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EVALUATING THE IMPACT OF DESIGN FAILURE ON THE PERAK TENGAH DISTRICT MOSQUE, PERAK, MALAYSIA

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Abstract

This study investigates how building structural defects affect maintenance management in mosques in the Perak Tengah District. As well as offering suggestions for improving maintenance effectiveness, it draws attention to the fundamental design defects that cause issues with maintenance. A literature study, semi-structured interviews, observation, and a survey were used to collect the data. According to the goal of this study, inadequate site supervision, an inadequate cover of reinforcing concrete, poor structural design, noncompliance with specifications, improperly placed or applied paint, and a failure to specify suitable materials are the main design flaws that lead to maintenance issues. These defects result in increased maintenance expenses, job loads, the labour force, and the frequency of maintenance. Based on the study, all departments should collaborate and employ weather-resistant materials to improve job standards and building upkeep.

Keywords: building design failures, maintenance management, mosque design failures, defects, design flaws, maintenance expenses

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INTRODUCTION

The research focuses on common mosque building defects in the Perak Tengah District, emphasise the importance of maintenance management and the impact of design on building longevity and performance. Furthermore, it addresses the challenges of maintaining mosques and the need for further study and international collaboration to resolve these issues. As illustrated by the analysis of defects in Singapore's wet building zones, the main causes of the problems are poor material selection, construction, maintenance, and design. A few possible keywords regarding this matter include maintenance management, mosque structures, international forums, and design flaws.

Table 1. Citations related to design failure in maintenance management

Citation	Related Keywords
Ortiz et al., (2020)	Poor design, building defects, construction, inadequate maintenance, unsatisfactory building performance, user discomfort, safety hazards, effective maintenance
Hauashdh et al., (2022)	Building design, building lifecycle, building defect, construction, maintenance, potential issues, continuous monitoring, effective maintenance
Alabdulkarim et al., (2013)	Maintenance management, a well-structured maintenance plan, a dedicated maintenance team, building safety, extending lifespan, reducing costs, and preserving value.
Kay Leng, S. T., et al. (2023)	Inadequate maintenance can lead to a number of factors, including vegetation growth, soil erosion, wear and tear, and weathering
Hassanain et al., (2021)	Building defects, maintenance management, and effective maintenance practices
Sarbini et al., (2021)	Poor maintenance management practices, a lack of skilled workers, inadequate budget allocation, and building defects

Source: Authors (2024)

Table 1 shows that building issues can arise from poor design, construction, or inadequate maintenance. Ortiz et al. (2020) highlight the need for proper maintenance to prevent defects and ensure safety. Alabdulkarim et al. (2013) stress that good maintenance management is crucial for safety, longevity, cost reduction, and value retention, recommending a detailed schedule and dedicated workforce. According to Kay Leng, S. T., et al. (2023) inadequate maintenance can lead to a number of factors, including vegetation growth, soil erosion, wear and tear, and weathering. Hauashdh et al. (2022) note defects can occur at any stage, making early issue resolution and continuous inspection vital. Hassanain et al. (2021) attribute 30% of defects to maintenance management issues, emphasising effective practices. Sarbini et al. (2021) identify budget, skilled labour, and management problems as the main defect causes.

Building defects can result from poor design, construction, or inadequate maintenance. This highlights the importance of efficient maintenance to prevent defects, ensure building performance, and avoid safety risks. Effective maintenance management is crucial for preserving a building's value, extending its lifespan, and ensuring safety. Defects can occur at any stage, so early issue resolution and continuous monitoring are vital. Maintenance management problems cause 30% of building defects, showing the importance of good practices. Insufficient maintenance funds, a lack of skilled staff, and poor management are the main defects, underscoring the need for excellent maintenance management.

LITERATURE REVIEW

This research aims to provide an overview of the current literature on building flaws and maintenance. It explores the types and importance of building maintenance, architectural design mistakes, their causes, and their impact on building upkeep. The study also examines various building flaws, using previous research from different universities. The main goals are to understand the issues related to building flaws and maintenance and to contribute to existing knowledge in the field. The collected data will form the basis for the study's design.

