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Original Article

Developing a Building Maintenance Strategy for Low-Rise, Low-Cost Housing in Malaysia's Northern Region: A Conceptual Framework for Addressing Tropical Climate Challenges

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Abstract

This conceptual paper explores the development of an effective building maintenance strategy for low-rise, low-cost housing in Malaysia's northern region, emphasising the challenges posed by the country's tropical climate. The region's high humidity, intense rainfall, strong solar radiation, and occasional storms accelerate structural deterioration, affecting both the functionality and longevity of these buildings. Key issues such as water penetration, corrosion, mould growth, and thermal expansion contribute to increased wear and tear, compromising structural integrity and aesthetic value. By adopting a mixed-methods approach, this study synthesises insights from literature reviews, surveys, interviews with occupants, and site observations to assess climate-induced maintenance challenges. The findings aim to establish a conceptual framework for proactive maintenance strategies, ensuring the sustainability and resilience of low-rise housing in tropical environments.

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1. Introduction

1.1. Background Research

Urban landscapes in rapidly developing regions such as Penang, Malaysia, are increasingly characterised by low-rise, low-cost housing, a critical solution to the growing demand for affordable housing. These buildings provide shelter for an expanding urban population and symbolise the country's economic growth and modernisation efforts. However, the maintenance and durability of these structures face significant challenges due to the tropical climate, which accelerates the degradation of

building materials and systems. Malaysia's climate, characterised by consistently high temperatures, high humidity, and heavy rainfall, significantly impacts the longevity of construction materials and building components, posing a unique challenge for maintaining low-rise, low-cost housing in the northern region [1].

As climate change continues to be a global concern, its localised effects, particularly on the built environment, have become more pronounced. Malaysia, situated in Southeast Asia and encompassing both Peninsular Malaysia and Malaysian Borneo, experiences a tropical climate marked by high moisture levels, intense rainfall, and frequent storms, primarily due to its coastal position and exposure to monsoonal weather patterns [2]. The continuous exposure of buildings to these environmental conditions accelerates the deterioration of materials and structures. Corrosion, mould growth, rotting of timber, and the weakening of concrete and masonry are common issues faced by low-rise buildings in this climate, leading to increased maintenance costs and reduced safety and comfort for residents. The problem is compounded by the growing urban population and limited resources available for maintaining these buildings, particularly in low-cost housing sectors where funding is constrained.

In particular, the high humidity levels in Malaysia create a perfect environment for mould and fungi to thrive. These biological agents lead to the deterioration of building materials such as timber and drywall and pose health risks to the inhabitants [3]. Mould growth is associated with respiratory issues, allergies, and other health problems, further underlining the urgency of addressing these maintenance challenges. Additionally, the facades of low-rise buildings, especially those constructed from stone, glass, and metal, are highly vulnerable to the impacts of rain, humidity, and extreme temperature fluctuations. Prolonged exposure to these environmental factors results in fading, rusting, and erosion of surface materials, contributing to the overall degradation of the structure [4,5].

This study aims to develop a comprehensive and climate-responsive maintenance strategy tailored to the specific needs of low-rise, low-cost housing in Malaysia's northern region. The proposed plan will consider the tropical climate's influence on material durability and propose a conceptual framework for proactive maintenance that addresses the core environmental challenges, such as high humidity, heavy rainfall, and exposure to coastal winds. By focusing on preventive measures and adaptive solutions, the framework will prioritise selecting durable materials resistant to corrosion, moisture, and fungal growth. It will also emphasise the importance of regular inspections, timely repairs, and innovative technologies that can help mitigate the long-term effects of environmental stress on building systems.

The framework will further explore sustainable building practices and the integration of energy-efficient technologies that improve the longevity and resilience of buildings and contribute to environmental sustainability. It will propose cost-effective and feasible solutions for low-cost housing projects, ensuring that maintenance practices do not burden residents or the local government. Moreover, the strategy will focus on community engagement and capacity building, empowering residents to take an active role in the upkeep of their homes and enhancing the overall effectiveness of maintenance initiatives.

