Jurnal Teknologi

Full Paper

IMPLEMENTING MAINTAINABILITY IN BUILDING MATERIAL SELECTION: A PRELIMINARY SURVEY

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Article history
Received
5 August 2015
Received in revised form
21 November 2015
Accepted
28 November 2015

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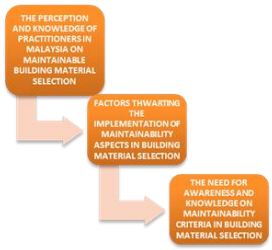
Graphical abstract



Abstract

The importance of maintainable designs has long been recognised. However, considering maintenance right from the beginning of choosing building material is rare. Building material selection without considering maintainability had posed greater maintenance problem in the post occupancy stage of building which have been emphasised by several researchers and practitioners in the construction industry. Conversely, the criticality of this issue to the implementation of maintainability in building material selection has yet to be empirically explored in the Malaysian perspective. As an effort to shed light into this issue, a questionnaire survey was carried out to architects, building maintenance engineers and structural engineers in Malaysia. Thus, this article discusses the benefits of implementing maintainability in material selection, the factors that thwart the implementation of maintainability in material selection, and the level of awareness and knowledge of practitioners in the construction industry on maintainability in material selection. Frequency calculations were carried out. The findings of this study is hoped to shed light to architects, building maintenance engineers and structural engineers on the critical aspects that demand examination and consideration of selection of maintainable building material in Malaysia.

Keywords: Maintainability, material selection, building, construction

1.0 INTRODUCTION

The construction industry has been facing a growth in the usage and development of new building material over the last three decades. Consideration on material selection during the design stage of a building ensures minimisation of maintenance requirements in the future. Unfortunately, architects and designers often overlook this as the most important factor, which has the potential to carry out future maintenance tasks. Subsequently, this has led to a rise in the maintenance workloads throughout the post construction phase; increasing the problems in maintenance. The main causes for such circumstances are inadequate design and planning with respect to maintainability at the initial design phase [1]. This circumstance has raised the necessity of involving the maintenance engineers in the early

stage of the material selection process. Silva *et al.* [14] mentioned that the participation of experience maintenance engineers during the material selection process is essential to enhance building maintainability. Proper leadership and the skills/competencies of the maintenance staff are useful to take efficient decisions. Many large organisations have qualified maintenance engineers to take the leadership to run the maintenance and further some of them have been involved in the development phase of the building to increase maintainability right from the beginning to avoid wastage in maintenance [32]. With the urge for achieving building maintainability; the needs of maintainability aspect in material selection have become one of the major concerns. According to Chew *et al*. [2], the material component in design plays an important role in maintainability since selecting right material for the building elements can lengthen the life span of the particular building elements and this will require less repair and replacement work.

Past researches have revealed that developed countries such as Singapore and United States, had already practiced maintainability principles in the design stage. For example, Singapore has taken initiatives to enhance the maintainability of building in their country. In 1999, Singapore's Ministry of National Development has established The Construction 21 Steering Committee (CTC) to emphasis and monitor the improvement of maintenance in order to aid greater productivity and innovations. Although Malaysia is listed as developing country, it is growing rapidly in every sector, especially in building construction. Considering the benefits that can be achieved by practising maintainability in material selection process, it is of great regret to see Malaysia still struggling to foster the knowledge on how to implement maintainability aspects in material selection. Therefore, this article discusses the benefits of implementing maintainability in material selection, the factors that thwart the implementation of maintainability in material selection, and the level of awareness and knowledge of practitioners in the construction industry of Malaysia on maintainability in material selection.

2.0 MAINTAINABILITY

In 1954, the notion of "maintainability" was introduced by the military services of the United States whom defined maintainability as *'a characteristic of equipment design and installation which is expressed in terms of ease and economy of maintenance, availability of the equipment, safety, and accuracy in the performance of maintenance actions'* [3]. After 21 years, the concept of maintainability was incorporated into building designs to facilitate future maintenance. This movement was brought about by [4] who defined maintainability as *'the condition for an item or a surface that permits its repair, adjustment, or cleaning with reasonable effort and cost'*.

Feldsman intended to make changes in the design of buildings from the perspective of ease of maintenance to balance the rising maintenance expenditures and the difficulty of finding and training maintenance personnel to deal with super-technological equipment in future [4]. Since then, research on maintainability of building was very limited. Right before the millennium, another wave of research on maintainability of building was triggered in Singapore who has identified improving maintainability as one of the key initiatives to be aimed at in improving the Singaporean Construction Industry. The benefits associated with building maintainability in saving maintenance costs and achieving better function of facilities have been realised by researchers [1,5-16]. Consequently, another definition of maintainability of buildings was proposed as *'achieving the optimum performance throughout the building life span within a minimum life cycle cost'* [1,6].

