Sustainable Repair & Maintenance of Buildings in the Developing Countries: A Risk Management Perspective and Proposal of Customized Framework

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Abstract: Repair & maintenance (R&M) activities of buildings and structures are inescapable: aging, constant use (causing wear and tear), likely defects of design and construction, and the consequences of environmental agents and vulnerabilities cause the deterioration of building components over a period of time. R&M decisions are partly dictated by policies and regulations in the developed world, however the situation exacerbates in developing countries where large number of externalities dictates these decisions: lack of budget, enforcing regulation and building standards to name a few. These and other inherent uncertainties grow to be considerable risks of strange and inimitable nature which demand an active and customized management. There is a strong incentive if effective risk management is launched and established in R&M projects: better cost control, higher serviceability, lower facility down time and improved reputation along with the enhanced satisfaction on part of occupants and users. The need to systematically manage the risk is paramount: starting from efficient risk identification to precise analysis, and appropriate response planning to thorough monitoring and control, a tailored and specialized project risk management (PRM) framework—a combination of specific tools and techniques—will greatly help by considering how risky these undertakings are, dealing with apparent threats and converting them into real opportunities. To this end, after reviewing the R&M state of affairs in developing countries, this paper proposes a functional PRM framework to manage R&M risk.

Key words: Project management, project risk management, repair & maintenance, sustainability, developing countries.

1. Introduction

Owing to their constant exposure to the external operating environment and deterioration due to continuous use, building components are prone to ageing and wearing away which results in a decreased service life. Therefore, it is important to take measures; otherwise if left to their fate, these components will eventually become inefficient, unreliable and may even fall apart, threatening the safety of very occupants as a result. To counter the serviceability and safety challenges, building components are maintained in such a way that they continue to perform their designated function. The British Standard 3811:1984 describes “maintenance” as the intricate combination of technical and associated managerial actions which are aimed at retaining a building component in (or restoring to) a state in which it can perform its required function [1]. The apparent objectives behind any maintenance operation are [2–3]:

- To ensure the safety of the buildings, their components and their associated services.
- To ensure the usability of the buildings and their components.
- To ensure satisfaction and fulfillment of all the necessary statutory requirements.
- To execute work necessary to maintain the quality and serviceability of the buildings.
The maintenance activities, irrespective of being “preventive” or “corrective” in their nature, must be treated as a project. Hence, the actions and objectives mentioned before are those associated with conception, planning, execution and close out—a typical project lifecycle.

In contemporary times, the notion of “sustainability” seems to dominate the debate; owing to quickly withering environmental conditions and ailments, the idea of “sustainable development” has emerged as an effective response. Sustainability (commonly defined as a complex-and often contradicting-interplay between economy, society and environment), in the context of built environment, is vital since the building activities have always had significant and sometimes unaccounted for consequences; globally, over 35% of industrial waste is contributed by these activities [4-5]: in Hong Kong alone this percentage is more than 38% [6]. Housing is another important factor, profoundly contributing in the environmental footprint of building activities [7].

The maintenance actions, where huge piles of waste are generated, are no less when it comes to threatening the sustainability and harming the environment. To curb this menace, a number of studies have taken place [8-13] and developed nations have come up with strong regulations [14-16].

The state of affairs (regarding the productivity and profitability) in construction industry of developing countries is impaired: from lower efficiency to shabby reputation, from frequent delays to quality compromises, the construction industry is marred with a lot of criticism [17]. Not only the situation is alarming for the clients, occupants and users, but the parties involved in execution are equally at risk [18]. In their seminal work on the plight of construction industry development in developing countries, Ofori and Toor [19] have traced the footsteps of some of the simmering problems which are at the base of construction industry’s predicament. In short, the construction industry in the developing countries lack the sort of maturity as deservingly boasted by that of industrially advanced countries [20].