In conclusion, developing a tailored building maintenance strategy for low-rise, low-cost housing in Malaysia's northern region is essential for enhancing the resilience and sustainability of these structures in the face of tropical climate challenges. By identifying the specific environmental factors that contribute to material degradation and proposing innovative and adaptable maintenance practices, this study seeks to bridge the gap between existing maintenance methods and the unique demands of Malaysia's tropical climate. The proposed framework will ensure that these buildings remain safe, functional, and durable while supporting the region's broader goals of urban modernisation, economic growth, and sustainability.

1.2. Literature Review

1.2.1. Building maintenance in Malaysia

Ageing infrastructure, tight resources, and inadequate staff training are some of the issues Malaysian building maintenance faces. Adoption of technology, involvement of stakeholders, and funding for training initiatives are all necessary for effective facilities management, improving maintenance efforts and guarantee adherence to safety and legal requirements. This statement was introduced by Zhi Ling et al. [6].

Since neglected maintenance can result in higher repair costs and a shorter building lifespan, building maintenance is essential in Malaysia to stop small problems from worsening. Delays are caused by several factors, such as growing expenses, bad scheduling, and insufficient preparation, all of which call for efficient mitigation strategies. This statement was introduced by Norazam et al. [7].

1.2.2. Low-rise low-cost building maintenance

Low-rise structures frequently use inferior materials, which causes serious degradation. The lack of progress in building maintenance is also a result of residents' bad maintenance practices, which are caused by professionals' poor participation in training programs. This statement was introduced by Lekan et al. [8].

Low-cost strata schemes often lack resources and support from residents, which may contribute to challenges in maintenance practices for all types of buildings. Low-rise buildings frequently have poor upkeep because of ageing, poor repair techniques, and neglect. Failures are caused by degradation that is made worse by environmental factors, underscoring the necessity of better maintenance procedures to avoid such problems. This statement was introduced by Kumalasari et al. [9].

1.2.3. Climate change definition and effects on the building

"Climate change" describes notable changes in temperature and weather patterns. It impacts buildings by making them more susceptible to severe weather events, which can cause structural damage, lower the dependability of vital infrastructure, and call for resilient, sustainable urban strategies. The statement was introduced by Liang et al. [10].

Human activities like burning fossil fuels, deforestation, and industrial processes, which emit significant volumes of greenhouse gases like carbon dioxide and methane into the atmosphere, are the main causes of these changes. These gases trapping heat cause global warming, ecosystem disturbances, and weather patterns.

- Heavy downpours can overwhelm drainage systems, leading to waterlogging, leaks, and flooding that damage building foundations and interiors.
- High humidity fosters the growth of mould and fungi, which can damage building materials and negatively impact indoor air quality.
- Moisture accelerates rusting in metal components such as reinforcements, beams, and fasteners, weakening the structure over time.
- Frequent heating and cooling cycles can cause materials to expand and contract, leading to cracks, leaks, and structural weaknesses.
- Climate change accelerates wear and tear on buildings, requiring more frequent inspections, repairs, and upgrades to ensure safety and functionality.

Table 1 summarises the 20 authors of this study on climate vs. building indications, the research methodology, and the findings of the peer studies. These studies ([13]-[32]) recapitulate the development of a building maintenance strategy for low-rise, low-cost housing in Malaysia's Northern Region.

2. Methodology

2.1. Qualitative Method

Understanding qualitative approaches is essential to comprehending research. They present a comprehensive and nuanced picture of the phenomenon being studied, offering deep insights that are frequently not possible with just quantitative approaches. Numerous disciplines, including the humanities, social sciences, and even the natural sciences, employ qualitative approaches as determined by Doris et al. [11].

The qualitative approach is crucial for this study because it offers deep insights into the difficulties and solutions associated with preserving low-rise low-cost structures in the northern region's tropical environment. The qualitative method enables the researcher to collect in-depth viewpoints from building managers, maintenance staff, residents, and industry experts through focus groups, interviews, and document analysis.

2.2. Quantitative Method

Quantitative analysis is a method of research that involves gathering, analysing, and interpreting numerical data using statistical techniques. As Devi et al. [12] stated, researchers can collect accurate information for statistical analysis through surveys, experiments, and secondary sources (see Figure 1).

The quantitative approach is essential to this study because it offers measurable and objective data to assess how Malaysia's tropical environment affects the northern region's low-rise, low-cost building upkeep. Numerical data on variables such as the frequency of maintenance tasks, expenses incurred, material deterioration rates, and climate metrics (e.g., humidity and rainfall levels) can be gathered using quantitative approaches.

