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Maintenance Decision Criteria in Facility Management

Authors:

Deniz Besiktepe, PhD[1], Mehmet E. Ozbek, PhD[2], and Rebecca Atadero, PhD, PE[3]

[1] Assistant Professor, The School of Construction Management Technology, Polytechnic Institute, Purdue University, denizb@purdue.edu

[2] Professor and Joseph Phelps Endowed Chair, Department of Construction Management, Colorado State University, mehmet.ozbek@colostate.edu

[3] Professor, Department of Civil and Environmental Engineering, Colorado State University, rebecca.atadero@colostate.edu

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1. Introduction and Purpose of the Study

Facilities Management (FM) involves a multi-disciplinary approach that ensures the built environment provides essential services to support an organization's mission and goals while enhancing occupant comfort. Since organizational needs evolve with long-term objectives, a successful FM strategy must align with these needs, as well as the organization's culture and values (Roper & Payant, 2014).

Building maintenance plays a critical role in ensuring that buildings perform according to required standards and minimizing the risk of equipment and system failures (Au-Yong et al., 2014). Maintenance and repair activities account for 79% of total FM responsibilities within FM organizations (Becerik-Gerber et al., 2012). Moreover, the International Facility Management Association's (IFMA) Operations and Maintenance Benchmarks report stated that average maintenance costs increased by 72% between 2007 and 2017 (IFMA, 2017).

Building maintenance decisions have significant importance on the effective work of building systems, components, and equipment simultaneously. Building maintenance decisions were stated as a a challenge for most facility management professionals in Cavalcante, Alencar, and Lopes' (2017) study. Given the complexity of maintenance processes, which involve numerous factors and complicate decision-making, there is a growing need for a mechanism that can help navigate these challenging scenarios. Multi-criteria decision-making (MCDM), a branch of operations research, led to the development of various methods to solve complex issues with conflicting criteria under different circumstances and fields of application (Jato-Espino et al., 2014).

Together with these, this study developed and ranked a set of fundamental and general criteria necessary for constructing an MCDM model for use in building maintenance across

various facility types. In this context, building maintenance decisions refer to repair, replace, defer, or 'do nothing' alternatives for a building system, component, or equipment. Each maintenance activity is treated as a discrete decision, with the selection of the system, component, or equipment subject to maintenance falling outside the scope of this study. To do so, the study utilizes the results of a nationwide survey conducted with the members of the International Facility Management Association (IFMA) and APPA - Leadership in Educational Facilities (APPA) in the United States, two globally recognized FM organizations. IFMA is the largest FM organization in the world, including more than 23,000 members in over 100 countries, and APPA represents more than 18,000 educational facilities professionals from 1300 learning institutions worldwide. The findings of this study will help establish the current state of facility management and contribute to the development of an MCDM model incorporating a condition assessment framework for use in building maintenance processes.

2. Background

Building maintenance and FM practices constitute a significant portion of buildings' life cycle (Lewis et al., 2014). Due to the complexity of building systems, FM and maintenance efforts are designed to extend the lifespan of these systems and the built environment. Several studies have identified key challenges that hinder the development of effective FM strategies including: 1) managing multiple maintenance projects, 2) integrating energy and workplace management, 3) adopting performance-based contracts, 4) leveraging technological advancements, 5) the absence of commissioning and handover models, and 6) issues related to outsourcing and service delivery (Atkin & Brooks, 2015; East & Liu, 2006; East et al., 2013; Rondeau et al., 2012).

Moreover, resource constraints and aging building stock were discussed in the context of FM and building maintenance as two main challenges that affect the performance and life cycle of the built environment (Kim & Ebdon, 2020; Kohler & Yang, 2007). The underperformance of facilities is primarily attributed to cost constraints, insufficient funding, budget cuts, and poor maintenance management (Eweda et al., 2015). Effective maintenance, as noted by Zavadskas and Vilutiene (2006), hinges on well-planned design and commissioning processes, which demand qualified personnel, specialized equipment, and technical expertise. Moreover, Olanrewaju and Abdul-Aziz (2015) argue that maintenance requires a multidisciplinary approach, integrating engineering, economic, commercial, environmental, cultural, and social considerations.

