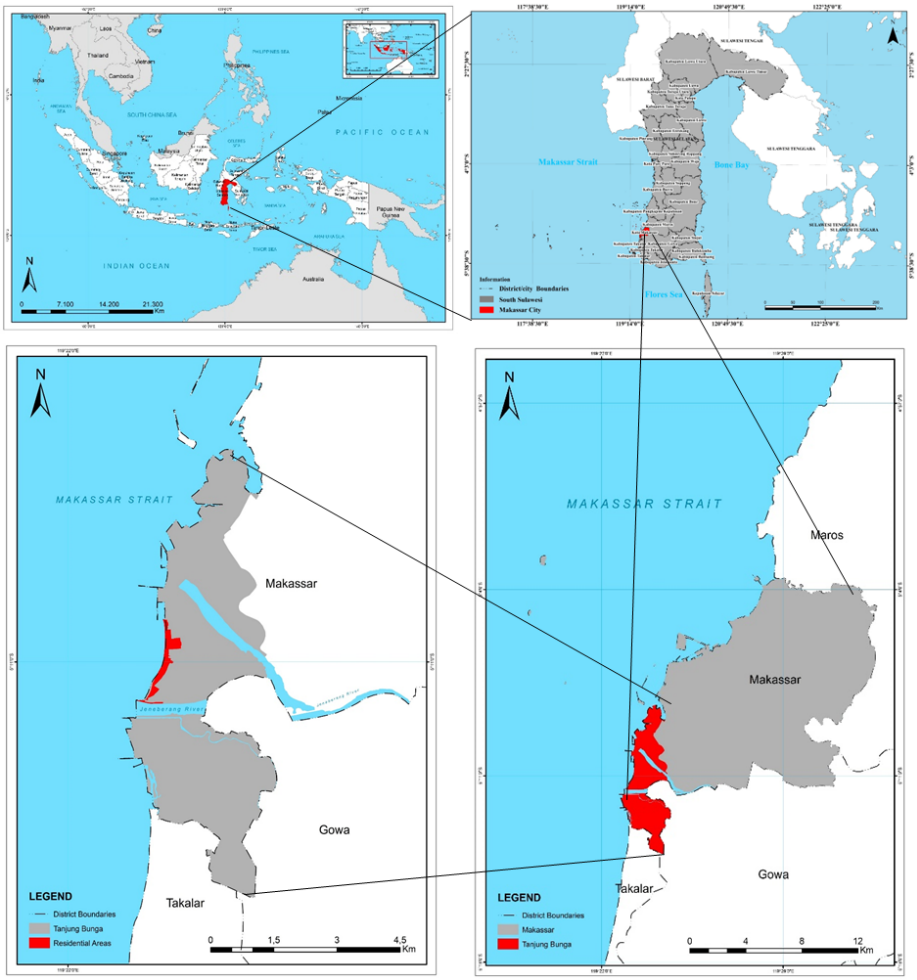


Figure 1: Location of study area, coastal settlement in Tanjung Bunga New Town, Makassar

Source: Regional Spatial Plan of South Sulawesi Province (RTRW) 2009-2029; Makassar City RTRW 2015-2034; self-digitization by Author (2025)

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RESULTS AND DISCUSSION

Periodization of Spatial Adaptation in Tanjung Bunga

Periodization was used as an analytical framework to examine spatial adaptation in Tanjung Bunga coastal settlements, focusing on key spatial and infrastructure events. Based on spatial mapping, systematic field observations, and qualitative data coding, the transformation of the Tanjung Bunga coastal settlement can be classified into four main phases of spatial adaptation, as illustrated in Figure 4 (A-E). Each phase represents a distinct configuration of settlement morphology, spatial orientation, and functional organization, indicating that adaptation unfolded incrementally rather than through abrupt or comprehensive restructuring. Figure 3 traces the chronological evolution of key spatial elements from 1989 to 2024, highlighting changes in circulation systems, dwelling orientation, communal spaces, and the utilization of the coastal-edge zone.

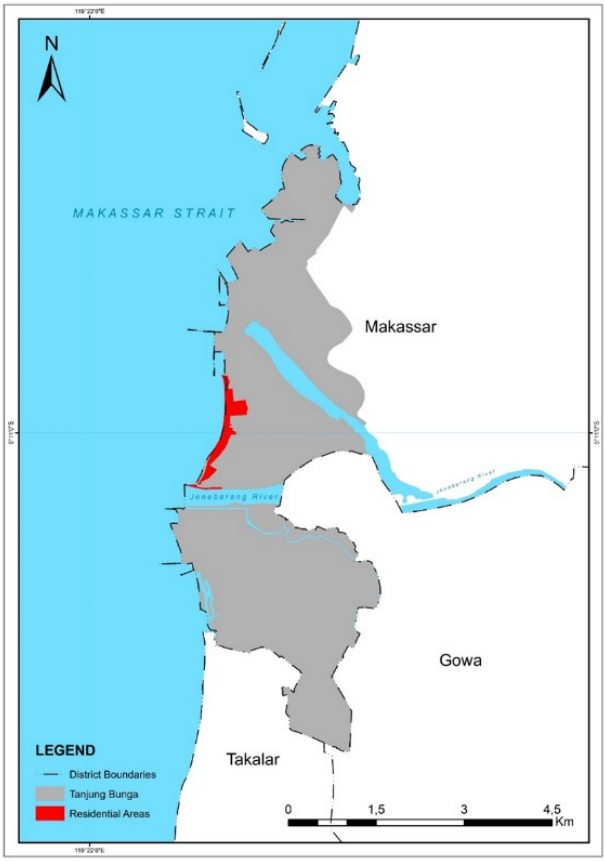


Figure 2: Observation Point Location
Source: Makassar City RTRW 2015-2034; self-digitization by Author (2025)

1. Vernacular Coastal Settlement Phase (Pre-1991)

Prior to the development of Tanjung Bunga New City, the area was a traditional, fishery-based and agricultural settlement with strong ecological dependence and a water-oriented spatial organization. In the vernacular phase, morphology is formed from the need to inhabit the transition zone between the sea and wetlands. As seen in Figure 3 (1989), the spatial structure develops linearly along the pond (the pond divider), which functions as ecological infrastructure, a circulation route, and a central space organizer. *Pematang* connects clusters of stilt houses, ponds, rice fields, and coastal activity zones.

Unlike the general pattern along the coastline, micro land lanes above the embankment path (*pematang*) form the spatial axis of Tanjung Bunga. These lanes provide higher access to inundation-prone land while maintaining pond productivity. Internal mobility relies on pedestrian movement across narrow embankments that remain accessible when flooded (Informant 1), connecting dwellings, ponds, rice fields, and communal spaces (Informant 2). River routes dominate external mobility; boats served as a link to markets, schools, and city centers along the Jeneberang River before the advent of formal roads (Informant 3; Informant 6).

Residents strategically place their homes to maintain dual land-water access and reduce the risk of high tide. They arrange the stilt houses in a linear, sea and circulation-path-oriented manner to respond to wind and mobility. Specifically, houses in Tanjung Alang Village (Anging Mammiri and Pantai Biru) face the sea; those in Lette Village (Layar Putih Beach) orient toward the moor, and residences in Kampung Bayang (Tanjung Bayang) follow the boundary of the pond. Communal elements such as *bale-bale* (fisherman shelter) function as social productive nodes for rest, repair nets, and coordination (Informant 3). Overall, this phase represents nature-based spatial adaptation, integrating ecology, livelihoods, mobility, and social organization into a permeable, flexible spatial system.

2. Infrastructure Transition Phase (1992-2010)

The construction of the Tanjung Bunga Metro Road in 1996 became a turning point in the spatial organization of coastal settlements. This intervention triggered a gradual shift from a water-based, embankment system towards a land-oriented system structured by metropolitan corridors. As seen in Figures 4B and 5 (2000), Jalan Metro introduces a new mobility hierarchy, making land connectivity the primary reference for settlement growth and reorganization.

Prior to the presence of formal roads, spatial structures were formed through a network of embankments and dense soil paths, associated with kinship-based land cultivation and soil cultivation (Informant 4). Instead of removing these paths, the community gradually widens and integrates them, allowing the

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vernacular configuration to remain alongside the new infrastructure. In the same period, the tourism industry emerged in Tanjung Bayang (1997) as residents constructed simple *bale-bale* (tourism shelter) on the beach. However, this phase does not yet reflect the consolidation of the tourism economy because access to the coast is not yet fully connected to the center of Makassar City via the Metro corridor; visitors still depend on the Barombong Bridge, so the flow of tourists remains local and limited.

In this context, Jalan Metro catalyzes selective adjustment rather than total replacement. Residents reoriented their residences and activity spaces towards the new road as a corridor to the city center (Informant 5), while still maintaining ponds and water-based access in daily practice. Locals gradually negotiate this shift from the water–terrestrial logic to the terrestrial system (Figure 5, 2000).

Adaptive responses differ between segments. In Tanjung Bayang, the community widened the dam and integrated it into the city's road network, which led to the emergence of initial tourism. In Anging Mammiri, adaptation occurs organically through incremental land access, and the northern sector (Tanjung Alang) is directly connected to the metropolitan corridor first. In Biru Beach, land acquisition triggered on-site relocation and a shift in kinship clusters to the coastline. In the White Screen, new access openings begin to form the initial territorial boundaries. Overall, this phase results in a hybrid configuration, suggesting that spatial adaptation occurs through layered accumulation rather than abrupt structural jumps.

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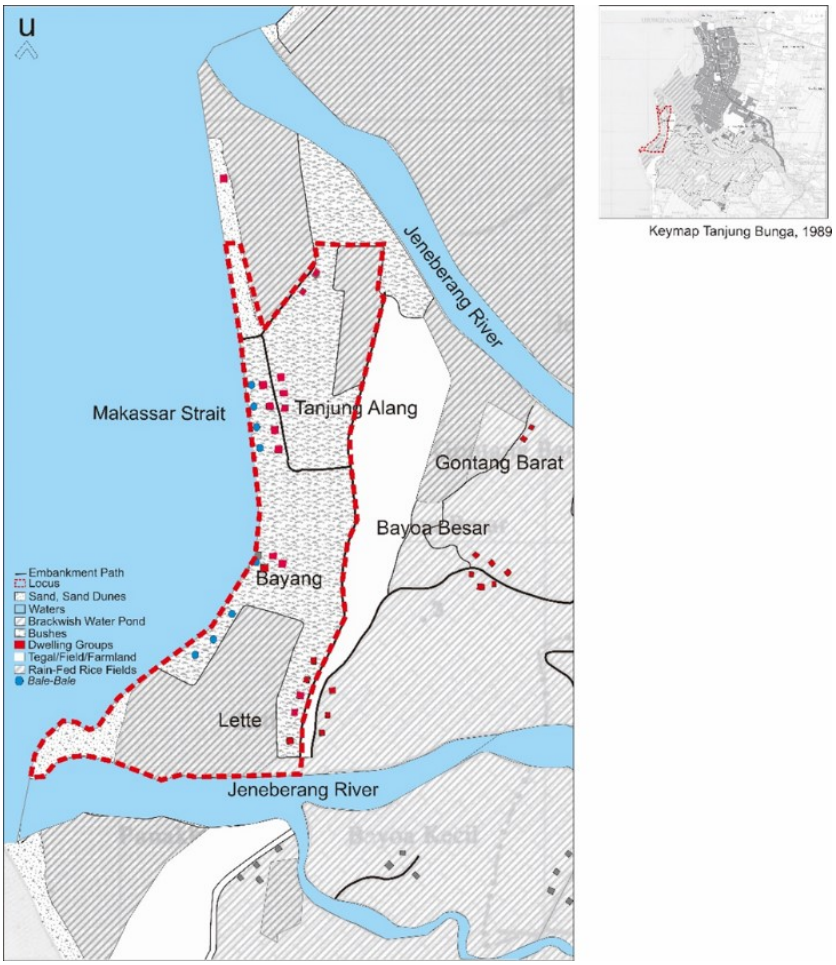


Figure 3: Distribution of Dwelling Groups Vernacular Settlement Phase (1989)
Source: Derived from Ujung Pandang Topographic Map (1991); Field Note (2024); Field Interview Interpretation (2024)

In the late 1990s, the city's infrastructure did not fully connect Tanjung Bayang Beach to Makassar's urban core. Because the Metro corridor remained incomplete despite ongoing road development, access depended primarily on the southern route via Barombong Bridge. As a result, visitor flows remained local and limited. As shown in Figure 5A (1989) and Figure 5B (2000), the settlement structure was still predominantly residential, with tourism facilities emerging sporadically and linearly along the shoreline. The early bale-bale followed the coastal edge, reflecting a community-based tourism logic rather than corridor-driven urban growth. Thus, 1997 represents a proto-tourism phase.

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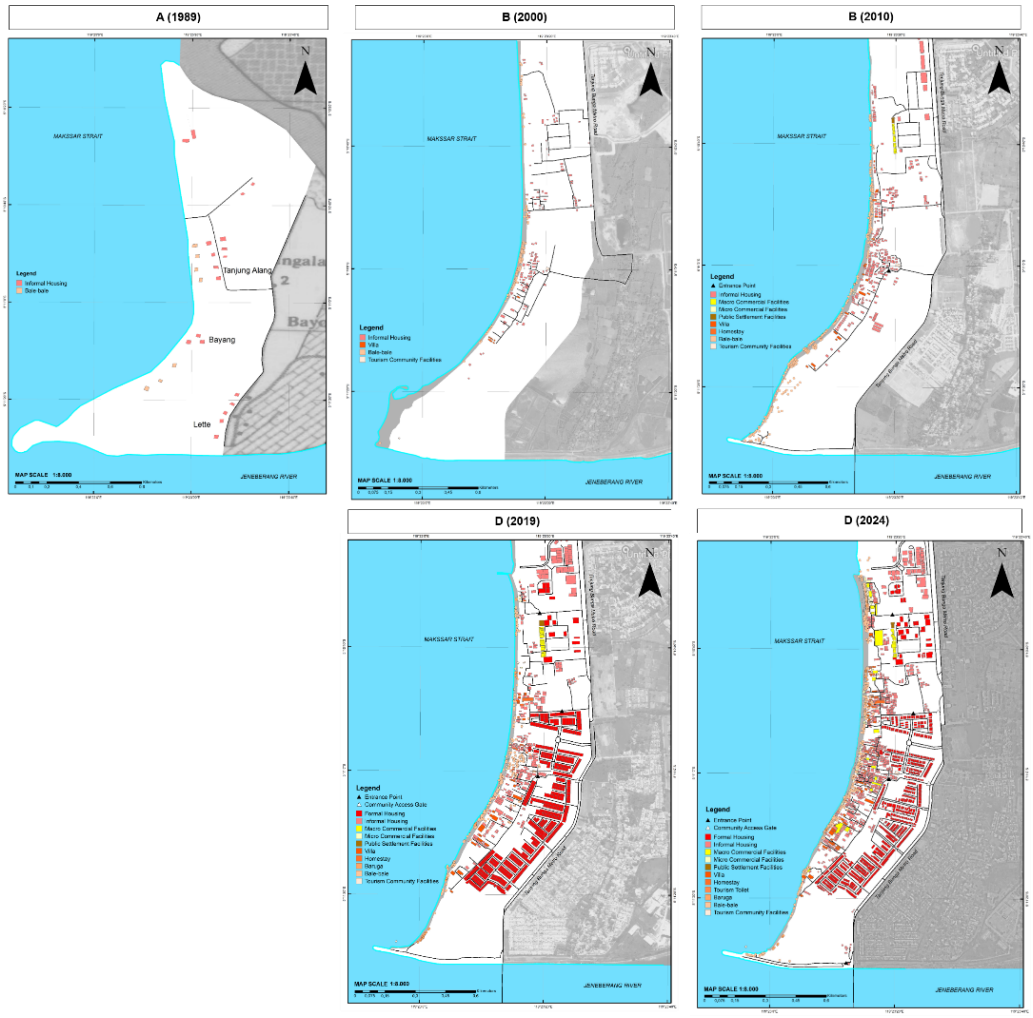


Figure 4: Spatial Key Elements of Morphological Coastal Settlement in Tanjung Bunga During the Years of (A) 1980, (B) 2000, (C) 2010, (D) 2019, and (E) 2024
Source: Derived from Ujung Pandang Topographic Map (1991); Google Earth Imagery of Tanjung Bunga (2025); and Tanjung Bunga Satellite Imagery (2024); Author's Field-Based Digitization Mapping (2023–2024)

A decisive shift occurred in 2010 (Figure 5C), when infrastructure became functionally integrated, improving accessibility and intensifying urban flows. Tourism growth in Pantai Akkarena and Tanjung Bayang generated spillover effects, prompting residents in Anging Mammiri to replicate the beach-tourism model. Figure 5C shows the emergence of villas, lodgings, and beach-oriented dwelling clusters, indicating a more systematic and economically

integrated adaptation. Rising visitor numbers led to incremental functional hybridization of domestic spaces. Residents maintained residential continuity in their homes while incorporating food stalls, homestays, public toilets, and rental facilities along the front-layer plots facing the shoreline. They repurposed the underfloor spaces of their stilt houses for parking and tourist services. Furthermore, the community redefined *bale-bale*, formerly fishermen's shelters (Figure 5A), as semi-public tourism shelters (Figure 5C), reflecting a shift toward economic logic and blurred public-private boundaries. As noted by Informant 3, these changes were perceived not as a loss of domestic meaning but as partial adjustments, illustrating layered spatial adaptation rather than wholesale transformation.

3. Territorial Intensification Phase (Post-2019)

The post-2019 phase shows a shift from economic-functional adaptation to territorial intensification, encompassing spatial, symbolic, and economic expansion. This process is not uniform, but manifests differently in each case unit. In the Tanjung Bayang Beach Settlement, a random and high-density fishing village, intensification is marked by the strengthening of residential-based tourism. On a micro scale (footprint), residents transform their stilt houses into homestays, adding bale-bale, gazebos, and tourist toilets, while repurposing the underside of the houses for parking and tourist services. Adaptation takes place incrementally; residential sites become spaces for economic negotiation as well as symbols of the community's claim to coastal space as sustainable.

In the Pantai Biru Coast Settlement, intensification occurs through kinship mechanisms and access controls. On a meso scale, negotiations with developers resulted in access restrictions, the establishment of an inlet, and the strengthening of family-based controls. Territorial strengthening is achieved through access regulation and social legitimacy, not just densification. Therefore, the spatial pattern is more structured along the coastline, with a linear composition of residential, parking, and business space. A very prominent mechanism is kinship-based zoning. The community organizes spatial order along family clans to secure control over land and coastal access. They use physical elements such as entrance gates and guard posts as symbols of spatial control over the outside.

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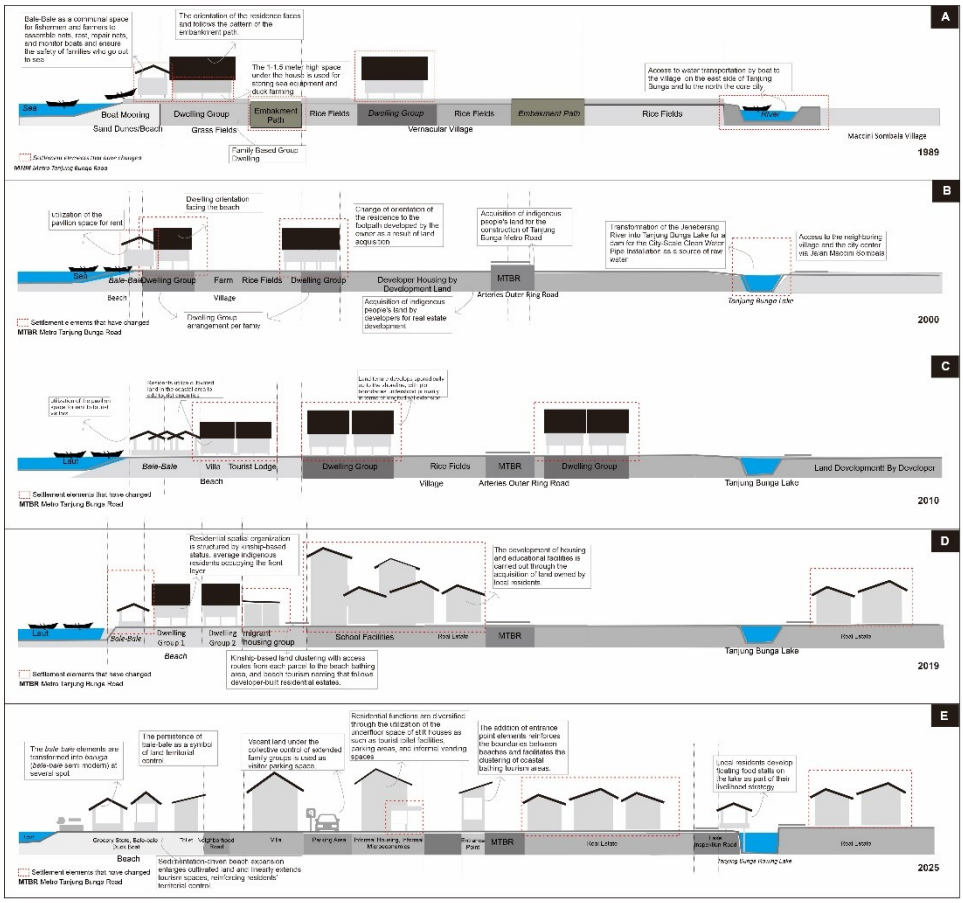


Figure 5: Longitudinal cross-sectional evolution of informal coastal settlements showing the adaptation of dwelling groups, micro-economic spaces, and public-private interfaces over three decades (1989, 2000, 2010, 2019, 2025)
Source: Field Interview Interpretation (2024); Google Earth (2000-2025)

In contrast to other cases, in Biru Beach, the adaptation mechanism involves symbolic reinforcement through the White Screen Monument. This structure predates the development of the Tanjung Bunga New City Area. The intensification was then marked by the addition of baruga and bale-bale as business spaces for settlers as well as land cultivators who play a role in protecting the developer's land. Fishing tourism activities and sunset views from Layar Putih are the main selling points of the area, which is directly adjacent to the river mouth and managed by the Kampung Lette fishermen's group. This configuration serves as a visual statement of the community's presence and their claim to the estuary area bordering government and developer land. The land

guard community consists of land guards from developers and the river area authority, who then move to the mainland due to abrasion and build guard houses near the entrance post to consolidate their presence and spatial control.

DISCUSSION

This study again reflects the tendency of the still-dominant adaptation literature to position spatial adaptation as a technical response to environmental risks or as a partial economic adjustment. Although incremental adaptations have been recognized (Turner, 1977; Dovey, 2012), how these changes accumulate and are organized at the settlement scale, especially in informal coastal contexts, remains relatively limited. The findings in Tanjung Bunga show that adaptation occurs as a layered spatial accumulation rather than a series of disconnected changes.

As shown in Figure 5A-5E and formulated in Figure 6, the four phases, namely vernacular, infrastructure transition, tourism, and territorial intensification, do not replace each other, but coexist in one configuration of settlement morphology. The vernacular phase forms the ecological foundation through maturation, sea orientation, and communal *bale-bale*. The infrastructure transition phase reorients circulation to the Metro corridor without removing the old network, resulting in hybrid mobility. The tourism phase presents a mixed residential-economic function through incremental domestic refunctionalization. Since 2019, adaptation has shifted toward territorial intensification through kinship clustering, access arrangements, entry gates, and the transformation of bale-bale into baruga as a semi-permanent communal-economic node (Figure 5D).

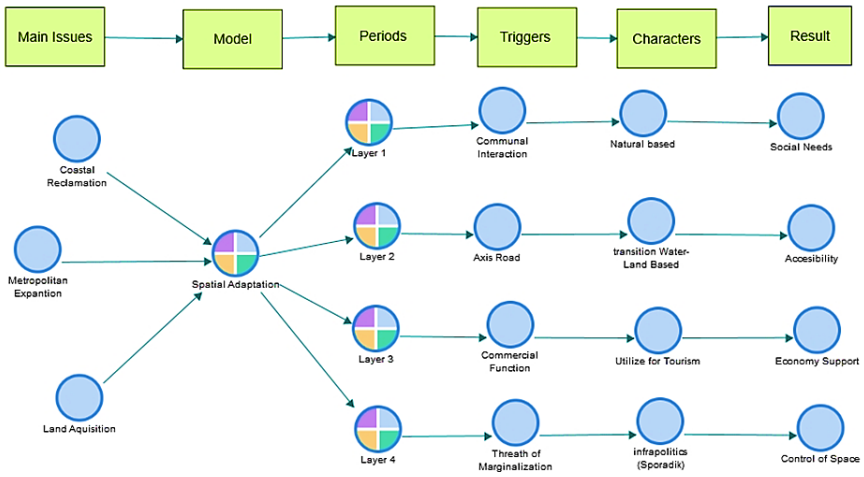


Figure 6: The Four Phases of Adaptation Forming Spatial Layers in Tanjung Bunga Coastal Settlement

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Beyond the spatial and economic mechanisms identified above, the findings reveal a dimension of social practice that operates continuously across all four phases: what this study terms "Everyday Play." This concept refers to the informal, recurrent, and non-instrumental social activities enacted in shared communal spaces, including collective net repair and conversation at *bale-bale* nodes, children's Play along the coastal edge, informal social exchange among residents at beachfront gathering areas, and communal leisure practices at Tanjung Bayang, Anging Mammiri, Pantai Biru, and Layar Putih. These activities are not peripheral to the settlement's adaptive logic; rather, they constitute a form of everyday social practice that reproduces interpersonal bonds, reinforces collective identity, and sustains the social capital necessary for coordinated territorial action (Nelson et al., 2007). Critically, Everyday Play persists across shifting economic and infrastructural conditions: *bale-bale*, which once hosted fishermen's rest and net repair (Phase 1), later accommodated tourist interaction and communal tourism coordination (Phase 3), yet the underlying social logic of shared, informal gathering endured. This continuity signals that Everyday Play functions not merely as cultural residue but as an active social resilience mechanism, one that maintains community cohesion and reproduces the relational infrastructure upon which collective adaptive responses depend. As such, it constitutes a qualitative indicator of social resilience that complements the spatial and territorial indicators identified in the morphological analysis.