Further aggravating the situation, the not-so-promising “attention to detail” tendency for sustainable development in the context of these countries is unsettling; restricted by weak and exhausted economies, vulnerable social conditions and insubstantial appeal to environmental concerns, developing countries risk bearing greater losses trying to avoid smaller ones (e.g. not performing routine maintenance operations and eventually facing serviceability problems). Correspondingly, proper and timely maintenance helps achieving longer economic life, resulting in lower depreciation costs and thus higher profitability. Although international efforts of venturing into sustainable development in these developing countries may seem promising, they are still far away from achieving justifiably green results without streamlining practically every aspect of sustainability.

Building repair & maintenance (R&M) decisions are critical in their nature owing to above mentioned facts. Also, based on evident reasons [21-23], the humble track record of developing countries in achieving sustainability in R&M actions is further complicated due to project externalities: lack of budget and enforcing regulation for example. One of the important reasons is the inconsistency of planning and development policies; mainly influenced and manipulated by the short-term political goals, rise in housing demand due to increasing urbanization and near-constant upheaval in economic conditions, developing countries witness speedy and hasty construction with lower level of planning and management precision, which eventually result in higher R&M operations. Inefficient and unproductive use of construction material, at the beginning, later triggers wasteful R&M actions: environment and economy suffer from constant construction and reconstruction and the money overspent, which could otherwise be used for social causes, harms the
sustainability. This becomes a vicious cycle of overspending and harming the environment. Therefore effort must be exerted to manage the risk posed by R&M operations. Starting from efficient and reliable identification to seamless analysis, and suitable response planning to detailed monitoring and control, attempts must be made to understand how risky these undertakings are and how to deal with apparent threats for successfully converting them in opportunities.

Since R&M projects have high impact in the realm of sustainability, it is opportune and justified to have a modified, specialized, systematic and formal PRM framework to accommodate the specific needs. However, the common practices do not seem to consider the R&M activities as full-fledged projects and advocate their risk management using customized approach. Also the literature seems lacking of such a methodical attitude and the diffusion of risk management techniques and standardized practices compared to other fields and industries. However these projects are vital concern for undertaking organizations and occupants as, if not managed correctly, the risk faced by the projects may not only cause failures [24] but also harm the notion of sustainability and serviceability. Taking on the motivation, it can be deduced that there is a strong case for disseminating the knowledge of project risk management (PRM) (and its effectiveness) in R&M sector and to learn the lessons from construction industry since both share common features.

However, it can be argued that logic for such a specialized framework is not well-grounded (and unsuitable, as a result) owning to the fact that R&M projects are considered small routine activities with fewer complexities. In response to that, the authors reckon that defying the market logic, which warrants for equal (if not more) return on investment, is not the aim of this proposal. On the other hand, curbing the frequency of such projects is more of the focus in the realm of small routine projects. The constant wear and tear, if not attributed to the extraordinary outdoor and occupancy conditions, hints towards lack of understanding of the ecosystem and modern materials among the multitude of other reasons. These details constitute the fundamental understanding of risk in such projects and the aim of this proposal is to be well-suited in the variety of R&M projects ranging from larger and more serious undertakings to the smaller and routine activities.

2. Risk Management Process

The risk management process is a systematic and well-structured way of managing risky situations in a project. In the context of a project, risk management turns into more specific set of guidelines termed as project risk management (PRM). PMI defines PRM as a subset of project management with four integral processes: risk identification, risk analysis, risk response development, and risk monitoring and control [25].

Risk identification is the initiation activity of a standard PRM process which entails identifying risks prior to managing them. Identification points out risks and threats before they become problems, and adversely upset a project [26]. What cannot be identified, cannot be managed; hence the rationale for risk identification. There are a number of techniques, different in nature and functionality, which assist in identifying potential risk. However, this proposal mostly relies on interviewing and brainstorming; later being a combinatorial technique for identifying as well as analyzing risks, whenever required [27].

