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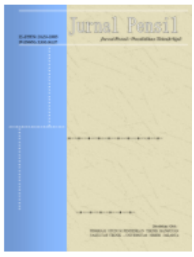

A COMPARATIVE STUDY OF PUBLIC BUILDING MAINTENANCE STRATEGIES USING MULTI-CRITERIA METHODS BASED ON CONDITION AND FUNCTION

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Abstract

Public buildings serve vital functions in supporting community services, yet they often experience quality degradation due to aging, weather conditions, and limited maintenance budgets. This study aims to conduct a comparative analysis of four public building maintenance case studies, each with different functions: administrative and educational dormitory buildings, traditional markets, churches, and elementary schools. The methods employed involve various Multi-Criteria Decision Making (MCDM) approaches. The comparative findings reveal that each method yields specific and adaptive outcomes tailored to the functional characteristics of the four public building types. The key findings indicate that maintenance planning based on priority and actual damage leads to more targeted outcomes, and highlight the need for a multidimensional approach in public building maintenance policy.

Keywords: Multi-Criteria Decision Making (MCDM), Public building maintenance, Public buildings

Introduction

The maintenance of functional public buildings is a crucial aspect in ensuring the continuous operation of community service facilities that support educational, commercial, and religious activities. The safety and comfort of these buildings directly impact the well-being of their occupants (Achuthan & Murali, 2015; Al-Hemoud & Al-Asfoor, 2006). Over time, or throughout the building's operational life, its physical condition inevitably deteriorates(Adeswastoto & Islah, 2018). Therefore, a sustainable maintenance strategy should be planned even before the construction project is completed (Mawardi et al., 2018). However, in practice, maintenance planning is rarely implemented due to budget limitations (Hartono & Saparudin, 2017). Many public buildings in Indonesia suffer from damage caused by aging, climate conditions, geological factors, natural disasters, poor material quality, and lack of sustainable maintenance planning (Fahruddin et al., 2020). The Indonesian climate, which alternates between dry and rainy seasons, can easily lead to material deterioration (Ariyanto, 2020). In the context of specialized works, there are six identified potential hazards mechanical, electrical, physical, biological, and ergonomic that reinforce the importance of continuous safety monitoring (Nabila et al., 2021). To effectively enhance building safety, attention should not be limited to the construction phase alone, but must also include proactive maintenance management and regular safety evaluations during the building's operational phase (Miraglia, 2020).

Building condition assessments can be conducted using various methods, such as visual inspection, destructive testing, non-destructive testing, or structural analysis with specialized tools (Wiyanto & Yesaya, 2022). Several condition evaluation methods have been applied in previous studies using Multi-Criteria Decision Making (MCDM) approaches, which are also classified as decision-making models (Begić & Krstić, 2024). However, there is still a lack of research that systematically compares the effectiveness of these approaches in the context of different building functions. This study focuses on maintenance planning outcomes for functional public buildings, specifically schools, dormitories, churches, and traditional markets. It presents a comparative analysis of four case studies, each employing a different assessment method to evaluate building condition and design maintenance strategies. The purpose of this comparison is to identify patterns, strengths, and weaknesses of each approach, and to formulate function-based recommendations for improving public building maintenance planning.

According to Law No. 28 of 2002, a building is defined as a place that functions as a space for human activities such as residence, religious practices, business, social and cultural activities, or other specific purposes. This definition underlines that buildings must be designed based on three fundamental elements: aesthetics, strength, and utility (Ratna Kusumastuti et al., 2022). Each building is designed with a style and characteristics suited to its intended function, which can be reflected in its form, choice of materials, and the period from design to construction (Ervianto, 2007). For example, a building designed as a shopping center will differ significantly from one intended for educational purposes. Structurally, each type of building also bears different loads, resulting in variations in structural dimensions. Educational buildings are generally not designed as a single mass like office buildings or hotels, but rather are divided into several zones or separated building masses (Olanrewaju & Ooi, 2022).

The unique characteristics of each building present challenges in their management and maintenance. Therefore, a planned and sustainable maintenance approach is necessary. In general, maintenance can be categorized into three types: reactive, preventive, and predictive. Reactive maintenance involves addressing defects on the building's surface, anomalies, or functional failures within systems. Preventive maintenance is carried out before any physical, functional, or performance changes occur in building components or systems. Predictive maintenance targets the degradation condition of specific building components (Baniya & Giurco, 2025).