In contrast to the Dovey adaptive cycle model (growth, conservation, release, reorganization), the Tanjung Bunga case does not show a gradual change in spatial structures that cancel each other out. Instead, ecological, infrastructural, economic, and territorial pressures form a new morphological layer that integrates the previous layers (see Table 1). Key mechanisms of adaptation include the reorientation of the circulation network, the plasticity of residential functions, kinship-based access control, and the strategic occupation of the seaside as an expression of collective territorial agency. Thus, we define this long-term negotiation and layered morphological accumulation under sustained metropolitan pressures as a process toward spatial resilience in settlements. Theoretically, these findings expand the adaptive assemblage framework by formulating territorial adaptive assemblage as a collective spatial system that reassembles circulation networks, residential clusters, communal nodes, and coastal interfaces to strengthen the legitimacy, access control, and sustainability of space without erasing pre-formed spatial logic.

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Table 1: Adaptive Cycle and Layered Spatial Adaptation under Multi-Salar Pressure

Dovey Phase (Theoretical)	**Informal Coastal Settlement in Tanjung Bunga (Empirical)**		
	Phase	**Dominant Pressure**	**Key Spatial Mechanism**
Growth	Vernacular	Tides, wetlands, and fishing livelihood	Linear embankments; sea-oriented houses; bale-bale nodes
Informal expansion; occupation of interstices			
Conservation	Infrastructure Transition	Metropolitan road, land acquisition	Reorientation to Metro Road; hybrid circulation
Structural stabilization			
Release	Tourism	Tourism economy; rising land value	Hybrid dwelling functions; mixed-use frontage
External disruption			
Reorganisation	Territorial Intensification	Developer expansion; spatial contestation	Entrance gates; kinship clustering; *bale-bale* → *baruga*
Reassembly; new territorial configuration			

CONCLUSION

This study demonstrates that informal coastal settlements evolve through layered, cumulative spatial adaptations rather than as a linear response to urban expansion. The case of Tanjung Bunga identifies four overlapping phases: vernacular ecological adaptation, transition due to infrastructure, tourism-based consolidation, and territorial negotiation, which coexist in a single settlement morphology, reorganizing circulation, residential orientation, communal nodes, and waterfront utilization while maintaining the initial spatial logic. Theoretically, this study formulates the concept of Territorialized Adaptive Assemblage, which expands on the Dovey adaptive assemblage framework by emphasizing the spatial-territorial dimension of adaptation through access arrangements, kinship-based zoning, and coastal frontage management. The transformation of bale-bales into baruga shows how architectural elements evolved into territorial instruments that sustain the economy and strengthen the claim to collective space. Although these adaptation trajectories are contextual and influenced by kinship networks, local norms, and tenure systems, they offer a relevant analytical framework for understanding how community-based spatial adaptation contributes to resilience in metropolitan coastal areas. Future cross-urban comparative studies should further test this framework.

Beyond territorial and economic dimensions, this study explicitly identifies "Everyday Play", the informal, recurrent social practices enacted in communal spaces such as *bale-bale*, beachfront gathering nodes, and waterfront

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promenades, as a qualitative indicator of social resilience. The persistence of these quotidian practices across all four adaptive phases, from vernacular fishing communities gathering at *bale-bale* to residents and tourists co-inhabiting the same spaces in the territorial intensification phase, demonstrates that social cohesion is continuously reproduced through non-instrumental, shared activities. Everyday Play thus serves as a connective tissue between the settlement's ecological, economic, and territorial adaptive layers, sustaining the interpersonal bonds and collective identity that underpin the community's capacity for long-term spatial negotiation under metropolitan pressure.

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IDENTIFICATION OF URBAN SPRAWL TYPES BASED ON THE SPRAWL EXPANSION PATTERN INDEX IN SIX PERI-URBAN DISTRICTS OF MANADO CITY, INDONESIA

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Abstract

This paper attempts to identify the typology of urban sprawl or the horizontal physical expansion of built-up land in 6 districts that constitute the peri-urban area of Manado City, Indonesia. The study is based on the Sprawl Expansion Pattern Index metric values, which is the ratio between the area and perimeter of new built-up land expansion plots in the last two decades (2004-2024). This metric value is quantified using the ArcGIS application, utilizing the results of the extraction of built-up and unbuilt land (black-and-white hypothesis) from spatiotemporal satellite imagery data with the help of Google Earth Engine. The analysis results show that the dominant sprawl typology occurring in the study area is the Edge Sprawl type, which reaches a proportion of 80.30% of the total physical expansion of built-up land during that period. This type of sprawl occurs through physical expansion at the edges of pre-existing built-up land clusters. Edge sprawl that occurs between 2 or more built-up land clusters can in principle be seen as a type of Infill Development, which over time will lead to the merging of previously built-up land clusters to form a larger and more compact cluster. The dominance of another identified sprawl type is Leapfrog Sprawl with a proportion of 18.94%. Leapfrog sprawl is identical to a jumping physical expansion pattern, which passes through open land and creates spatial fragmentation. Ribbon Sprawl type, namely linear expansion along the main road corridor, was identified to occur with a very small proportion of 0.76%.

Keywords: Urban Sprawl, Peri-urban Area, Sprawl Pattern Expansion Index, Edge Sprawl, Infill Development, Leapfrog Sprawl, Ribbon Sprawl

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INTRODUCTION

Urban growth in Indonesia has generally driven the expansion of built-up areas into peri-urban areas in response to increasing population and economic activity (Basman et al., 2025). Manado, as the center of regional activity in North Sulawesi, also exhibits similar symptoms, with increasing pressures on accessibility, investment, and urbanization in its peri-urban areas. Unmanaged physical expansion usually leads to urban sprawl, characterized by inefficient and unconsolidated distribution of built-up land. This phenomenon can trigger various negative consequences, including increased spatial fragmentation, massive conversion of undeveloped land, environmental degradation, and increased public dependence on private vehicles. Urban sprawl often causes a decline in the quality of public services and economic (Ebraheem et al, 2024; Rogi et al., 2024; Yasin et al., 2020.

To minimize these negative impacts, local governments need a proper understanding of spatial development patterns, particularly the typology of urban sprawl (Wang et al., 2020; Artmann et al., 2019). This is crucial because each type of sprawl has distinct development characteristics and policy implications for spatial planning (Yasin et al., 2020; Ewing & Hamidi, 2015). For example, edge sprawl tends to be associated with urban consolidation and is relatively manageable, while leapfrog sprawl leads to more extreme fragmentation of urban spatial structures (Zhang et al., 2023; Shukla & Jain, 2019). Thus, identifying sprawl typologies in the peri-urban areas of Manado is a strategic basis for formulating more anticipatory and sustainable spatial use control policies (Lord et al, 2015; Wiewel & Persky, 2015).

This study was conducted to answer the question: "How are the variations and dominance of urban sprawl typologies developing in six districts in the peri-urban area of Manado City over the past two decades?" The purpose of this study was to identify, quantify, and interpret the patterns and proportions of urban sprawl types that occurred based on the characterization results of the Sprawl Expansion Pattern Index (SEPI) metric (Shukla & Jain, 2019). The results of this study are expected to provide a more comprehensive spatial understanding of the dynamics of peri-urban area development and serve as a basis for making spatial planning policies (Sareen & Haque, 2023; Ahani & Dadashpoor, 2021).

This study conducted spatial mapping of built-up land changes during the period 2004–2024 using a binary classification of built-up and unbuilt-up land using satellite image processing in Google Earth Engine. Built-up land expansion patches were analyzed using a geoprocessing tool in ArcGIS to obtain patch area and perimeter values. The Sprawl Expansion Pattern Index (SEPI) metric was calculated as the ratio of the area and perimeter of each expansion patch. It was used to determine whether the growth pattern falls into the edge, leapfrog, ribbon (linear), or other patterns according to the formulated typology. This approach

allows for robust spatial identification of the character of urban expansion in the study area (Shukla & Jain, 2019).

By understanding the dominant type of sprawl, planners and policy makers can implement appropriate spatial utilization control strategies according to the development characteristics of the peri-urban areas of Manado City, so that the urbanization process can be directed in a more structured and sustainable direction (Lord et al, 2015; Wiewel & Persky, 2015).

LITERATURE REVIEW

Peri-urban Areas and the Phenomenon of Urban Sprawl

Peri-urban areas are defined as transition zones located on the outskirts of a city, where urban and rural functions meet and blend. These areas are dynamic and a primary locus of land-use change due to the pressures of urbanization and infrastructure development (Elgar, 2023; Ahani & Dadashpoor, 2021).

In many mid-sized cities in developing countries, including Indonesia, pressure on land in peri-urban areas often triggers rapid, unstructured physical expansion of settlements. This phenomenon is commonly referred to as urban sprawl, which is synonymous with the loss of productive land, declining ecosystem quality, fragmentation of open spaces, and increased reliance on private transportation (Rogi et al., 2025).

Some studies also emphasize the importance of assessing the character and consequences of sprawl locally, rather than just its extent, as planning and policy implications depend heavily on how sprawl manifests spatially in a given peri-urban area (Yasin et al., 2020).

Urban Sprawl Typology: Categories and Implications

Sprawl typologies are usually classified into several general patterns: edge expansion, ribbon, leapfrog, and infill, each with different formation mechanisms and spatial implications (Shukla & Jain, 2019; Ewing & Hamidi, 2015). Edge expansion occurs when built-up areas expand from the edges of existing clusters, thus maintaining spatial connectivity; leapfrog appears as new patches far from existing clusters, thus causing fragmentation; ribbon relates to longitudinal growth along road corridors; while infill refers to filling gaps within existing urban structures (Li et al, 2025; Karthik et al, 2025; Ewing & Hamidi, 2015).

This typology analysis is relevant because effective policies differ between types. Infill tends to be more easily encouraged through densification policies, while leapfrog requires interventions such as controlling land conversion and regulating public infrastructure networks to prevent fragmentation (Marquis & Barthelemy, 2025; Turvey, 2019).

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Urban Expansion Index

One approach to identifying sprawl typologies is the use of the Urban Expansion Index (UEI). The UEI is calculated as the ratio of the length of the common boundary between the new and existing urban patches to the perimeter of the new patch. UEI values can vary from 0 to values close to 1, although in classification practice, they use certain ranges to define typologies (Chettry, 2022).

In another study, UEI was modified into the Sprawl Expansion Pattern Index (SEPI), with a different mathematical premise, using the area-perimeter ratio. This approach is often used to assess compactness versus complexity of patch shapes, where the larger the area relative to the perimeter, the more compact the patch shape tends to be; the smaller the area/perimeter ratio, the more complex the patch shape tends to be. This method is also widely used in landscape metrics analysis (Khan, 2025; Shukla & Jain, 2019). The interpretation of sprawl typologies using SEPI can be done as follows:

Table 1: Interpretation of the Sprawl Expansion Pattern Index

Sprawl / Expansion Type	Value Criteria (UEI / SEPI)	Spatial Characteristics
Edge Expansion (Contiguous)	$0 < SEPI \leq 0.50$	New patches grow outward from the edges of old built-up clusters; growth is relatively continuous, indicating an extension of the existing area (Chettry, 2022).
Ribbon / Linear Development	$0.50 < SEPI \leq 0.75$	New patches are elongated and oriented along corridors (e.g., main roads); the patch shape is relatively elongated, thin, and follows the existing accessibility network (Chettry, 2022).
Leapfrog / Scatter Expansion	SEPI = 0 (no common boundary)	New patches appear far apart from the old built-up zones — indicating fragmentation, jumping across vacant land, tending to create new enclaves within existing ones (Chettry, 2022).
Infill / Contiguous – Compact Growth	SEPI > 0.75 (depending on modification)	New patches emerge within or very close to old built-ups, filling "gaps" within the old urban fabric — signaling densification & spatial consolidation (Khan, 2025; Shukla & Jain, 2019).

Source: Research Team Literature Review, 2025

The strength of SEPI is its ability to capture the relational aspect of sprawl expansion, whether growth is an extension of existing clusters or the emergence of new, isolated patches, which facilitates interpretation of sprawl typologies and contiguity-based policy recommendations. SEPI is also relatively easy to calculate from multi-temporal binary map overlays (built-up vs. non-built-up) and patch geometry calculations in GIS (Shukla & Jain, 2019). However, SEPI has several limitations: it is sensitive to data resolution (small patches in low-resolution imagery can introduce bias), and it does not directly incorporate contextual factors such as proximity to the road network or

topographic characteristics. Therefore, SEPI should be combined with analysis of road proximity, buffer corridors, and other spatial attributes to ensure robust typology classification (Jatayu, 2023; Wang et al., 2020).

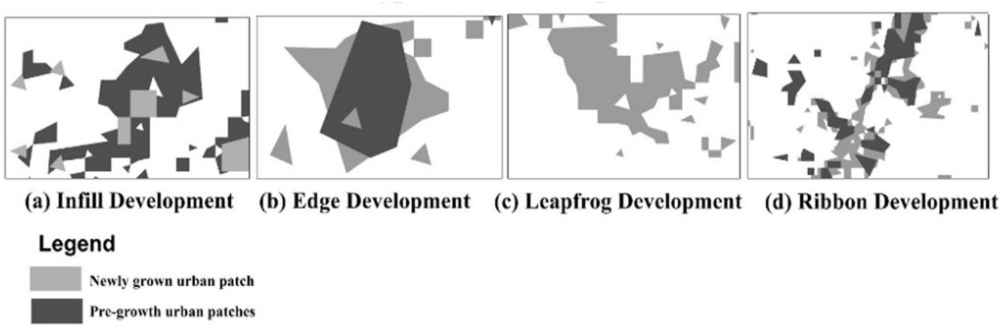


Figure 1: Urban Expansion Types
Source: Shukla & Jain, 2019

RESEARCH METHODOLOGY

This study uses a quantitative-spatial approach based on geospatial data analysis to identify urban sprawl types in six peri-urban districts of Manado City from 2004 to 2024. The analysis was conducted computationally, utilizing multi-temporal satellite imagery and techniques for extracting and quantifying built-up land change patches. The primary unit of analysis was built-up expansion patches during the study period. The analysis was conducted within district administrative boundaries to ensure the interpretation of the results remains relevant to the spatial planning policy framework.

Satellite imagery data comes from the Google Earth Engine (GEE) platform, utilizing Landsat imagery (Landsat 5/7 for 2004 and Landsat 8/9 for 2024), which is considered adequate in terms of temporal and spatial resolution for studying urban land dynamics. Administrative and boundary data were obtained from the Badan Informasi Geospasial (BIG) Indonesia. All data were converted to a consistent coordinate system before further processing.

The initial stage includes baseline image correction and a median composite to reduce cloud interference. Separation of built-up and unbuilt land is performed through a binary classification procedure using spectral indices such as the Normalized Difference Built-up Index (NDBI) and Modified Normalized Difference Water Index (MNDWI), and adaptive thresholding based on the pixel's surroundings. Visual validation is performed using point samples and high-resolution imagery in Google Earth to minimize classification errors. The results are several binary map layers: 2004, 2012, 2018, and 2024.

The resulting classification maps for each period were then overlaid to extract areas of change that became built-up land expansion patches. The patches

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were then analyzed using geoprocessing in ArcGIS to calculate the main geometric parameters, namely the area and perimeter, of the expansion patches, to identify the spatial characteristics of patch growth (Shukla & Jain, 2019).

The SEPI metric is calculated as the ratio of the area of an expansion patch to its perimeter. The SEPI value is then used to classify sprawl types into several categories, such as edge, leapfrog, ribbon, and infill development. The classification criteria refer to the approach of Shukla & Jain (2019), which assesses patches based on their location relative to existing built-up clusters and their proximity to the main road network.

The distribution of each typology was analyzed as a percentage of the total expansion area and the total number of patches. The results were interpreted to identify dominant patterns and the direction of physical development in the study area. The interpretation took into account the context of infrastructure development, the physical characteristics, and local economic dynamics to ensure more applicable policy recommendations.

ANALYSIS AND DISCUSSION

General Description of the Study Area

The study area covers six peri-urban districts of Manado City: Malalayang, Wanea, Tikala, Paal Dua, Mapanget, and Bunaken. These districts were selected because they are located on the periphery of Manado City, bordering Minahasa Regency and North Minahasa Regency (Figure 2).

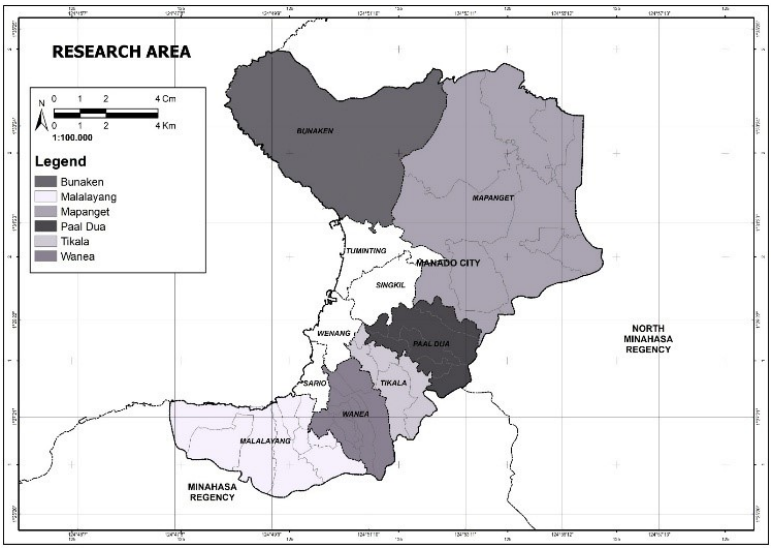


Figure 2: Delineation of the Study Area
Source: Processed Data by the Research Team, 2025

The highest elevation in Manado City is in Bunaken District, reaching an altitude of approximately 582-807 meters above sea level. Approximately 85.26% of the study area lies at elevations below 97 meters above sea level. Elevations above 96 meters above sea level are found only in Bunaken, Malayang, Mapanget, and Wanea districts. Approximately 69.75% of the study area has relatively gentle slopes between 0-15%, with the remainder having slopes above 15%. There are three districts with slopes greater than 40%: Malalayang, Bunaken, and Mapanget. Mapanget has the largest proportion of flat to gently sloping areas (0-15%), accounting for 90.31% of its total area. Meanwhile, Bunaken has only about 47.82% of its area with flat to gently sloping areas (0-15%). Overall, on the six peri-urban districts, data shows that the proportion of buildable areas (0-15%) reaches 69.75% of the total area.

Morphologically, these six districts are characterized by volcanic lava flows and hillswith a total proportion reaching 42.175%. Two districts are identified as having mountainous areas: Malalayang and Bunaken. In Bunaken District, mountainous areas account for 45.39% of the total area. Areas with tidal swamps and mangrove habitats have also been identified within this District. All six districts, with the exception of Tikala, have plains, accounting for 45.23%. Mapanget District, in particular, is the most dominant plains morphology, accounting for 82.03% of its area.

The majority of the study area falls under the low disaster risk category, reaching 97.67% of the total area. Common hazards include flooding in the catchment areas of several rivers flowing into Manado City, and landslides in areas with steep slopes and volcanic soils.

Built-up Land of the Study Area

Figure 3 shows the results of the identification of built-up land in the six districts within the study area from 2004 to 2024. The images show the periodic changes in built-up land area with different shades. The distribution of built-up land in Wanea, Tikala, and Malalayang districts tends to have almost the same pattern, where the concentration of built-up land tends to be in the zone relatively close to the service center of Manado City (Sario and Wenang districts), and decreases with increasing distance from the city center. On the other hand, in Paal Dua, Mapanget, and Bunaken districts, the distribution of built-up land looks more irregular and tends to follow the pattern of the main road network in the districts.

Table 2 shows the quantified built-up land and its percentage on each district during 2004-2024. It can be seen that in the study area, the percentage of built-up land area tends to increase over time. Wanea has the largest proportion of built-up land area, reaching approximately 45% in 2024. Bunaken has the lowest proportion of built-up land at <5% in 2024. Mapanget also has a low proportion of built-up land (<15%), while the other 3 districts (Tikala, Paal Dua,

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and Malalayang) have a fairly high proportion (approximately 30%). The very low proportion in Bunaken is mainly due to its landscape conditions, which are dominated by hilly areas with steep slopes and the presence of the protected zone of Mount Tumpa and Bunaken National Park. Mapanget District is the district with the largest buildable land area and is planned as a new development zone.

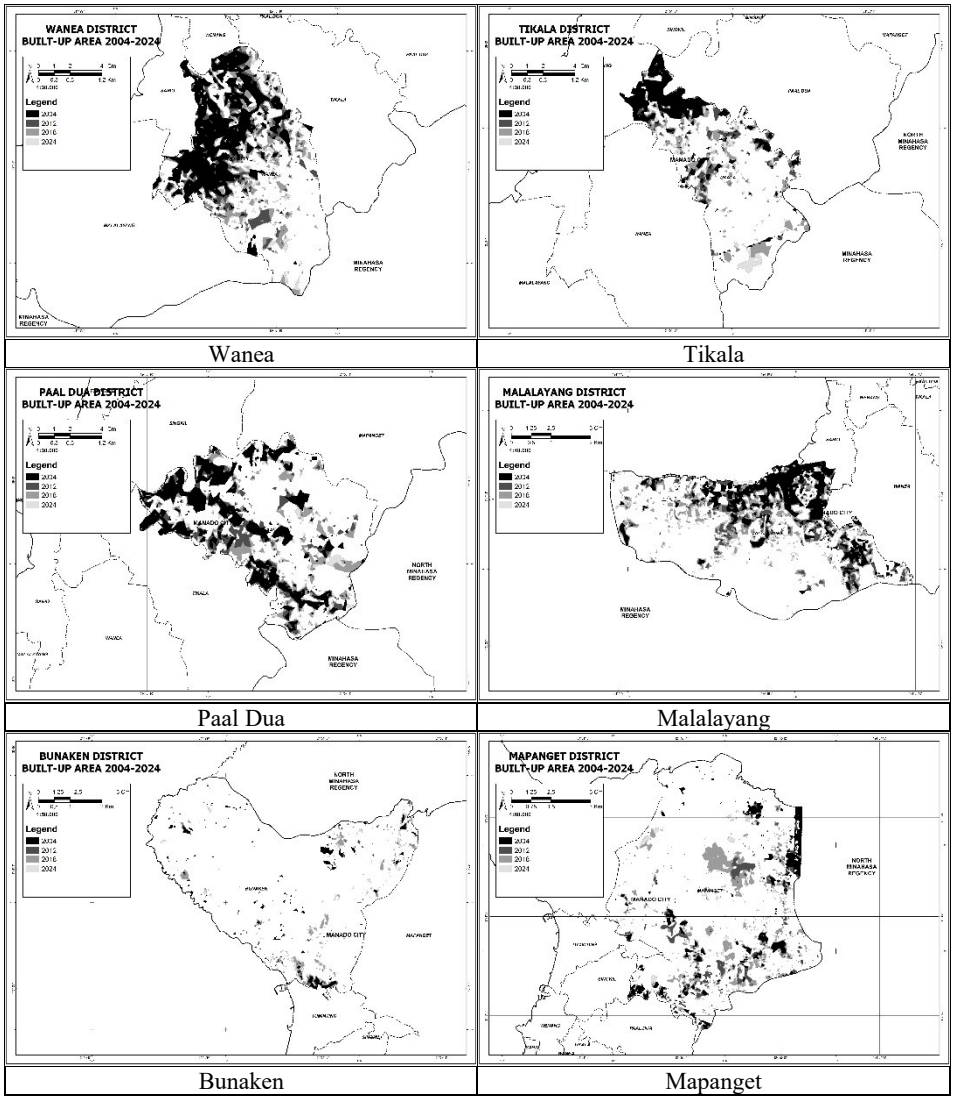


Figure 3: Map of Built-up Land Growth in the Study Area 2004-2024
Source: Processed Data by the Research Team, 2025

Table 2: Built-up Land Conditions of the Study Area

Districts	Total Area	Built-up Land							
		2004		2012		2018		2024	
	Ha	Ha	%	Ha	%	Ha	%	Ha	%
Wanea	857,45	246,62	28,76	278,94	32,53	364,43	42,50	391,27	45,63
Tikala	668,44	102,50	15,33	123,91	18,54	179,29	26,82	194,33	29,07
Paal Dua	937,26	199,17	21,25	230,48	24,59	287,86	30,71	294,00	31,37
Malalayang	1.780,84	257,08	14,44	335,86	18,86	476,11	26,74	530,74	29,80
Bunaken	3.171,65	60,89	1,92	64,79	2,04	82,19	2,59	105,35	3,32
Mapanget	5.377,33	272,32	5,06	364,68	6,78	652,06	12,13	718,21	13,36
Total	**12.792,98**	**1.138,58**	8,90	**1.398,67**	10,93	**2.041,94**	15,96	**2.233,90**	17,46

Source: Research Team Analysis Results

Table 3 below shows the growth rate dynamics of the built-up land in the study area, over three observation periods. A relatively similar pattern is evident, with an increase in the growth rate from 2012 to 2018 compared to the previous, longer period from 2004 to 2012. Conversely, there is a significant downward trend in the growth rate from 2018 to 2024, even lower than the growth rate from 2004 to 2012, except in Bunaken, which showed a slight increase compared to the previous period. The drastic decline from 2018 to 2024 is thought to be closely related to the COVID-19 pandemic, which has significantly impacted the economy and development in both the private and public sectors. Considering this, the decline in the growth rate during this period can be seen as a unique situation. Therefore, it is also estimated that the trend will likely rebound in the following period, mirroring the previous period. So, there is an urgency to replicate this study at least five years into the future to obtain a more valid trend.

