A Review towards a Standardized Approach in Building Structure Inspection for Maintenance Management

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ABSTRACT

Maintenance is a combination of several management methods without changing the basic features and functions of building structures and service systems. Effective maintenance planning ensures optimal use of the structure and reduces operating costs. Building inspection is one of the methods in maintenance management for assessment of building physical condition. Moreover, this method is a preliminary analysis to gather information, assess and identify damages to building structures. This paper discussed variety of structural inspection methods including inspections for pitched roof and fade. Literature was collected from journals, conference proceedings, standards and books. These methods were compared and classified according to defect. The results demonstrated that there are weaknesses in the method of building structure inspection. For example, there are varieties of information in the verification of damage causing inconsistencies in the inspection. Hence, causing inconsistent final report on maintenance performed. Besides, the assessments also depend on the discretion and experience of the inspector resulting in subjective evaluations. For instance, the final reports were interpreted differently from individual perspectives. In conclusion, building structure inspection requires a guide to standardize the inspection process. In addition, specific strategies are required to ensure the documents provided can be reduced consistently by various inspectors.

Keyword: Building Inspection, Maintenance Management, Standardization, Structural Assessment, Building Performance.

INTRODUCTION

Maintenance is defined as a continuous process carried out without altering the basic features and functions of a building system after its construction is completed [1]. Maintenance management integrates various activities to ensure that the building components and systems remain in optimal condition. However, some maintenance activities are unpredictable and may involve certain risks [2]. Building maintenance management is closely associated with building life cycle management, asset management, and health and safety management [3]. It encompasses activities involving various building components such as basements, interiors and exteriors, walls, columns, building services, and roof systems. The optimal operation of building service systems requires continuous maintenance management. Poor maintenance practices may result in significant financial losses to building owners [4]. Effective maintenance management can optimize and maximize system performance [5]. It also helps to delay deterioration, defects, and failures [6]. Furthermore, maintenance can reduce operating costs and extend the overall building life cycle [7]. Therefore, maintenance activities play a crucial role, as approximately 70% of operating costs are typically allocated to building maintenance planning [3]. Hence, effective maintenance management represents a sound investment for building owners [8]. Maintenance management also involves early planning in several aspects, including budget control, maintenance scheduling, and the allocation of financial resources [9]. This is particularly important because many organizations consider maintenance work to be a financial burden on operating costs [10]. As noted by [11], approximately 90% of a

building's life cycle requires maintenance work, which often results in maintenance costs exceeding the allocated budget [12].

The main objective of this review paper is to identify and evaluate the existing methods currently practiced in building structure inspection as part of maintenance management activities. This study seeks to examine the various inspection techniques used to assess the physical condition of building components, including both visual and non-destructive approaches. It also aims to analyze the strengths, limitations, and inconsistencies associated with these inspection methods that may affect the reliability and accuracy of maintenance evaluations. Furthermore, this paper highlights the need for standardization in building inspection procedures to ensure consistency, repeatability, and objectivity in the assessment process.

Maintenance Inspection

Maintenance inspection is an essential component of building maintenance management that helps determine the physical condition and performance of building elements. Its primary purpose is to identify defects, deterioration, and potential failures in building structures before they develop into serious problems. Generally, maintenance inspection methods can be categorized into visual inspection, non-destructive testing, and instrument-based assessment. An effective inspection strategy plays a crucial role in minimizing maintenance costs, enhancing building safety and health, and reducing the failure rate of building service systems [13]. In addition, systematic inspection facilitates proper planning of repair works to prevent defects from worsening and to avoid structural failures [14]. Furthermore, inspection results can assist maintenance teams in determining appropriate repair actions and ensuring that maintenance interventions are performed efficiently [15].

Table 1: Assesssment of Inspection Methods.

Inspection Method

No.	Authors	Source / Structure	Inspection	Elements to Inspect	Description of Defect	Level Defect Assessment
1	[22]	Wooden House in Cambodia	Need to be identified by the inspector	Depending on the cause and type of defect	Description by inspector	—
2	[23]	Wooden House in Melaka	Need to be identified by the inspector	Depending on the cause and type of defect	Description by inspector	—
3	[8]	Flat roofs, facades, windows and doors	Building materials	Checklist	Description by inspector	—
4	[24]	Pitched Roof	Element building material	Checklist	Inspectors need to clarify the current condition	—
5	[25]	Building	Subjective component	Need to be described by inspector	Inspectors need to clarify the current condition	—
6	[26]	Building	Moisture contents in building	Need to be described by inspector	Inspectors need to answer every question regarding the moisture content	—
7	[27]	Building	General information to	Need to be described by inspector	Inspectors need to clarify the current condition	—

			identify element of the building			
8	[28]	Roof school building	Inspect external roof, drainage and down pipe	Need to be described by inspector	Description by inspector	—
9	[29]	Pitched roof	General information to identify element of the building	Need to be described by inspector	Description by inspector	—

The review of studies presented in Table 1 demonstrates that building inspection and defect assessment practices are predominantly qualitative and depend heavily on the professional judgment of inspectors [16]. Across various studies, such as those involving wooden houses, pitched roofs, and general building structures, the inspection elements are not standardized but are instead identified by inspectors based on the specific type, cause, and extent of the defect [17]. The inspection process typically involves visual examination of materials, structural components, and external features such as façades, roofs, drainage systems, windows, and doors. In several studies, defect descriptions are documented through checklists or narrative assessments that describe visible signs of deterioration, material degradation, or moisture-related problems. The level of defect assessment, in most cases, is determined through the inspector's interpretation and clarification of the building's current condition [18]. This indicates that the assessment relies on subjective evaluation rather than quantitative measurement or a standardized scoring framework [19].