Building operation and maintenance constitute the final stage in a facility's life cycle. Key maintenance factors include the level of facility utilization, building characteristics, maintenance methods, maintenance costs, the total number of facilities (assets), and the maintenance period

(Duan et al., 2020; Kim et al., 2020; Wu et al., 2021). Poor building operation and maintenance can adversely affect the quality of buildings and their facilities, as well as increase maintenance expenditures (C. Chen & Tang, 2019; W. Chen et al., 2018; Park & Lim, 2021; Wang et al., 2022). Building maintenance management should be optimally designed to preserve functionality and serviceability (Misriani et al., 2020; Nugrahayu et al., 2021; Nurulita Sari et al., 2022).

Maintenance activities are carried out to ensure that buildings remain in usable condition. According to the Indonesian Ministry of Public Works Regulation No. 24/PRT/M/2008, maintenance is classified into three types: routine, periodic, and rehabilitative. Maintenance implementation is not always straightforward, as it is influenced by various factors such as building characteristics, constraints, and differing needs-ranging from physical condition and spatial layout to function and resource availability. As a result, maintenance strategies that prove effective in one context may not be directly applicable in another. Therefore, a contextual and adaptive understanding is essential in designing maintenance systems. In light of this, the present study conducts a multi-criteria comparison of several maintenance approaches that have been implemented across various types of public buildings. By comparing these methods, the study aims to provide deeper insights into their effectiveness, challenges, and potential applicability in the context of public facilities.

Research Methods

The study uses a Multi-Criteria method to evaluate building damage and determine maintenance priorities. This method consists of the Composite Condition Index (CCI), Customer Satisfaction Index (CSI) & IPA, AHP-TOPSIS, and CSP 1 (Condition Survey Protocol). The CCI method combines the damage of each component to obtain an overall building condition index. This method is used to calculate the overall condition of a building by integrating the condition of each building component, such as the roof, walls, floors, and other systems. Research data was obtained by conducting a direct survey at the research location. The research data includes the types of damage identified in structural and architectural components, along with measurements of damage volume and the number of non-conformities present in building elements.

Each component is assessed using a specific rating scale and then assigned a weight based on its level of importance, resulting in a single comprehensive building condition index score. The CCI method facilitates decision-making in both short-term and long-term maintenance planning (Lavy et al., 2010; Shohet, 2003). The CSI and IPA methods are used to measure user perceptions and map repair priorities based on the level of importance and performance.

The CSI method assesses users' satisfaction with various aspects of service and facility conditions, such as comfort, cleanliness, and safety. Meanwhile, the IPA method maps these attributes into four quadrants based on their importance and performance levels. By using measurement scales with relatively high sensitivity and reliability, these methods can provide valuable information for future improvements and objectives-particularly in relation to building maintenance activities (Agustina et al., 2022; Dian Anggraini et al., 2015).

The combination of CSI and IPA is highly effective in identifying areas that require immediate improvement based on user perceptions, making it especially suitable for public buildings such as schools or hospitals (Martilla & James, 1977; Tzeng & Chang, 2011). The CSI score is calculated using the following formula (Sabaruddin et al., 2024):

$$\text{CSI} = \frac{\text{WA}}{\text{HS}}$$

Explanation:
WA = Weighted Average
HS = Highest Scale (maximum scale)

Table 1. CSI Value Criteria

CSI Value (%)	CSI Criteria
81-100	Very Satisfied
66-80	Satisfied
51-65	Quite Satisfied
35-50	Less Satified
0-34	Satisfied

The AHP-TOPSIS method is used to determine maintenance priorities based on multi-criteria decision-making. This method allows for multi-criteria decision-making, which is commonly applied in prioritizing building maintenance. AHP is used to calculate the weights of various criteria such as cost, urgency, impact, and technical condition. Moreover, AHP helps to produce accurate results in handling complexity in decision-making (Ramadhani et al., 2022).

TOPSIS is then used to rank the alternatives based on their relative closeness to the ideal solution. This combination provides an objective and systematic approach to determining the priority order of maintenance actions (Da Silva & De Brito, 2015; Saaty, 1984; Tzeng & Chang, 2011).