Successful identification prepares ground for risk analysis. It is important to understand that apparent constraints on the resources may never allow managing all the possible risks in any activity, therefore it is important to prioritize them. Risk analysis is the process of prioritizing the identified risks based on qualitative and quantitative assessment by investigating their probability of occurrence and resulting impact. In order to simplify the task, qualitative and semi-quantitative techniques are
widely used [28]. Qualitative techniques do not operate on numerical data but present results in the form of descriptions. The risk is evaluated in more conceptual terms, such as high, medium or low, regarding collected opinion and risk tolerance boundaries in the organization. The purpose of qualitative risk assessment is to determine the degree of the probability and impact of risk in characteristic form. Examples of qualitative techniques are brainstorming, cause and effect diagram, checklists, Delphi, event tree analysis, etc. [29]. On the other hand, semi-quantitative techniques, which are basically a derivative group, associate a scale factor to nonnumeric ranking. For example, a score of 1 to 5 can be assigned for ranking risk factors affecting the project performance. Likert scale is a well-disseminated example of this kind of analysis. Some other examples are interviewing, probability and impact matrix, risk probability and impact assessment, etc. [30].

As a result of analysis, ranking of risk is attained and based on the tolerance level and criticality indices, a cut-off point is set. Risk items falling under the purview of this exclusion are further managed by developing respective responses for them; it is the process of exploiting options and decisions for increasing the positivity and decreasing the negativity. Finally, the lifecycle process of monitoring and control takes place, which supervises the implementation of risk responses, identifies any new risk and brings them in the risk management process, and evaluates the overall effectiveness of the entire process [31].

3. Proposal of PRM Framework for R&M Projects

3.1 Context of the Framework

The proposed framework offers a practical and convenient methodology to implement the PRM in the R&M projects. Based on the work of De Marco et al. [32], and found on the knowledge of maintenance project drivers and general industry context, the framework recommends convenient and easy-to-use risk analysis techniques, such as qualitative and semi-quantitative. Undoubtedly, there is an apparent trade-off between convenience and precision, however, in order to introduce the notion of risk management in R&M projects, the authors consider it worth opting for. The more sophisticated (and to a certain degree demanding in terms of their input parameters) techniques, such as quantitative or simulation-based, may later be proposed later based on the industry’s response to inculcating the PRM culture and equipping itself for the complexity and requirements of higher expertise required for such techniques.

3.2 Risk Identification Techniques

In order to find risk events, the proposed framework suggests the use of interviewing, brainstorming and documentation review [25]. The rationale behind interviewing is driven by the apparent value offered by personal-contact the form of specified and focused data gathering. In situations where it is not easy to find risk taxonomies and checklists easily, interviewing by human interaction can by helpful in gathering important information.
Multidisciplinary interview sessions are proposed involving experts with prior background in R&M projects. The diverse team of participants may ascertain the identification of risk events pertaining to a broad spectrum, such as construction, materials, commerce, sustainability, etc. Further, to ensure more in-depth and holistic information gathering, semi-structured and non-structured interviews are suggested.

Brainstorming is also proposed as a potential identification and ranking technique. It can have two prong uses: it may help finding out more risk, which may have been overlooked during personal interviews and afterwards rank them narrowing down the identified risks, thus it helps in refining the overall process.

Wherever possible, the risk identification phase may also benefit from reviewing previous documents. Documentation reviews involve reviewing as-built drawings, maintenance plans, detailed specifications, assumptions, historical information from a total project perspective as well as at the individual deliverable- or activity-level. This review may help the stakeholders identify risks associated with the objectives set out in the first place.

3.3 Risk Analysis Techniques

The proposed framework, as deliberated initially, constrains the risk analysis part within the qualitative and semi-quantitative techniques for the sake of convenience. It suggests using risk probability and impact assessment, which is a twofold analysis technique: risk probability assessment explores the probability of occurrence of risk and impact assessment examines the resulting effect on project objectives should the risk occur. This assessment can be performed by individual interviewing (high bias chances) or brainstorming (low bias chances). The participants pertaining to various expert areas of R&M and sustainable development nominate probability and impact of risks and later rank the risks in the order of their significance.

For semi-quantitative analysis, the framework proposes the use of probability and impact matrix. A Likert scale, from 1 to 5, is advised for determining the subjective probabilities and resulting impacts for each identified risk from the experts. The suggested probability and impact scales are: 1-Very Low, 2-Low, 3-Medium, 4-High and 5-Very High. The numerical parameters are then put into the matrix (Probability and Impact Matrix by PMI [25]) to find out the risk ranks in terms of their significance, such as High, Medium and Low.