Researchers have increasingly focused on addressing the challenges in building maintenance and facilities management by developing more effective management strategies. Technological advancements, such as building information modeling (BIM) (Pishdad-Bozorgi et al., 2018; Wang & Piao, 2019), data exchange systems, computerized maintenance management systems (CMMS), asset management frameworks, and preventive maintenance approaches, have been explored in the literature (Cigolini et al., 2008). However, studies highlighted the need for further investigation in building maintenance and FM to address the growing complexities in these areas.

One approach to addressing the challenges in building maintenance and facilities management is to enhance decision-making outcomes through a structured and systematic process. Given the complexity of maintenance decisions, which often involve conflicting criteria, utilizing a multi-criteria decision-making approach can be an effective method to tackle these challenges. The application of MCDM allows decision-makers to establish their own set of key

criteria for selecting maintenance strategies based on specific needs and characteristics (Lin et al., 2014). Additionally, Yin et al. (2011) emphasized the significance of involving various stakeholders in the building maintenance decision-making process. Key stakeholders include FM executives, project managers, supervisors, occupants, and property owners. To ensure effective decisions, a decision-making approach that supports group input and collaboration is crucial in the context of building maintenance.

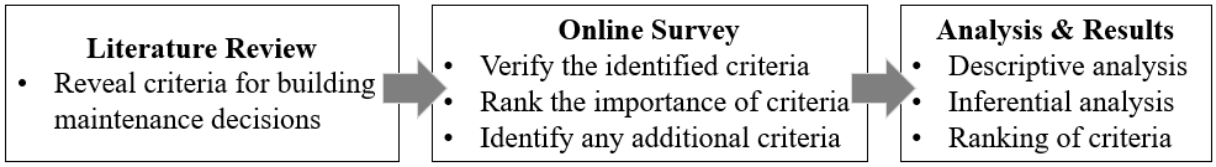
Although decision-making is critical in building maintenance and facilities management, there is a noticeable lack of focus on this issue in the current literature. Furthermore, only a few studies have explored the integration of MCDM approaches into FM decision-making processes. To address these gaps, this study takes the first step in developing an MCDM model by establishing a set of criteria for building maintenance in FM, derived from both a comprehensive literature review and an online survey.

3. Research Methodology

The methodology of this study comprises a literature review to reveal the significant criteria for building maintenance decision-making processes and a nationwide online survey with the IFMA and APPA members to verify the criteria identified through the literature, rank their importance, and identify any additional criteria for the potential decision-making models. The steps of the methodology are presented in Figure 1.

Figure 1

Research Methodology



3.1. Literature Review

The literature review targeted studies in the last two decades, to focus on the most recent efforts that were conducted in a wide range of areas, including maintenance management in manufacturing and industrial production, together with building maintenance. The following keywords were utilized for the search: "maintenance management," "facility management," "building maintenance," and "decision-making," in several combinations with "criteria," "factor," "strategy," "policy," and "prioritization." Studies reporting criteria or factors that influence building maintenance processes and decision-making practices were included in the literature review for criteria identification (Johnson & Wyatt, 1999; Bevilacqua and Braglia, 2000; Parida and Chattopadhyay, 2007; Chang and Pan, 2007; Reichelt et al. 2008; Ali et al. 2010; Flores Colen et al. 2010; Yau 2012; Kim et al., 2019) .

The factors or criteria identified in the selected literature formed the basis for determining the criteria utilized in this study. Consequently, criteria were identified from the literature based on the frequency of their occurrence The most frequent criteria in the studies reviewed were, respectively: 1) cost, 2) occupancy, 3) health and safety, 4) condition, and 5) sustainability.

Various facility types were presented in the literature and this study focused on identifying fundamental decision-making criteria for any building type. For example, specific

criteria such as *functional spaces*, which refers to clinical, nursing, and support areas in healthcare facilities, should be considered in healthcare facilities (Ali & Hegazy, 2014).

In addition to these five criteria frequently mentioned in the literature, four more criteria were also discussed in the literature and considered relevant, therefore they are also included in this study: 6) funding availability, 7) code compliance, 8) duration, and 9) scheduling. The criteria identified from the literature review are presented in Table 1.