Such reliance on individual expertise can lead to inconsistencies in reporting and variations in assessment outcomes between inspectors. Moreover, the lack of uniform criteria makes it difficult to compare inspection results across different building types and research contexts [20].

Therefore, it is evident that while current inspection methods provide flexibility and adaptability, they also highlight the need for more systematic, data-driven, and standardized assessment models [21]. Future studies should aim to integrate objective indicators, measurable parameters, and digital tools such as sensors or defect detection software to enhance the accuracy, consistency, and reliability of building defect inspection and evaluation processes.

METHODOLOGY

The methodology adopted in this review paper is primarily based on an extensive literature study. Various sources, including reference books, academic journals, conference papers, technical reports, magazines, and industry publications, were systematically reviewed. A structured approach was employed to examine the current monitoring techniques applied in wooden structure maintenance.

The review also includes an evaluation of previous methods developed by researchers for defect detection and assessment in timber structures. By comparing approaches from different studies and standards, this paper identifies the current level of advancement in assessment for timber materials.

Overall, this comparative synthesis highlights current best practices, technological gaps, and emerging trends in moisture monitoring systems. The findings are expected to provide valuable references for researchers, engineers, and conservation professionals involved in the maintenance and preservation of wooden structures.

Issues And Challenges in Current Inspection Practices

Inspection is a visual assessment method of the components [30]. This method reviews the visual condition of the defect at component based on their nature or performance parameters. Visual inspection is a non-assistance process of assessment alongside various visual aids for assessment of conditions during inspection.

Table 2: Summary of Issues in Inspection.

No	Author Source	Issue In Inspection
1.	[22]	The inspector assumes condition of defects on component
2.	[31]	Record the condition on the component without having the knowledge in the level of defects.
3.	[32]	The inspector's view is limited
4.	[33]	Lack of knowledge is a problem in the assessment of defects
5.	[34]	Assessment is guided by own judgment, perception or self-assumption
6.	[35]	Assessment based on knowledge, feelings and emotions
7.	[36]	Inspection depending on the memory of the framework
8.	[37]	Assessment based on the experience of the inspector
9.	[38]	The inspection is conducted in its own way

Based on table 2, several issues and challenges can be identified in current inspection practices. One of the main issues is that inspectors often rely on their own assumptions about the condition of defects on components without having sufficient knowledge about the actual level of defects [24]. This method goals is to get feedback during a inspection on the performance of the component. This lack of knowledge leads to inaccurate assessments and evaluations that depend heavily on personal judgment and perception [39].

Furthermore, inspectors' limited viewpoints [12] and reliance on memory or personal experience [40] affect the objectivity and consistency of inspection results. In some cases, inspections are conducted according to individual methods without following standardized guidelines or frameworks [41], resulting in inconsistencies in outcomes. Overall, the challenges in current inspection practices mainly stem from human factors such as insufficient knowledge, dependence on personal experience and assumptions, as well as the absence of a systematic and standardized approach to inspection assessment.

The review of previous studies reveals several recurring issues that affect the reliability and consistency of building inspection practices. One of the most critical problems is the subjectivity of assessment, where inspectors often make assumptions about the condition of defects without sufficient technical knowledge or supporting evidence [24]. In many cases, inspections are influenced by the limited visual access to structural components, resulting in incomplete evaluation and misinterpretation of the actual condition [12]. Furthermore, a lack of knowledge and technical competency among inspectors contributes to inaccuracies in defect assessment and reporting [39].

Another key issue identified is that inspections are frequently guided by personal judgment, perception, and self-assumption, rather than standardized assessment criteria [42]. This subjectivity causes the evaluation process to depend heavily on the experience, memory, and emotions of the inspector, which leads to inconsistent findings between individuals [40]. Additionally, it is found that inspection activities are often conducted in a non-standardized manner, where each inspector applies their own methods and interpretation framework [41].

Overall, these issues highlight the absence of a consistent and systematic approach in building inspection practices. The heavy reliance on individual perception and experience results in inconsistent, unreliable, and non-reproducible inspection outcomes. Therefore, there is a clear need to establish a standardized inspection framework to improve objectivity, ensure uniform data collection, and support effective maintenance decision-making.

Various assumptions of the life expectancy of the structure will also results in an unreliable report [43]. This causes weaknesses of the current methods of data collection such inconsistencies, unrealistic assumptions and manipulation of data [11]. The consequences are there will be various information from different inspectors [43].