The Concept of Building Maintenance

Building maintenance involves various tasks to ensure a building, its components, and its systems operate effectively and serve their intended purpose throughout their lifespan. Hassanain et al. (2021) state that it includes maintaining physical conditions, services, and surroundings to meet users' needs. Maintenance types include preventive, corrective, and predictive maintenance. Preventive maintenance involves scheduled tasks to detect issues early. Corrective maintenance addresses problems as they occur by repairing or replacing faulty parts. Predictive maintenance uses data and analytics to foresee and prevent issues before they arise (Alghanmi et al., 2022). Building maintenance is crucial for prolonging a structure’s life, reducing repair costs, and ensuring occupant safety. Several articles, including those by Alabdulkarim et al. (2013), discuss building upkeep. The British Standard BS 3811 also provides guidelines for building maintenance.

Types of Maintenance

Referring to Figure 1, BS 3811 information is used to give building maintenance guidelines that include a wide range of subjects, such as structural elements, finishes, services, and equipment.

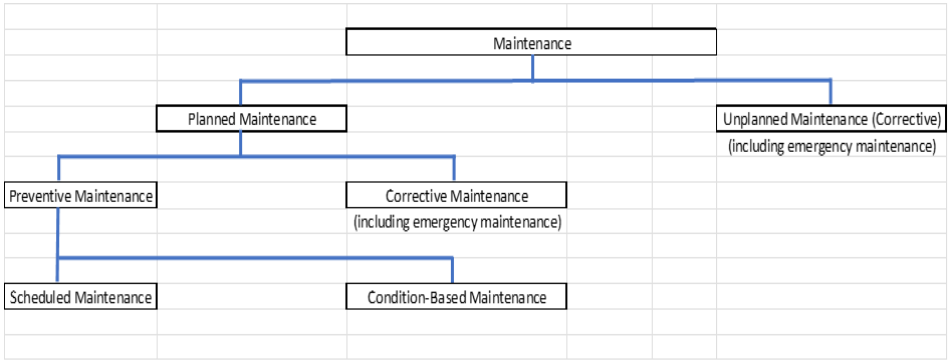

Figure 1. Relationship between various forms of maintenance
Source: BS 3811 (1984)

It explains the various types of upkeep, including:

1. Reactive maintenance: repairing faults and failures as they occur.
2. Planned maintenance: scheduled routine maintenance to prevent failures and prolong the life of building components.
3. Preventive maintenance: activities to prevent the deterioration of building components.
4. Condition-based maintenance: maintenance is based on monitoring the condition of building components.
5. Predictive maintenance: maintenance is based on predicting when failures are likely to occur.

BS 3811 highlights the importance of a systematic approach to building maintenance and suggests using maintenance management systems to ensure that maintenance tasks are completed effectively and efficiently. A framework model can help illustrate the relationship between several types of maintenance. This paradigm allows for scheduled, preventive, condition-based, and predictive maintenance, with reactive maintenance at the bottom of the hierarchy. The model can also demonstrate how to integrate various maintenance chores to produce a comprehensive maintenance schedule that ensures the building's long-term functionality and safety.

Building Defects

A building defect is defined as any flaw or malfunction in the design, construction, or maintenance of a structure that reduces its usability, safety, or aesthetic appeal. Table 2 shows the types of architectural faults found in a previous investigation.

Table 2. Citations related to types of building defects

Citation	Types of Building Defects
Ismail et al. (2016)	Maintenance management problems
Othman et al. 2015)	Water leakage, faulty plumbing, and poor ventilation in wet areas
Riadh, D., & Mohamed Osman, M. (2021).	Housing policies are currently poorly structured.
Mohd-Noor et al. (2016)	Structural cracks, water leakage, and electrical faults in mosques
Olanrewaju & Lee (2022)	Poor workmanship, inadequate supervision, and a lack of maintenance in Malaysia
Alriwaimi & Akasah (2014, February)	Faulty factors in building maintenance during the design stage

Source: Authors (2024)

Structures develop defects due to various reasons. Structural problems affect components like the foundation, beams, and columns and can result from poor planning and policies, workmanship, or materials. Figures 2, 3, 4, and 5 illustrate these defects. Water-related issues stem from infiltration, leakage, or flooding linked to waterproofing, plumbing, or drainage flaws. Electrical faults involve wiring, fixtures, and appliances and are potentially dangerous. Other issues include problems with finishes, doors, windows, and external factors like noise and air quality. Research shows defects arise from poor design, construction, maintenance, and a lack of control. Maintenance management errors cause 30% of construction faults. Effective maintenance practices that address issues early can extend a building's life and prevent costly repairs.