In the selected literature, cost is determined as critical in building maintenance decision-making. Together with this, if the available funds are not adequate, building maintenance practices will be ineffective or insufficient (Riley & Cotgrave, 2005). Building codes have also significant influence in building maintenance decision-making addressing the structural, electrical and mechanical systems, fire safety, accessibility, security, building envelope, energy consumption, and materials that are fundamental regulations for building construction in the United States. Code compliance is mandatory for new construction as well as any repair or replace activity in existing buildings to protect public health and safety (Martin, 2005).

The complexity of maintenance activities with conflicting tasks requires effective planning and scheduling of these activities. Hence, maintenance scheduling, which is the timing of any maintenance activity in the calendar year, should be considered along with business objectives. In addition, the duration of the maintenance activity is an integral part of maintenance scheduling (Hopland & Kvamsdal, 2016). Subsequently, the identified criteria and their definition in this study are presented in Table 2 in alphabetical order. The authors acknowledge that the identified criteria may be interpreted differently based on the maintenance activity or the context of the decision-making problem (e.g., code compliance requirements differ for roofing and heating, ventilation, and air conditioning (HVAC) maintenance needs), the identified list

provides fundamental and general criteria for decision-makers in building maintenance activities. Having said this, it is important to note that based on the needs of individual problems, decision-makers may add specific criteria to this fundamental list.

Table 1

Identified criteria for building maintenance decision-making through literature review

Criterion
Code Compliance
Condition
Cost
Duration
Funding
Availability
Health and Safety
Occupancy
Scheduling
Sustainability

Considering the definition of these criteria (i) “code compliance” represents the compliance of the equipment with the most recent building codes, (ii) “condition” refers to the existing condition of the equipment at the time of the maintenance activity decision, (iii) “cost” is the total estimated cost of the maintenance activity, (iv) “duration” is the total time span if the maintenance activity in days, months, or years, (v) “funding availability” refers to the available funds of the maintenance budget related to the maintenance activity, (vi) “health and safety” is the threats caused by the failure of the equipment, (vii) “occupancy” represents the purpose and occupancy of the building such as office, education, and healthcare, (viii) “scheduling” is the time of the maintenance activity in the calendar year such in April or from May to July, and (ix)

"sustainability" reflects the impact of the maintenance activity on the sustainability of the equipment.

3.2. Online Questionnaire Survey and Data Collection

The survey development started with the informal conversations with facility management professionals to discuss the identified criteria from the literature. Even though cost and funding availability were confirmed as dominant criteria, other factors such as health and safety, condition, code and regulatory requirements, and sustainability were mentioned with higher priority in various instances.

Together with these, an online survey was developed to verify the criteria identified through the literature, ranking their importance, and identifying any additional criteria for building maintenance decision-making. Moreover, to support the exploratory nature of this study and to help establish the current status of FM, one question was focused on current decision-making practices in building maintenance.

Members of IFMA and APPA who are decision-makers in FM and building maintenance were the main target population of the survey. These associations are widely recognized for having a large majority of professionals engaged in corporate and higher education facility management practices both in the United States and globally. The survey participants held various roles, including directors of facilities, assistant directors of facilities, and facility managers.

The survey questionnaire comprised 21 questions including ranking, multiple-choice, and open-ended questions, with the approximate time of 10–15 minutes to complete. Qualtrics XM web-based account provided by Colorado State University was utilized for conducting the survey

and data storage. Twenty-three academic and professional members of FM were selected from the FM professionals and academics in Colorado and participated in the pilot survey process. Based on feedback from the pilot survey, minor revisions were made to the multiple-choice questions, such as the ability to select more than one answer as an option.

The online survey instrument was approved by the Colorado State University Institutional Review Board (IRB) in the exempt category and distributed by personalized emails, email listings of IFMA and APPA, online forum groups, and social media networks of FM professionals in LinkedIn on the second half of 2018. Given that the survey was promoted in LinkedIn groups composed of professionals working in the FM domain who can be non-members of IFMA and APPA, the authors used the demographic questions to confirm that the participants had relevant experience in FM, as presented in the following sections.

The online survey was open for ten weeks, and two reminders were sent to the target groups. Out of 219 recorded responses, and 127 complete results were included for full analysis. Even though the response rate was impossible to calculate due to promotion of the survey in social media of FM professionals with membership numbers not known, the authors acknowledge that they value the responses that were provided by qualified and experienced FM professionals in this survey. It is important to note that this study does not make any inference about the entire FM population based on our sample size.