Studies conducted by [44] shows there is an existence of bias in the validation of structural defects. The assumption with no knowledge on the gravity of defect would cause the method of maintenance to be biased or irrelevant.

DISCUSSION

Knowledge and understanding of building maintenance programs is a prelude for an effective management. Maintenance management should identify all operating systems in the building to facilitate the design of regular maintenance schedules. This paper discusses on the building maintenance management system to achieve the maintenance objectives. Reliable inspection also requires the arrangement of components and subcomponents for strength assessment to determine structural stability [48]. It to ensure that the inspector can identify the components to be inspected.

There are several methods of inspection depending on the of choice of the inspector. This problem described in the study of maintenance based on the conditions conducted by [45] for social housing summarizes as follows:

1. The purpose of the inspection and the framework is unclear because the inspector is unfamiliar with the components.
2. There is several experiences of inspectors in conducting inspections.
3. The level of disability is not realistic by the inspector.
4. There is incomplete or inappropriate data in the report inspection.
5. Lack of information or lack of clarity in providing maintenance programs is a major contributing factor to the level of dissatisfaction among building owners.

To ensure a more effective method of inspection, some improvements are needed in visual assessment so that inspection is easy and fast based on the studies conducted by [46]:

1. A standard hierarchy or sequence of components and sub-components are required for inspection.
2. A guide such as the use of color code to indicate good, medium and bad condition on floor plans are required.
3. Can be used in mobile PCs for easier movement.
4. Picture of damages from each point of inspection need to be collected.
5. A picture database is required as a guide during the inspection to reduce subjective assessment.

Despite the usefulness of existing inspection practices in identifying visible defects, several limitations have been observed in previous studies. The reliance on visual observation and inspector experience introduces a high degree of subjectivity, leading to potential bias and inconsistency in evaluation outcomes. In addition, many inspections are carried out manually, which makes the process time-consuming and prone to human error, especially in large or complex buildings. The absence of standardized evaluation criteria further complicates defect classification, making it difficult to establish clear thresholds for severity levels or maintenance prioritization. Moreover, the documentation methods such as manual checklists or descriptive notes lack integration with digital data systems, thereby limiting traceability and long-term performance monitoring.

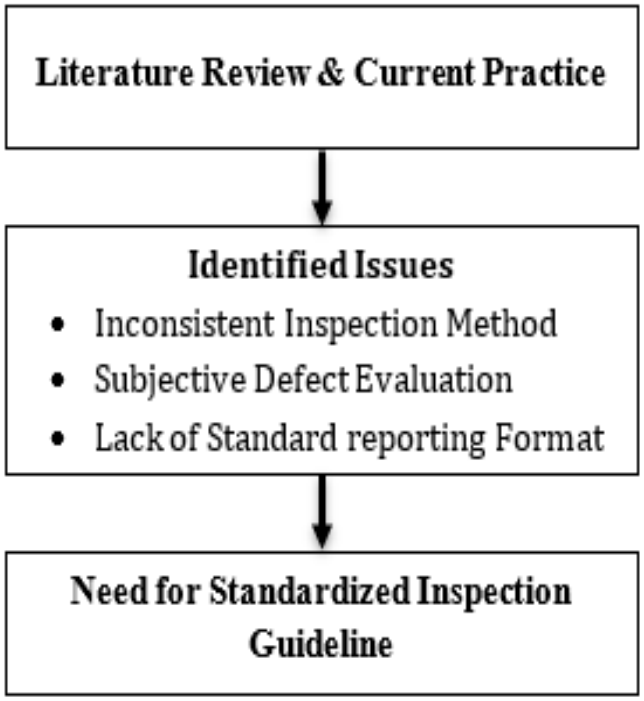

Figure 1: Conceptual Standardized Guideline

To overcome these limitations, recent research has suggested the development of a more systematic and technology-driven inspection framework. This conceptual approach could integrate digital tools such as Building Information Modelling (BIM), sensor-based monitoring systems, and computer vision techniques for automatic defect detection. The incorporation of quantitative indicators, supported by image analytics and data-driven decision models, would enable objective and repeatable assessments. Furthermore, the establishment of standardized rating systems and performance benchmarks would promote consistency and comparability across different building types and conditions. By merging traditional visual inspection with emerging digital technologies, future frameworks could significantly improve the accuracy, efficiency, and reliability of building defect assessments, ultimately supporting proactive maintenance and sustainable building management practices.

CONCLUSION

Maintenance activities are important to building management. Building maintenance management needs to be planned before the building is built and monitored during construction to ensure contractors comply with the specifications. Since, the level of effectiveness of some elements in the building service system will deteriorate and needs continuos maintenance. This paper described the importance of maintenance planning to building structures based on inspection methods. Guide framework for visual inspection are required so the inspection process is faster, less subjective and more suitable for less experienced inspector.

Therefore, based on studies of previous works, a guide framework is the key to achieve uniform inspections. In addition, specific strategies are required to ensure the documents provided can be interpreted consistently by various inspectors.

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