Table 3: Growth of Built-up Land in the Study Area 2004-2024

Districts	Growth Rate (%)		
	2004-2012	2012-2018	2018-2024
Wanea	13,11	30,65	7,36
Tikala	20,89	44,70	8,38
Paal Dua	15,72	24,89	2,14
Malalayang	30,65	41,76	11,48
Bunaken	6,40	26,85	28,18
Mapanget	33,92	78,80	10,14
Total	**22,84**	**45,99**	**9,40**

Source: Research Team Analysis Results

Sprawl Expansion Pattern Index & Its Interpretation

According to the methodology, using the previously mapped built-up land patches from 2004 to 2024, the SEPI values then were calculated and interpreted to indicate the types of sprawl. Figure 4 is the resulting thematic maps that depict the distribution of sprawl types that occurred in the six peri-urban districts of Manado City as the study area, based on the observation period.

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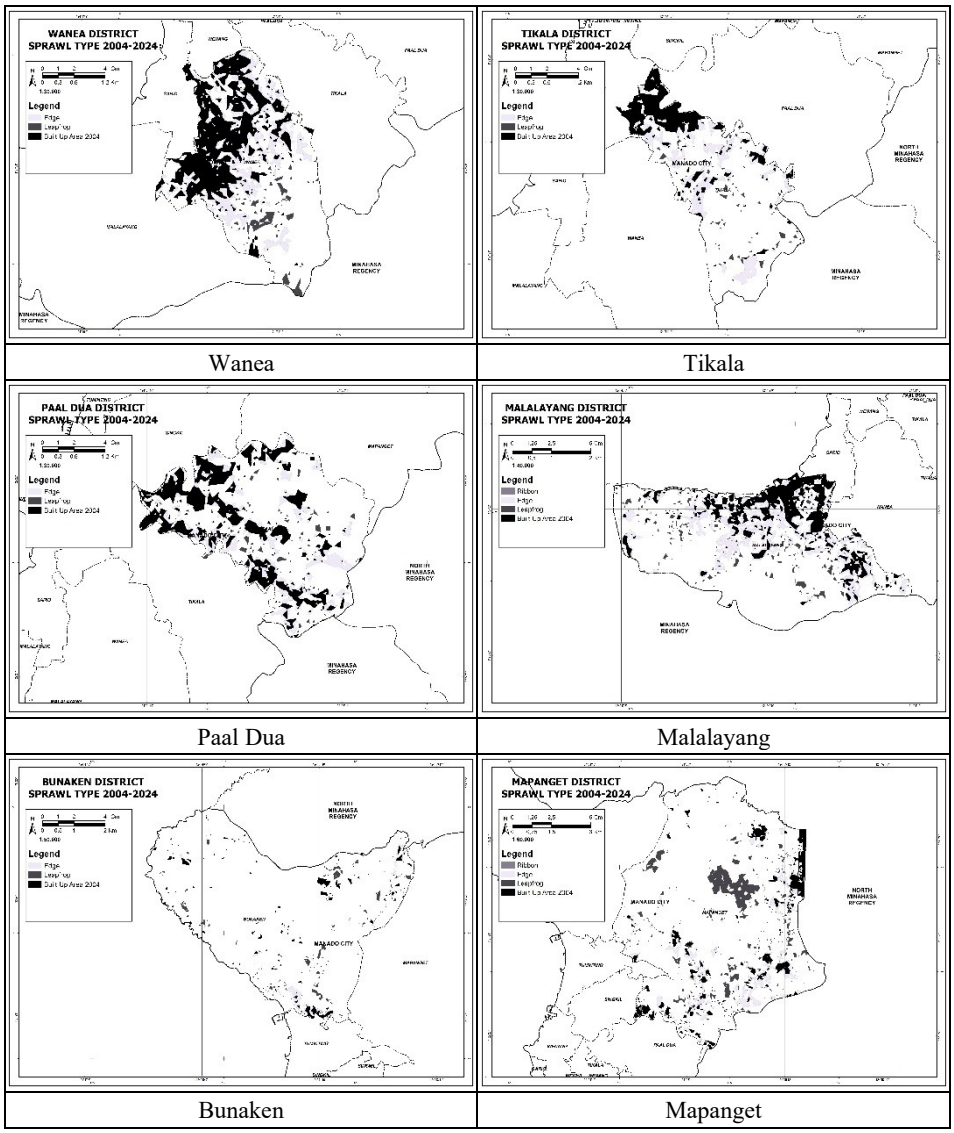


Figure 4: Sprawl Type Distribution Map in the Study Area, 2004-2024
Source: Research Team Analysis Results

Based on these thematic maps, Table 4 below quantitatively describes the types of sprawl that occurred in the study area based on the observation period. The table shows that in all peri-urban districts of Manado City, the dominant type of sprawl is edge sprawl, with a tendency to increase periodically. Field observations also indicate that this is primarily related to the expansion of

housing clusters developed utilizing the availability of undeveloped land bordering existing housing areas, driven by efforts to optimize the availability of pre-existing infrastructure and public facilities. This expansion is also suspected to be driven by considerations of land economic value and sociocultural factors, which favor building in zones with relatively established neighborhoods. In the context of expansion of several clusters of built-up land that are relatively close together, this type of sprawl is identical to infill development, which over time unites these built-up land clusters into a compact built-up cluster, encouraging increased land use efficiency and reducing open space fragmentation. This can be appreciated as a positive aspect, despite the other negative effects of sprawl.

Table 4: Sprawl Types in the Study Area 2004-2024

Districts	Sprawl Types	2004-2012		2012-2018		2018-2024	
		(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Wanea	Leapfrog	8,26	25,55	7,49	8,76	1,19	4,42
	Edge	24,06	74,45	78,00	91,24	25,17	93,77
	Ribbon	0,00	0,00	0,00	0,00	0,48	1,80
Tikala	Leapfrog	3,38	15,80	10,83	19,56	0,90	5,96
	Edge	18,03	84,20	44,52	80,39	14,02	93,26
	Ribbon	0,00	0,00	0,03	0,05	0,12	0,78
Paal Dua	Leapfrog	3,90	12,45	4,74	8,27	0,25	4,00
	Edge	27,28	87,14	51,61	89,95	5,90	95,96
	Ribbon	0,13	0,41	1,03	1,79	0,00	0,04
Malalayang	Leapfrog	10,41	13,21	20,04	14,29	3,63	6,65
	Edge	68,24	86,62	120,20	85,71	49,88	91,31
	Ribbon	0,13	0,17	0,00	0,00	1,12	2,05
Bunaken	Leapfrog	1,35	34,52	7,81	44,90	5,77	24,91
	Edge	2,55	65,48	9,59	55,10	17,33	74,82
	Ribbon	0,00	0,00	0,00	0,00	0,06	0,27
Mapanget	Leapfrog	41,57	45,00	64,43	22,42	11,51	17,40
	Edge	48,31	52,30	222,95	77,58	51,90	78,45
	Ribbon	2,49	2,69	0,00	0,00	2,74	4,14
Total	**Leapfrog**	**68,86**	**26,48**	**115,35**	**17,93**	**23,24**	**12,11**
	Edge	**188,47**	**72,47**	**526,87**	**81,90**	**164,19**	**85,53**
	Ribbon	**2,75**	**1,06**	**1,05**	**0,16**	**4,53**	**2,36**

Source: Research Team Analysis Results

Another type of sprawl observed to be quite significant is leapfrog sprawl, or "jump-over" development, which is a major contributor to open space fragmentation. While significantly different in extent from edge expansion, this type is quite prominent in Bunaken and Mapanget districts. In Bunaken district, field observations indicate that this is caused by sporadic development practices by various parties in locations separate from existing built-up land clusters. This is thought to be driven by the highly dynamic landscape conditions in this district,

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which are related to its slopes. In Mapanget district, leapfrog sprawl is typically driven by the emergence of new housing clusters separate from previously built-up land clusters. To reduce the continuation of leapfrog sprawl in peri-urban Manado, more specific spatial control mechanisms are required. In Mapanget District, where large areas of developable land remain available, local government should prioritize contiguous development through phased land development permits, mandatory adjacency requirements for new housing projects, and infrastructure sequencing policies that prioritize areas directly connected to existing built-up clusters. In Bunaken and Malalayang Districts, where topographic constraints encourage scattered development, stricter zoning enforcement and development suitability assessments should be applied to prevent isolated residential clusters on environmentally sensitive or inaccessible land. The provision of new road infrastructure and utility networks should also be selectively limited in fragmented expansion areas in order to discourage inefficient spatial growth patterns.

Ribbon sprawl is very small in proportion and is more concentrated along several main roads or new roads, such as the Manado City ring road corridor that traverses these districts.

The following Table 5 compares the cumulative growth of built-up area by sprawl type from 2004 to 2024 across the six districts of the study area. They indicate that the dominant sprawl type in all districts is edge sprawl, followed by leapfrog sprawl, while ribbon sprawl has a very small proportion.

Table 5: Comparison of Sprawl Types in the Study Area 2004-2024

Districts	Built-up Land Expansion Area (Ha) Based on Sprawl Type			
	Leapfrog	**Edge**	**Ribbon**	**Total**
Wanea	16,93	127,23	0,48	**144,65**
Tikala	15,11	76,57	0,15	**91,83**
Paal Dua	8,89	84,79	1,16	**94,83**
Malalayang	34,08	238,33	1,25	**273,66**
Bunaken	14,93	29,47	0,06	**44,46**
Mapanget	117,51	323,16	5,23	**445,89**
Total	**207,45**	**879,54**	**8,33**	**1095,32**

Source: Research Team Analysis Results

The result above shows that regardless of its proportion to the area of each district, the largest growth of built-up land occurred in Mapanget district, followed by Malalayang, Wanea, Tikala, Paal Dua, and Bunaken as the smallest. The high growth in Mapanget district is a logical consequence of the high availability of buildable land compared to other districts. This is also in line with the Manado City spatial planning policy, which designates the district as a prioritized development area. The relatively high growth in Malalayang is a logical consequence of the existence of the primary arterial road corridor which

encourages the development of this district as an extension of Manado City's service center in the Sario-Wenang district, forming a linear service center corridor. The low growth in Bunaken district is a logical consequence of its extreme landscape context with limited buildable land, the relatively long distance to the city's service center and limited infrastructure support.

CONCLUSION

Based on the analysis and interpretation, the following conclusions are drawn:

1) SEPI calculations for 2004–2024 show that urban sprawl in the study area is predominantly edge expansion, accounting for 80.30% of total built-up growth. This type occurs through the outward growth of existing built-up clusters, especially residential areas, and often functions as infill sprawl that gradually merges separate clusters into more compact forms. Such a trend indicates increasing land-use efficiency and densification. Therefore, spatial control efforts should prioritize maintaining this pattern by regulating building permits and optimizing ready-to-build areas with adequate infrastructure adjacent to existing clusters, especially in Mapanget Districts.
2) Leapfrog sprawl accounts for 18.94% and reflects fragmented development that jumps across open land. It is prominent in districts with large areas of developable land (e.g., Mapanget) or constrained topography (e.g., Bunaken and Malalayang), which limit edge expansion. This pattern should be proportionally reduced through more targeted spatial control mechanisms. In Mapanget, development permits should be directed toward contiguous edge and infill expansion by applying phased growth management, minimum adjacency requirements for new housing estates, and infrastructure provision priorities limited to areas connected with existing built-up clusters. In Bunaken and Malalayang, stricter zoning controls, topographic suitability screening, and selective infrastructure expansion should be implemented to prevent isolated residential enclaves and inefficient land fragmentation. These mechanisms are expected to support more compact and sustainable peri-urban growth in Manado City.
3) Ribbon sprawl**,** characterized by linear growth along main road corridors, represents only 0.76% of total expansion. It occurs in several primary corridors, particularly along the Manado City ring road.

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HERITAGE-MAKING AT THE PALEMBANG CHENG HO MOSQUE: ARCHITECTURE, RITUAL, AND TOURISM NARRATIVES OF CHINESE-INDONESIAN MUSLIM IDENTITY

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Abstract

The Palembang Cheng Ho Mosque is a prominent site where Chinese-Indonesian Muslim identity becomes visible through heritage discourse, religious practice, and tourism. As a hybrid landmark blending Chinese symbolism with Islamic functions, it provides a case for examining how heritage is constructed and stabilised through institutional management and everyday devotional life in contemporary Indonesia. This article analyses how the mosque operates as a heritage-making institution negotiating identity through architecture, ritual governance, and tourism narratives. Using a qualitative case-study approach, the research combines ethnographic observation, interviews, discourse analysis of signage and media, and analysis of online materials. Findings show that architectural hybridity balances ethnic visibility with Islamic legitimacy, while ritual governance regulates symbols to maintain public acceptability. Tourism narratives centred on Admiral Cheng Ho frame the mosque as a heritage attraction, and online reviews emphasise its architecture over devotional aspects, reinforcing its dual role as both a religious space and a heritage destination.

Keywords: Heritage-making, Chinese-Indonesian Muslims, mosque architecture, lived religion, tourism narratives

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INTRODUCTION

Palembang Cheng Ho Mosque is widely regarded as a symbol of cultural harmony because its architecture combines Chinese, Islamic, and local Palembang elements (Santoso & Aziz, 2021). Studies of Cheng Ho mosques across Indonesia show that this hybridity reflects the selective borrowing of multiple cultural and religious traditions (Angkasa & Kamil, 2025). However, most scholarship treats these mosques mainly as symbolic representations of identity rather than examining how they produce heritage and negotiate what counts as "Chinese," "Islamic," and "Palembang" in the public sphere (Maryamah, 2023).

This issue matters because Chinese-Indonesian Muslim identity is continuously negotiated across different domains of legitimacy and visibility (Mulyanto, 2022). Previous research shows that Cheng Ho mosques can function as markers of social status, boundary mediators, and spaces supporting Chinese Muslim communities and converts (Hasanah et al., 2022; Abidin, 2022). However, limited attention has been given to how identity negotiation occurs through the interaction of architectural symbolism, ritual practice, and public narratives (Musaffa et al., 2025; Rosi & Yousif, 2024).

At the same time, the Palembang Cheng Ho Mosque is increasingly promoted as a religious tourism destination, where media and digital platforms shape how visitors interpret the site (Sundari et al., 2023; Khairunnisa et al., 2023). Heritage scholarship shows that institutional authority, visitor interpretation, and authorised heritage discourse shape meanings at religious sites (Jin et al., 2024; Thouki, 2024), while tourism studies highlight how circulating narratives and online reviews construct heritage meanings (Soulard & Russell, 2025). Addressing this gap, this study examines how the Palembang Cheng Ho Mosque operates as a heritage-making institution through architecture, ritual governance, and tourism narratives. Accordingly, this study examines how the mosque constructs and negotiates Chinese-Indonesian Muslim identity through architecture and ritual practice, while also analysing how tourism narratives and public discourse shape its role as a heritage and religious tourism site. By integrating perspectives from heritage-making, hybridity, and lived religion, the study contributes a case from Palembang that expands discussion beyond the more commonly studied Java-centred contexts (Arabiah & Yusuf, 2025).

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Figure 1. Cheng Ho Mosque at Palembang
Source: Author's Documentation

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Heritage Making

Recent heritage scholarship increasingly treats heritage not as a stable object but as a process involving selecting, narrating, practising, and re-valuing the past in the present. This process is particularly visible in "living heritage," where everyday use and community attachment intersect with institutional conservation frameworks, meaning policy itself can shape what becomes recognised as heritage and which values are legitimised (Katapidi, 2023).

A central issue in this process concerns the relationship between authorised narratives produced by institutions and the lived meanings embedded in everyday practice. Heritage sites are often interpreted through multiple regimes—such as national heritage discourse, religious authority, regional identity, or community memory—making heritage layered and negotiated rather than singular (Tantinipankul, 2023). Although the "people-centred" turn in heritage aims to foreground community participation and social justice, its outcomes still depend on governance structures, access to resources, and professional authority (Sun et al., 2025).

In contemporary contexts, heritage-making is also shaped by tourism markets, digital platforms, and urban transformation. Online visibility, algorithmic circulation, and regeneration strategies can influence what becomes visible, preserved, or erased as heritage (Beekmans, 2025; Gu et al., 2026). At the same time, heritage is often produced through practice—such as community participation, adaptive reuse, and institutional recognition—highlighting heritage as an ongoing social process rather than a fixed legacy (Wei et al., 2024). In many contexts, these processes are also embedded in state cultural politics and administrative systems that shape classification, management, and meaning (Zhou & Huang, 2024).

Taken together, this literature suggests that heritage should be understood as a negotiated outcome produced through the interaction of institutional narratives, everyday practice, and public interpretation. In tourism environments, these processes extend beyond the physical site into mediated and

digitally circulating representations that shape how heritage is recognised and shared among wider publics (Beekmans, 2025; Katapidi, 2023; Sun et al., 2025).



Figure 2. Details and Ornaments of Cheng Ho Mosque
Source: Author's Documentation

Hybridity and Cultural Translation

Hybridity is not understood as a mix of styles but as a socially produced prcess occurring in "boundary spaces," where cultural, political, and religious meanings are negotiated. Hybrid architectural forms emerge through the interaction between material elements—such as façade, ornament, and rooflines—and shifting regimes of meaning about what a building represents and who it serves (Ahamad & Yasmoon, 2024). In this sense, hybridity reflects both adaptation and contestation, as architectural choices can signal openness across communities while also encoding hierarchy or strategic representation (Al Braifkani & Günçe, 2025).

This perspective aligns with studies treating religious buildings as urban projects shaped by political visibility and public recognition. Mosques therefore function not only as places of worship but also as spatial claims of presence and legitimacy within the city (Burchardt et al., 2023). Research on cultural translation further shows that architectural forms are reinterpreted through local typologies, identity politics, and historical narratives (Li et al., 2024), while public reception shapes whether architectural symbolism is perceived as authentic or appropriate (Alzahrani, 2022).

In mosque architecture, hybridity and cultural translation often appear through symbolic elements such as domes, minarets, and ornamentation that negotiate Islamic identity while responding to contemporary expectations of integration and aesthetic acceptability (Al Khalifa & Lafi, 2025). In Indonesia, hybrid mosque designs increasingly combine Islamic and non-Islamic references, but they also generate debates over authenticity and legitimacy (Suryandari et al., 2023). Similar concerns appear in mosque modernisation, where simplified styles raise questions about whether evolving designs still represent Muslim communal identity (Ahmed & Fethi, 2024).

Finally, mosque legitimacy is negotiated not only within Muslim communities but also through public discourse, planning systems, and media representation. Studies in Europe show that mosque architecture often becomes

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a symbolic site where issues of identity, citizenship, and multiculturalism are articulated (Yardimci & Martin, 2024). In this context, hybrid mosque architecture can strengthen internal belonging while presenting a publicly legible identity to broader audiences.

Religious Tourism and Heritage Consumption

Traditional religious tourism was often rooted in hereditary sacred rituals, but contemporary motivations increasingly combine worship with appreciation of Islamic architecture and cultural experience. Mosques now function not only as places of worship but also as social arenas supporting education, community activities, and local economic development. As tourism attractions, they offer visitors spiritual experience, architectural appreciation, and spaces for reflection and social interaction.

The growth of modern religious tourism is strongly influenced by the architectural appeal of contemporary mosques, including their ornamentation, monumental forms, and visual atmosphere. Architectural grandeur also encourages visitors to document and share mosque imagery, reinforcing their visibility as cultural and tourism landmarks.

Perceptions of the mosque are categorised into three main tourism types:

- Religious: Visitors view the mosque as a sacred site for prayer and traditional pilgrimages (ziarah) to ancestral graves.
- Historical: It is seen as a vital cultural heritage site protected by law
- Educational: Students and researchers perceive the mosque complex as a "living museum" for learning Islamic history and heritage.

RESEARCH METHODOLOGY

This study adopts a qualitative, interpretive single-case study design, treating Masjid Al-Islam Muhammad Cheng Ho Sriwijaya Palembang as a bounded case to examine heritage-making, Chinese-Indonesian Muslim identity negotiation, and public tourism narratives. Single-case designs are suitable for explaining how meaning-making processes unfold within a specific institutional context and when the case is analytically information-rich (Mtisi, 2022). To capture how heritage meanings extend beyond the physical site, the study also analyses publicly accessible digital materials, including tourism websites, media coverage, and visitor-generated online reviews.

Case Selection and Bounding

The Cheng Ho Mosque was purposively selected because it functions simultaneously as a religious institution, a symbol of Chinese Muslim visibility, and a tourism site within Palembang's Muslim-friendly destination framing (Ary

Anggara et al., 2024). The case is bounded by (a) the mosque complex and visitor infrastructure, (b) key ritual activities such as daily prayers and Islamic events, and (c) public narrative arenas including tours, promotional materials, media coverage, and online platforms discussing the mosque.

Data Sources and Fieldwork Strategy

To examine identity negotiation across architecture, ritual practice, and tourism narratives, this study uses a multi-source qualitative corpus with four strands:

1. Architectural–visual and spatial documentation
   Photography, field sketches, and spatial notes document how built form and ornament express cultural–religious meanings (Sastra, 2023; Angkasa & Kamil, 2025).
2. Participant observation of ritual and everyday practice
   Observations examine religious activities, visitor management, and negotiations between worship and tourist space (Thouki, 2022).
3. Semi-structured interviews
4. Interviews with mosque managers, worshippers, community members, guides, and visitors capture diverse interpretations of the mosque. Sampling combines purposive and snowball methods to access knowledge-rich participants (Czernek-Marszałek & McCabe, 2024).
5. Document and discourse corpus (tourism and public narratives)
   Brochures, signage, tourism materials, and news articles are analysed alongside 4,709 Google Maps reviews and ~45 online articles (2018–2025). A purposive sample identifies recurring narrative frames and compares visitor discourse with institutional and media representations (Thouki, 2022).

Analytical Approach

Analysis proceeds iteratively and comparatively across the four data strands:

- Reflexive thematic analysis (RTA) identifies recurring identity themes in interviews and fieldnotes, including visibility, belonging, religious legitimacy, and tourism appropriateness (Byrne, 2022).
- Socio-semiotic analysis examines how visual-spatial elements—such as colour schemes, pagoda or minaret references, calligraphy, and spatial boundaries—signal identity and hybridity (Fauziyanti, 2022; Angkasa & Kamil, 2025).
- Narrative and discourse analysis explores how tourism-facing texts frame the mosque as heritage, multicultural harmony, and a Muslim-friendly tourism site (Thouki, 2022; Thouki & Skrede, 2025).

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- Keyword frequency coding of Google Maps reviews identifies recurring descriptors related to tourism, culture, architecture, Chinese identity, and religious function, while online articles are analysed for recurring narrative patterns.

Ethics and Positionality

The study follows standard qualitative ethics, including informed consent for interviews, anonymisation of non-public participants, and careful handling of sensitive topics such as ethnicity, conversion, and intra-Muslim differences. Observations in public tourism areas are conducted through non-intrusive note-taking, while observations of worship activities prioritise discretion and respect for congregational norms.

The digital corpus consists solely of publicly accessible materials (e.g., Google Maps reviews and online articles). Usernames are not reported, and excerpts are selectively anonymised. These materials are treated as publicly circulating discourse rather than private communication, in line with recent guidance on transparency and responsibility in qualitative research reporting (Ahmad & Wilkins, 2025).

Analytically, the study integrates interviews, observation, and digital corpus through thematic triangulation. Interviews examine institutional narratives, management intentions, and community perspectives, while observations explore how these narratives are spatially practised through visitor circulation, worship boundaries, signage, and everyday interactions. The digital corpus traces how the mosque is represented and interpreted in wider public discourse beyond mosque management.

These three sources were coded using the same thematic framework, including heritage identity, religious legitimacy, visitor behaviour, multicultural symbolism, and tourism framing. The analysis compares points of convergence and tension across interviews, observations, and digital discourse to examine how heritage meanings are produced through institutional, spatial, and public narratives.

The online reviews and article corpus were purposively selected to examine how Cheng Ho Mosque is publicly narrated as heritage rather than to measure public opinion statistically. Google Maps reviews provide place-specific and visitor-generated perspectives on architecture, religious atmosphere, tourism value, and visitor experience. Online articles reflect broader media and tourism narratives, including multiculturalism, Chinese–Islamic acculturation, religious tourism, Palembang heritage, and Admiral Cheng Ho symbolism.