Figure 2. Defect: water leaking
Source: Authors (2024)

Figure 3. Defect: peeling of paint (external wall)
Source: Authors (2024)

Figure 4. Defect: stagnant water
Source: Authors (2024)

Figure 5. Defect: poor ventilation in wet areas
Source: Authors (2024)

Factors of Building Design That Related Building Maintenance

There are several factors of building design that are related to building maintenance. These factors can be referred to in Table 3 below.

Table 3. Citations related to building design factors

Building design factors	Citation
Materials used in construction	"Buildings constructed with high-quality materials are likely to require less maintenance compared to those made with low-quality materials" (Dahal & Dahal, 2020).
Design and layout of the building	"Mosques with complex designs and layouts may be more challenging to maintain" (Yawer et al., 2023).
Building systems and components	"The design and installation of building systems can affect how easy they are to maintain and repair" (Ismail, 2021).
Building codes and regulations	"Building codes may require regular inspections of building components or systems to ensure their safety and longevity" (Hatem, et al.,2021).
Accessibility and safety	"Mosques that are designed to be accessible to people with disabilities or that have safety features may require more frequent maintenance to ensure these features are functioning properly" (Putri et al., 2022).

Source: Authors (2024)

The above information demonstrates several design-related elements that may affect building upkeep:

1. ***Materials****:* The materials used in construction affect maintenance needs. Materials like steel and concrete can corrode and deteriorate over time, requiring regular upkeep. Poor material choices can shorten building lifespans and increase maintenance costs.
2. ***Layout and Design****:* Building design impacts the ease and efficiency of maintenance. Complex architecture or hard-to-reach areas may need

special tools or methods. Designers should consider ease of maintenance to save on future costs.

3. ***Building Age****:* Older buildings require more maintenance to stay safe and functional. Ageing structures, especially poorly constructed ones, often face more maintenance issues.
4. ***Technology****:* Using technology can reduce maintenance needs. Smart building systems monitor and maintain existing systems, reducing the need for manual inspections and repairs, saving costs, and improving efficiency.
5. ***Construction Quality****:* Poor construction quality leads to early breakdowns and higher maintenance costs. Ensuring high construction standards can reduce future maintenance needs.

METHODOLOGY AND SAMPLE CRITERIA

This study employed two methods. First, it conducted literature research and interviews with the mosque management to identify 67 design and construction issues, along with eight (8) implications for building maintenance (see Table 4). Second, it used a survey to assess how these issues affected maintenance. This mixed-methods approach investigated the impacts of poor design on mosque maintenance management. Questionnaires were physically administered, and an interview was also done for clarification. Data analysis provided insights to meet the study's goals, as detailed in the conclusion.

Table 5 shows the criteria selection for the mosques in Seri Iskandar, Perak Tengah District, Perak, all five of which were chosen for the research with the principal's agreement for their management of facility upkeep, design, and style.

Table 4. Design and Construction Flaws & 8 Implications of Flaws Impact on Building Maintenance.

