

DESIGN CONSIDERATIONS FOR MAINTENANCE: FACILITY MANAGERS' PERSPECTIVE

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Maintainability is one of the considerations designers take into account in the design stage of building construction projects. In other words, maintainability is a design consideration that may improve ease of maintenance during operation. The designer is expected to include maintenance knowledge and experience into the design, including planning for specific tools to facilitate implementation. Maintainability issues appear during the occupancy stage and have a direct impact on the cost of owning and operating a facility. Annual operation and maintenance expenses during the life cycle of a building could amount to many times the initial construction cost. Design deficiencies constitute one of the main reasons for high annual maintenance cost. Facility management involves activities to maintain and operate a constructed facility. It is essential to evaluate facility managers' perspective on how maintainability characteristics should be considered at design phase of facilities. A survey of 168 facility managers in the mid-west region of the US is uncovered that (1) maintainability should be top priority in design, especially for mechanical systems, (2) deferred maintenance should be avoided because it increases costs over the life-cycle of buildings, and (3) constructed facilities should be handed over with a maintenance schedule provided by the designer. Paying special attention to maintainability in the design phase is expected to help reducing the cost of operation.

Keywords: Facility management, Maintainability, Design priorities, Design deficiencies, Maintenance methods, Operation phase.

1 INTRODUCTION

After a building is constructed, facility managers are usually in charge of maintaining the building. Different maintenance methods are available to keep various systems and equipment at the required functional level. The selection of the appropriate method is based on the architect's recommended maintenance schedule. In case there is no maintenance schedule provided by the architect, facility managers choose an appropriate method for each component based on their experience.

In addition to operating a building's systems, facility managers take care of the maintenance of these systems. Occupants' demands evolve during the life cycle of a facility, which requires different maintenance strategies for different situations. Generally, maintenance can be preventive or corrective. Preventive maintenance includes a routine schedule for different components of each system to be checked, serviced or replaced. Corrective maintenance happens once a system breaks down.

There are several considerations an owner and a designer take into account in the design of a building (Ogburn and El-adaway 2014). Owners and designers attach priorities to these considerations. Paying special attention to maintainability in the design phase helps to reduce the cost of owning and operating because taken over the life of a facility, maintenance may cost more than the initial cost of construction.

The main objective of this research is to collect and evaluate the opinions of facility managers about the extent to which maintainability is considered in design, the impact of different maintenance methods on facility costs, and the effect of a designer-provided maintenance schedule on facility management.

2 MAINTENANCE AND MAINTAINABILITY

In order to facilitate maintenance, during the life of a building, designers should consider maintainability as a serious design parameter. Injecting a combination of maintenance knowledge and experience into the project delivery process is a formal method of easily including maintainability into the process. For a better prediction of malfunctions and breakdowns in building systems, the building must be planned and designed for maintainability and a pre-defined maintenance program with a structured process should be in place and should be supported by corporate resources.

Facility managers are typically responsible for fixing the defects discovered after handover (Tay and Ooi 2001), but there are notable liabilities for inferior design and construction (Chong and Low 2006, Lam 2000). Design error-related defects often cause a chain effect, restrain performance, and lead to almost half of the maintenance cost (Arditi and Nawakorawit 1999a, 1999b, Josephson and Hammarlund 1999, Ilozor *et al.* 2004).

The life cycle cost analysis of a facility begins in the preliminary design phase and ends when the facility is decommissioned. In an effort to minimize the cost of construction, design decisions made during the preliminary design and construction phases typically consider only the construction costs. Deficiencies in the use of constructability standards at the design phase often lead to difficulties in maintenance. The concept of maintainability addresses this concern and can become an extension of the constructability process. As such, the formal constructability process may also incorporate a maintainability review (Dunston and Williamson 1999).

According to Chong and Low (2006), there are many maintenance issues that designers are not able to prevent. However, by using property managers' experience in regards to repeated maintenance issues; designers can improve overall building quality if they concentrate their efforts on a few major maintenance issues.