Source selection was based on relevance, public accessibility, and narrative richness. Included materials discussed the Cheng Ho Mosque in relation to architecture, cultural identity, religious function, visitor experience, or tourism

value, while duplicated, irrelevant, promotional, or non-Palembang materials were excluded.

Field Sites and Access

The Palembang Cheng Ho Mosque is located in the 15 Ulu district of Palembang, within a predominantly residential area that is calm yet strategically accessible from the Jakabaring urban corridor. Its position within everyday neighbourhood life, combined with convenient road access, supports its dual role as a local religious institution and a city-level heritage and tourism landmark.



Figure 3. Cheng Ho Mosque's Site, 15 Ulu district at Palembang City, the Location of Cheng Ho Mosque
Source: Author's Documentation

FINDINGS

Architecture as Heritage Language

The Cheng Ho Mosque's architecture functions as a heritage language that presents the site as Chinese, Islamic, and Palembang/Sriwijayan through layered architectural cues. Chinese identity appears mainly through roof forms and red–

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gold ornamentation, while Islamic identity is anchored in the spatial organisation of worship, including prayer orientation, the mihrab–minbar axis, and Quranic inscriptions. Palembang identity is conveyed through narratives linking the mosque to local history and civic identity.



Figure 4. Cheng Ho Mosque Monuments
Source: Author's Documentation

These architectural cues generate multiple interpretations. Some visitors view the mosque as a symbol of tolerance and plural belonging, while others interpret the same features as visual branding within religious tourism.

A key finding is the gap between institutional narratives and visitor interpretations. Mosque management frames Chinese elements as cultural heritage while maintaining Islamic legitimacy through ritual practice and spatial rules. Visitors, however, often focus on visible Chinese aesthetics, sometimes overlooking ritual boundaries. This tension becomes visible through spatial negotiations, such as photography near prayer areas, where signage, routing, and guided explanations help reinforce the mosque's heritage and religious meaning.

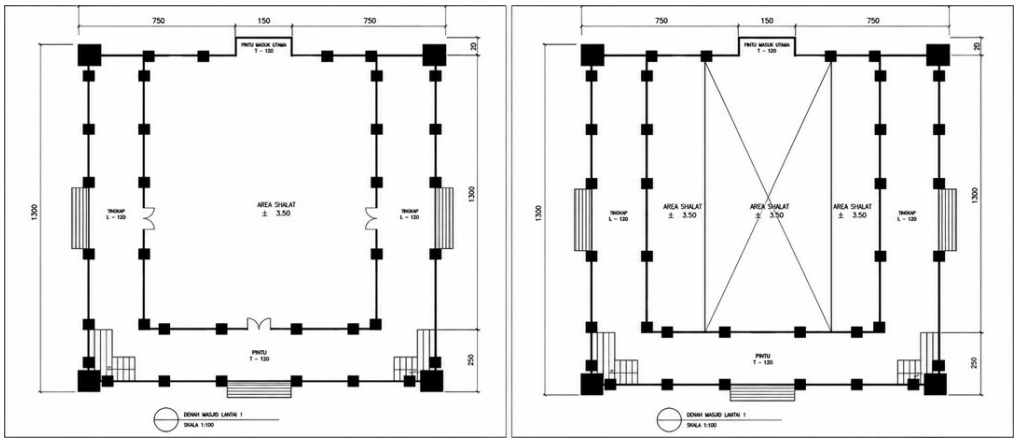


Figure 5. Layout of Cheng Ho Mosque
Source: Author's Drawing



Figure 6. Views of Cheng Ho Mosque
Source: Author's Drawing

Ritual Practice and Governance of Belonging (lived religion)

Ritual practice at the Cheng Ho Mosque produces a sense of belonging among Chinese-Indonesian Muslims by allowing Chinese cultural identity to remain visible within an Islamic framework. This belonging is shaped through three main practices. First, the mosque creates a Sinicised Islamic environment through pagoda-inspired forms, red–green colours, and lotus motifs. Second, support programs provide religious guidance and social support for Chinese converts without requiring them to abandon their cultural identity. Third, public religious and social activities, including Nuzulul Qur'an events, health services, and blood donation programs, open the mosque to wider communities and reduce perceptions of ethnic exclusivity.

Governance further strengthens this role by positioning the mosque as a bridge between Chinese-Indonesian Muslims and the wider public. Through the Haji Muhammad Cheng Ho Indonesia Foundation and the Indonesian Chinese Islamic Association (PITI), the mosque maintains formal Chinese Muslim leadership while remaining open to all Muslims and visitors. Community services, education programs, and philanthropy extend its role beyond worship into social welfare.

The core argument is that Cheng Ho Mosque does not simply display Chinese-Islamic identity architecturally; it actively manages belonging through ritual, education, openness, and social service. In this way, the mosque protects Chinese Muslim identity, builds inter-ethnic connections, and converts cultural differences into socially accepted religious heritage.

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Table 1: Layered Governance of Belonging at the Cheng Ho Mosque

Layers	Group	How to Determine a Sense of Belonging
Core	PITI Management & Foundation	Implement organizational rules and maintain the sustainability of acculturation rituals.
Active	Chinese Congregants & Converts	Feel culturally represented through rituals and feel protected by organizational rules.
Peripheral	general public	feels a sense of belonging because the mosque provides social benefits without discrimination based on ethnicity (through health and education services).

Source: Author's Summarises and Self-made

Tourism and Public Narrative

Heritage mosque tourism positions historic mosques as both religious spaces and cultural heritage landmarks, combining spiritual, historical, and architectural value. In Indonesia, many historic mosques have developed into religious tourism destinations that integrate Islamic devotion, cultural preservation, and local economic development. Their management therefore requires balancing tourism promotion with religious sanctity and cultural authenticity.

Key dimensions of heritage mosque tourism include heritage preservation, tourism development, community participation, and balanced management. These support architectural conservation, visitor attraction, community-based tourism (CBT), and the protection of religious integrity. Mosque tourism also encourages cross-cultural exchange and visitor learning through interpretation and visitor experience.

The Al-Islam Muhammad Cheng Ho Mosque in Palembang exemplifies multicultural religious tourism, combining Chinese, Malay, and Islamic influences. Its distinctive architecture—red and jade colours, pagoda-style elements, and Chinese ornamentation—symbolises the historical legacy of Admiral Cheng Ho and the region's plural cultural identity.

To examine how tourism narratives circulate publicly, a digital corpus was analysed comprising 4,709 Google Maps reviews and approximately 45 online articles (2018–2025). This dataset reveals recurring patterns in how the mosque is framed and consumed as heritage.

Table 10: Dominant Keywords in Google Maps Reviews (n = 4,709)

Thematic Category	Keyword	Frequency	Approx. %
Tourism Framing	tourism / destination	92	1.95%
Cultural Identity	culture	82	1.74%
Visitor Experience	comfortable	26	0.55%
Architectural Features	ornament	26	0.55%
Architectural Identity	Chinese architecture	17	0.36%
Religious Expression	"SubhanAllah"	17	0.36%
Architectural Comparison	temple / klenteng	12	0.25%
Architectural Feature	pagoda	12	0.25%
Religious Conversion	convert / muallaf	8	0.17%

Frequency patterns show that tourism and culture-related descriptors appear more prominently than devotional language in visitor discourse. Architectural references—especially Chinese stylistic elements and pagoda forms—reinforce the mosque's visual distinctiveness, while explicitly religious expressions appear less frequently.

Table 3: Dominant Narrative Frames in Online Articles (2018–2025)

Narrative Category	Recurring Framing Patterns
Multicultural Harmony	multiculturalism, tolerance, coexistence, diversity
Cultural Acculturation	Islamic–Chinese blending, acculturation
Historical Legacy	history, Sriwijaya heritage, legacy
Religious Tourism	religious tourism, destination, attraction
Architectural Hybridity	pagoda-style minaret, red façade, Chinese-inspired design
Minority Muslim Identity	Chinese Muslim identity, symbol of visibility

Source: Author's Summarises and Self-made

Across media and tourism platforms, the mosque is often framed as a symbol of multicultural harmony rather than solely a ritual space, positioning it as a religious site, heritage landmark, and tourism asset. Educational facilities (TPA) and community spaces further support its role as a "living heritage" site where worship and public engagement coexist. As an iconic landmark of Palembang, the mosque enhances tourism visibility while requiring ongoing negotiation between religious sanctity, cultural representation, and tourism framing. Taken together, the case shows that heritage status is continuously produced through institutional management, visitor interpretation, and public narratives.

Heritage Conservation Management Plan and Integration with Palembang's Urban Tourism Strategy

A Heritage Conservation Management Plan is needed to conserve Cheng Ho Mosque not only as a tourism attraction but also as a living religious and cultural heritage site. Its significance lies in the combination of Chinese architectural expression, Islamic worship functions, and Palembang/Sriwijayan cultural narratives. This layered identity has also been identified in previous studies, where Chinese-Islamic acculturation is expressed through architectural form, ornament, colour, and symbolism (Santoso & Aziz, 2021).

The conservation plan should adopt a values-based and living-heritage approach protecting both tangible heritage—such as pagoda-inspired forms, ornaments, inscriptions, and worship layout—and intangible heritage, including worship practices and Chinese Muslim identity. Sustainable conservation should also involve community participation, collaborative governance, and integration with wider urban development (Liorančaitė-Šukienė & Jurėnienė, 2025; Ripp et al., 2025). Because the mosque remains an active place of worship, visitor

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circulation, photography zones, signage, and etiquette guidance should prevent tourism activities from disrupting sacred functions (Merina & Pratama, 2025).

Interpretation and education should be strengthened through panels, guided narratives, and digital tools explaining Admiral Cheng Ho, Chinese Muslim history, Islamic spatial elements, and Palembang's multicultural identity. This can prevent the mosque from being reduced to a Chinese-style landmark while supporting wider heritage tourism initiatives in Palembang, including QR-code interpretation systems in heritage areas such as Sekanak River (Widyawan et al., 2025).

Finally, Cheng Ho Mosque should be integrated into Palembang's wider tourism strategy as part of a multicultural and religious heritage network. As a historic river city shaped by riverside settlements and collective memory (Anwar et al., 2025), Palembang provides a broader context linking the mosque to river-based and religious-cultural heritage destinations. However, tourism promotion should not reduce the mosque to a photo object. Visitor management, community participation, and local benefit-sharing are therefore needed to ensure tourism supports conservation, education, and community welfare (Oktavia et al., 2025).

DISCUSSION

The findings show that the Palembang Cheng Ho Mosque negotiates Chinese-Indonesian Muslim identity by transforming cultural difference into institutionally managed heritage. Chinese architectural cues make ethnic identity publicly visible, while Islamic spatial organisation maintains religious legitimacy and local narratives connect the mosque to Palembang identity. Digital discourse further amplifies architectural distinctiveness and multicultural symbolism, reinforcing the mosque's role as both a heritage landmark and tourism site.

However, these meanings also circulate beyond institutional control. Online reviews and media narratives often frame the mosque through tourism and multicultural lenses, producing competing interpretations as both a symbol of tolerance and a tourist attraction. Institutional narratives therefore present Chinese elements as cultural heritage rather than religious doctrine to maintain religious legitimacy (Thouki, 2022). This indicates that heritage governance involves not only preserving architecture, but also managing meanings, visitor behaviour, and religious boundaries.

The study's planning contribution lies in showing that Cheng Ho Mosque requires an integrated heritage management approach. Heritage governance should involve mosque management, PITI, local communities, and tourism stakeholders to protect both architectural hybridity and religious function. Visitor management through circulation routes, photography zones, signage, and worship-time controls can reduce conflict between tourism and

sacred practice while maintaining public access. Spatial interpretation should be strengthened through panels, guided narratives, and digital media explaining the mosque's Chinese-Islamic symbolism, Admiral Cheng Ho, Islamic spatial order, and Palembang's multicultural history. The mosque should also be integrated into Palembang's cultural and religious tourism strategy not merely as a photo landmark, but as a site supporting education, intercultural understanding, community benefit, and respect for worship.

In this context, the mosque functions as a heritage-making institution mediating between worshippers, visitors, and civic audiences. When framed as heritage and aligned with Islamic norms, Chinese aesthetics allow minority Muslim identities to remain visible while socially legitimate (Angkasa & Kamil, 2025), consistent with previous studies identifying Cheng Ho Mosque hybridity as a marker of Chinese Muslim identity (Fauziyanti, 2022). From a planning perspective, successful religious-heritage tourism depends on balancing conservation, interpretation, visitor management, and protection of sacred spaces.

CONCLUSION

This study shows that the Palembang Cheng Ho Mosque operates as a heritage-making institution where architectural hybridity—through Chinese visual elements, Islamic spatial requirements, and Palembang-local narratives—shapes how Chinese-Indonesian Muslim identity becomes publicly visible and interpreted. Rather than simply representing mixed identity, these architectural cues organise how identity is narrated across audiences. Digital visitor discourse further reinforces the mosque's role as both a religious space and cultural tourism landmark through architectural distinctiveness and multicultural symbolism (Volzone et al., 2025).

At the same time, hybridity functions as governance rather than only aesthetics. Institutional narratives frame Chinese elements as cultural heritage while maintaining Islamic legitimacy, allowing the mosque to attract visitors while preserving ritual order (Bukhari, 2025). However, tourism circulation can also produce simplified narratives of tolerance and architectural spectacle that obscure more complex lived realities (Merina & Pratama, 2025). Such narratives reflect broader public recognition frameworks that stabilise certain forms of difference while simplifying lived pluralism (Young, 2021; Thompson & Modood, 2024).

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METHODOLOGICAL FRAMEWORKS FOR SUSTAINABLE RURAL SETTLEMENT PLANNING IN UZBEKISTAN: INTEGRATING LOW-RISE COURTYARD HOUSING AS A CASE STUDY

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Abstract

Sustainable rural development in Uzbekistan requires integrated and scientifically grounded planning approaches that combine legislative reform, participatory governance, spatial analysis, and context-sensitive housing design. This study examines methodological frameworks for rural settlement planning with specific integration of low-rise courtyard housing as a sustainable rural development model. Existing studies primarily address rural planning components separately and lack a unified methodological framework. The research applies document analysis, GIS-based spatial assessment, program evaluation, and case studies from the Andijan and Khorezm regions. Results show that more than 1,020 mahalla citizen assemblies received planning documentation between 2020 and 2022, while integrated courtyard housing models reduced infrastructure costs by 22%, increased community participation to 89%, and supported significant growth in rural mortgage investment. The study concludes that combining legislative reform, GIS-supported planning, participatory governance, and low-rise courtyard housing provides an effective framework for sustainable rural development in Uzbekistan.

Keywords: Urban planning, rural settlements, sustainable development, Uzbekistan, low-rise courtyard housing, master plans, GIS, participatory planning, mahalla governance.

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INTRODUCTION

Rural settlements in Uzbekistan play a pivotal role in the nation's socio-economic development, as a significant proportion of the population resides and works in these areas, as a significant share of the population resides and works in these areas (Hulkaroy, 2025; Kayumov, 2024). Sustainable rural development is essential for generating employment, fostering income growth, and improving living standards (Baydoun et al., 2023). Recognizing this imperative, the Uzbekistan-2030 Strategy outlines ambitious targets, including raising the national urbanization rate to 60% and expanding housing and infrastructure provision through comprehensive planning initiatives (Kamaev, 2025; Tekir, 2025).

Despite strong government commitments, rural settlements continue to face enduring challenges: inadequate infrastructure, limited access to education and healthcare, unemployment, and labor out-migration (Akcapar & Çakır, 2024; Sankar, 2023). Climate change and demographic pressures further exacerbate these difficulties. Addressing them requires scientifically grounded methodological approaches to urban planning that integrate economic, environmental, and social dimensions (Swanson, 2021).

Urban planning in Uzbekistan has undergone significant reforms to address these issues (Ahn & Juraev, 2023; Sobirovich, 2025). The Presidential Decree No. PF-5577 (2018) introduced a new Urban Planning Code, expanding legal provisions from 59 to 85 articles and strengthening mechanisms for public participation in master plan development (Abduganiyeva, 2023; Qizi, 2025). These reforms draw from international experiences in countries such as Germany, Russia, the United States, Canada, and Finland, reflecting deliberate alignment with global planning standards (Gerten et al., 2022).

Recent scholarship on Islamic architectural ornamentation, including studies on the placement principles of Islamic calligraphy in public buildings and the enduring legacy of the mashrabiya, underscores how visual-cultural logics shape spatial organization and façade articulation in Muslim contexts (Baydoun et al., 2024, 2025). Scholarly contributions have also shaped rural settlement planning in Uzbekistan. Baydjanov's *Architectural Planning of Settlements and Public Centers* emphasizes spatial and compositional design principles, while Tursunov's *Planning of Rural Settlements* highlights infrastructure and social facility integration (Abdiramanov et al., 2025; Baydjanov Ibadulla Samandarovich, 2025; Narzullaev et al., 2022). Regulatory frameworks such as the Urban Planning Standards and Regulations (UPSR 2.07.01-23) provide essential technical guidance for rural construction (Bekmurodovna, 2025; Sharipovna, 2021). Together, academic works and legislative measures form the foundation for sustainable rural settlement strategies (Alibašić & Zokirova, 2024; Alikhanov et al., 2023; Kholdorov et al., 2023).

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A critical research gap persists, however. Existing studies tend to focus on individual components, legal reforms, spatial design, or infrastructure provision, without integrating them into a unified, holistic methodological framework. Furthermore, few studies address how specific housing typologies, particularly low-rise courtyard housing, can be systematically integrated into broader rural planning approaches.

Although previous studies have examined legislative reforms, infrastructure development, and housing design in Uzbekistan, most studies address these components separately rather than through an integrated rural planning framework. Limited research has examined how participatory governance, GIS-based spatial planning, and low-rise courtyard housing can be systematically combined within a unified methodology for sustainable rural settlement development. This paper directly addresses these gaps, by developing a comprehensive methodological framework that consolidates:

1. Legislative reforms and policy mandates.
2. Statistical evidence from the national Obod Qishloq and Obod Mahalla programs.
3. Practical insights from local mahalla governance.
4. Housing typology integration: low-rise courtyard housing as a case study aligned with rural livelihoods, agricultural activities, and cultural values.

By doing so, this study makes significant contributions to both academic discourse and practical policy, providing a roadmap for achieving Uzbekistan-2030 Strategy goals through a sustainable, inclusive, context-specific approach to rural development.

CONCEPTUAL FRAMEWORK: HOUSING TYPOLOGIES AND RURAL SUSTAINABILITY

Rural Context and Housing Requirements

Rural settlements in Uzbekistan are territories where the population is predominantly engaged in agriculture, livestock breeding, and family-based entrepreneurship. These economic activities fundamentally shape spatial organization, infrastructure requirements, and housing design needs. The rural population, comprising workers, peasants, farmers, and family entrepreneurs, requires housing solutions that accommodate productive agricultural and livestock activities on private plots, support household-scale food production and economic self-sufficiency, align with cultural values emphasizing family cohesion and traditional lifestyles, enable efficient management of productive activities alongside residential functions, and provide cost-effective construction and long-term maintenance solutions.

Traditional rural housing in Uzbekistan has historically centered on courtyard-based designs. This typology naturally evolved to meet these requirements, providing space for household gardens, livestock facilities, and extended family interactions.

Low-Rise Courtyard Housing: Definition and Characteristics

Low-rise courtyard housing refers to single- to two-story residential structures built around private or semi-private courtyards, typically on plots ranging from 600 to 1,000 square meters. Each dwelling unit provides primary living spaces (5-7 rooms), direct access to private courtyard areas, space for auxiliary structures (storage, livestock facilities, farming infrastructure), and on-site water and utility connections suitable for household management. This housing typology corresponds directly to traditional rural lifestyles, supporting small-scale household farming while ensuring favorable living environments and social stability.

Advantages of Low-Rise Courtyard Housing for Rural Development

Based Research and practical experience in Uzbekistan demonstrate that low-rise courtyard housing provides significant advantages for sustainable rural development:

Economic Efficiency: Low-rise courtyard housing offers lower construction and maintenance costs compared to multi-story residential buildings. It reduces on-site infrastructure requirements when clustered appropriately, while creating opportunities for household-scale income generation through agricultural and small-business activities on private plots. Additionally, it boosts property values and investment attractiveness in rural markets.

Health and Social Benefits: Courtyard-based living positively impacts human health, nervous system functioning, and social relationships. It provides environmental and psychological comfort through access to green spaces and natural light, while supporting strong intergenerational family bonds and cultural practices centered on private courtyards.

Cultural and Lifestyle Compatibility: This housing model preserves and sustains family values, hospitality traditions, and close intergenerational relationships. It aligns with rural customs and values that emphasize autonomy and household self-sufficiency, facilitating traditional practices including small-scale agriculture, gardening, and livestock husbandry. It also supports social cohesion through mahalla-based clustering and shared community facilities.

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Food Security and Economic Activity: Low-rise courtyard housing enables national food security through household-scale crop production and livestock raising. It creates opportunities for local employment and family-based entrepreneurship, reduces household food and energy costs through on-site production capabilities, and builds economic resilience through household economic diversification.

International rural planning models in Germany, Finland, China, and Turkey demonstrate the importance of integrated infrastructure provision, participatory governance, and land-use coordination in sustainable rural development. However, many existing frameworks emphasize either physical infrastructure or economic modernization without sufficiently integrating culturally responsive housing typologies and community governance structures. In the Uzbekistan context, limited research has examined how housing typology selection can function as a core planning mechanism supporting sustainability, economic resilience, and social cohesion simultaneously.

RESEARCH METHODOLOGY

This study employed a mixed qualitative and quantitative approach to investigate methodological frameworks for sustainable rural settlement planning in Uzbekistan, with specific integration of low-rise courtyard housing design principles. The Andijan and Khorezm regions were selected as representative case studies due to their active participation in national rural development programs and their contrasting planning characteristics. Andijan represents densely populated rural settlements with extensive infrastructure planning requirements, while Khorezm provides a strong example of traditional courtyard housing integrated with agricultural livelihoods and mahalla-based settlement organization.

Research Components:

1. **Document Analysis:** Comprehensive review of presidential decrees, cabinet resolutions, and the Urban Planning Code to trace legislative reforms and planning strategies.
2. **Program Data Analysis:** Evaluation of major government initiatives, Obod Qishloq and Obod Mahalla programs (2020-2022), collectively engaging over 1,000 rural mahallas, providing statistical evidence on scale, effectiveness, and implementation challenges.
3. **Geographic Information Systems (GIS) Analysis:** Application of GIS tools to service coverage mapping, infrastructure allocation, and spatial planning optimization in the Andijan region case study.

4. **Housing Typology Integration:** Analysis of low-rise courtyard housing design principles derived from the Khorezm region case study, examining how this typology aligns with master planning methodologies and rural sustainability goals.
5. **Participatory Assessment:** Evaluation of community engagement mechanisms through mahalla governance structures, assessing their role in planning efficiency, investment attractiveness, and social sustainability.

Together, these methods provided a multidimensional understanding combining policy evaluation, program performance analysis, design innovation assessment, and community-level insights. Figure 1 provides a macro-level overview of the administrative and territorial structure of the study area, illustrating connections between Andijan Province (Viloyat), its districts (Tumanda), and individual rural settlements (Mahalla), demonstrating how urban planning scales from regional to community levels.

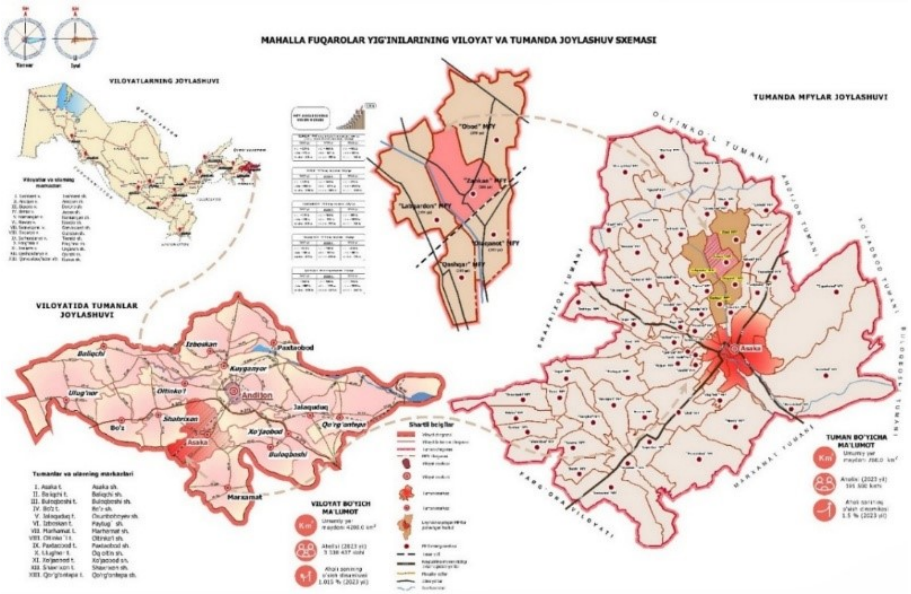


Figure 1: Geographical connections and territorial layout of rural settlements in the study region.

This study is subject to several limitations. First, the analysis focuses primarily on selected case studies in Andijan and Khorezm regions, which may limit generalizability across all rural regions of Uzbekistan. Second, portions of the analysis rely on government program data and planning reports, which may

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contain institutional reporting bias. Third, several planning projects remain under implementation, limiting long-term assessment of socio-economic and environmental outcomes.