Building condition assessment based on visual inspection and damage classification can use the CSP 1 method as a Condition Survey Protocol. CSP is a standardized method used in visual building inspections to assess the level of damage and the actual condition of each building component. The assessment is carried out by classifying damages according to their type and severity, then summarized systematically. This method is commonly used in technical building audits because it is practical and can be performed by field technicians (Chew, 2004; Olanrewaju & Ooi, 2022).

The CSP 1 method evaluates building conditions through three protocols: the first protocol involves visual inspection, the second protocol involves non-destructive testing (NDT), and the third protocol involves sampling with destructive testing (DT). The application of this method uses a standardized assessment form. The condition assessment scale can be described as follows (Ifran Che-Ani et al., 2011):

Table 2. CSP 1 Assessment Matrix

Scale		Priority Assessment			
		E4	**U3**	**R2**	**N1**
Condition Assessment	5	20	15	10	5
	4	16	12	8	4
	3	12	9	6	3
	2	8	6	4	2
	1	4	3	2	1

This study uses a comparative-qualitative approach to explore and analyze the similarities and differences among four case studies, each addressing public building maintenance with different focuses and contexts. The research objects include various types of public buildings such as educational facilities, traditional markets, government offices, and places of worship. These categories of public-use buildings have diverse physical characteristics, functions, and maintenance challenges. Each case study employs different assessment and analysis methods, ranging from the visual inspection-based Condition Survey Protocol (CSP), the Analytic Hierarchy Process (AHP) for prioritizing maintenance, the Composite Condition Index (CCI) for aggregate building condition assessment, to the Customer Satisfaction Index (CSI) and Importance-Performance Analysis (IPA), which focus on user perception and experience.

The diversity of these approaches allows this study to identify how building function, usage context, and evaluation methods influence the resulting maintenance recommendations. The data analyzed from the four studies covers three main aspects:

1. Type and function of the building, including the building type, primary users, and the intended purpose of the facility;
2. Damage and maintenance analysis methodology, referring to the techniques and instruments used to assess the building's condition and to establish maintenance priorities;
3. Key findings and recommendations, which are the main outcomes of each study along with the proposed maintenance strategies.

The comparison process was conducted through qualitative and descriptive analysis, presented in the form of a comparative matrix table. This table details key aspects of each study, allowing for the identification of patterns, significant differences, and commonalities across the approaches. In addition, thematic analysis was employed to categorize emerging issues from each study into main themes such as cost efficiency, user participation, or the accuracy of technical assessments. Through this approach, the study aims to provide a comprehensive synthesis of the strengths and limitations of various public building maintenance methods, as well as to offer a methodological basis for more appropriate recommendations for other types of functional public buildings.

Research Results and Discussion

In the first study, the damage observed in the Administration Building and Dormitory of the Bitung Marine and Fisheries Polytechnic was largely caused by visual factors and previous damage due to flash flooding. The evaluation was conducted using the Composite Condition Index (CCI) method, with results indicating that all three buildings were still in excellent condition according to the Building Condition Index (BCI), although they required architectural and utility maintenance. Maintenance cost estimates were also calculated based on the actual level of damage (Lolowang, 2023).

The second study, which focused on a market in North Jakarta, employed a user satisfaction approach using the Customer Satisfaction Index (CSI) and Importance-Performance Analysis (IPA) methods. The results showed a CSI score of 76.63%, indicating that users were moderately satisfied. However, four architectural components were identified as top priorities for improvement, particularly those related to cleanliness and basic facilities-factors heavily influenced by the market's location in a flood-prone area (Virginia Nathaniela, 2024).

In the third study, which focused on an elementary school in Bogor City, the AHP-TOPSIS approach was used to determine maintenance priorities for building components. The analysis revealed that the ceiling, roof structure, and wall painting were the top three priority components, as they are vulnerable to environmental conditions such as high rainfall and the use of wooden materials. This prioritization scale aims to optimize budget allocation in the context of limited resources and the large number of buildings (Cornelius et al., 2024).