DESIGN & CONSTRUCTION FLAWS		
A	Defects in civil design	1. Inadequate provisions for movement. 2. Ignoring aggressive environment and weather condition effects. 3. Ignoring biological effects. 4. Inadequate structural design such as foundation. 5. Ignoring variation in soil conditions. 6. Ignoring the effect of load on structural stability. 7. Exceeding allowable deflection. 8. Ignoring the impacts of wind on the structure. 9. Deficient concrete cover on the reinforcement. 10. Conduits and pipe holes at crucial structures are improperly located.
B	Architectural defects in design	1. Narrow stairs, passages & door. 2. Not relating exterior material selection to climatic condition. 3. Specify the finish that has to be completely repaired (such as wallpaper) 4. Not considering the local climatic condition when designing the exterior shape. 5. Deficient joints between finished Faces.
C	Design defects in maintenance practicality and adequacy	1. No consideration for access or escape for maintenance workers or equipment. 2. Designing for a permanent fix that could be removed for maintenance. 3. Not taking into account the maintenance equipment available while designing. 4. Not considering the maintenance requirements in design.
D	Defects due to consultant firm administration & staff	1. Lack of QA/QC program during Design. 2. Poor technical updating or staff training. 3. Hiring unqualified designers. 4. Designers field experience. 5. Designer technical background. 6. Designer unawareness of materials Properties. 7. Misjudgment of climatic condition. 8. Misinterpretation of the intended usage of the user.
E	Defects due to construction drawings	1. Lack of references. 2. Conflicting details. 3. Lack of details.
F	Defects due to construction inspection	1. Lack of inspection. 2. Unqualified inspector. 3. Proponent (owner) negligence of the importance of inspection. 4. Weakness of inspection rule in implementing corrective actions during job execution.
G	Defects due to civil construction	1. Inaccurate measurement. 2. Damaged formwork. 3. Excavation too close to the building. 4. Painting in inappropriate conditions or on inappropriate surface. 5. Deficient water proofing and drainage. 6. Insufficient reinforcement concrete cover. 7. Cold joints. 8. Loss in adhesion between materials. 9. Early formwork removal. 10. Poor soil compaction. 11. Deficient curing. 12. Lack of communication.
H	Defects due to contractor administration	1. Not complying with specification. 2. Unable to read the drawings. 3. Insufficient site supervision. 4. Weak interaction with the design firm and the owner. 5. Unqualified supervision. 6. Rapid completion or cheap quality work. 7. Unqualified work force. 8. Multinational construction experience.
I	Defects due to construction materials	1. Differential thermal movements in dissimilar material. 2. Material selection that is improper for the current climatic conditions. 3. Use of nondurable material. 4. Use of expired material. 5. Poor material handling & storage.
J	Defections due to construction equipment	1. Wrong use of equipment. 2. Inadequate performance of equipment. 3. Lack of required number of equipments.
K	Defects due to specification	1. Unclear specification. 2. Not defining adequate materials. 3. Not specifying the QA/QC construction procedure. 4. Not specifying the allowable load limits. 5. Specifying inadequate concrete mix design.

8 IMPLICATIONS OF FLAWS IMPACT ON BUILDING MAINTENANCE	
1	Increase in maintenance budget.
2	Increase workforce.
3	Increase in maintenance work.
4	Increase in maintenance quality.
5	Difficulties in maintenance planning.
6	Increase maintenance frequency.
7	Maintenance works become obsolete.
8	Lower maintenance quality.

Source: Misrun, A., et al., (2023).

Table 5. Criteria selection for the case study

Location	Mosque Name	Date of Built	Detail Facilities	Category of Mosque
Perak Tengah (Seri Iskandar), Perak	Masjid Sultan Yussuf Izuddin Shah (MSYIS)	2008	The Masjid Sultan Yussuf Izuddin Shah comprises 8400 square meters. Its serene structure holds a main prayer hall, a covered praying area, a holding room for visitors, and ablution facilities. There is an institution for a folk religious school in two (2) buildings. Open-hall facilities suitable for education ceremonies and weddings	Masjid Daerah/Jajahan
	Masjid Al-Muhajirin, Fecra Nasaruddin (MAMFN)	2007	Masjid Al-Muhajirin, Fecra Nasaruddin, comprises 3350 square meters. Along with the mosque hall, there are also bathrooms for both male and female pilgrims, as well as disabled people. A storage room and a bathroom for the mortuary are also provided. There is a cooking hall and a dining hall for Ahli Qariah's banquet facilities.	Masjid Mukim/Kariah
	Masjid Bandar Universiti, Seri Iskandar (MBUSI)	2018	Masjid Bandar Universiti, Seri Iskandar, comprises 4300 square meters. There is also a large, open prayer room that can fit up to 900 pilgrims. Toilets, ramps, and disabled parking spots are just a few of the facilities that make it easier for disabled pilgrims to pray in the mosque.	Masjid Mukim/Kariah
	Masjid As-Siddiq, Seri Iskandar (MASSI)	2005	Masjid As-Siddiq comprises 3000 square meters. Its serene structure holds a main prayer hall, a covered praying area, a holding room for visitors, and ablution facilities.	Masjid Mukim/Kariah
	Masjid An-Nur, UTP (MANUTP)	2003	Masjid An-Nur is a majestic floating mosque spanning 4000 square meters. Its serene structure holds a main prayer hall, a covered praying area, a holding room for visitors, and ablution facilities.	Masjid Institusi