4. Analysis and Results

Microsoft Excel, IBM Statistical Package for the Social Sciences (SPSS) Statistics 26, and NVivo qualitative data analysis software were utilized for data analysis, with descriptive and inferential statistical analysis methods. Percentages and mean ranking determination were calculated in the descriptive analysis, while the inferential analysis includes a two-sample t-test.

Content analysis was performed for qualitative data from open-ended questions with conceptual analysis.

4.1. Descriptive Results

Ninety-seven survey participants comprising almost 80% of the collected responses were from United States. Ten percent of the responses were from Canada, and the remaining responses were from Australia, China, India, Malaysia, Qatar, Trinidad and Tobago, United Arab Emirates, and the United Kingdom. Forty-four percent of the participants were employed in educational institutions; the remaining 56% were in non-educational sectors. In addition, 46.8% of the participants work in the public sector and 53.2% work in the private sector.

Directors, associate directors, facility managers, and other managerial positions in FM comprise 85% of the survey participants, as the targeted population of the online survey was decision-makers in FM and building maintenance. The distribution of the survey participants' positions is presented in Figure 2. Almost 75% of the survey participants had more than 15 years of FM experience, as presented in Figure 3. Considering these, it can be concluded that most responses were collected from experienced FM executives who have a significant role in the decision-making process of building maintenance.

Figure 2

Job titles of survey participants

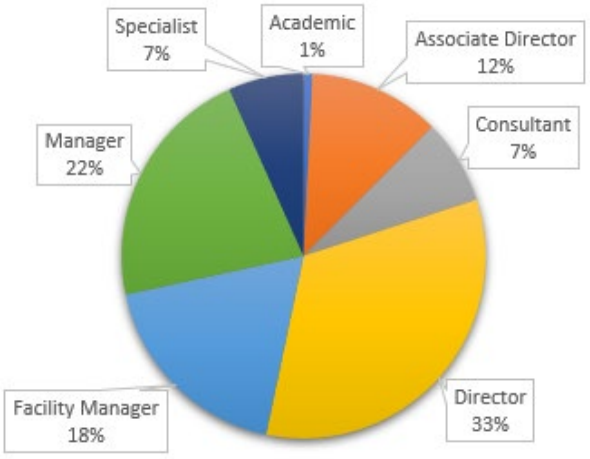
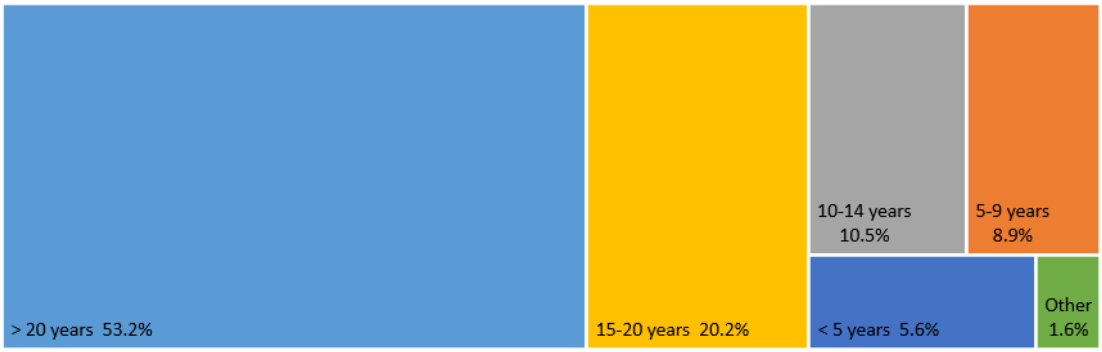


Figure 3

Participants' work experience in FM



These demographics showing that the respondents are composed of professionals with relevant positions and experiences support the reliability of the results. The main purpose of the study is to develop a set of criteria in building maintenance decision-making and having the vast majority of the survey participants (85%) as decision-makers is a significant indicator of the reliability of their responses. In addition, it is important to note that the years of experience

provided by survey responders are specific to their experience in FM, which also supports the reliability with almost 75% of respondents reporting more than 15 years of experience.