Apart from that, BIS [18] defines maintainability as *'the ability of an item, under conditions of use, to be retained in or restored to a state in which it can perform its required functions, when maintenance is performed under stated conditions and using prescribed procedures and resources'*. Moreover, Colen and Brito [15] defined maintainability as the *'ability of a functional unit, under given conditions of use, to be kept in, or restored to a state in which it can perform a required function when maintenance is performed under given conditions and using stated procedures and resources'*.

When these definitions are considered collectively, it can be interpreted that maintainability stresses on enhancing the maintenance practice through designing, planning and managing building with a minimum life cycle cost while achieving the functional performance requirement. Therefore, the maintainability principle should be implemented in the early stage of a building project which is in material selection process.

The main concern of this article is on maintainability of building materials. Therefore, the definition of the maintainable materials was first brought by Sjo¨stro¨m [17] who defines maintainable materials as *'materials that are able to meet aesthetic and functional performance requirements at minimal intervals for cleaning and inspections for defects'*.

3.0 BUILDING MATERIAL AND MAINTAINABILITY

Building material is any material which is used for construction purposes. Building materials typically account for between 30-60% of construction project

costs. The types of materials selected at the design stage of building will impact fundamentally on its longer-term maintainability [2,7-8,10]. Building material play an essential role in increasing the maintainability of buildings and contributing to economic prosperity. The usage of building material has a substantial impact on the building maintenance. Moreover, all building material affects the maintainability of building during their life cycles if the material is not selected according to the doctrine of maintainability. The use of defective, poor quality material and/or design details are common incident in numerous projects, creating major defects during the service and consequently have led to short service lives of many buildings. Construction practitioners have begun to pay attention to controlling the maintainability aspect from their activities. The selection of material has attracted scrutiny. In the past, sustainability, cost, availability and appearance were the main criteria influencing the choice of building materials [22]. Thus, the source for building material selection criteria put more emphasis on environmental and intangible factors, ignoring maintainability factors. However, nowadays maintainability is another important criterion that is being acknowledged by construction practitioners that need to be included in material selection [2,7-10].

4.0 THE ISSUES

An important issue to be considered in achieving design maintainability churning the design stage of a building project is selecting suitable building material. The utilisation of defective, poor quality material and/or design details are common incidents in numerous building projects, creating major defects during the post construction service. Consequently, this has led to short service lives of many buildings. Three main factors that can be connected to design defects in the perspective of Malaysian environment, i.e. the choice of material, shape of the building and its elements, and construction procedures to suit the design [19]. The enormous amount of the country's maintenance resources is being spent on remedial or corrective works to buildings due to design defects. Therefore, decreasing the amount of design faults will result in the declining of maintenance cost [20].There are a number of researches that had been carried out to show that buildings are experiencing enormous maintenance workloads due to faulty material selection:

i) Maintenance costs analysis in buildings which is less than 25 years old unveiled fair deterioration at fifty-six percent, design specification errors at twenty percent, and repairs caused by defective material at thirteen percent; the remaining twelve percent was specific to additional causes [21]. This shows that repair caused by defective materials are the second largest cost of maintenance.

ii) Failure to follow well-established design criteria in choosing material; use of new material or advanced systems of construction which have not been appropriately tested for usage; ignorance of the basic properties of material; poor communication between different colleagues of the design and construction teams; and misjudgments of climatic conditions under which the material has to perform had let to short service life of many buildings [1,21-22].

iii) Lack of knowledge and integration between the design and maintenance teams in addressing the issues related to maintainability of building and it causes huge maintenance defects [1].

5.0 THE NEEDS FOR IMPLEMENTING MAINTAINABILITY CRITERIA IN BUILDING MATERIAL SELECTION

The use of maintainable building materials will simultaneously enhance building maintainability. Therefore, the importance of maintainability of building can be seen in five parts, which are investment value; aesthetic; function; heritage; and reduction of maintenance cost [25].

5.1 Investment Value

A real estate investment is one that targets to own a building in the form of short or long-term profits [25]. A short-term profit is the gain acquired over the transaction of buildings. The long-term profit is related with gaining the rental rates or holding interest. Yahya and Ibrahim [30] mentioned that the value of buildings depends on the achievement of the maintenance invested in them. Therefore, the better the building maintainability, the higher the investment value of that building.