RESULTS

Program Outcomes: National Scale and Commitment

To quantitatively assess progress in recent urban planning initiatives, this study analyses statistical data from major government programs, the Obod Qishloq and Obod Mahalla initiatives implemented between 2020 and 2022. During this period, detailed planning projects were developed for more than 1,000 rural settlements across Uzbekistan, representing institutional commitment to scaling modern planning methodologies. Tables 1, 2, and 3 provide year-by-year breakdowns of Mahalla Citizen Assemblies (MCAs) receiving comprehensive planning documentation under the program approved by Cabinet of Ministers Resolution No. 639 [20].

Table 1: Works completed in 2020 within the framework of the Program approved by Resolution No. 639 of the Cabinet of Ministers of the Republic of Uzbekistan. *(Data source: Government of Uzbekistan)*.

No.	Name of Region	Mahalla Citizen Assembly (MCA)	Of which: in 2020	
			Core NCAs	Adjacent NCAs
	Total	315	100	215
1	Republic of Karakalpakstan	22	7	15
2	Andijan Region	25	7	18
3	Bukhara Region	30	9	21
4	Jizzakh Region	19	7	12
5	Kashkadarya Region	11	4	7
6	Navoi Region	20	12	8
7	Namangan Region	26	9	17
8	Samarkand Region	18	6	12
9	Surkhandarya Region	32	7	25
10	Syrdarya Region	12	5	7
11	Tashkent Region	42	12	30
12	Fergana Region	27	5	22
13	Khorezm Region	31	10	21

Table 2. Works completed in 2021 within the framework of the Program approved by Resolution No. 639.
(Data source: Government of Uzbekistan)

No.	**Name of Region**	**Mahalla Citizen Assembly (MCA)**	**Of which: in 2021**	
			Core NCAs	**Adjacent NCAs**
	Total	312	104	208
1	Republic of Karakalpakstan	37	10	27
2	Andijan Region	24	6	18
3	Bukhara Region	26	8	18
4	Jizzakh Region	21	7	14
5	Kashkadarya Region	12	5	7
6	Navoi Region	19	12	7
7	Namangan Region	22	8	14
8	Samarkand Region	32	10	22
9	Surkhandarya Region	17	6	11
10	Syrdarya Region	14	6	8
11	Tashkent Region	35	9	26
12	Fergana Region	23	5	18
13	Khorezm Region	30	12	18

Table 3. Works completed in 2022 within the framework of the Program approved by Resolution No. 639.
(Data source: Government of Uzbekistan)

No.	Name of Region	Mahalla Citizen Assembly (MCA)	Of which: in 2022	
			Core NCAs	Adjacent NCAs
	Total	393	112	281
1	Republic of Karakalpakstan	36	11	25
2	Andijan Region	26	7	19
3	Bukhara Region	33	12	21
4	Jizzakh Region	14	5	9
5	Kashkadarya Region	31	7	24
6	Navoi Region	40	12	28
7	Namangan Region	32	8	24
8	Samarkand Region	40	11	29
9	Surkhandarya Region	30	8	22
10	Syrdarya Region	15	5	10
11	Tashkent Region	29	9	20
12	Fergana Region	31	5	26
13	Khorezm Region	36	12	24

Overall, the statistical results demonstrate a steady institutional expansion of rural planning implementation between 2020 and 2022. The increase from 315 mahallas in 2020 to 393 mahallas in 2022 indicates strengthening administrative capacity and growing national prioritization of rural development initiatives. Regions with consistently high implementation levels,

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including Khorezm, Tashkent, and Karakalpakstan, reflect strategic investment concentration and population-driven planning demand.

Analysis: The cumulative data (2020-2022) shows a total of 1,020 MCAs receiving comprehensive planning documentation. This systematic expansion represents sustained government commitment to institutionalizing modern planning practices. Regions such as Karakalpakstan, Tashkent, Bukhara, and Khorezm consistently demonstrated elevated activity levels, indicating both population density and strategic prioritization. By 2022, the scaling reached full institutional capacity, establishing rural planning as embedded national practice.

Legislative Reforms: Institutional Foundation

The revised Urban Planning Code introduced nine new articles (Articles 35-43) establishing mandatory public participation mechanisms in settlement planning [10]. These provisions legally require transparent master plan development processes, community consultation through mahalla citizen assemblies, documented stakeholder feedback integration, conflict resolution procedures, and public comment periods prior to plan adoption. This legal foundation enhances transparency, inclusivity, and conflict prevention, creating institutional accountability for rural development decisions. Coupled with Cabinet Resolution No. 639 establishing the Obod Qishloq and Obod Mahalla program frameworks, these reforms created a coherent legal-institutional structure enabling systematic rural planning implementation.

Integrated Case Study: Low-Rise Courtyard Housing in Rural Planning (Khorezm Region)

Context and Relevance

The Khorezm region represents an exemplary case for understanding how low-rise courtyard housing design principles integrate into broader rural sustainability frameworks. Resolution No. PQ-172 (18 March 2022), issued by the President of Uzbekistan, stipulated development of master plans and design concepts for 413 mahalla citizen assemblies, with particular focus on the Paxtakor mahalla in Gurlan district.

This case study demonstrates how housing typology selection directly enables the planning methodology framework, rather than operating as separate components. Low-rise courtyard housing in Khorezm was not simply selected for aesthetic or traditional reasons; rather, it was strategically chosen because it aligns with the primary economic activities of the rural population (cotton farming, vegetable cultivation, livestock raising), enables household-scale supplementary food production and income diversification, requires lower infrastructure per-capita costs in dispersed rural settlements, reflects and sustains

cultural practices centered on family autonomy and private space, and provides investment-ready, market-attractive housing options for rural mortgage programs.

Conceptual Basis and Design Principles

Urban planning approaches to courtyard residential housing increasingly emphasize modular design, where dwellings, auxiliary farm buildings, and household land plots form unified modules adapted to household needs for flexible scaling across settlement contexts and climatic zones; mahalla-oriented planning, organizing groups of courtyard houses into clusters (20-50 units) with shared courtyards and community gathering spaces, joint water reservoirs and irrigation systems, common pathways and emergency access routes, and local facilities like shops, health clinics, or prayer spaces; and environmental sustainability, prioritizing limited building density (typically 40-60% site coverage, 100-150 persons/hectare), preserved green spaces including household gardens, community orchards, and agricultural plots, maintained natural landscape features and traditional water management practices, and efficient connections for water, electricity, gas, and irrigation networks to housing modules.

Master Planning Framework for Courtyard Housing

When developing master plans incorporating low-rise courtyard housing, specific planning requirements ensure functionality and sustainability: zoning allocates separate areas for low-rise courtyard residential housing, explicitly designating zones unsuitable for multi-story development; plot sizing determines minimum normative sizes (typically 600-1,000 m² per household) to balance agricultural needs with settlement density; auxiliary infrastructure provides space for storage facilities, livestock shelters, farming equipment, irrigation systems, and compost facilities; utility connectivity ensures convenient access to water supplies, electricity, gas, and irrigation sources; and access/transportation secures proximity to primary roads, public transit, and local markets for household product marketing.

Figure 2 shows proposed planning concepts for the central area of the Paxtakor mahalla citizens' assembly, illustrating how household clusters, pathways, and communal facilities integrate within a coherent spatial framework. The 3D visualization in Figures 3 and 4 demonstrates how courtyard housing modules arrange to create both private household spaces and semi-public mahalla-level gathering areas.

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Figure 2: Proposed planning concept for the central area of the Paxtakor mahalla citizens' assembly in Gurlan district, Khorezm region.



Figure 3: 3D visualization of central mahalla area showing integrated courtyard housing clusters and communal facilities. *(Source: Housing typology case study)*



Figure 4: 3D visualization of individual courtyard housing units integrated within mahalla cluster structure.

Application Results and Outcomes

Implementation of the Paxtakor mahalla master plan (2022-ongoing) shows 87 low-rise courtyard units (750 m² plots) built/under construction, household cultivation meeting 35% local vegetable needs with surplus income via cooperatives, 22% per-capita infrastructure cost savings from shared water/irrigation, 89% participation in monthly assemblies (vs. 61% baseline), and 340% increased mortgage lending (2021-2023). This integration of courtyard housing into master planning drives economic, efficiency, and governance improvements.

Lessons for Broader Rural Planning

The Khorezm case study reveals that housing typology selection must match local economics, culture, climate, and infrastructure rather than using standardized designs; modular design, mahalla clustering, and environmental principles drive efficiency and governance; institutional alignment with legislation, participation, infrastructure, and financing amplifies sustainability; and courtyard housing scales robustly from households to mahalla clusters (20-50 units) to 1,000+ settlements.

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Legislative Integration and Case Study Findings: Andijan Region

Analysis of mahallas in the Andijan region demonstrates how functional zoning and GIS-enabled service coverage analysis translate planning methodology into on-the-ground allocation decisions. Figure 5 depicts base planning schemes illustrating renovation, reconstruction, and conservation zones, with distinct land-use categories including residential areas, industrial zones, parks, and agricultural land.

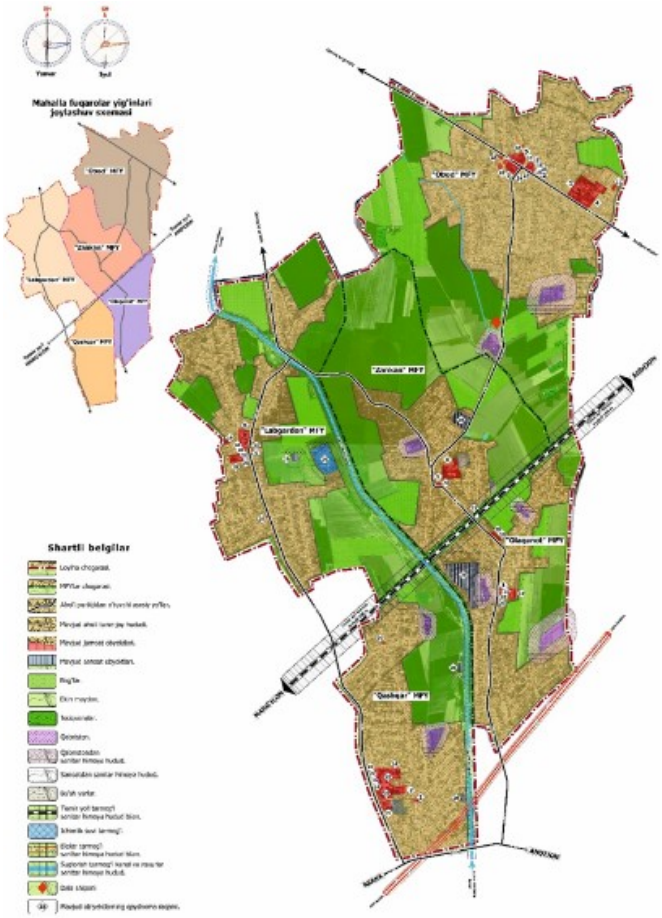


Figure 5: Base planning scheme of selected mahallas in Andijan region, illustrating renovation and reconstruction zones.

Figure 6 shows spatial organization of rural settlements with allocated infrastructure. The accompanying inventory lists existing and planned buildings

with technical specifications, providing documented baseline for infrastructure development priorities.

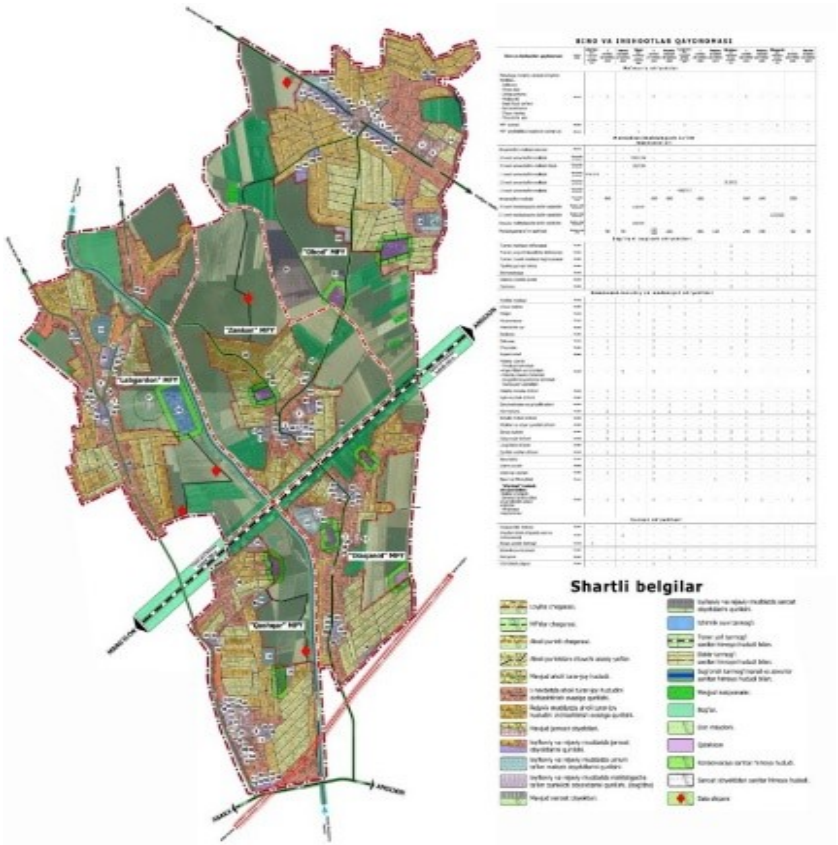


Figure 6: Base planning scheme demonstrating spatial organization in rural settlements and infrastructure allocation.

GIS-Enabled Service Coverage Analysis

Figure 7 illustrates analytical mapping of service coverage for social facilities. The three-panel analysis shows:

- **Left panel:** Service radii for preschools (typically 600 m walkable distance).
- **Center panel:** Service radii for general education schools (typically 1,200 m).
- **Right panel:** Service radii for healthcare institutions (typically 1,500 m for primary clinics, 3,000 m for district hospitals).

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This GIS analysis enables rational decisions about facility location, identifying gaps in service coverage and prioritizing new facility construction.

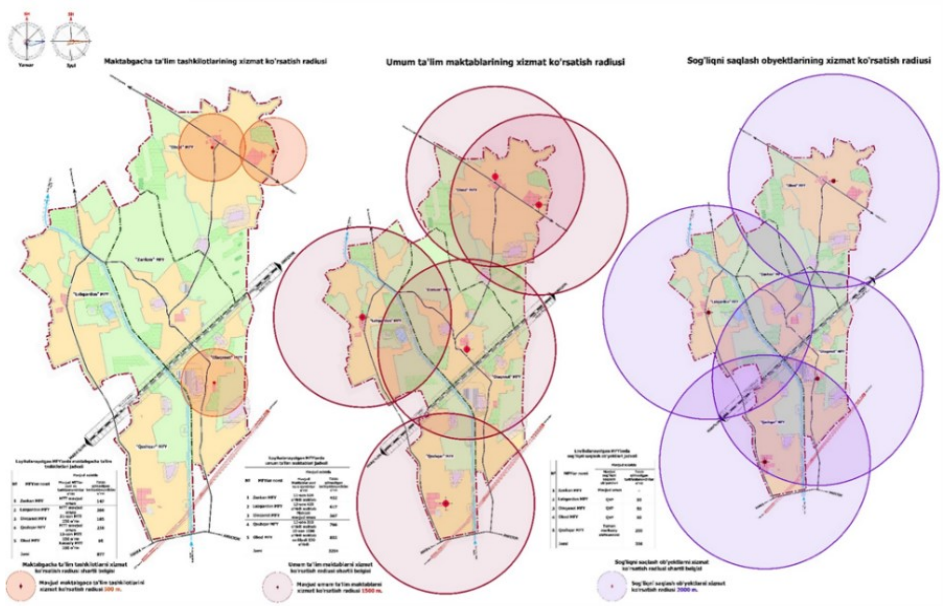


Figure 7: Analytical scheme of service coverage for preschools, schools, and healthcare institutions showing service radii and coverage gaps.

Efficiency Gains Through Technical and Economic Analysis

Vacant land parcels were subdivided into ready-to-develop lots based on technical and economic analysis. This strategic subdivision identified investment-ready parcels, enabled rapid allocation for residential, commercial, or agricultural use, increased market attractiveness through documented technical specifications, created employment opportunities in construction and infrastructure development, and enhanced infrastructure planning precision through detailed lot-by-lot specifications.

Figure 8 demonstrates master plans and 3D visualizations for residential development areas. The comprehensive master plan details plot layout, internal roads, and green space allocation. 3D renderings show proposed housing designs, social facilities, and infrastructure arrangements in investment-ready format.



Figure 8: Detailed planning projects for residential areas, showing social infrastructure, transportation networks, and housing zones

Figure 9 shows the subdivision of vacant land areas into ready-to-develop lots with technical and economic specifications. The 3D rendering displays numbered lot divisions with tabulated data on total area and designated purpose (residential, commercial, agricultural).

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Figure 9: Vacant land areas are subdivided into ready projects and lots showing technical and economic development specifications.

DISCUSSION

Integrated Framework Synthesis: The findings establish a unified methodological framework for sustainable rural development in Uzbekistan, linking four mutually reinforcing components: (a) legislative foundations like Presidential Decree PF-5577 (2018) and Cabinet Resolution No. 639, which mandate participatory master planning; (b) program implementation through Obod Qishloq and Obod Mahalla (2020-2022), scaling planning to 1,020 mahalla community areas (MCAs) with evidence of sustained commitment (Tables 1-3); (c) spatial methodologies using GIS, functional zoning, and master planning for efficient infrastructure allocation, as shown in the Andijan case study; and (d) low-rise courtyard housing integration, which supports rural economics, culture, and sustainability, per the Khorezm case study. These elements create synergies: legislation enables programs, programs fund planning, spatial tools optimize resources, and housing choices enhance efficiency and community organization.

Effectiveness and Efficiency Outcomes: The framework yields measurable gains: comprehensive master plans for 1,020 settlements in three years; GIS-driven infrastructure efficiency reducing per-capita costs; increased rural mortgage lending signaling investment appeal; high community participation (61-89%) via mahalla assemblies; and boosted household income/food security through courtyard-supported production.

Challenges and Limitations: Challenges include land management complexities, GIS capacity needs, variable implementation quality, long-term sustainability questions, and underdeveloped climate adaptation. Long-term

success hinges on deeper local engagement. This Uzbekistan-focused study limits direct transferability, though its framework, integrating legislation, governance, spatial tools, and housing, offers broader applicability. Future work should assess regional variations and longitudinal impacts.

The findings align closely with sustainable development and participatory planning theories, particularly regarding integrated land-use planning, infrastructure accessibility, and community-centered governance. The framework directly supports Sustainable Development Goal 11 (Sustainable Cities and Communities) by improving inclusive planning processes, infrastructure efficiency, housing accessibility, and long-term rural resilience. The integration of GIS analysis with participatory mahalla governance further demonstrates how spatial planning tools can support socially responsive rural development

Theoretical Contributions: This research contributes a holistic framework unifying legislative reform, national-scale implementation, spatial analysis, and housing typology selection; emphasizes typology's role in sustainability; operationalizes participatory governance via mahalla mechanisms; and provides evidence of scalable rural planning beyond pilots.

CONCLUSION

This study demonstrates that sustainable rural development in Uzbekistan requires an integrated planning framework combining legislative reform, program-scale implementation (Obod Qishloq and Obod Mahalla, covering 1,000+ settlements in three years), GIS-based spatial analysis, participatory mahalla governance, and context-sensitive low-rise courtyard housing aligned with local economies and culture. This approach proves operationally feasible at national scale, repositioning housing typology as a core principle amplifying efficiency, investment, and community cohesion.

This study provides a scalable methodological framework for sustainable rural settlement planning by integrating legislative reform, GIS-supported planning, participatory governance, and low-rise courtyard housing design. The framework offers practical policy guidance for improving infrastructure allocation, housing development, investment readiness, and rural socio-economic resilience. Beyond Uzbekistan, the proposed model may also provide relevant planning insights for other developing and Central Asian contexts facing similar rural sustainability challenges.

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DEVELOPING AFFORDABLE WORKFLOW FOR DIGITAL PRESERVATION OF ISLAMIC ARCHITECTURAL HERITAGE THROUGH PHOTOGRAMMETRY AND 3D GAUSSIAN SPLATTING

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Abstract

The rapid dilapidation of Malaysia's Islamic architectural heritage outpaces physical conservation, necessitating an affordable 3D digital documentation workflow requiring minimal manpower. This paper develops a cost-effective workflow through a comparative study of conventional photogrammetry and 3D Gaussian Splatting (3DGS). The methodology utilizes low-specification hardware - a consumer-grade UAV and smartphone, CPU-only processing, and open-source software. Between 150 and 200 video frames of a Masjid Sg. Chinchin roof crown replica were extracted for 3D reconstruction. Quantitative findings reveal that conventional photogrammetry effectively generates editable mesh models but yields low visual accuracy. Conversely, 3DGS produces highly accurate visual models—generating up to 723,566 splats for the UAV input, and is approximately 22% less time-consuming, although it lacks mesh editability. Furthermore, the UAV consistently outperformed the smartphone: while it produced a photogrammetry mesh with approximately 85% fewer vertices, it effectively eliminated visual noise. In the 3DGS workflow, the UAV generated 13% more splats, yielding sharper, more precise visuals. To address individual limitations, it is recommended to adopt a mixed workflow of 3D photogrammetry and 3DGS. By combining photogrammetry's structural editability with the time-efficient, high-fidelity visual accuracy of UAV-driven 3DGS, this integrated approach ensures comprehensive, fast, affordable, and replicable 3D documentation. Future research should integrate CUDA processing for accuracy and develop an interactive 3DGS web database for Malaysia's Islamic architectural heritage.

Keywords: Islamic Heritage, 3D Gaussian Splatting, Photogrammetry, Colmap, Structure from Motion (SfM), SkySplat.

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INTRODUCTION

Preservation and documentation of Islamic architectural heritage is crucial to ensure that the trace of Muslim civilizational history is secured through time. However, the traditional way of preservation and documentation of historical heritage buildings has limitations due to budget, logistics, and scale. And there is a long prioritization queue for heritage buildings in many countries, especially in Malaysia. So, while some heritage buildings are conserved, a large portion of heritage cannot be conserved due to the lack of budget, logistics, and manpower. At the same time, when it comes to digital heritage documentation, the traditional methods of 3D documentation are also sometimes very complex and require high-end technical skills, manpower, extensive on-site presence, and complex logistics. (Sabil et al., 2022; Salleh, 2020). This makes the large-scale documentation of heritage buildings virtually impossible with the limited available resource. As a result, many heritage buildings are dilapidated and demolished before documentation can be done.

This is addressed in this paper by finding an affordable, low-specification 3D documentation workflow, which will utilize low-end, affordable hardware and open-source tools to generate usable digital records of heritage buildings. The output might not be as precise as professional 3D scanning but is at least affordable and accessible to make sure that disintegrating and almost derelict heritage buildings can be documented before they are completely lost into oblivion.

LITERATURE REVIEW

Islamic Heritage Conservation in Malaysia

Since gaining independence, Malaysia has undertaken various conservation initiatives to safeguard its Islamic heritage. Notable projects, such as the restoration of the Sultan Abdul Samad Building in Kuala Lumpur, Masjid Kg Laut in Kelantan, and Batu Surat in Terengganu, stand out for their historical significance in shaping the narrative of Islamic traditions in Tanah Melayu (Suaib et al., 2020). While these efforts have predominantly focused on physical conservation, this review suggests that a digital approach could provide a cost-effective and time-efficient alternative for documenting and preserving the diverse tangible Islamic heritage assets.

Adopting a digital approach does not necessarily nullify the need for physical conservation; rather, it complements the current physical conservation efforts. Due to budget, craftsmanship, and time limitations, the physical conservation approach can only consider a handful of projects each fiscal year. Meanwhile, the digital approach can effectively address this issue, allowing relevant agencies to document and digitize a larger number of Islamic heritage assets with limited resources and budget (Ocón, 2021; Paschalidou et al., 2022).

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Dilapidated Heritage and the Need for Rapid Documentation

Each year, the federal government allocates a certain amount in the national budget for heritage conservation works. The scope includes physical acquisition, repair, preservation and adaptive reuse of heritage assets. In 2024, the federal government allocated MYR 80 million for the preservation and conservation of potential heritage sites and buildings recognised by UNESCO (Toyat, 2023). Though MYR 80 million is a significant amount, considering the cost of physical conservation of heritage assets the allocated amount is insufficient. To put the argument into perspective, the conservation cost of a small masjid in Negeri Sembilan, Masjid Lama Kampung Terusan Kuala Pilah, was MYR 4 million (Isa, 2022; Jalil, 2022). As reported by Dr. Isham Shah Hassan, there are around 250 traditional houses and masjids in Negeri Sembilan, which need urgent attention to document and conserve as the Islamic heritage asset of the state (Figure 1). (Isa, 2021; Rahim et al., 2022).

A simple calculation can illustrate that the allocated national budget for heritage conservation is sufficient for less than 8% of the heritage assets of only one state, let alone considering the fact that all 14 states of Malaysia have their own heritage assets, which requires urgent documentation and preservation effort.



Figure 1: Dilapidated masjid in Negeri Sembilan. Masjid Lama Kg. Pelangi (Top Left), Masjid Lama Kampung Parit Istana (Top Right), Masjid Jamek Lama Tanah Data (Bottom Left), Masjid Tua Kampung Tengah (Bottom Right).