Source: Authors (2024)

DATA ANALYSIS

Based on interviews with the mosque maintenance management, common building defects and their causes were identified. 11 common reasons for design failures were studied extensively. Table 6 shows that poor collaboration is the

primary issue across five mosques, highlighting the need for effective communication to prevent delays and misunderstandings. MSYIS, MBUIS, and MANUTP lack knowledge in fundamental material science aspects, leading to similar conclusions. MASSI faces unique challenges with complex elements, detailed in Table 7 for this case study.

Table 6. Causes of design failures

No.	Causes	MSYIS	MAMFN	MBUSI	MASSI	MANUTP
1	Poor detailing and jointing				/	
2	Insufficient thickness of concrete cover.	/		/		/
3	Insufficient jointing between finish faces		/		/	
4	Incorrect location of conduits and piping at critical structure locations		/		/	
5	Insufficient length of awning	/			/	
6	Insufficient provision for thermal movement		/		/	
7	Insufficient structural design		/		/	
8	Maintenance access was ignored during the design process	/	/	/	/	/
9	Lack of concern for aggressive environments and weather conditions	/		/		/
10	Lack of consideration for the availability of maintenance tools in the design process	/	/	/	/	/
11	Not relating exterior construction material selection to weather and climatic conditions		/		/	

Source: Authors (2024)

Table 7. Defects related to faulty designs occur in building maintenance

Rank	Code	Question	Mean	Severity Index
1	I2	Material selection that is improper for the current climatic conditions	3.84	95.96
2	F1	Lack of inspection	3.73	93.21
3	A6	Ignoring the effect of load on structural stability	3.68	91.96
4	B4	Not considering the local climatic conditions when designing the exterior shape	3.68	91.96
5	G5	Deficient waterproofing and drainage	3.62	90.46
6	H7	Unqualified work force	3.62	90.46
7	K2	Failure to define suitable materials	3.62	90.46
8	A1	Deficient provisions for movement	3.57	89.21
9	C4	Failure to consider the maintenance requirements in design	3.53	88.24
10	G5	Deficient water proofing and drainage	3.53	88.24

Source: Authors (2024)

After analyse the survey responses, key issues with building maintenance were identified. Table 7 lists the top ten design and construction defects based on severity index and mean scores from the 67 identified issues. Table 6 further details the average severity caused by poor design and construction. The survey pinpointed seven major issues:

1. Inappropriate material selection for weather conditions received an average score of 3.84 with a severity rate of 94.96%.
2. The inspection coverage was inadequate, receiving a score of 3.73 and a severity rating of 93.21%.
3. Ignoring load impact and local weather in exterior design resulted in a score of 3.68 and a severity of 91.98%.
4. Civil errors in waterproofing and drainage, unqualified workforce management, and inadequate material specifications were grouped under specification defects with a severity of 90.46%.
5. Civil design issues affecting movement provisions scored above 3.57 in all eight categories, representing 89.21% of the total severity.
6. Neglecting civil design considerations for maintenance needs, lacking quality assurance or control during design, and inadequate drainage and waterproofing scored 88.24% on the severity index.

These findings highlight critical areas where improvements in design, construction oversight, and material selection could significantly reduce maintenance issues and enhance building longevity.