5.2 Aesthetic

Good maintenance will preserve the appearance of buildings. Besides that, buildings are maintained in order to lessen damage to them [25]. Some of the factors that fade and deteriorate the aesthetic of a building are: extreme dirt; influence of the atmosphere, comprising climate, weather and air pollution; attack of fungi; pests; decay of the building due to dampness; and natural disasters and unforeseen accidents [28]. Therefore, the better the building maintainability, the better the appearance of the building.

5.3 Function

Maintainability of building materials is very essential to sustain the building functions in order to prolong the life span of a building. According to Kanniyapan *et al.* [31], the use of materials for achieving building maintainability depends on selecting materials which have the potential to resist defects from common deterioration so that they would continue to achieve their potential function throughout their lifespan. Eizzatul *et al.* [28] also mentioned that maintainability is vital to ensure the building functions well because it will maintain and meet the requirement of the building owner; maintain the original design and construction goals; maintain and meet the requirements of the Local Authority; ensure all building facilities are fully functional and can be used all the time. Therefore, the better the building maintainability, the better the function of the building.

5.4 Heritage

Heritage influenced by the value of the property, but the value of the property relate on how well the property maintained [28]. If a property well maintained it becomes tourist hotspot [28]. They can also provide an income to the country as a whole. Therefore, the better the building maintainability, the better the heritage value of the building.

5.5 Reduction of Maintenance Cost

Using a maintainable building material will increase the building's function. Simultaneously, it will reduce the maintenance cost in the future from repair and replacement work. The main criterion to achieve building maintainability is through maximising performance of building through minimising maintenance cost [33]. Therefore, the better the building maintainability, the lower the maintenance cost for the building.

6.0 CONSIDERATION OF MAINTAINABILITY ASPECT IN BUILDING MATERIAL SELECTION: MALAYSIA CONTEXT

The former Prime Minister YAB (Tun) Abdullah Ahmad Badawi launched the Government Asset Management Manual (DPAK) and the Government Total Asset Management Manual (MPAM), introducing asset and facilities management into Malaysia on 31st March 2009. Facilities management attempt to organise and control the design process, construction, engineering and operation. The aim of facilities management is to organise and ensure safety and security, operational aspects for a good environment and maintenance of facilities at an acceptable cost over the long term for the facilities value. However, the role of facilities management is fully required in the design stage of a building in order to preserve the building in a good, secure and safe state. This is because most building failures are triggered by lack of integration of facilities management with design.

Maintainability issues are very much in its infancy in Malaysia. In practice, maintainability in material selection has yet to gain much attention in Malaysia. There are very few effort has been heard about implementing maintainability principles in building material selection in the Malaysian construction industry. Maintainability has still failed to become a part of the standard practice in building design. Forty-seven percent of architectural defects are caused by design defects, seventeen percent by material, fifteen percent by construction, eighteen percent by misuses of facilities, fifteen percent by poor maintenance, and five percent by vandalism [24]. Majority of the deficiencies identified are architectural works, followed by electrical works, and civil and structural defects [26]. These conclusions suggest that defects could have been prevented if the architectural building elements were considered. Furthermore, Chohan *et al.* [27] point out the needs for architects to prevent these defects by using more appropriate material and better design and layout.

Based on research studies by Eizzatul *et al.* [28], it is acknowledged that most of the design failure especially faulty material had increased the maintenance costs in post occupancy stage. Based on the findings, the Majlis Perbandaran Johor Bahru Tengah administration building's external walls were made from glass and required to be maintained every 6 months in order to ensure it always seen attractive and clean. Hence, the maintenance costs have reached around RM25,000 every six months. Additionally, in Taman Impian Emas public market, which has an aesthetic roof design will incur renovation cost about RM300,000 if the public market floods. A number of tall residential buildings such as Angkasa Vista, Kuala Lumpur and Champaka Apartments in Kuala Lumpur also experienced problem with their exterior cladding, lift shafts and other elements. It obviously shows that inappropriate material selection and lack of understanding concerning to material properties will affect the building maintenance in post occupancy stage.

Therefore, it can be concluded that the influence of maintainability on material installed as well as the life cycle of each component of building should be considered before selecting material for building construction. Thus, it is critical to incorporate the maintainability criteria into building material selection process.