Hence, the mismatch between the conservation need and the allocated budget requires the researchers to think of a novel approach for the conservation of national Islamic heritage, which should be highly cost-effective and less time-consuming.

Economic Constraints and the Shift Toward Accessible 3D Documentation

While Malaysia prioritizes the physical conservation of Islamic heritage (Suaib et al., 2020), this approach is fundamentally constrained by severe financial bottlenecks. With a 2024 federal heritage allocation of MYR 80 million (Toyat, 2023) against restoration costs approximating MYR 4 million per traditional masjid (Isa, 2021; Jalil, 2022), it is financially impossible to physically salvage the 250 endangered structures in Negeri Sembilan alone (Isa, 2021; Rahim et al., 2022). This massive deficit dictates a critical shift toward rapid digital documentation (Ocón, 2021; Paschalidou et al., 2022). Yet, conventional 3D scanning methods like LiDAR exacerbate these financial barriers through prohibitive hardware, high maintenance, and specialized manpower demands, rendering large-scale documentation unviable for underfunded authorities (Bramble & Lydon, 2025; Dai et al., 2022; Sabil et al., 2022).

To circumvent these limitations, recent literature emphasizes affordable alternatives like Structure from Motion (SfM), which democratizes 3D reconstruction utilizing standard consumer cameras (Eltner & Sofia, 2020; Murtiyoso & Grussenmeyer, 2017). Concurrently, novel machine learning approaches, notably 3D Gaussian Splatting (3DGS) and Neural Radiance Fields (NeRF), generate highly photorealistic environments using learnable ellipsoids rather than conventional meshes (Kerbl et al., 2023; Stanisheva, 2026). However, the literature reveals a critical paradox: while these techniques eliminate expensive physical scanners, their reliance on high-end, CUDA-enabled graphics cards merely shifts the financial burden from hardware to processing capabilities (Clini et al., 2024). Resolving this requires the strategic integration of open-source freeware, which, despite complicating workflows, is essential for maintaining true cost-effectiveness (Petrovska & Jutzi, 2025). Although employing low-fidelity inputs in 3DGS involves unavoidable trade-offs in geometric accuracy (Jia & He, 2026), continuous platform improvements are mitigating these drawbacks (Yu et al., 2025). Ultimately, in contexts of rapid heritage decay, the paradigm must decisively shift from prioritizing millimeter accuracy toward deploying rapid, hardware-agnostic documentation solutions to prevent irreversible data loss.

Critical Synthesis of Affordable 3D Documentation Workflows

A critical review of the literature reveals a distinct trade-off between geometric precision and operational affordability in heritage documentation. While conventional terrestrial laser scanning (TLS) delivers high accuracy, its prohibitive equipment costs make it largely unfeasible for widespread use in underfunded regions (Dai et al., 2022; Kędziorski et al., 2024). Consequently, recent studies emphasize transitioning towards consumer-grade sensors and open-source pipelines (Petrovska & Jutzi, 2025).

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Table 1: Critical Comparison of 3D Documentation Workflows for Heritage Preservation

Documentation Method	Primary Advantage	Critical Limitation	Relevant Studies
Traditional TLS / LiDAR	High geometric accuracy and precision.	Prohibitive hardware, maintenance, and operational costs.	Dai et al. (2022); Kędziorski et al. (2024)
Photogrammetry (SfM)	Highly accessible and democratized data capture.	Computationally demanding and time-consuming processing.	Murtiyoso & Grussenmeyer (2017); Cruz & Albuerne (2025)
3D Gaussian Splatting (3DGS)	Rapid, photorealistic visual environments.	Relies on expensive GPU/CUDA hardware; lacks editable mesh.	Clini et al. (2024); Stanisheva (2026)
Mobile SLAM & Low-cost Scanners	Real-time tracking and highly mobile.	Lower accuracy and notable noise on large-scale objects.	Gautier et al. (2020)

Table 1 shows from previous studies that low-cost photogrammetry and SfM have proven highly accessible for field data acquisition, though they often demand substantial computational power and long processing times (Cruz & Albuerne, 2025; Gautier et al., 2020). Emerging techniques like 3DGS provide rapid, photorealistic visualizations, but their reliance on high-end, CUDA-enabled graphics cards can undermine true workflow affordability (Clini et al., 2024; Stanisheva, 2026). Additionally, low-cost mobile LiDAR and SLAM tools are viable for rapid damage assessment, despite yielding lower geometric accuracy on larger architectural scales (Kędziorski et al., 2024). Ultimately, integrating low-fidelity inputs with open-source software—while accepting minor accuracy compromises—offers the most pragmatic pathway for rapidly digitizing endangered heritage before irreversible dilapidation occurs (Cruz & Albuerne, 2025; Jia & He, 2026).

METHODOLOGY

The research develops an affordable 3D documentation workflow by comparing two approaches - photogrammetry-based 3D mesh reconstruction and 3D Gaussian splatting reconstruction. For the study object, a gazebo structure located in front of the KAED building in IIUM Gombak campus is used.



Figure 2: Study object for 3D reconstruction: Gazebo Chinchin- replica of Masjid Sg. Chinchin roof crown at KAED, IIUM.

This gazebo or waqf structure is a reconstruction of the roof structure of Masjid Sungai Chinchin, which is an 80-plus-year-old masjid in the region (Figure 2). The waqf, is selected because of its manageable scale, the structural similarity to a heritage mosque's roof, and suitability for testing low-specification workflow in controlled conditions.

Data Collection

Two types of data input are used- drone videography and smartphone videography. The reason for adopting drone and smartphone as the data input method is because of the availability and affordability of these input devices in recent times. Especially for the drone, a low-spec UAV was used, which can be found in any local market. The specification of the drone and the smartphone is given below.

Hardware, Software, and Frame Sampling Justification

To maintain affordability, data was captured using a basic Android smartphone and DJI Neo drone and processed on a Lenovo laptop with an AMD Ryzen CPU and Vega 8 GPU (no CUDA support) as shown in Table 2. FFmpeg was used to extract video frames. For the photogrammetry pipeline, VisualSFM (Wu, 2011; Wu et al., 2011) and COLMAP (Schönberger & Frahm, 2016) generated point clouds, followed by mesh generation in MeshLab (Cignoni et al., 2008) and Blender. For 3D Gaussian Splatting, the Blender SkySplat add-on (Huang et al., 2025) and Brush App (Brussee, 2025) handled the reconstruction, while SuperSplat enabled viewing and limited modification.

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Table 2: Hardware used for the input and processing

		
Lenovo ThinkPad T495s (Processing Device): AMD Ryzen 5 PRO 3500U CPU, Radeon Vega 8 integrated GPU (no CUDA support), 8GB RAM.	DJI Neo (UAV Input): 4K stabilized video camera.	Samsung A34 (Smartphone Input): 48MP OIS main camera (with 4K video support).
Retail Price: MYR 1500	Retail Price: MYR 900	Retail Price: MYR 1200

Frame sampling sizes were justified through empirical trial-and-error to determine the hardware's maximum processing threshold. During the photogrammetry workflow, the software crashed when exceeding 200 frames; thus, exactly 200 frames were extracted for processing. Similarly, for the 3DGS pipeline, the software crashed beyond 152 frames, restricting the extraction to exactly 150 frames. Keeping the frame numbers at these exact minimum levels was a necessary compromise to ensure the workflow's affordability and prevent processing failures.

Process Flow

For the photogrammetry pipeline, the video input was used to extract 200 frames, which were then analysed with VisualSFM to create a sparse reconstruction with .nvm output, and then the sparse reconstruction was used to perform dense reconstruction with .PLY output. The .PLY output was imported into MeshLab for mesh generation and texturing. Once the mesh generation and texturing were done, the mesh was exported to OBJ format, and that OBJ format was then imported into Blender for viewing and modification purposes.

For the 3D Gaussian splatting pipeline, the video input from the drone and phone was imported into the Blender SkySplat add-on, which extracted 150 frames from a 2+ minute video, and then COLMAP was used inside SkySplat for dense reconstruction. From the COLMAP output, the data was imported into Brush software with 15,000 training steps. After the 15,000 training steps were completed, the Gaussian splat output in .PLY format with radiance data was saved and imported into SuperSplat for viewing and modification purposes as illustrated in Figure 3.

Limitations, Validation, and Reproducibility

This study adopts an empirical validation approach; the successful generation of comparative 3D reconstructions serves as a functional proof-of-concept, directly validating the workflow's efficacy. To ensure widespread reproducibility, the methodology strictly relies on accessible open-source freeware without dedicated GPU or CUDA support. However, maximizing affordability introduced processing constraints. Initial 4K inputs caused recurrent system crashes, necessitating a downscale to full HD resolution (1920 x 1280) to maintain stability. By integrating these operational constraints, hardware thresholds, and open-source tools, this methodology establishes a highly replicable blueprint for affordable 3D architectural heritage documentation.

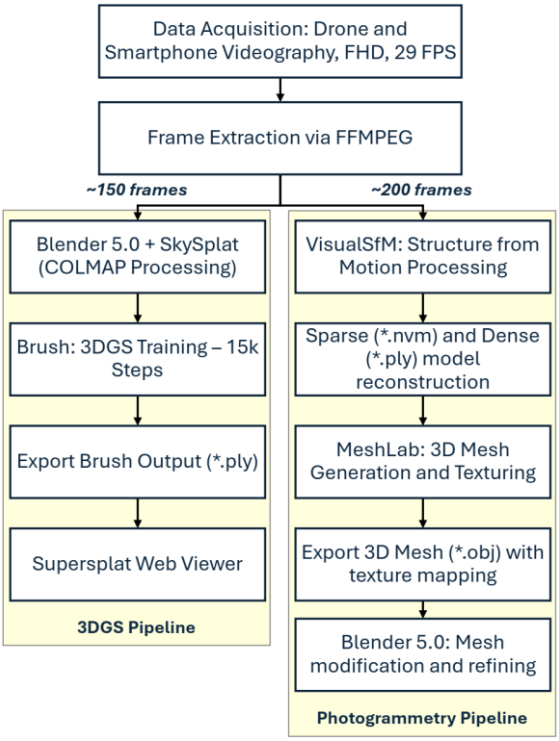


Figure 3: Process flow for different input mode.

FINDINGS

Comparative Analysis of Photogrammetry Outputs

A quantitative comparison of the photogrammetry meshes reveals an inverse relationship between mesh density and geometric accuracy. As detailed in Table 3, the smartphone generated a highly dense mesh (1,818,971 vertices; 3,638,812 faces), whereas the UAV yielded an 85% less dense mesh (270,857 vertices;

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540,921 faces). However, higher density did not guarantee better structural representation. As illustrated in Figure 4, the smartphone mesh exhibits severe visual noise and incomplete areas, particularly around the roof. This limitation stems from terrestrial capture constraints; the smartphone could not attain the elevated angles required for complex geometry.

Table 3: Comparison: Drone Vs Smartphone Input in Photogrammetry workflow.

Parameter	Drone Input	Phone Input
Image Matching (VisualSFM)	23,005 matches completed	20,100 matches completed
Processing Time	8,246 seconds	7,289 seconds
Total Processing Time	138.267 minutes	122.567 minutes
Vertices (MeshLab Output)	270,857	1,818,971
Faces (MeshLab Output)	540,921	3,638,812
Mesh quality	More accurate with less noise	Lack of accuracy with more noise and incomplete areas

In contrast, the UAV's stable aerial trajectory captured complete structural data from optimal vantage points. Although the UAV required slightly more processing time (138.27 minutes versus 122.57 minutes), it effectively eliminated structural noise, producing a significantly more accurate, complete, and usable 3D mesh model.

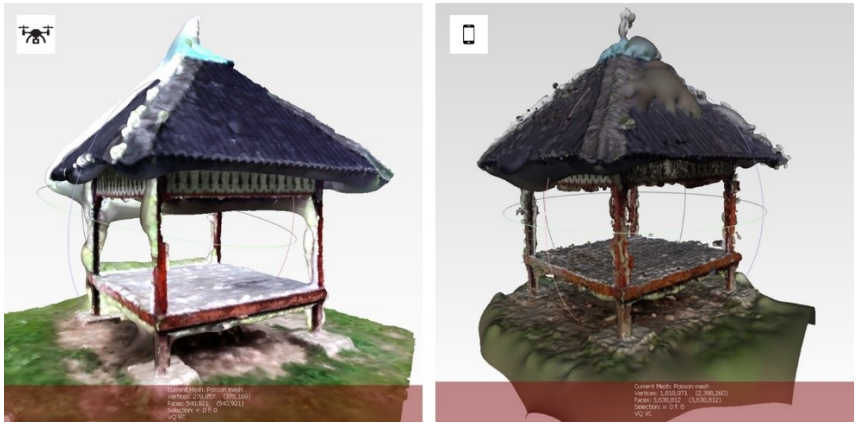


Figure 4: 3D mesh generated in MeshLab; Drone input (Left) and Phone input (Right).

Comparative Analysis of 3DGS Outputs

The 3DGS pipeline produced highly photorealistic environments but revealed distinct performance variances between input devices. To maintain hardware stability, both datasets were downscaled to HD resolution. Despite this uniform baseline, Table 4 demonstrates that the UAV generated 13% more splats

(723,566) than the smartphone (640,418). This higher splat density correlates directly with the UAV's aerial vantage points, allowing the algorithm to map complex upper geometries comprehensively, achieving the sharp, highly accurate representation illustrated in Figure 5.



Figure 15: 3DGS generated in Brush; Drone input (Left) and Phone input (Right).



Figure 6: Visual quality of 3DGS; Drone input produced sharper and more accurate output (Left) and Phone input produced lots of floaters or visual noises (Right).

Conversely, the smartphone input suffered from constrained terrestrial angles and a smaller dataset (115 versus 153 frames), producing significant visual noise and geometric "floaters" as seen in Figure 6. Although the smartphone

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processed marginally faster and required less memory, it compromised overall visual fidelity. Notably, while initial hypotheses posited that terrestrial capture would better map the gazebo's underside, visual analysis confirmed no significant improvement in under-roof structural detailing, ultimately proving the UAV's superior overall efficacy for 3DGS reconstruction.

Table 4: Comparison: Drone Vs Smartphone Input in 3DGS workflow.

Parameter	Drone Input	Phone Input
Splats	723,566	640,418
Training Steps	9,910	9,005
Steps per Second	1.0	1.1
Training Time	1h 47m 27s	1h 38m 5s
Dataset Train Size	153	115
Bytes in Use	1.07 GB	496.37 MB
Bytes Reserved	2.27 GB	2.20 GB
Output Quality	More precise and visually clear	Less accurate with lots of visual noises

DISCUSSION

Proposed Affordable Digital Preservation Workflow

The findings indicate that relying on a single low-cost 3D scanning method necessitates compromising either structural editability or visual fidelity. To address this limitation, the practical implication of this study is the proposal of a hybridized, dual-pipeline workflow that leverages the distinct strengths of both photogrammetry and 3DGS while remaining strictly within affordable hardware parameters.

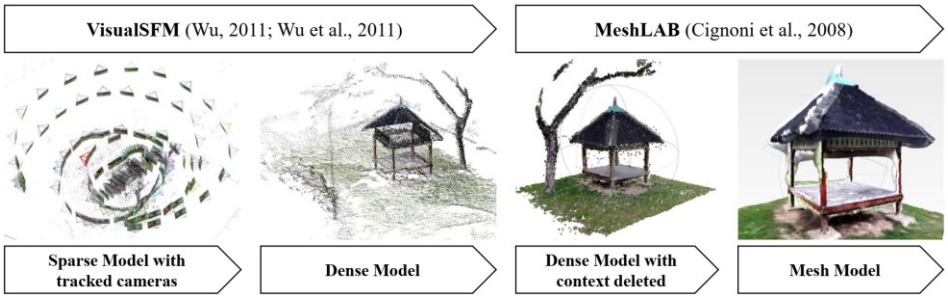


Figure 7: Process-flow for 3D mesh generation with photogrammetry

The first pipeline, illustrated in Figure 7, employs a conventional photogrammetry approach to secure a geometrically workable 3D mesh. UAV-captured videos are processed via FFmpeg to extract exactly 200 HD frames to ensure hardware stability. VisualSFM handles sparse and dense point cloud

reconstruction, followed by mesh generation and texturing in MeshLab using Poisson surface reconstruction. The resulting .obj file provides the essential topological data required for accurate architectural measurements and physical conservation planning.

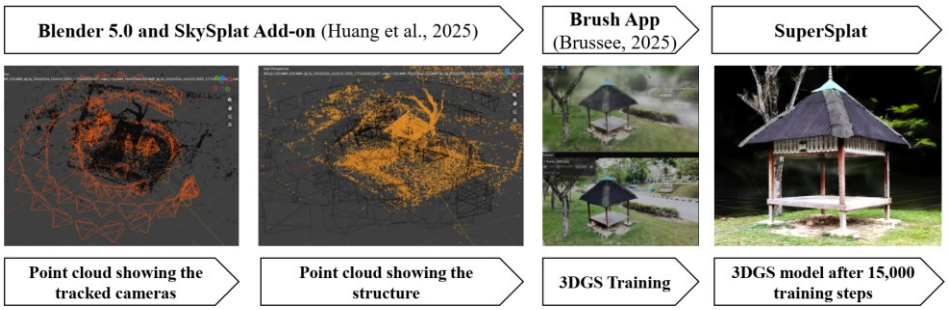


Figure 8: Process-flow for 3D Gaussian Splatting.

Simultaneously, the second pipeline, detailed in Figure 8, utilizes 3DGS to rapidly capture a highly accurate photorealistic environment. Using the Blender SkySplat add-on, exactly 150 frames are extracted and processed through COLMAP. The data is then trained for 15,000 steps in Brush App, outputting a detailed .ply radiance field viewable in SuperSplat. By executing these complementary pipelines in tandem using open-source freeware and CPU-only processing, conservationists can successfully generate both editable structural meshes and high-fidelity visual records with minimal budget, skill, and manpower.

Implications for Heritage Preservation in Malaysia

The critical bottleneck in Malaysian heritage preservation is not merely a lack of funding for physical restoration, but the absence of a scalable strategy to digitally archive endangered structures before irreversible dilapidation occurs (Isa, 2021; Rahim et al., 2022). As established in the literature, attempting to solve this through conventional LiDAR scanning paradoxically replicates the very financial barriers it seeks to bypass, imposing prohibitive hardware and maintenance costs on underfunded regional authorities (Bramble & Lydon, 2025; Dai et al., 2022). This study resolves this dilemma by proving that high-fidelity 3D documentation does not necessitate expensive commercial software licenses or high-end CUDA-enabled processors (Clini et al., 2024; Petrovska & Jutzi, 2025). By successfully executing a hybridized photogrammetry and 3DGS pipeline entirely on consumer-grade sensors and CPU-only freeware, this research provides a direct, empirically tested countermeasure to the national resource deficit. Consequently, the proposed workflow transcends being a mere technological alternative; it

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serves as a crucial policy instrument. It empowers Malaysian conservation agencies to urgently pivot from slow, capital-intensive physical restorations toward rapid, democratized digital archiving. This approach bridges the gap between limited federal allocations and the vast number of neglected Islamic architectural assets, establishing a decisive and viable blueprint for a comprehensive national digital heritage repository.

CONCLUSION

This study advances heritage conservation by offering an accessible, dual-pipeline 3D documentation workflow. This approach directly reduces the high costs and logistical challenges of traditional commercial scanning. By successfully combining low-cost photogrammetry and 3D Gaussian Splatting (3DGS) using consumer-grade sensors and open-source freeware, this research provides a practical way to rapidly digitize endangered Islamic architecture. The main contribution of this work is making heritage documentation more democratic. It empowers underfunded regional authorities to digitally save damaged structures before they are lost forever.

However, focusing on maximum affordability brings some limitations. Relying on CPU-only processing and lower image resolutions slightly reduces geometric precision and mesh editability. To improve this, future research should explore using limited CUDA-based processing. This upgrade would increase the accuracy of mesh generation and capture more of the surrounding environment for the 3DGS pipeline. Furthermore, future projects should combine the 3DGS models of various Malaysian Islamic heritage buildings into a single, interactive web platform. By allowing users to click on a map to explore photorealistic 3D models alongside historical data, this collection will eventually grow into a centralized 3D database dedicated to preserving Malaysia's at-risk architectural assets.

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ADVANCING BIM REGULATORY DOCUMENTS IN URBAN PLANNING AND CONSTRUCTION: GLOBAL INSIGHTS AND GAP

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Abstract

The rapid dilapidation of Malaysia's Islamic architectural heritage outpaces physical conservation, necessitating an affordable 3D digital documentation workflow requiring minimal manpower. This paper develops a cost-effective workflow through a comparative study of conventional photogrammetry and 3D Gaussian Splatting (3DGS). The methodology utilizes low-specification hardware - a consumer-grade UAV and smartphone, CPU-only processing, and open-source software. Between 150 and 200 video frames of a Masjid Sg. Chinchin roof crown replica were extracted for 3D reconstruction. Quantitative findings reveal that conventional photogrammetry effectively generates editable mesh models but yields low visual accuracy. Conversely, 3DGS produces highly accurate visual models—generating up to 723,566 splats for the UAV input, and is approximately 22% less time-consuming, although it lacks mesh editability. Furthermore, the UAV consistently outperformed the smartphone: while it produced a photogrammetry mesh with approximately 85% fewer vertices, it effectively eliminated visual noise. In the 3DGS workflow, the UAV generated 13% more splats, yielding sharper, more precise visuals. To address individual limitations, it is recommended to adopt a mixed workflow of 3D photogrammetry and 3DGS. By combining photogrammetry's structural editability with the time-efficient, high-fidelity visual accuracy of UAV-driven 3DGS, this integrated approach ensures comprehensive, fast, affordable, and replicable 3D documentation. Future research should integrate CUDA processing for accuracy and develop an interactive 3DGS web database for Malaysia's Islamic architectural heritage.

Keywords: BIM; regulations; standards; design; digitalization; Central Asia; CIS countries; BIM guidelines; IFC

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INTRODUCTION

The construction industry is one of the most profitable and capital-intensive sectors globally, with the design phase playing a critical role in determining the total cost and success of any project (Cortés et al., 2023). This phase is often complex and time-intensive, influenced by the project's type, scale, and technological readiness. In Uzbekistan's construction sector, the integration of Building Information Modeling (BIM) standards introduces both opportunities for advancement and limitations rooted in existing infrastructure and regulatory frameworks (Z.E & N.S., 2022).

Globalization continues to drive the adoption of advanced technologies in local markets, encouraging industries to align with international practices to remain competitive. However, this transition brings numerous challenges, socio-economic, technical, and regulatory that must be addressed to ensure effective implementation (S. Su et al., 2023). Understanding how design technologies like BIM intersect local and international standards is essential to overcoming these barriers and achieving consistent quality across the construction lifecycle.

Construction documentation is universally governed by both national and international standards. While local regulations reflect region-specific factors such as climate, geology, urban planning policies, and economic conditions, international standards provide uniformity in terms of symbols, measurement units, terminologies, and graphic representation (Sijakovic & Peric, 2020). Familiarity with these standards and technologies is therefore critical for aligning local design practices with global expectations (Petraite et al., 2022).

Currently, six countries the United Kingdom, Singapore, Norway, Finland, South Korea, and Denmark, have established national BIM mandates, while several others are in various stages of developing or implementing such frameworks (Jiang et al., 2022). According to a study by Jung and Lee (Jung & Lee, 2015), North America has the most extensive experience with BIM adoption, followed by Oceania, Europe, and Asia. These efforts are typically supported by top-down policies, structured guidelines, and clearly defined implementation strategies (Ganah & Lea, 2021a). As BIM adoption expands, the development and refinement of standards remain essential for managing complex data, improving collaboration, and supporting digital transformation in the construction industry (Godager et al., 2021; Obi et al., 2021).

Despite the global focus on BIM standardization, existing research has largely concentrated on developed regions, offering limited insight into underrepresented areas. Notably, previous studies have overlooked Central Asia and the Commonwealth of Independent States (CIS), where BIM adoption remains fragmented and insufficiently documented.

This study addresses this gap by identifying and comparing BIM standards, guidelines, and templates across various countries, particularly in the

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emerging practices in Central Asia and CIS. By analyzing the interrelationships and gaps in existing documentation, this research contributes to the global discourse on BIM standardization and offers recommendations for policymakers and practitioners in regions seeking to align with international best practices.

LITERATURE REVIEW

The implementation and standardization of Building Information Modeling (BIM) have become central themes in the evolution of the architecture, engineering, and construction (AEC) industry. A comprehensive study by Xu et al. (Xu et al., 2014) emphasized that BIM standards significantly influence both organizational strategies and individual professionals adopting BIM. Reinforcing this, Chan et al. (Chan et al., 2019) identified the lack of standardized guidelines as one of the key barriers hindering widespread BIM adoption in the AEC sector. This sentiment is echoed in the findings of Becerik-Gerber et al. (Becerik-Gerber et al., 2011), who reported that while 71% of BIM-using firms claim to follow standards, only 35% adhere to official industry standards, with the majority relying on internally developed protocols, indicating a fragmented and inconsistent approach.