4.2. Ranking of Criteria

Participants were asked to rank the nine criteria identified through the literature review based on the order of importance. The ranking scale was from 1 to 9, representing: "1" is the most important, and "9" is the least important. The mean ranking values of each criterion showed that "Health and Safety" ranked as the most important criteria with the mean ranking value of 1.90. "Code Compliance (2.93)" and "Condition (3.28)" criteria were ranked as the second and third most important criterion, respectively. The mean importance of rankings of the identified criteria is presented in Table 2.

Table 2

The mean importance ranking of building maintenance decision-making criteria

Criteria	Mean Ranking
Health and Safety	1.90
Code Compliance	2.93
Condition	3.28
Cost	4.44
Funding Availability	4.94
Occupancy	6.02
Sustainability	6.98
Duration	6.98
Scheduling	7.52

The ranking values established that "Health and Safety," "Code Compliance," and "Condition" are predominant compared to "Cost" and "Funding Availability." Considering these, the researchers aimed to reveal any statistically significant differences within criteria ranking

among the sample population between public and private organizations. Consequently, the mean importance of criteria rankings and their statistically significant differences (if any) were investigated between public and private organizations.

A statistically significant difference was identified ($p < .05$) in public vs. private organization participants for the ranking of the "Condition" criterion. The public organization participants ranked "Condition" higher than private organization participants. Moreover, the "Sustainability" ranking was significantly statistically different ($p < .05$) between public vs. private organization participants. Private organization participants ranked "Sustainability" higher than public organization participants. The p-values of two-sample t-tests are presented in Table 3 within related sample groups.

Table 3

Mean importance ranking and two-sample t-test p-values for private and public organization participants

	Public	**Private**	
	Mean	**Mean**	***p*-Value**
Health and Safety	1.9123	1.7879	0.6080
Condition	**2.8421**	**3.6212**	**0.0030 ***
Code Compliance	3.0702	2.8788	0.6240
Cost	4.4912	4.4545	0.8810
Funding Availability	4.7895	5.0455	0.4800
Occupancy	5.9649	6.0758	0.7700
Duration	7.1053	6.9545	0.5620
Sustainability	**7.3860**	**6.6212**	**0.0450 ***
Scheduling	7.4386	7.5606	0.6460

* $p < .05$

Statistically significant differences for individual criterion can be considered as an indicator to determine the FM organizations' efforts based on their existing challenges.

Particularly in the "sustainability" criterion case, the reason behind the higher ranking of this criterion in private organizations compared to public ones might be due to the additional costs of sustainable practices. Although it is not possible to determine the causes of the statistically significant differences in the mean rankings as part of this study, these results are interesting in terms of supporting the need for further research.

4.3. Additional Criteria

Participants were also asked to provide additional decision-making criteria that were not suggested in the ranking question of the survey. Eighty-one survey participants provided 198 additional criteria or factors for building maintenance decisions. However, 51 out of 198 were similar to the identified nine criteria of the study, such as "regulatory issues," "financial considerations," "occupant satisfaction," etc., and they were excluded from further analysis. The remaining 147 criteria or factors were analyzed in NVivo qualitative data analysis software. The purpose of the content analysis performed in NVivo software is to identify the frequency of the additional criteria suggested by the respondents in the survey. NVivo grouped linguistically similar words in single word categories with their frequencies from the list of 147 criteria. The participants also had the opportunity to provide the importance of their suggested criteria as "major" or "minor." The provided importance for the suggested criteria was "major" for 124 criteria out of 147.

Two main concepts were observed from the word category and frequency results of the NVivo analysis: "Strategic Business Planning" and "Impact of Failure." The word frequencies of "plan," "business," "operations," "critical," "future," and "requirement" were associated with the concept of "Strategic Business Planning." In the concept of FM and building maintenance, strategic business planning can be defined as aligning FM functions with the organization's

business continuity with a clear understanding of the organization's goals and objectives in the short-term and long-term (Atkin & Brooks, 2015; Chotipanich, 2004). For instance, in the case of relocation planning of the organization, maintenance activities need to be rescheduled or sustained.