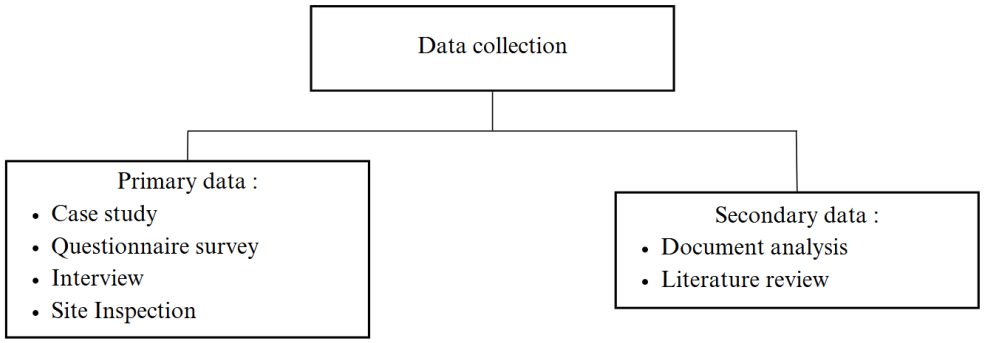

Figure 1: Data collection method in research methodology.

Table 1: Summarise this peer review on climate vs building indications and research methodology.

No.	Author	Title	Journal Name	Aim and Objectives	Method	Main Findings	Year
1.	Norsafiah Norazman, Naziah Muhamad Salleh, Siti Nurul Asma, Wan Norisma	Strategic planning of sustainable maintenance in heritage school buildings: Malaysia perspective	International Journal of Building Pathology and Adaptation	To preserve the heritage buildings' culture and history while being given a new lease.	Qualitative method	Developing a strategic planning framework and maintenance for heritage school buildings in Malaysia to achieve sustainable maintenance. [13]	2023
2.	Shamsuddin Shahid, Sahar Hadi Pour, Xiaojun Wang, Sabbir Ahmed Shourav, Anil Minhans, Tarmizi Ismail	Impacts and adaptation to climate change in Malaysian real estate	International Journal of Climate Change Strategies and Management	To analyze the current knowledge regarding future climate changes to understand their possible impacts on the real estate sector of Malaysia.	Qualitative method	These changes will pose risks of property damage and increase property lifecycle costs. [14]	2017
3.	Andrew Ebekozien, Mohamad Shaharudin Samsurijan, Clinton Aigbavboa, Andrew I. Awo-Osagie	Developing a framework for building maintenance: A case study of Malaysia's low-cost housing via soft system methodology	International Journal of Building Pathology and Adaptation	To investigate the state of LCH and develop a framework to improve LCH maintenance practices in Malaysia.	Qualitative method	There is an absence of a framework to improve maintenance practices, especially in LCH across Malaysia's cities. [15]	2022
4.	Ellemy Iskandar Khalid, Shardy Abdullah, Mohd Hanizun Hanafi, Shahru Yani Said	The consideration of building maintenance at design stage in public buildings: The current scenario in Malaysia	Facilities	To determine the current scenario of the building maintenance approach at the design stage in public buildings in Malaysia.	Qualitative & Quantitative methods	Shows that the building maintenance in public building in Malaysia still uses the reactive approach. [16]	2019
5.	Umi Kalsom Zulkafli, Norhanim Zakaria, Aina Mohamad Mazlan, Azlan Shah Ali	Maintenance work for heritage buildings in Malaysia: Owner's perspectives	International Journal of Building Pathology and Adaptation	To establish the impacts of good maintenance work on heritage buildings in Malaysia.	Quantitative method	Shows the factors that lead to the lack of maintenance of heritage buildings are limited to finance, the absence of maintenance guidelines and ill-defined maintenance policy. [17]	2018
6.	Olanrewaju Abdul Lateef, Mohd Faris Khamidi, Arazi Idrus	Building maintenance management in a Malaysian university campus	Australasian Journal of Construction Economics and Building	To identify, describe, and assess the maintenance management system used by the university.	Qualitative & Quantitative methods	Many academic organizations view building maintenance management as a burden rather than as a value-added strategy. [18]	2011
7.	M.S. Khalid, A.H. Ahmad, M.F. Sakdan	The challenges of maintaining and managing high-rise buildings: Commercial vs residential buildings	International Journal of Recent Technology and Engineering	To identify from the MC's perspective the challenges of maintaining and managing high-rise commercial buildings compared to	Qualitative method	High-rise commercial properties MCs faced significant challenges and issues such as tenancy management, marketing strategy, and sustainability of investment. [19]	2019