One of the main concerns of the construction industry is construction defects that require excessive maintenance, repair, or replacement. The performance of a building component depends on the function, system type, and materials used. Systems and materials are the main subjects of most research studies about defects.

The conventional construction management focus on saving money during design and construction is only a small percentage of the potential savings during the life cycle of facilities. Significant cost savings could be obtained by delivering facilities' complete construction information to facility managers. There are many approaches chosen by owners to transfer construction information to facility managers. Paper manuals are typically stored in a room on site at each facility (East *et al.* 2013).

3 METHODOLOGY

The investigation was conducted in two phases. The first phase involved a literature review. The maintainability considerations that should be accounted for in the design of a building were identified in this phase. In the second phase, a questionnaire was developed, using the considerations identified in the literature review. A survey tool was designed to collect facility managers' points of view. In addition to demographic information about annual revenue, years of experience in the industry, and the type of building designed, the questions explored (1) the efficiency of commissioning, (2) the existence of maintenance schedules provided by architects, (3) the reasons for high maintenance cost, (4) the most important considerations taken into account by architects in designing a building, (5) the systems that generate the highest maintenance expenditures, (6) the most important factors considered by architects in selecting equipment/materials, (7) the method of maintenance used, and (8) the impact of BIM and sustainability considerations on maintenance decisions. The findings were tabulated and organized in charts and bar diagrams. Justification for the three most pertinent factors is presented in the following subsections. The findings are discussed in some detail in Section 4.

3.1 Annual Maintenance Cost

The annual cost of maintenance depends on different factors but maintenance issues constitute the predominant factor. Maintenance issues arise when there is a shortcoming in the design concept, defective workmanship, or inappropriate material used. In order to avoid inappropriate decisions in the design phase, early contractor and facility management involvement is suggested (El-Haram and Agapiou 2002, Song *et al.* 2009). Facility managers were asked to state their opinions about the impact of inappropriate maintenance practices, deferred maintenance and inadequate design on annual maintenance cost.

3.2 Design Priorities

In the design phase, architects prioritize different considerations. Studies show that cost, time and quality are the most important considerations for architects. Barnes (1988) refers to them as the triangle of project objectives. According to Meng (2013), designers keep a balance between considerations such as aesthetics, reliability, durability, conformance, functionality and practicability. The lack of maintainability among these considerations is driven by the separation of design from the post-design process. Facility managers were asked about their preference about design considerations in addition to time, cost, and quality.

3.3 Maintenance Budget

Each building consists of different systems, including the structural, sanitary, mechanical and electrical systems. Each system requires a separate maintenance plan as well as a separate annual budget for maintenance activities. One of the responsibilities of a facility manager is to identify the budget for each system. Facility managers were asked to identify the causes for high annual maintenance costs.

4 FINDINGS AND DISCUSSION

The survey was electronically sent to 3,845 facility managers who are members of the International Facility Management Association (IFMA) in twelve mid-west states as defined by the U.S. Census Bureau, namely Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin. A total of 168 facility managers participated in the study, which amounts to a response rate of 4.4 %. This is a low rate of response, but it is not unexpected in online surveys. It should nevertheless be noted that even though the number of respondents is as large as 168, the responses may not necessarily reflect the opinions of the much larger facility manager population at large. This was an exploratory study that aimed to detect trends in the industry, and as such, 168 responses is a respectable sample size.

The results indicate that only few buildings are handed over to facility managers with a maintenance schedule provided by the architect. Indeed, almost three quarters of facility managers (73%) stated that the handover documents include a maintenance schedule in less than 25% of buildings. Whereas facility managers believe they receive most completed facilities without a maintenance schedule, in a parallel survey administered to architects (Jalali Sohi 2015), most architects stated that they deliver facilities mostly with a maintenance schedule at handover. This discrepancy in opinions is controversial. If it is true that only few buildings are received by facility managers with a maintenance schedule at handover, this may be an explanation for the high costs of maintenance throughout the life of these buildings. Scarponcini (1996) demonstrated that savings in design and construction (e.g., by avoiding the expense of generating a maintenance schedule) is only a fraction of the probable savings (e.g., in maintenance costs) throughout the life of a facility. According to East *et al.* (2013), who has collected information from facility managers over a decade, owners are trying to transfer construction information to facility managers by different methods. Although electronic data storage and management has gained ground, storing paper data manuals is still the most common method of retaining construction specifications. Shifting to computerized data storage practices is expected to reduce maintenance costs in the long run.