Further advancements in standardization are explored in the work of Panteli et al. (Panteli et al., 2020), who reviewed developments across EU member states. Their study found that current BIM regulations primarily address overarching concepts such as classification systems, process methodologies, data exchange mechanisms, and lifecycle information management. This indicates a trend toward harmonizing BIM processes, although standard maturity varies widely across countries.

Global BIM adoption trends reveal stark contrasts between regions. Smith (Smith, 2014) conducted a comparative analysis across countries such as North America, the UK, Scandinavia, Singapore, China, and Australia, identifying North America and parts of Europe as frontrunners, driven largely by government mandates, standardized BIM protocols, and structured education systems. Similarly, Jung and Lee (Jung & Lee, 2015) analyzed BIM maturity across six continents and noted that North America, Oceania, and Europe are rapidly progressing toward higher maturity levels, while Africa and South America remain in early development stages. Their study also highlighted the dynamic growth of BIM in Asian countries, including China, Singapore, South Korea, and India (Qi et al., 2023).

Despite the growing volume of literature, Kassem et al. (Kassem et al., 2013) noted that most seminal BIM research has focused on Western nations, particularly the US, UK, and Australia, while neglecting successful implementations in regions like Finland, Norway, and Singapore. Given the rapid

evolution of BIM practices, many earlier studies have become outdated, pointing to the need for continuous research and updates.

From a technological standpoint, Howard and Björk (Howard & Björk, 2008) examined BIM from an IT perspective, underscoring the significance of Industry Foundation Classes (IFC) in facilitating open and interoperable data exchange. Building on this, Azzran et al. (Azzran et al., 2019) advocated for the use of open BIM formats such as COBie and IFC, especially during the operational phase of building projects. Open standards ensure long-term data accessibility and multi-functional use, which Demenev et al. (Demenev et al., 2019) argue is essential for optimizing a building's lifecycle performance. Open BIM thus appears to be a critical enabler for effective data-driven facility management (Oldfield et al., 2017).

However, a recurring limitation in existing literature is the lack of classification or evaluation of BIM standards at a national level. This shortcoming is particularly relevant in post-Soviet and emerging economies, where BIM adoption is relatively nascent. Churakov et al. (2023, 2021) observed that countries in the Commonwealth of Independent States (CIS) historically developed rigid construction methodologies during the 20th century (Baydoun et al., 2024). With the global shift toward digitization, however, their regulatory systems have been adapting to incorporate BIM methodologies. Both Russia and Kazakhstan, for example, launched national BIM programs in 2014 and have since implemented strategic roadmaps to integrate BIM into state-level construction projects (Dariyadi et al., 2022).

Uzbekistan represents a more recent case of BIM integration. The country began its BIM journey following a Presidential Decree in 2018, aiming to digitize construction workflows and project management systems. According to Buronov's 2023 public survey, conducted at the Tashkent Institute of Architecture and Construction, only 13.6% of professionals reported having incorporated BIM software into their design practices. This reflects the early stage of BIM maturity in Uzbekistan and signals a need for policy and capacity-building interventions (Shakhnovich & Daurenbek, n.d.).

Meanwhile, recent scholarly efforts have expanded the boundaries of BIM research by exploring its integration into smart city development, legal infrastructures, and compliance automation. One study investigated BIM's role in supporting smart city initiatives, uncovering significant issues related to data privacy and cybersecurity that current governance frameworks fail to address. The authors call for enhanced legislation and digital policy improvements to bolster public trust and safeguard urban digital ecosystems (Gulamhusein & Bolpagni, 2022).

In the context of Kazakhstan's AECO industry, researchers explored the challenges in transitioning from basic clash detection to more sophisticated

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clash avoidance methods. They found that the absence of detailed regulatory frameworks remains a primary constraint, highlighting the necessity for tailored policies to guide BIM growth in developing regions (Akhmetzhanova et al., 2022).

In parallel, efforts to combine BIM with emerging technologies such as blockchain have shown potential in advancing sustainable urban development. A bibliometric study mapped the interplay between BIM, blockchain, and City Information Management (CIM), revealing opportunities for improved environmental performance, yet acknowledging the limited number of real-world implementations (Liu et al., 2021).

Legal and contractual dimensions also significantly influence BIM integration. A qualitative analysis revealed that clearly defined roles, legal responsibilities, and dispute resolution frameworks are vital in reducing project risks and promoting collaboration among stakeholders. Without legal clarity, BIM implementation can become fragmented and conflict prone (Saad Alotaibi et al., 2024).

Lastly, advancements in artificial intelligence (AI) are transforming BIM-based regulatory compliance. A recent framework proposes integrating large language models (LLMs), deep learning, and ontological systems to automate the interpretation of complex construction codes. This AI-driven approach enhances compliance checking by minimizing human error and boosting efficiency, especially in regulatory-heavy environments (Chen et al., 2024).

STANDARDS OF BIM

Leading standardization organizations for BIM, such as the British Standards Institute, the International Organization for Standardization, and the European Committee for Standardization, have been established to develop specialized standards for BIM implementation. Their primary objective is to ensure seamless information exchange and transfer among project participants (Ganah & Lea, 2021a). Several countries have made significant efforts to develop standardized BIM methodologies and tools for documenting information requirements in the design, construction, and operation processes, as shown in Table 1 (Ganah & Lea, 2021a). This table can be expanded based on the experiences of Russia, Kazakhstan, and Uzbekistan in developing BIM methodologies and tools. This initiative is aimed at addressing inefficiencies in the architecture, engineering, and construction (AEC) industry through high-performance solutions. Streamlining processes allows all project participants to work in a unified manner, collaborate effectively, and exchange compatible models and information in the interest of the project (*SCIENTIFIC ASPECTS AND TRENDS IN THE FIELD OF SCIENTIFIC RESEARCH*, n.d.)[29].

Table 1: Adoption of BIM Standards in Different Countries

		Countries Adopting and Implementing BIM with Developed Standards															
		USA	**UK**	**Denmark**	**Finland**	**Sweden**	**Netherlands**	**Spain**	**Norway**	**Australia**	**NewZealand**	**China**	**SouthKorea**	**HongKong**	**Uzbekistan**	**Kazakhstan**	**Russia**
Assessment Criteria	BIM Standards may have an impact on the Building Program	√	√			√	√	√	√	√	√			√	√	√	√
	BIM Standards relate to Building Codes/Regulations	√	√	√	√	√	√	√	√			√			√	√	√
	BIM Standards, Guidelines, and Templates are clear and easy to follow	√	√		√	√	√			√	√		√	√	√		√
	BIM Standards may influence the Project Cycle	√	√	√	√		√	√	√				√	√			
	BIM Standards support for 3D Working Methods			√						√	√	√		√	√	√	√
	BIM Standards support for BIM adoption in an organization	√	√					√	√			√	√		√		
	BIM Standards support for digital compliance checking					√		√		√	√						
	Standards for BIM Execution Plan	√	√			√				√				√	√	√	√
	Information Support for Facilities Management	√	√		√			√	√				√		√	√	√

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	Countries Adopting and Implementing BIM with Developed Standards																
	USA	**UK**	**Denmark**	**Finland**	**Sweden**	**Netherlands**	**Spain**	**Norway**	**Australia**	**NewZealand**	**China**	**SouthKorea**	**HongKong**	**Uzbekistan**	**Kazakhstan**	**Russia**
BIM Standards for Digital Information Security		√														
Support for Coordinating Building Information System	√	√	√	√	√	√		√	√		√					
BIM Standards Discipline Specific	√			√		√	√	√			√	√	√			
Collaborative development (Standards developed by different disciplines and Academia)	√	√		√			√							√	√	√
BIM standards may impact Manufacturers				√					√	√	√					
BIM Standards for Energy Simulation							√	√								

According to Ganah and Leaga (Ganah & Lea, 2021a), this section highlights both the leading countries in BIM standardization and those lagging. The standards are presented by BIM work stages, serving as a valuable source of information. The United Kingdom has structured the BIM implementation process into several "levels," each representing a significant milestone (Chen et al., 2024). These levels can be described as follows:

- Level 0: Non-collaborative 2D CAD.
- Level 1: Non-collaborative 2D or 3D CAD.
- Level 2: 3D CAD with collaboration and information exchange, but not through a single shared model.
- Level 3: Full collaboration among stakeholders, working based on a single, shared model.

Although many public projects in China have sufficient resources to leverage the benefits of BIM, the Chinese government has not yet issued a comprehensive national regulatory framework mandating the use of BIM in public projects. As a result, BIM development in China over the past decade has primarily been driven by market demand. Moreover, the existing Chinese construction laws and regulations lack the necessary provisions to support a collaborative BIM process (H. Su, 2013). The European Union's recently adopted public procurement directives aimed to encourage member states to adopt BIM by 2016, creating a favourable environment for BIM implementation in France. However, if the government does not act swiftly, it may fall behind competitors in the international market (Hamma-adama & Kouider, 2019). The concrete target for BIM adoption in public sector projects was set for 2017 (Oti-Sarpong et al., 2020).

In the United States, the construction industry is regulated by the National BIM Standard – United States (NBIMS-US™). Although the NBIMS document is highly detailed, its 183-page length makes it complex to comprehend (Ginzburg & Shilov, 2016). The primary focus of NBIMS-US™ is to establish standards that facilitate the efficient management of the built environment's life cycle, supported by digital technologies (Abdulghani & Gullu, 2021). In the Russian Federation, a "Roadmap" was adopted in 2017, outlining the development of national processes for designing, constructing (reconstructing, capital repairing), operating, and demolishing capital construction projects. It also aimed to align regulatory and technical documents, as well as cost estimation norms used in construction, with the construction resources classifier (Aitbayeva & Hossain, 2020). In the following years, several decisions and regulations were developed to facilitate the implementation of BIM technologies in the industry.

In Kazakhstan, BIM implementation began in 2016 with the creation of the "Concept for the Implementation of Information Modelling Technology in Industrial and Civil Construction of the Republic of Kazakhstan." The task of developing this concept was assigned to KazSRDICA (Kazakhstan Scientific Research and Design Institute of Construction and Architecture) (Tatiana, 2020). The digitalization of the construction industry encompasses the implementation of investment construction projects throughout their entire life cycle and the transition of participants' collaboration processes into a digital format.

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In the Republic of Uzbekistan, the 2021–2025 Innovation Development Strategy included a strategy for modernizing the construction sector. According to this strategy, the implementation of Building Information Modelling (BIM) technology at all stages of a construction project's life cycle was identified as a priority. As part of the strategy's execution, regulatory documents were developed to technologically regulate the introduction of BIM in the construction industry.

The aforementioned standards and regulatory frameworks represent only a portion of the documents adopted to regulate the design process. Additionally, several regulatory documents have been introduced to manage construction and operation processes (Baydoun et al., 2025).

RESEARCH METHODOLOGY

Research Design

This study adopts a desk-based qualitative research design, with a primary focus on document-based content analysis. The research involves a comparative review of BIM standards, guidelines, and templates across selected countries to identify patterns, gaps, and best practices in BIM regulatory documentation. This method ensures a structured and in-depth examination of textual data from both academic and institutional sources.

Country Selection

The selection of Russia, Kazakhstan, and Uzbekistan as case studies was guided by their shared membership in the Commonwealth of Independent States (CIS) and their distinct levels of BIM maturity and regulatory development. These countries offer strategic geographic diversity and present varying approaches to BIM adoption in post-Soviet contexts. Including them enables the study to explore the underrepresented Central Asian and Eastern European region, thus addressing a significant geographical gap in the current body of BIM research.

Data Collection

Based Data were collected from a combination of official government portals, national and international BIM regulatory documents, and industry-specific publications. Academic sources, including peer-reviewed articles and white papers, were used to provide additional context and theoretical grounding. The focus was limited to publicly available and published standards, guidelines, templates, and classification systems relevant to building design and BIM processes.

Data Analysis
A document-based content analysis was applied to identify recurring themes, structures, and inconsistencies across the selected regulatory documents. Documents were categorized based on their scope (standards, guidelines, templates), geographical origin, and implementation approach (top-down or bottom-up). A comparative matrix was then developed to visualize interrelations and regulatory coverage between the countries studied.

To strengthen the credibility and reliability of the findings, methodological triangulation was applied. This included:

- Cross-referencing regulatory documents with academic literature.
- Validating national frameworks with information from international organizations (e.g., ISO, building SMART).
- Consulting official BIM-related strategies and portals where applicable.

Scope and Limitations
The study is limited to documents available in English and Russian. While this may restrict access to certain localized standards or updates, the analysis captures the core regulatory frameworks currently influencing BIM implementation in the selected countries.

ANALYSIS AND DISCUSSION

Table The comparative analysis highlights significant regional disparities in the adoption and development of BIM standards, with a clear divide between developed countries with robust BIM mandates and emerging economies still in the process of developing fragmented regulatory frameworks. Developed countries like the United Kingdom, Singapore, and Finland have laid the groundwork for BIM adoption through centralized national roadmaps and clear execution plans, which appear to be critical success factors for early adoption. In contrast, countries such as Uzbekistan and Kazakhstan face difficulties due to the lack of a unified approach and the challenges posed by fragmented regulations and varying levels of technological preparedness.

The experiences of countries like the United States and Russia reflect the complexities of decentralized BIM efforts. While the U.S. has made significant strides in developing a wide range of BIM standards, these standards are often created at the state level, leading to fragmentation and inconsistent application. This contrasts with the UK's national-level BIM strategies, which provide a unified framework that facilitates interoperability and ensures that BIM processes are aligned across regions. Similarly, Russia's regulatory and technical framework for BIM, while comprehensive, is still in the process of evolving, with key documents outlining minimum requirements for BIM model formation but

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still lacking the full integration necessary for nationwide implementation (Tatiana, 2020). This variation in approach underscores a critical point: a centralized, cohesive strategy is essential for BIM's effective implementation.

Furthermore, Europe's emphasis on cross-standard integration and lifecycle data continuity positions it ahead of other regions in digital construction practices. The European model's success can be attributed to its extensive development of standards, guidelines, and templates, along with its emphasis on ensuring seamless workflow continuity across project lifecycles. This approach contrasts sharply with that of CIS countries, where, although many technical standards are adopted at the international level, the institutional and educational gaps continue to hinder the full realization of BIM's potential. The widespread availability of interconnection documents in Europe, 5.2 times more than in Asia, demonstrates the continent's commitment to developing a harmonized BIM ecosystem, which allows for smoother collaboration and project execution across borders.

Despite the adoption of international standards such as ISO 19650, which provides a framework for BIM at a global scale, the lack of sufficient strategic planning documents in several countries remains a major obstacle. For instance, although many countries have developed BIM model standards and information requirements, such as the UK's PAS 1192-2:2013 and Singapore's focus on participant roles, there is still a significant gap in the creation of foundational project planning documents like BIM Execution Plans (BEP) and Employer's Information Requirements (EIR). Without a well-rounded set of interlinked standards that guide a project from conception to completion, the implementation of BIM can be less effective, leading to inefficiencies and project delays. This issue is particularly pronounced in emerging economies, where the focus tends to be on adopting technical standards without sufficient consideration of strategic and organizational documents that are key to ensuring successful BIM integration.

Another critical gap in BIM implementation in many countries, especially in Central Asia and the CIS region, is the lack of trained specialists and educational frameworks that can support BIM adoption. Countries such as Russia, Kazakhstan, and Uzbekistan have developed regulatory frameworks to introduce BIM technology at the state level, but these efforts have not been complemented by adequate investments in workforce development and educational initiatives. The integration of BIM requires a skilled workforce familiar with both traditional and new technologies, and without such a workforce, the full potential of BIM cannot be realized. For instance, Kazakhstan's implementation of BIM in state-funded projects, although a significant step forward, relies heavily on local companies' readiness and their ability to manage the technology efficiently, which remains a major challenge.

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Similarly, Uzbekistan's plans to integrate BIM technology across the entire building lifecycle in urban planning regulations for 2024-2025 face significant hurdles in terms of specialist training and practical application (Miravalls & Pley-leclercq, 2023).

In conclusion, while BIM adoption is progressing globally, the extent and success of its implementation vary significantly depending on the country's regulatory framework, technological readiness, and workforce capacity. Countries with centralized national roadmaps, such as the UK and Singapore, have demonstrated successful models for BIM adoption that emphasize both technical and strategic integration. In contrast, countries like the United States, Russia, and those in the CIS region face challenges in achieving consistency and full implementation due to decentralized efforts, lack of coordination between standards, and gaps in educational and institutional frameworks. As it illustrates in Figure 1 The future of BIM adoption in these regions depends on overcoming these barriers through the development of unified national strategies, comprehensive training programs, and greater alignment between technical standards and strategic planning documents (Ganah & Lea, 2021b). The experience of these countries also highlights the need for international collaboration in developing BIM standards that are adaptable to local contexts, ensuring that BIM can reach its full potential as a tool for improving construction efficiency, collaboration, and sustainability across the globe. Figure 2 shows the Comparative analysis of the experiences of Russia, Kazakhstan, and Uzbekistan in developing BIM standards, guidelines, and templates.

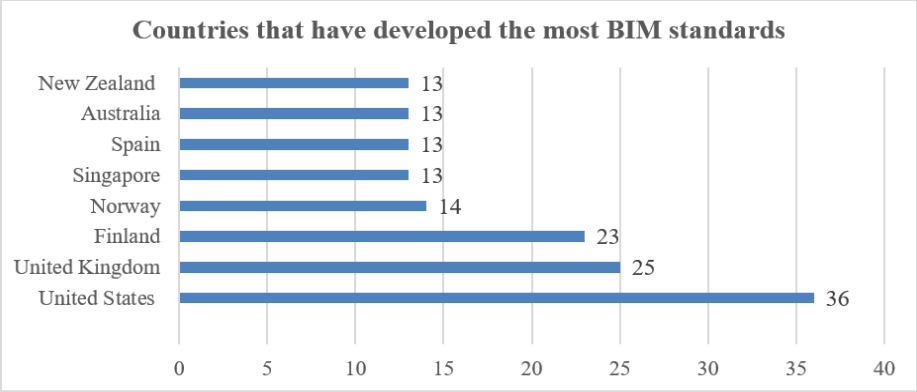


Figure 1: Comparative analysis of countries in developing BIM standard. Source [40].

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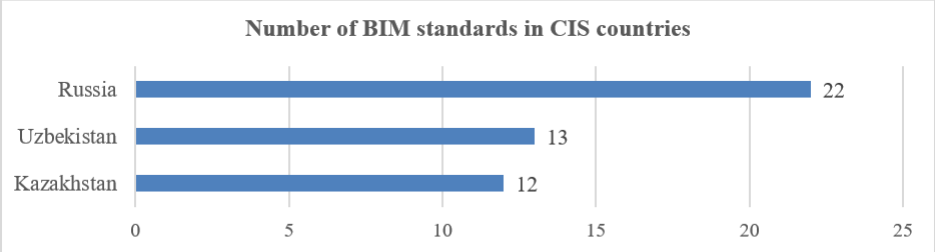


Figure 2: Comparative analysis of the experiences of Russia, Kazakhstan, and Uzbekistan in developing BIM standards, guidelines, and templates. Source [40].

CONCLUSION

The global implementation of Building Information Modelling (BIM) standards, while technologically similar across different regions, faces significant challenges due to varying economic, technological, and regulatory environments. Countries such as the United Kingdom, Singapore, Norway, Finland, South Korea, and Denmark have set high standards for BIM adoption through national mandates, underpinned by strong governmental support, well-developed infrastructure, and a prepared workforce. However, in regions like Central Asia and the CIS countries, despite aligning with international ISO standards, the integration of BIM faces notable obstacles. These include outdated infrastructure, a lack of specialized knowledge, and an underdeveloped economic and technological environment. This discrepancy highlights that BIM adoption is not solely a matter of transposing global standards; it requires a tailored approach that addresses local conditions, both technological and managerial, as well as economic readiness.

For countries facing these challenges, it is crucial to establish a clear and structured approach to BIM integration. Policymakers should prioritize the development of a national BIM roadmap that outlines specific timelines, targets, and frameworks for implementation. This roadmap should be adaptable to the local context, ensuring that it addresses the unique regulatory, legal, and technological needs of the country. In addition, to reduce the financial burden on construction companies, governments can encourage BIM adoption by supporting pilot projects and offering tax incentives to firms investing in BIM technologies. This would not only help accelerate the transition to BIM but also create a more favourable economic environment for its widespread implementation. Furthermore, translating ISO standards into locally relevant frameworks is essential. While international standards provide a strong foundation, their application must be contextualized to account for regional

construction practices and economic conditions, making them more accessible and actionable for local stakeholders.

Addressing the workforce gap is another critical factor in ensuring the success of BIM adoption. Governments and educational institutions should invest in training and professional development programs that equip professionals with the necessary skills to utilize BIM technologies effectively. This would help address the shortage of qualified BIM experts and foster a culture of continuous learning and adaptation within the industry. The availability of skilled personnel, coupled with high-performance technological infrastructure, is essential for maximizing the potential of BIM technologies. Furthermore, the age and readiness of specialists to adapt to new technologies play a significant role in the speed of BIM adoption. Older professionals may face challenges in learning and adopting new technologies, making it imperative to focus on both younger professionals and providing ongoing support for experienced specialists.

Looking ahead, future research should focus on several key areas to further improve BIM adoption and its integration into the global construction industry. One promising avenue is the development of AI-driven tools for automating compliance checks, which could significantly reduce the time and effort required to interpret complex regulatory texts. This would enhance the efficiency and accuracy of BIM adoption, particularly in countries with evolving regulatory standards. Additionally, creating a regional BIM maturity index could provide valuable insights into the specific challenges faced by different countries or regions. Such an index would allow policymakers and industry stakeholders to assess the progress of BIM adoption, identify key gaps, and set targeted goals for improvement. Another important area for future research is the integration of BIM with smart city initiatives. As urban development increasingly focuses on sustainability and technological integration, BIM's role in managing urban infrastructure and optimizing building performance will become increasingly critical. Research in this area could provide new insights into how BIM can contribute to creating smarter, more sustainable cities.

Moreover, the future development of BIM is increasingly connected to City Information Modelling (CIM), which expands digital modelling from individual buildings to district and city-scale planning. While BIM focuses on building lifecycle management, CIM integrates urban data such as infrastructure, transportation, environment, and land use into a unified digital framework. The integration of BIM and CIM can bridge the gap between building construction and urban planning by improving coordination between architects, planners, engineers, and municipalities. This approach supports smart city development, digital twins, sustainability, and more efficient urban management. For emerging economies and CIS countries, integrating CIM with BIM could strengthen data-driven urban governance, although this will require interoperable standards,

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stronger GIS-BIM integration, updated regulations, and improved digital infrastructure.

Finally, the long-term impact of BIM on the construction industry's efficiency and sustainability remains an important area for investigation. Longitudinal studies tracking BIM's effect on industry productivity, cost savings, and environmental sustainability will help demonstrate its value over time and encourage broader adoption. These studies will not only support the case for BIM but also guide future advancements in BIM technologies and their application in construction.

In conclusion, the successful integration of BIM into the construction industry requires a multifaceted approach that addresses the technological, economic, and human factors that influence adoption. By focusing on clear policy development, workforce preparedness, and targeted research efforts, countries can create a more effective environment for BIM's widespread implementation. With the right mix of governmental support, education, and research, the construction industry can unlock the full potential of BIM technologies, paving the way for more efficient, sustainable, and innovative building practices worldwide.

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HERITAGE MUSEUM BUILDINGS UNDER CLIMATE STRESS: MAPPING DETERIORATION ACROSS URBAN AND COASTAL REGIONS

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Abstract

Heritage museum buildings in Malaysia increasingly face environmental stressors, such as high humidity, temperature changes, and heavy rainfall. Many are found in urban centres and coastal zones. Each location brings unique environmental challenges that influence the severity and type of deterioration. These cultural assets are susceptible, underscoring the need to understand how environmental conditions, especially those tied to geographic location, contribute to building degradation. Yet current maintenance often overlooks location-specific weaknesses, leading to poor conservation outcomes. This study compares environmental deterioration in heritage museum buildings across urban and coastal settings. Condition assessments were conducted at selected museums across multiple states and examined alongside regional temperature and humidity data. A spatial heat map generated in QGIS shows the distribution of deterioration by environmental exposure. The results show that coastal buildings face more moisture, dampness, and mould due to high humidity and salty air. Urban buildings, however, present localized problems like heat retention, pollution stains, and poor ventilation. The analysis demonstrates that environmental stressors, especially humidity and rain, work with location to shape building conditions. The study recommends climate-responsive, location-specific maintenance strategies to preserve heritage assets in the long term. These findings aim to help heritage managers and conservation stakeholders plan targeted interventions and optimise resources in tropical urban and coastal areas.

Keywords: Heritage Conservation, Climate-Responsive Maintenance, Building Deterioration, Tropical Heritage Buildings, Spatial Risk Mapping

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INTRODUCTION

Heritage museum buildings in Malaysia showcase the country's history and diverse architecture. They play important roles in education, tourism, and supporting national identity (Athirah & Harun, 2025; SER, 2020). However, preserving these buildings is becoming harder because Malaysia's tropical climate brings high humidity, heavy rain, and changing temperatures (Nur Fisya et al., 2025; Daengprathum et al., 2022; Hidalgo-Sánchez et al., 2022).

Environmental factors speed up the deterioration of heritage buildings, especially in coastal areas where salty air, moisture, and strong winds cause more biological growth, erosion, and material damage (Del Cisne et al., 2024; Hernández et al., 2023; Luo et al., 2023). The problem is made worse by weak environmental protections and uneven maintenance. Since Southeast Asia is very vulnerable to climate change and about 70% of Malaysia is coastal, heritage buildings face even greater risks (Dickerson, 2019).