Table 8. The effects of defects on building maintenance

Rank	Question	Mean	Severity Index
1	Increase in maintenance work	3.59	89.71
2	Increase in the maintenance budget	3.59	89.71
3	Increase workforce	3.59	89.71
4	Increase in maintenance quality	3.53	88.24
5	Maintenance works has become obsolete	3.47	86.76
6	Difficulties in maintenance planning	3.29	82.35
7	Increase maintenance frequency	3.29	82.35
8	Lower maintenance quality	3.18	79.41

Source: Authors (2024)

Table 8 summarise the survey results, detailing the impacts on building maintenance. It ranks eight impacts based on severity indexes and mean scores. The top impact, increasing maintenance workload, budget, and manpower, has a severity index of 89.71% and a mean score of 3.59. This is followed by improved maintenance quality (severity index = 88.24%, mean = 3.53) and obsolete maintenance practices (severity index = 86.76%, mean = 3.47). Other impacts include enhanced maintenance quality (severity index = 86.76%, mean = 3.47), increased maintenance frequency and planning difficulties (severity index = 82.35%, mean = 3.29), and lower maintenance quality (severity index = 79.41%, mean = 3.18). These findings underscore the significant effects of various factors on building upkeep, guiding strategies to improve maintenance efficiency and effectiveness.

FINDINGS

The top 10 flaws that significantly impacted the maintenance building are listed below:

- *Material selection that is improper for the current climatic conditions*: Choosing materials unsuitable for local climates can lead to durability issues and structural problems.
- *Lack of inspection*: Skipping inspections can lead to hidden errors and safety issues, compromising building safety.
- *Ignoring the effect of load on structural stability*: Neglecting to consider varying loads can lead to structural issues endangering occupants.
- *Failure to consider the local climatic conditions when designing the exterior shape*: Designing without climate considerations can increase energy use and maintenance costs.
- *Deficient waterproofing and drainage*: Inadequate systems cause water damage and mould growth.
- *Unqualified workforce*: Inexperienced workers can lead to construction errors and maintenance problems.

- *Failure to define suitable materials*: Unclear material choices can reduce building durability and increase maintenance needs.
- *Deficient provisions for movement*: Design flaws restricting movement can cause structural failures.
- *Failure to consider the maintenance requirements in design*: Neglecting maintenance in design can complicate repairs and inspections.
- *Deficient waterproofing and drainage*: Poor design can lead to water leaks and structural damage.

To address these issues, thorough analysis, expert advice, and corrective actions are necessary. This involves structural assessments, quality control systems, fixing design flaws, ensuring the fulfilment of standards, using suitable materials, and improving overall construction and maintenance practices. Flaws significantly impact maintenance processes and outcomes, which emphasises how crucial they are to building management.

- **Increase in Maintenance Budget**: Building defects can escalate maintenance costs, requiring more resources, materials, and labour.
- **Increase in Maintenance Work**: Defects necessitate repairs, replacements, and corrective actions, increasing the workload for maintenance crews.
- **Increase in Workforce**: Resolving faults may require additional staff or specialised workers, potentially straining existing maintenance teams.
- **Increase in Maintenance Frequency**: Defects disrupt regular maintenance schedules, necessitating more frequent inspections and preventive measures.
- **Increase in Maintenance Quality**: Defects highlight the importance of stringent standards and prompt resolution, prompting improvements in maintenance methods and quality control.
- **Difficulties in Maintenance Planning**: Unforeseen defects can disrupt maintenance plans, requiring adjustments and prioritisation of tasks.
- **Maintenance Work Becomes Obsolete**: Neglecting to address defects can render previous maintenance efforts ineffective, leading to recurring issues and higher long-term costs.
- **Lower Maintenance Quality**: Unresolved defects compromise building performance and longevity, necessitating comprehensive understanding and effective solutions to maintain quality and durability.

CONCLUSION

It's clear how important it is to find problems as soon as possible, carefully consider them, and then fix them when you know how flaws affect building

maintenance. By fixing issues quickly and implementing good maintenance procedures, building owners and maintenance teams can lower the negative effects, improve long-term maintenance results, and ensure the structure will last and work. The last part of the declaration says that people who design buildings should consider how they will be maintained before starting the design process. Future maintenance needs depend on several factors, such as the type of materials used, the layout of the building, its age, how well technology is integrated, and the quality of the construction. By thinking about these things and making designs that are easy to maintain, designers can make structures last longer and save money on ongoing costs. This includes choosing materials that will last, making sure the layout is easy to use, thinking about how the building will age, adding smart technologies, and making sure the quality of the construction is high. When you design with maintenance needs in mind, you save money, make the building work better, and make users happier.

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