Forty five percent of facility managers think deferred maintenance is the main reason for high annual maintenance cost. Inappropriate design practices scored 32% and inadequate design received 23% as the second and third factors, respectively. Deferred maintenance may be a result of limited budgets, incapable staff, lack of planning, and deficient understanding of consequences. In the ASCE's 2015 Report Card, the reason why the infrastructure and structural facilities obtained low ratings was mainly because of deferred maintenance. Moving away from deferred maintenance is expected to have a positive impact on maintenance costs. Judging from the responses of 55% of the facility managers, the impact of design problems on maintenance has to be recognized too. A study conducted in 2013 of the curricula of all architecture programs in the U.S. showed that the word "maintenance" did not appear in any course description. There seems to be a disconnect between the wishes of facility managers and the education of architects relative to building maintenance.

Cost, duration, and quality of construction are considered to be important factors in designing a building. Other considerations, some of which are as important, include constructability, maintainability, aesthetics, occupants' comfort, and functionality. In

addition to cost, time, and quality, 40% of facility managers' top two concerns were found in this study to be about maintainability and functionality. Aesthetics is considered to be the least important concern as it was marked by less than 2% of facility managers. On the other hand, architects usually seem more interested in aesthetics and constructability (Jalali-Sohi 2015). Again, there seems to be a disconnect between facility managers' needs and the priorities of architects.

A building involves four major systems, including structural (walls, slab, frames, etc.), sanitary (plumbing, fire protection, etc.), mechanical (HVAC), and electrical (elevators, circuits, cables, etc.) systems. The findings show that the large majority of facility managers (86%) think that mechanical systems have the highest annual maintenance cost, whereas only 8% think that annual maintenance cost is driven by structural or sanitary systems. Electrical systems were rated to have an impact on maintenance cost by only 6% of the respondents. These findings agree with the findings of an earlier study by Ardit and Nawakorawit (1999) who found that the mechanical system is the most troublesome component in maintenance activities. Mechanical systems deserve special consideration during design.

5 CONCLUSION AND RECOMMENDATIONS

Typically, an owner's goal is to minimize the cost of design, construction and operation, and to maximize occupant comfort and environmental quality over the life of a building. Maintenance is an important part of this equation. A variety of factors affect maintenance issues in the design, construction and operation of buildings. These factors include but are not limited to maintenance schedules, methods of maintenance, maintenance cost, maintenance considerations during design, and building systems that need special attention for maintenance. The factors that affect maintenance in the operation of buildings were explored by means of a survey administered to facility managers. The results highlight interesting facts that may have long lasting impact on the research literature and on actual practice.

The findings show that about three quarters of facility managers provide or receive a maintenance schedule for less than 25% of buildings at handover. Computerized management practices during design and construction are expected to alleviate this problem.

The findings also show that deferred maintenance and design problems are ranked by facility managers as the most important reasons for high annual costs of maintenance. Shifting to preventive maintenance practices is a good solution to this problem. Additionally, recognition of the importance of maintenance by educators in architecture appears to be an important part of the cost reduction equation. Design checklists such as the one developed by Hassanain *et al.* (2015) for water supply and drainage systems could help.

While this study shows that facility managers' priority rests with maintainability, architects are usually preoccupied by aesthetics and constructability. Injecting maintainability considerations to constructability reviews is most desirable.

Finally, facility managers believe that mechanical systems cause the highest annual cost of maintenance compared to other building systems. This finding reconfirms the outcome of previous studies and draws the attention of architects and facility managers

alike that mechanical systems have to receive special attention during design and during operation.

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