The fourth study evaluated the condition of a church in West Jakarta using the Condition Survey Protocol (CSP) 1 method. The visual assessment showed that most of the church buildings were in good condition (63%) and fair condition (37%), with no buildings classified as severely damaged. However, several minor issues were identified, such as structural cracks, loose electrical sockets, and paint deterioration. The main challenges were the lack of maintenance planning and limited funding available to small congregations (Marlissa et al., 2025)alysis method, key findings, and maintenance challenges is presented in Table 3 below.

Table 3. Comparison of Case Studies

No.	Case Studies	Evaluation Method	Damaged Components/ Priorities	Main Maintenance Challenges
1.	Campus and Dormitory	Composite Condition Index	Structure, architecture, utilities	Comprehensive evaluation, flood impact
2.	Market	CSI & IPA	Cleanliness, user facilities	Flood-prone location, user perception
3.	Elementary School	AHP-TOPSIS	Ceiling, roof structure, wall painting	Large number of buildings, limited budget
4.	Church	Condition Survei Protocol 1	Peeling paint, structural cracks, loose sockets	Limited planning, small congregation funding

Overall, the case studies highlight the importance of a structured and data-driven evaluation approach in determining maintenance needs. Selecting the appropriate method based on the building type is highly beneficial in setting work priorities and budgeting. In the context of public asset management, this is essential for ensuring the sustainability of building functions and the safety of users.

Table 4. Comparison of Case Studies

No.	Method	Advantages	Disadvantages	Suitable for
1.	CCI	Objective, based on damage data	Does not capture user perception	Technical buildings
2.	CSI-IPA	User-focused	Subjective, lacks technical detail	Markets, public facilities
3.	AHP-TOPSIS	Systematic, weighted	Requires data and matrix	Large-scale and multiple buildings
4.	CSP I	Quick and simple visual assessment	Less quantitative	Religious/community buildings

The selection of methods greatly depends on data requirements, building type, and the availability of human resources and time. For example, CCI is well-suited for in-depth and quantitative technical assessments, while CSI-IPA is more appropriate when the goal is to capture user experience. AHP-TOPSIS is suitable for large-scale projects that require prioritization systems and weighted analysis. In contrast, CSP 1 is ideal for situations with technical and budget constraints, such as in religious buildings. By understanding the strengths and limitations of each method, facility managers or government agencies can choose the most appropriate and efficient approach according to the specific context of the building.

Based on the analysis of the four studies, several patterns emerged indicating common root causes of issues in public building maintenance. The main contributing factors to building damage generally include weather conditions (especially heavy rainfall and high humidity), aging infrastructure, the use of low-durability building materials, and the absence of a systematic maintenance plan. These four factors often lead to recurring damages that are not properly addressed.

The building components most frequently found to be damaged are ceilings, roofs, floors, and wall paint. These elements are particularly vulnerable due to direct exposure to the elements and are often neglected in routine maintenance. This situation is worsened when financial resources are limited, causing minor damages to be left unattended until they escalate into more severe issues.

Despite differences in context and building types, the four studies demonstrate a relatively consistent approach-emphasizing the importance of prioritizing maintenance and conducting

regular condition assessments. The focus on structured evaluation is intended to optimize budget use and prevent more serious future damage. This underscores the critical need for data-driven planning and decision-making in the management of public building assets.

The findings suggest that maintenance method selection cannot be uniformly applied but must be adapted to the building's function, actual condition, user perception, and specific needs. A combination of technical methods such as the Composite Condition Index (CCI) and Condition Survey Protocol (CSP) with perception-based methods such as the Customer Satisfaction Index (CSI) and Importance-Performance Analysis (IPA) can produce a more comprehensive evaluation. Moreover, patterns observed across the studies highlight the importance of regular assessments, maintenance prioritization, and efficient budget management to ensure the sustainability of public building functions.

Conclusion

The research findings indicate that the approach to public building maintenance must take into account the building's function, physical condition, and user perceptions. A combination of technical methods (such as CCI and CSP) with perception-based methods (such as CSI and IPA) can provide a comprehensive assessment. Future research development could involve coordination with government authorities or public facility managers to integrate both technical and non-technical approaches in maintenance planning. Buildings with community functions (such as schools and churches) should be prioritized for maintenance based on functional needs and primary damage risks. Additionally, there is a need for data-driven and priority-based maintenance policies at the city level.

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