3.4 Project Management Process

R&M projects involve a multitude of competencies and need a team composed of, but not limited to, architects, engineers, technicians, managers, sustainability experts, environmentalists etc. Managing such diverse teams may prove to be extremely challenging. Therefore, it can be conclusively established that the management of R&M projects stipulates for specialized and customized PM process. Inspired from the works of Owolabi et al. [22] and Croci [33], a detailed lifecycle of R&M projects is proposed, as shown in Fig. 1.

3.4.1 Motivation/Need for R&M

The process starts with establishing the motivation and the need for repair and maintenance. It is definitely the most important element of the entire PM cycle. In the first phase, the physical analysis (synonymous to “damage analysis”) is carried out which involves thorough inspections. The material and structure are examined for damages and decay, and the need to repair is realized as it is always significantly cheaper than replacement. It is essential to fully understand the physical damage (and its degree) before making any R&M decisions. Further a climatic analysis is carried out since it is very essential to consider the atmospheric conditions of the surroundings of the building because determining the
kind of climate the building interacts with, it will be easier to take critical decisions regarding material selection. It is essential to reassert the importance of material selection at this juncture because the usage of improper and unfitting material is at the core of higher frequency of maintenance and reduced service life.

Afterwards, an analysis of variation is carried out where changes in geophysical and political/statutory conditions are examined. The upgraded hazard maps show increasing seismic risk in previously undocumented zones of the world which clearly indicates a variation in geophysical conditions resulting in seismic retrofitting as critical R&M action. Also the changing environmental and atmospheric conditions pose risks of their own kind, thus the maintenance is sometimes only motivated due to exogenous changes.

Corresponding to this phase of PM and with standard PRM process, the framework suggesting carrying out risk identification due to its importance as it will expose most of the threats and opportunities the project will be subjected to. There is a wide array of techniques suggested at this stage: ranging from visual inspection to interviewing the specialists, reviewing old documents and as-built drawings to brainstorming amongst the experts, this initial stage demands for rigorous usage of tools and techniques for effective and holistic risk identification. At the end of this phase, the project stakeholders may obtain a checklist of risks which may also be arranged into a taxonomy for future use. It is pertinent to mention here that the surveyed distance between academic and industrial versions of risk taxonomies is alarming in the field of construction [34]. Therefore an industry-driven initiative to form taxonomy for R&M risk will hold more ground and relevance for future projects of similar nature.

3.4.2 Feasibility

The second phase of process deals with the feasibility study which aims at establishing the viability of maintenance viewed from different perspectives. The present level of structural integrity and its capacity to undergo a ‘therapeutic’ procedure must be determined. Therefore, it is opportune to carry out the structural feasibility of building before making any restoration decisions. This may involve NDT investigation over various structural and non-structural building components. Further, feasibility of maintenance in terms of repair/renovate/replace/refurbish is done with chief importance to the sustainability. In case of developed countries, where there are higher landfill taxes, there may be some incentive to repair and reuse but same can only be justified in developing countries based on replacement cost. Lastly, the financial feasibility, in terms of cost, revenues and taxes, must also be established and transformed into a Cost Management Plan [25]. Since the serviceability of buildings is extended as a result of active R&M, the new depreciation accrued must be taken into account. In case of public buildings, the serviceability is further affected by the use-value.

At the end of the feasibility phase, a conclusive decision may be made in favor of R&M project or vice versa. The PRM proposal for this phase stresses for further risk identification. Apart from interviewing, it is also advisable to perform brainstorming by bringing on-board experts from various disciplines, such as architecture, engineering, building, economics, environmental engineering, and project management. Also financial, structural and historic documents must be reviewed to countercheck, validate and strengthen risk identification. At the end of this phase, the project stakeholders may revise the taxonomy by updating newly identified risks.