				residential buildings.			
8.	Azlan Shah Ali	Cost decision making in building maintenance practice in Malaysia	Journal of Facilities Management	To systematically identify important factors that are considered in decision-making of maintenance cost.	Qualitative & Quantitative methods	Associative test results reveal that variance in maintenance cost could be improved by considering the condition of the building and complaints about building performance during decision-making. [20]	2009
9.	Shirley Jin Lin Chua, Najilah Bt Zubbir, Azlan Shah Ali, Cheong Peng AuYong	Maintenance of high-rise residential buildings	International Journal of Building Pathology and Adaptation	To identify the characteristics of preventive maintenance and establish the relationship with maintenance performance in high-rise residential buildings.	Quantitative method	There are seven maintenance characteristics significantly correlated with maintenance performance indicators. [21]	2018
10.	Isma Haniza Fakhrudi, Mohd Zailan Suleiman, Roslan Talib	The need to implement Malaysia's Building and Common Property Act 2007 (Act 663) in building maintenance management	Journal of Facilities Management	To focus on the involvement of the Commissioner of Building and the rights of the Joint Management Body.	Qualitative method	To ensure its optimal performance over its life cycle. [22]	2011
11.	Hayrol Azril, Jeffrey Lawrence, Nurani Kamarudin, Siti Zobaidah Omar	The coastal community awareness towards the climate change in Malaysia	International Journal of Climate Change Strategies and Management	-To investigate the awareness of coastal community towards climate change in Malaysia. -To explore the factors associated with their awareness towards climate change	Quantitative method	There are significant differences regarding coastal community awareness to changes relating to the sea, temperature, and coast. [23]	2015
12.	Andrea Parisi Kern, Fabiana Pires Rosa, Luis Braganca	BIM-FM in existing buildings: a case study on educational and high-rise residential buildings	Journal of Facilities Management	To analyse the building's current facility management processes for educational and high-rise residential areas.	Qualitative method	Different in how FM is conducted because of scattered, disconnected, and incomplete information on both. [24]	2024
13.	Ali Hauashdh, Junaidah Jailani, Ismail Abdul Rahman, Najib AL-fadhali	Building maintenance practices in Malaysia: a systematic review of issues, effects and the way forward	International Journal of Building Pathology and Adaptation	-To carry out a comprehensive review of building maintenance issues, their effects, and the way forward. -To develop a conceptual model that can support future research.	Qualitative method	-This study has identified and classified building maintenance issues, their effects and the way forward. -Developed a conceptual model that demonstrates the association between issues, their effects and the way forward. [25]	2020
14.	Ahmed Eweda, Abobakr Al-Sakkaf,	Condition assessment model of building	International Journal of Building	To develop a condition assessment (CA) model for a	Quantitative method	Each space type was found to have its own IEQFs weights, which confirms the	2023