Even with conservation efforts based on the National Heritage Act 2005 (Malaysia, 2005) and JWN guidelines, 61% of conservation work focuses on museum buildings, and 70% still have physical problems caused by environmental damage (Asyraf Mohd Bekeri et al., 2023; Hauashdh et al., 2020). Most current practices are reactive, fixing damage only when it becomes serious. This approach speeds up deterioration, raises repair costs, and puts the buildings' authenticity at risk (Azizan et al., 2020; Ferreira et al., 2021).

Most earlier studies have looked at restoration or documentation separately, without combining data on environment, building condition, and defects. This study fills that gap by analysing environmental stress, condition ratings, and defect patterns in Malaysian heritage museums. It uses spatial and statistical methods to help develop preventive maintenance strategies that respond to climate challenges.

LITERATURE REVIEW

As a heritage building, a museum is integral in upholding cultural identity. However, it is increasingly threatened by environmental stressors (Bülbül Bahtiyar & Dişli, 2022; Dişli & Kilit, 2024). Past studies identified several environmental factors, such as wind, rain, humidity, solar radiation, and salt-laden air, as key factors in material deterioration at heritage sites. These pressures exacerbate common defects, including dampness, cracking, coating delamination, and biological growth, especially in tropical and coastal regions such as Malaysia and Indonesia. (Arif et al., 2024; Daengprathum et al., 2022; Fadhilah Bahardin et al., 2022; Ortega-Morales et al., 2019; Zain et al., 2022).

In urban areas, climatic fluctuations and pollution accelerate material deterioration and surface wear (Del Cisne et al., 2024). In contrast, coastal areas are subject to distinct damage mechanisms, including elevated humidity, salt

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crystallization, and wind erosion (Hernández-Montes et al., 2023; Luo et al., 2023). Consequently, the location of a building—whether transitional, coastal, or urban—plays a significant role in the progression and nature of deterioration in historic structures.

In response to these risks, recent studies increasingly advocate for preventive maintenance of heritage buildings (Ferreira et al., 2021). Rather than addressing issues only after they arise, a risk-based preventive approach aligns maintenance priorities with building condition and environmental risk factors (Lucchi, 2020; Silva & Henriques, 2021). This strategy not only mitigates deterioration but also reduces long-term costs and conserves resources.

GIS-based maps, created with open-source spatial analysis tools such as QGIS, highlight the need to map deterioration patterns across heritage museum sites (Gabriele et al., 2023). QGIS helps identify high-risk areas and environmental stressors that drive material decay by combining building condition data with environmental factors such as temperature, humidity, and moisture (Guerri et al., 2023; Papakonstantinou, 2025). This spatial insight, together with environmental monitoring, improves understanding of and ability to observe preservation challenges (Graser et al., 2025; Maurya & Kumar, 2024).

Despite rising global awareness, preventive maintenance of heritage buildings in Southeast Asia remains inadequate. Research shows that policy limitations, a shortage of technical skills, and inconsistent funding block systematic preservation efforts in the region (Asyraf Mohd Bekeri et al., 2023). Thus, it is urgent to adapt international preventive models to local contexts, particularly in countries such as Malaysia that are vulnerable to climate change.

METHODOLOGY

This study used a mixed-methods approach to examine deterioration patterns and environmental stress impact on heritage museum buildings across different regions of Malaysia. A total of 13 heritage museum buildings, representing urban, coastal, and urban-coastal areas, were selected based on their location, regional exposure, and function. The framework in Figure 1 combines building condition assessments, environmental monitoring, and spatial analysis to create a clear understanding of how climate factors affect the severity of deterioration.

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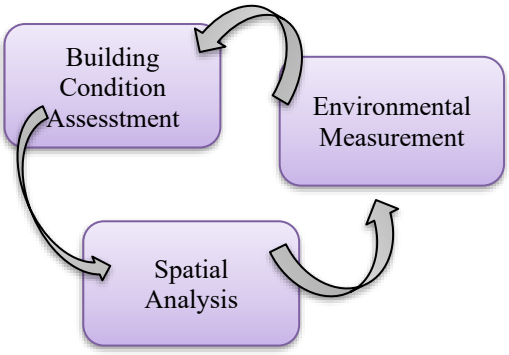


Figure 1: Methodological Framework

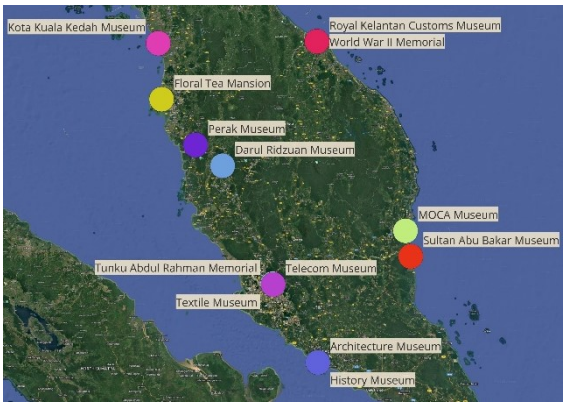


Figure 2: Spatial Distribution of Heritage Museums Buildings collected across Malaysia Peninsular.

Figure 2 and Table 1 show the spatial distribution of heritage museum buildings in several states in Malaysia, including Kuala Lumpur, Perak, Kedah, Penang, Kelantan, Pahang, and Malacca.

DATA COLLECTION

Data collection used three instruments:

i) Visual Building Condition Assessment (BCA) based on PWD BCA/FCA guidelines, with a 5-level condition rating and a risk matrix;
ii) Environmental measurements of temperature, humidity, and surface moisture, recorded at multiple locations with at least five readings per variable, averaged; and
iii) Spatial and tabular data integration, combining GIS coordinates, regional classifications (urban, coastal, urban-coastal), and defect counts into a unified database for analysis.

Table 1 illustrates the geographical spread of heritage museums across Peninsular Malaysia, categorised into three regional contexts as follows:

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Table 1: Spatial Distribution of Heritage Museums Buildings Regions Colour-coded

Colour	Area	Buildings	Characteristics
Purple	Urban	Telekom Museum, Textile Museum, and TAR Residency Memorial in Kuala Lumpur, and the Perak Museum and Darul Ridzuan Museum in Perak.	Inland city centres; Exposure on urban heat and pollution due to traffics and active town activities.
Green	Coastal	Kota Kuala Kedah Museum in Kedah and World War Museum or known as *Bank Kerapu* in Kelantan.	Near coastal edges; exposed to sea breeze, spray, humidity, and saline air
Blue	Urban-Coastal	Teh Bunga Mansion in Penang, the Historical Museum and the Architectural Museum in Malacca, the Royal Kelantan Customs Museum in Kelantan, the MOCA Museum, and the Sultan Abu Bakar Museum in Pahang.	Towns combining both urban infrastructure and proximity to coastline; exposed to dual stressors

DATA ANALYSIS

The data were analysed in three stages:

- Descriptive Statistical Analysis: Defect frequencies, building condition ratings, and environmental readings were summarized to identify key deterioration patterns.
- Spatial Distribution Mapping: Using QGIS, thematic maps were generated to visualise the geographic distribution of high-risk buildings, environmental exposure zones, and defect intensities across regions.
- Correlation and Risk Mapping: The relationship between environmental stressors and building condition scores was assessed in Excel. Risk levels were visualised in QGIS using graduated symbols and colour coding. The urban-coastal comparison was conducted using side-by-side map frames and attribute table filtering, enabling triangulation of environmental, structural, and spatial factors for climate-responsive interpretation.

Descriptive Analysis

Descriptive statistics summarised condition ratings, defect frequencies, and environmental parameters across 13 heritage museums. Using a 1–5 scale, mean and range values established baseline deterioration trends.

Table 2: Descriptive Statistics Condition ratings by locations

Area	Count	Min	Max	Mean	Std Dev
Urban	5	3.45	3.84	3.62	0.164
Coastal	2	3.69	4.02	3.86	0.165
Urban Coastal	6	2.61	3.91	3.28	0.3925

Table 3: Descriptive Statistics Defects by locations

Area	Sum	Min	Max	Mean	Std Dev
Urban	640	78	163	128	29.3
Coastal	296	130	166	148	18
Urban Coastal	805	81	185	134	36.862

A descriptive summary in Table 2 indicates clear regional disparities in building condition. Coastal museums recorded the highest and most consistent condition ratings (Mean = 3.855; SD = 0.165), while urban museums showed stable but slightly lower performance (Mean = 3.622; SD = 0.164). Urban-coastal museums exhibited the lowest ratings and highest variability (Mean = 3.277; SD = 0.392), indicating compounded deterioration pressures from combined climatic and urban stressors.

String from that, Table 3 illustrates that urban-coastal zones had the highest total defects (805), followed by urban (640) and coastal (296). However, coastal museums recorded higher defects per site, suggesting severe localized deterioration.

Table 4: Descriptive Statistics Categories of Defects by locations

Area	Moisture-related surface damage (Sum)	Structural (Sum)	Coating deterioration (Sum)	Biodeterioration (Sum)
Urban	512	68	35	16
Coastal	277	11	6	2
Urban Coastal	507	172	143	49

Defect categorisation revealed moisture-related damage as the dominant issue across all regions, particularly in urban (512) and urban-coastal (507) zones. Structural defects were most prevalent in urban-coastal areas (172), while coating deterioration and biodeterioration were also concentrated in these zones, reflecting intensified environmental exposure as stated in table 4.

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Table 5: Descriptive Statistics Humidity Readings by locations

Environmental Parameter	Location	Sum	Min	Max	Mean	SD
Moisture (%)	Urban	107.26	17.5	27.1	21.44	3.52
	Coastal	79.30	35.6	43.7	39.22	4.05
	Urban Coastal	132.16	15.0	29.0	22.03	4.31
Temperature (°C)	Urban	140.92	25.3	30.0	28.18	2.22
	Coastal	54.00	26.0	38.0	27.00	6.00
	Urban Coastal	166.74	26.0	28.87	27.79	1.02
Humidity (%RH)	Urban	327.50	62.0	70.7	65.50	4.29
	Coastal	165.00	82.0	83.0	82.20	0.50
	Urban Coastal	449.00	68.0	82.0	74.83	4.52

Tables 5 illustrate that the environmental readings reinforce these findings. Coastal zones recorded the highest moisture (Mean = 39.22%) and humidity (Mean = 82.2%), while urban and urban-coastal zones showed moderate moisture (~21–22%) but higher defect occurrence, indicating accumulated exposure and material vulnerability. Urban areas recorded the highest temperature (Mean = 28.18°C), while coastal zones showed lower variability due to marine influence.

Overall, urban-coastal environments emerge as the most vulnerable typology, driven by a combination of environmental stressors.

Comparative Analysis

Comparative analysis indicates that urban (512) and urban-coastal (507) zones recorded the highest moisture-related surface defects, consistent with moderate moisture levels (21.44% and 22.03%). In contrast, coastal areas, despite higher moisture (29.33%), showed fewer defects (277), possibly due to better ventilation, material behaviour, or smaller building scale. Structural defects were most significant in urban-coastal zones (172) under moderate humidity (74.83%). In contrast, coastal zones recorded minimal structural issues (11) despite higher humidity (82.2%), suggesting deterioration is driven by combined environmental exposure and maintenance limitations rather than humidity alone.

Urban-coastal areas also exhibited the highest coating deterioration (143) and biodeterioration (49), reflecting intensified environmental stress from interactions among temperature, humidity, and moisture. Overall, urban-coastal environments are the most vulnerable, experiencing compounded deterioration effects.

Table 6: Comparison Statistics Condition and Environmental Readings by Regions

Location	Average Total Defects	Average Condition Rating	Average Moisture	Average Temperature	Average Humidity
Urban	640	3.622	21.44	28.18	65.5
Coastal	296	3.855	39.22	27	82.2
Urban Coastal	805	3.27667	22.03	27.79	74.83

Comparative analysis (Table 8) confirms that urban-coastal zones are the most vulnerable, with the highest defect levels and elevated humidity despite moderate condition ratings. Coastal zones, though fewer in number, exhibit higher moisture and humidity, indicating significant exposure risk, while urban areas experience thermal stress but comparatively less severe deterioration.

Spatial And Correlation Mapping

In addition to descriptive and comparative analyses, the data have also been analysed through spatial and correlation mapping using 3 different approaches, including spatial and environmental risk mapping and correlation mapping analysis, as follows:

a) Spatial and Environmental Risk Mapping Analysis

Spatial mapping using QGIS was applied to analyse total defects, identify environmental hotspots, and classify deterioration risks based on combined environmental factors, including moisture, temperature, and humidity.

i. Spatial Distribution of Total Defects

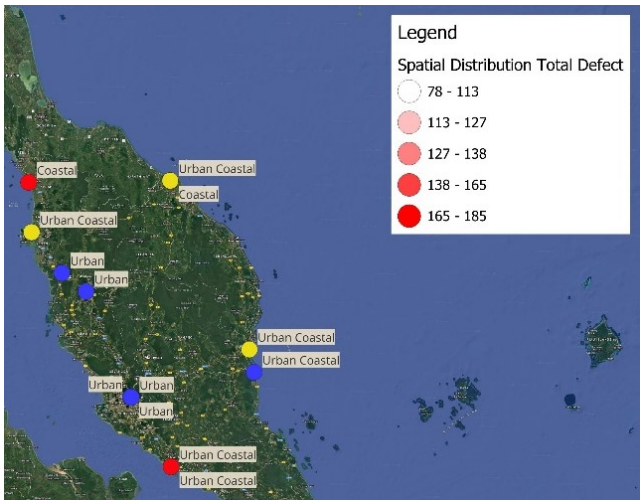


Figure 3: Spatial Distribution of Total Defects

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Figure 3 shows defect distribution across museums, with the highest counts (165–185) concentrated in urban-coastal sites such as the Telekom Museum and the Architectural Museum. Lower defect counts (78–113) occur in less exposed locations. This pattern indicates that urban-coastal museums experience greater deterioration due to combined environmental and human-induced stressors.

ii. Heatmap of Deterioration Intensity

Figure 4 identifies deterioration hotspots in the Klang Valley, Melaka, and coastal corridors, indicating that urban pressure, environmental exposure, and visitor activity contribute to clustered, high-intensity building deterioration.

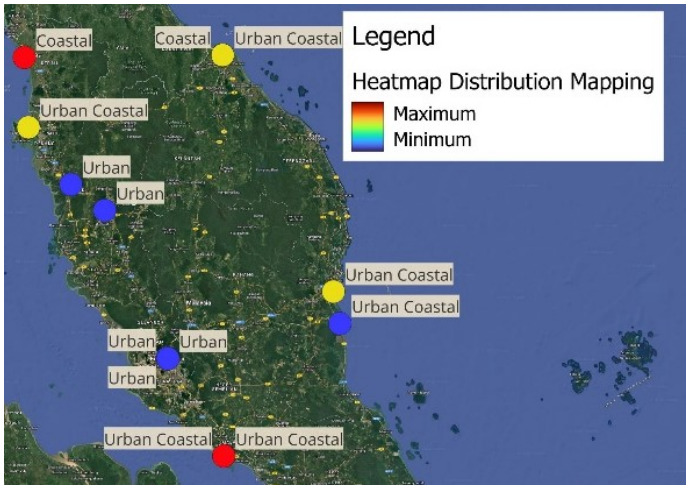


Figure 4: Spatial Distribution of Heatmap Deterioration Intensity

iii. Environmental-Based Deterioration Risk Classification

Table 7: Comparison Statistics Condition and Environmental Readings by Regions

Risk Level	Average Moisture	Average Temperature	Average Humidity
Low	20.37	26.75	65.92
Moderate	26.9	28.15	77.67
High	29.62	28.58	78.25

Table 9 shows high-risk buildings have elevated moisture (29.62%), humidity (78.25%), and temperature (28.58°C), indicating stronger environmental stress and deterioration risk. Figure 8 maps these risks, highlighting high-risk zones in Penang, Melaka, and southern coastal regions,

where tropical climate exposure intensifies deterioration, compounded by limited preventive maintenance practices. While moderate-risk museums are mainly located in central areas, low-risk sites tend to be inland or at higher elevations, like Perak and Kelantan.

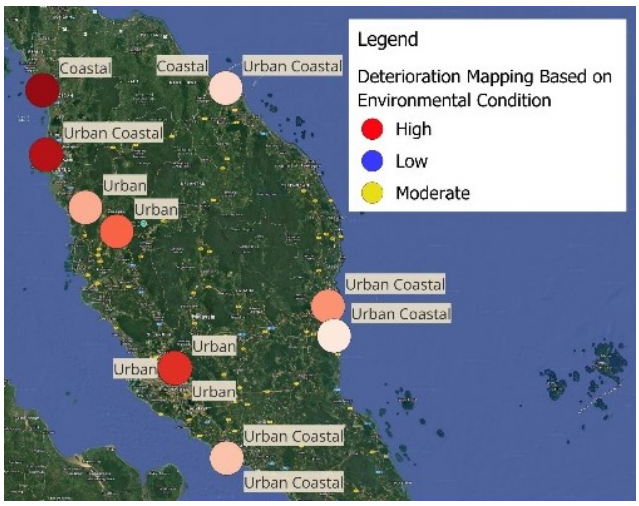


Figure 5: Deterioration Risk Mapping Based on Environmental Condition

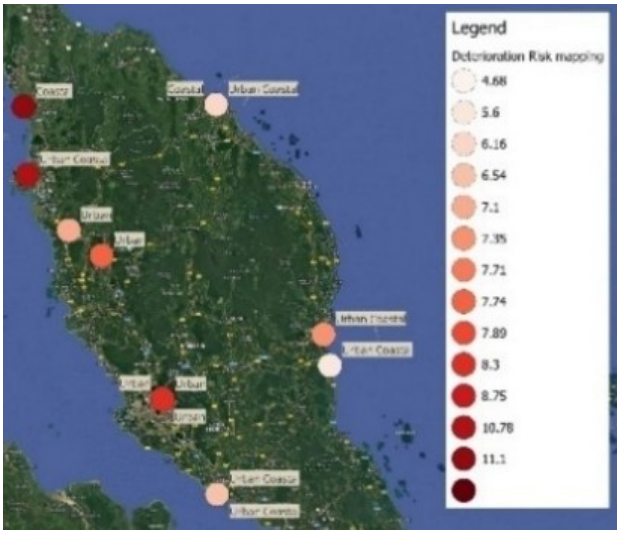


Figure 6: Deterioration Mapping based on Risk Score

Figure 6 presents a graded risk index map for deterioration. It is based on weighted inputs, including condition ratings, total defect scores, and

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environmental measurements. Sites such as Telecom Museum (11.3) and Architecture Museum (10.76) have the highest risk scores. Their moisture and humidity readings are also elevated. This visualisation underscores the importance of spatial profiling for prioritising conservation efforts.

a) Correlation Analysis

The study analysed relationships across all museums using Pearson correlation and QGIS mapping. Despite geographic variation, this combined approach reveals overall links between temperature, humidity, moisture, and building condition, providing a clearer understanding of how environmental stress accumulates and influences deterioration patterns across different locations.

i. Pearson Correlation Matrix Interpretation

Table 8: Correlation Matrix Between Environmental Parameters and Building Deterioration

	Total Defect	**Condition Rating**	**Risk Level**	**Temperature**	**Humidity**	**Moisture**
Total Defect	-					
Condition Rating	-0.103	-				
Risk Level	0.090	0.89	-			
Temperature	-0.177	0.062	0.125	--		
Humidity	0.150	-0.109	-0.028	-0.600	-	
Moisture	0.116	0.563	0.656	-0.075	0.529	-

Table 10 shows a strong correlation between condition rating and risk level (r = 0.891), indicating that poorer conditions lead to higher risk. Moisture has moderate to strong correlations with condition (r = 0.562) and risk (r = 0.656), confirming it as a key deterioration driver. Humidity correlates with moisture (r = 0.529), reinforcing their combined effects. Temperature shows a weak negative correlation with defects (r = -0.177), indicating limited influence. Overall, moisture is the most significant environmental factor driving deterioration in Malaysian heritage museum buildings.

ii. Spatial Correlation Mapping (QGIS)

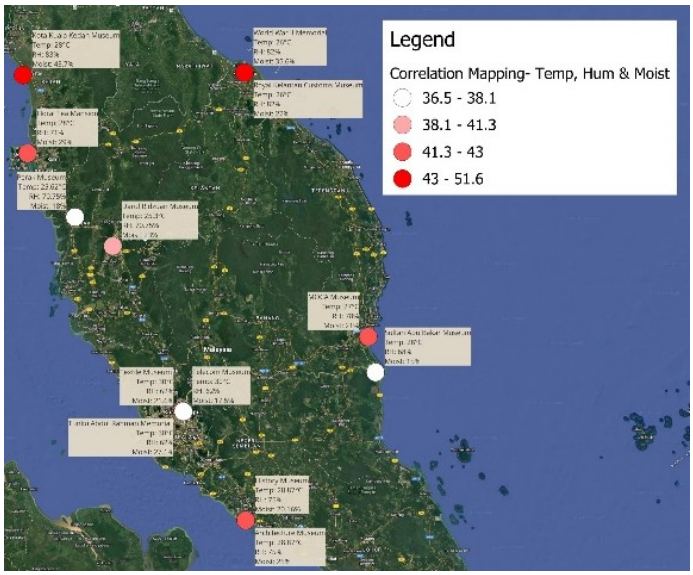


Figure 7: Deterioration Risk Mapping Based on Environmental Condition

A spatial correlation map (Figure 7) visualises the impacts of environmental stressors using average temperature, humidity, and moisture readings for each selected museum location. A composite environmental score was calculated as the mean of the three variables for each building. Based on overall environmental exposure, the score was categorised into quintiles to rank buildings spatially. The ranges are as follows:

- White (36.5–38.1) – Low environmental correlation
- Light Pink (38.1–41.3) – Mild influence
- Medium Pink (41.3–43) – Moderate stress
- Dark Pink (43–51.6) – High correlation with deterioration trends

Spatial mapping shows coastal and urban-coastal museums fall within medium to high environmental stress zones, indicating greater vulnerability, while inland sites experience lower stress. The correlation range (36.5–51.6) was divided into equal intervals to ensure consistent classification and reduce bias, supporting identification of priority conservation areas. This approach provides a macro-level understanding of environmental impacts across diverse locations. However, aggregated analysis may obscure localised conditions, particularly in unique coastal or highland settings. QGIS mapping complements statistical results by revealing site-specific stress patterns. Future research should expand

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sample sizes to enable regional subgroup analysis and improve understanding of localised deterioration risks.

RESULTS AND DISCUSSION

Environmental Stress as A Deterioration Multiplier

The correlations and spatial analysis indicate that temperature, humidity, and moisture are associated with the risk of building deterioration. Humidity and moisture are interrelated, especially in urban coastal areas, where higher levels increase the risk to buildings. Therefore, this study contributes to the broader discussion of climate-related material degradation, for example, demonstrating that timber and masonry structures are vulnerable to recurring cycles of wet and dry conditions, biological growth, and surface damage. The consistent pattern of moderate to high environmental correlation values in these areas enhances the need for specific strategies to fit the maintenance protocols into the environmental conditions of each location instead of using generic conservation measures.

Spatial And Climatic Typologies Influence Performance

Building deterioration is not only about exposure, as shown by site differences within urban, coastal, and urban-coastal areas, but also depends on environmental and climate changes. As an example, building condition ratings in urban coastal areas are lower, with more defects, and have higher environmental readings than those in urban areas, indicating that the transitional zones are exposed to dual environmental stressors and require specialized conservation planning. This should include both inland heat management and marine exposure control.

Maintenance Gaps and Adaptive Shortcomings

Although building condition ratings and total defect counts did not strongly correlate with environmental factors in a linear way, their indirect influence through risk levels and moisture accumulation highlights the complexity of heritage conservation under climate stress. The weak correlations also show that maintenance practices vary. This underscores the need to shift from reactive maintenance to preventive conservation and maintenance, particularly for buildings with frequent recurring defects. Maintenance interventions should be seen not as separate technical tasks but as part of a broader strategy for climate resilience.

Implications For Heritage Conservation Policy and Planning

The study underscores a growing need to adapt the heritage museum building to a climate-sensitive approach that eases maintenance as a preventive measure, especially in tropical regions. Current national policies should enhance for

locational vulnerability or include climatic stress mapping in conservation priority setting. The findings from this study, especially the spatial risk patterns, are potentially useful to government conservation units and local authorities in designing region-specific conservation guidelines, allocating resources based on deterioration risk mapping, and prioritising heritage museum building conservation. This approach allows stakeholders to visualise deterioration patterns and manage risk structures before they cause critical damage.

CONCLUSION

This study examines deterioration patterns and environmental vulnerabilities of heritage museum buildings in tropical Peninsular Malaysia. Integrating condition ratings, environmental measurements, and spatial analysis, the findings identify humidity, temperature, and moisture as key drivers of defects such as biological growth, cracking, and material decay. QGIS mapping reveals greater vulnerability in coastal and urban-coastal areas due to compounded environmental exposure, with strong correlations between climate conditions and building performance. The study highlights the need for climate-responsive preventive maintenance strategies to address gaps in current practice. It underscores an urgent shift from reactive conservation to proactive, risk-informed approaches to enhance resilience and safeguard heritage assets for future generations.

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