3.4.3 Design Phase

Following the successful feasibility phase, a design of maintenance is planned in terms of materials, structure and other PM variables (cost, time, quality). The previously used materials may not be available in some cases due to a number of reasons. Therefore, it is important to first investigate for available ones which
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Fig. 1 PM process for R&M projects.

not only possess similar characteristics, but are also capable of facing modern challenges and are environmentally sustainable. Thus, a design phase is carried out where the suitable R&M materials are either selected from a range of available ones or designed on-demand, followed by structural design necessary for the intervention. It is important to design and guarantee the structural reliability of the building in the face of new material, possible additional fixtures and loads, and modern protecting techniques, such as retrofitting. Also, the standards and regulation pertaining to sustainable development must be considered on priority to ensure not only economic gains but also the environmental and social impacts.

During this phase, the PRM includes identification of risks introduced due to design, followed by their analysis. For qualitative analysis, risk probability and impact assessment must be performed and risks be ranked according to their importance. For semi-quantitative analysis, probability and impact assessment must be performed where, based on the expert judgment and physical data, relative probabilities and resulting impacts are allotted to these risk items. Since all the identified risks can never be managed due to limited resources, only the most significant and threatening risks are responded to. So, the analyzed and ranked risks are further filtered, based on a brainstorming, for selection of most significant ones for which the effective responses are developed.

3.4.4 Development

After the design, the R&M works are executed which involve onsite physical activities employing
engineers, construction and restoration workers. The building is more susceptible and at risk during this phase than at any other time due to exposure to external environment, health and safety concerns to occupants or passersby, etc. Therefore, the project and site managers must be required to look for any new risks evolving due to the on-going site work. Especially during the phases of deconstruction and dismantlement, it is important to hunt for the areas of concern; identify risky situations, analyze them and quickly come up with some practical response. Risk identification by visual analysis and interviewing the site staff is advisable. For risk analysis, semi-quantitative techniques are suggested, which will help in further proposing the corrective measures. Also, the notion of occupational health and safety must be deliberated and appropriate measures must be taken to ensure secure and protected site by providing necessary PPE (personal protective equipment) to site staff.

3.4.5 Closeout

After the successful development of the project, it is closed out. Starting with a detailed intervention report, it is advised to document the entire PRM process in this phase, mentioning the risks identified, threats faced and opportunities exploited along with their probability of occurrence and impact of consequence. Also, the corresponding preventive and mitigating measures must be documented. Together with that, other important project documents are suggested to be prepared. Moreover, the layout and as-restored drawings should be prepared to be made part of the record, which may be referred to and reviewed at a later stage or for the next maintenance.

4. Conclusion

Repair and maintenance works are creating nuisance for sustainability and, apart from a myriad of internal and external drivers, “waste regulation” is dictating R&M decisions, which are not aptly streamlined with the established PRM framework. The story is even more aggravated in case of developing countries where environmental concerns are further burdened by weak economies, and indifferent and dispassionate societies. The local culture does not seem to value the environment enough to advocate and effort for proactive (or even the reactive) measures. An overly laid-back attitude is displayed towards environmental concerns and sustainability seems to be taken for granted possibly due to lack of awareness and understanding of importance attributed to these naturally (and freely) available resources. This, however, poses greater need to streamline sustainability concern into active project management and project risk management practices by advocating for, promoting and offering customized frameworks and tools. This paper proposes a theoretical framework customized to manage the R&M projects and deal with their risks in a sustainable manner. The framework is further tweaked keeping in account the conditions and challenges of developing countries where priorities can be drastically diverse and focus can be short sighted, where the expertise is mostly reserved for more complex and financially-stringent activities and where the ascertaining precision seems quite challenging.

For improving the efficiency of R&M projects and ensuring the sustainable development, the proposed framework seems promising for achieving the objectives in a systematic manner. Further, the proposed techniques will ensure required level of details for risk identification, analysis and response development.

Based on the novelty of PM and PRM areas of knowledge for the R&M context, the framework has been restricted to convenient tools and techniques due to inadequate maturity of the industry. In order to improve the efficiency of the current framework, more sophisticated tools and techniques are planned to be included at later stages strongly based on acceptance and positive feedback from practitioners.
References

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