	Tarek Zayed, Sabah Alkass	indoor environment: Engineering, Construction and Architectural Managementa case study on educational buildings	Pathology and Adaptation	building's indoor 21 environments and to improve the building's asset management process.		hypothesis that the importance and allocation of each IEQF are dependent on the function and tasks carried out in each space. [26]	
15.	Huthaifa AL-Smadi, Abobakr Al-Sakkaf, Tarek Zayed, Fuzhan Nasiri	An integrated space-based building maintenance management model using multi-objective optimization	Smart and Sustainable Built Environment	To minimize cost and minimize building condition.	Sensitivity analysis method	The window system type has the most rapid deterioration in educational buildings. [27]	2023
16.	Zul-Atfi Ismail	Planning the maintenance of green building materials for sustainable development: a building information modelling approach	Journal of Financial Management of Property and Construction	To monitor the GB material components for corrective and preventive maintenance actions.	Qualitative method	The results show how decision-making support in maintenance planning can be unsuccessful. [28]	2021
17.	Tristan Gerrish, Kirti Ruikar, Malcolm Cook, Mark Johnson, Mark Phillip	Using BIM capabilities to improve existing building energy modelling practices	Engineering, Construction and Architectural Management	To present a review of the implications building information modelling (BIM) is having on the building energy modelling (BEM) and design of buildings.	Qualitative method	The extent of information required for accurate BEM at stages of a building's design is key to understanding how best to record performance information in a BIM environment. [29]	2017
18.	Khai Ying Soh, Shirley Jin Lin Chua, Azlan Shah Ali, Cheong Peng Au-Yong, Anuar Alias	Relationship between building maintenance sourcing strategy selection factors and performance	Journal of Facilities Management	To examine the relationships between the selection factors and performance measurements of sourcing strategy.	Quantitative method	The ability to fulfil client's need and requirement as well as the ability to deliver the service with reasonable reliability and predictability are identically important performance measurements. [30]	2019
19.	Hans Lind, Henry Muyingo	Building maintenance strategies: planning under uncertainty	Property Management	To critically evaluate maintenance strategies and determine to what extent models from other sectors can be applied to building maintenance.	Quantitative method	There are a number of specific uncertainties that affect building maintenance planning making more detailed long-term plans less meaningful. [31]	2012
20.	Nor Zaimah CheGhani, Nik Elyna Myeda, Azlan Shah Ali	Efficient operation and maintenance (O&M) framework in managing stratified residential properties	Journal of Facilities Management	To identify critical success factors (CSFs) affecting service delivery factors of O&M services at stratified residential buildings.	Qualitative & Quantitative methods	This study concludes that the CSFs directly affect the performance of O&M. [32]	2023

3. Results

The literature review summarises building maintenance adaptation in estate and housing schemes in Malaysia. Several specific uncertainties affect building maintenance planning, especially regarding operational, action, and stockholders' tasks. The author suggests applying building information modelling (BIM) in building energy modelling (BEM) and building design. There are also significant differences regarding coastal community awareness of changes relating to the sea, temperature, and seaside location. 13 out of 20 studies have developed suggestions to adopt a mix of qualitative and quantitative research to ensure the survey on Building Maintenance Strategy for Low-Rise, Low-Cost Housing in Malaysia's Northern Region.

In conclusion, the maintenance and longevity of low-rise, low-cost housing in Malaysia's northern region are deeply affected by the region's tropical climate, which presents unique challenges such as high humidity, frequent heavy rainfall, extreme heat, and the corrosive influence of coastal winds. These environmental factors significantly accelerate the deterioration of building materials, leading to increased maintenance needs and potential safety concerns. Therefore, it is essential to develop maintenance strategies specifically designed to address the challenges of the tropical climate.

This study identifies the critical climate-related factors that influence the durability of low-rise buildings, including the impact of moisture accumulation, temperature fluctuations, and wind-driven rain. It also explores how these elements contribute to degrading structural components such as roofing, walls, and foundations. Furthermore, the research assesses existing maintenance practices and their ability to address these issues, revealing a gap between current approaches and the region's specific environmental demands.

The study proposes a conceptual framework for an adaptive and cost-effective building maintenance strategy incorporating local environmental conditions to bridge this gap. This includes recommendations for materials selection, proactive maintenance scheduling, and the integration of sustainable building technologies that can enhance resilience. Additionally, the framework emphasises the importance of community involvement and capacity building to ensure the long-term success of maintenance initiatives, particularly in low-cost housing settings where resources are limited.

4. Conclusions

By adopting these tailored maintenance strategies can greatly enhance the durability and sustainability of low-rise, affordable housing in Malaysia's northern region, ensuring residents' safety and comfort. Furthermore, this strategy is consistent with overarching objectives related to urban modernisation, sustainable development, and economic advancement, thereby fostering a built environment that is both resilient and highly liveable. Future research may synthesise years of studies and reviews to uncover additional factors for effective repair and maintenance in the housing sector. Since this work remains conceptual, empirical research is needed to refine and validate these factors.

Declaration of Conflict of Interest

The authors declared no conflict of interest with any other party in the publication of the current work.

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