In addition, "impact," "failure," "consequence," "risk," and "replacement" related to "Impact of Failure." The failure of any system, equipment, or component has several consequences, such as threats to health and safety, environment, occupant comfort, and loss of energy and operational efficiency (Wu et al., 2010) For example, the failure of HVAC equipment or systems may affect the entire building, since these systems are complex and centralized (Au-Yong et al., 2014).

As a result of the content analysis, researchers incorporated "Strategic Business Planning" and "Impact of Failure" into the list of identified criteria in this study. The two additional criteria were synthesized based on the researchers' observations of the similarities and frequencies of the linguistic meanings of keywords, as described above. Table 4 represents the criteria for building maintenance decision-making identified in this study.

Table 4

The final list of building maintenance decision-making criteria in this study

Criteria
Code Compliance
Condition
Cost
Duration
Funding Availability
Health and Safety
Impact of Failure
Occupancy
Scheduling
Sustainability
Strategic Business Planning

5. Discussion and Conclusions

This study aimed to develop and rank a set of criteria needed for constructing an MCDM model to be utilized in building maintenance processes in FM. A comprehensive literature review and an online survey with FM professionals were performed to achieve the purpose of the study. A total of 11 criteria were identified in the study to use in building maintenance decision-making: 1) code compliance, 2) condition, 3) cost, 4) duration, 5) funding availability, 6) health and safety, 7) occupancy, 8) impact of failure, 9) scheduling, 10) strategic business planning, and 11) sustainability. It is important to note that these criteria comprise a fundamental and general list for building maintenance decision-making problems, and individual systems and facility types might require the consideration of additional criteria.

The survey results assisted in revealing the importance of nine of these criteria identified through the literature review representing the most important, respectively: 1) health and safety, 2) code compliance, 3) condition, 4) cost, 5) funding availability, 6) occupancy, 7) sustainability, 8) duration, and 9) scheduling. Interestingly, the mean importance rankings highlighted the importance of "Health and Safety," "Code Compliance," and "Condition" above "Cost" and "Funding Availability," which were anticipated to be dominant criteria. In addition, the researchers determined two more criteria from the feedback of survey participants regarding additional criteria to be considered in the process: "Impact of Failure" and "Strategic Business Planning."

"Condition" was identified as one of the top criteria in building maintenance decision-making, highlighting the need for effective condition assessment practices. Further research is required to better reveal the time interval, capacity, and process of condition assessment

practices with the possibility of including innovative applications in condition assessment. In addition, documentation and reporting of condition assessment practices are important to get the maximum benefit from condition assessment outputs.

"Sustainability" criterion was ranked with lower importance compared to other criteria in the survey. Possible reasons behind this might be the misconception of sustainability, the multifaceted nature of sustainability as a concept in terms of social, economic, and environmental considerations, and the additional upfront costs of sustainable practices. In some cases, repairing equipment might be considered as more sustainable compared to replacement, and overall building maintenance practices assist sustainability concepts in the long term. However, it is not possible to determine the main reason for the lower importance of the sustainability criterion within this study, and further research on sustainability practices in FM is necessary.

The criteria identified in the context of this study fills a gap in the lack of comprehensive criteria in building maintenance decision-making. Additionally, the findings of the study revealed that criteria such as "Health and Safety," "Code Compliance," and "Condition" have higher importance compared to "Cost" and "Funding Availability." Even though financial constraints largely influence FM practices, the nature and complexity of building maintenance requires comprehensive criteria, as evidenced by the summarized findings.

In addition to the criteria developed, this study revealed statistically significant differences in the mean rankings of some of these criteria between public and private organization participant groups. These differences support the need for the development of an MCDM framework that could be customizable by each organization. As a first step in developing an MCDM approach, the scope of this study is limited to identifying and ranking a

set of criteria that can be used for building maintenance decisions. Future studies can utilize the identified criteria in the development of a full-scale MCDM model. Moreover, the applicability and significance of identified criteria in different FM contexts such as healthcare, industrial, educational, and office can be investigated. In addition, future studies can reveal the differences in building maintenance and decision-making practices in public and private institutions.

The findings further revealed that the current decision-making practices depend mostly on expert opinion; however, the decision-makers in the FM industry are aging. Systematic and structured decision-making practices in building maintenance will have a significant contribution to address this challenge as well as establishing effective FM strategies.

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