7.0 THE PERCEPTION AND KNOWLEDGE OF PRACTITIONERS IN MALAYSIA ON MAINTAINABLE BUILDING MATERIAL SELECTION

Although maintainability has been recognised as one of the major concerns in any building project, little has been done to integrate maintainability criteria in building material selection process that could lead to continuous improvement. The selection of building materials is regarded as a multi-criteria decision problem [34], largely based on trusting experience rather than using numerical approach, due to lack of formal and availability of measurement criteria [35]. Therefore the list of building material selection criteria, especially maintainability criteria is lacking. A preliminary survey was conducted as an initial part of a PhD research entitled 'Building Material Selection Criteria for Optimising Building Maintainability'. The survey involved three groups of respondents; architects, maintenance engineers and structural engineers. The objective of the study was to determine their perception and knowledge on maintainability criteria in building material selection. Considering various benefits rendered from carrying out maintainability principles in material selection as discussed previously, it is important to understand how the practitioners in the Malaysian construction industry perceive maintainability aspects in material selection and the extent to which they are familiar with the approach. The preliminary survey was undertaken to verify whether the issues pertaining to the practitioners' disregard on maintainability criteria in material selection (as discussed previously) is true in the Malaysian context. The aim of the survey was:

i) To explore the perception of practitioners on implementing maintainability criteria in building material selection process.
ii) To learn whether the practitioners possess the knowledge on implementing maintainability criteria in building material selection process.
iii) To understand the current practice on building material selection for building projects in Malaysia.

Three groups of respondents were selected for the preliminary study that comprised of 50 architects, 50 maintenance engineers and 50 structural engineers. These three groups were taken as respondents for the study because architects involved in selecting building materials, maintenance engineers involved in maintaining building materials and structural engineers involved in constructing the building materials. Since this article considering maintainability criteria during material selection, which is more on specification criteria of a material, the involvement of these three groups seems to be appropriate. Hence, these three groups were mentioned as practitioners in this article. A short questionnaire comprising questions related to their experience and familiarity with maintainability in material selection process was prepared. The questionnaires were mailed to the respondents. After strenuous follow ups, 20 architects, 20 maintenance engineers and 20 structural engineers responded. Although received few responses compared to the actual population, statistically, the number of responses was satisfactory to reach a reliable result as reliability is recognised by collecting data from 20 to 30 research samples [29]. The data was then evaluated using frequency analysis. The summary of the findings are shown in the Section 7.1, 7.2 and 7.3.

7.1 The Perception of Practitioners on Implementing Maintainability Criteria in Building Material Selection Process

The Figure 1, 2 and 3 demonstrate the perception of the practitioners in Malaysian construction industry on implementing maintainability criteria in building material selection. The questions dealing with the perception of the practitioners could be divided into 3 categories:
i) The importance of incorporating maintainability criteria in building material selection.
ii) The benefit of incorporating maintainability criteria in building material selection for better building maintainability.
iii) List of maintainability criteria for selecting building materials can be easily found in Malaysia.

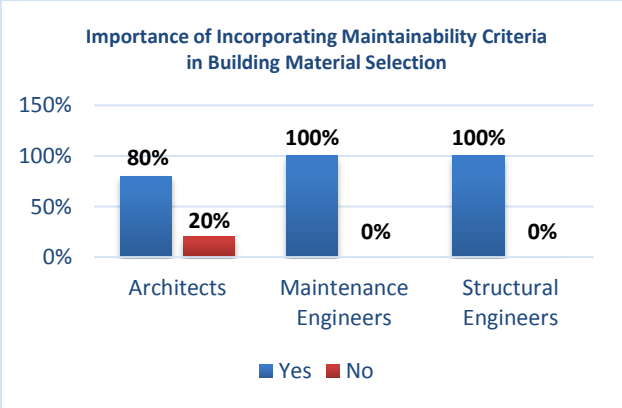


Figure 1 Importance of incorporating maintainability criteria in building material selection

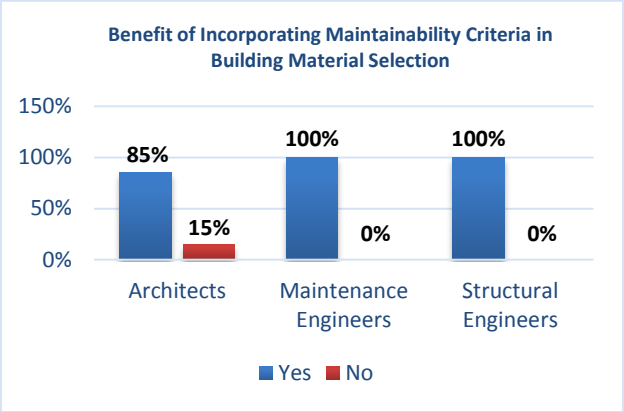


Figure 2 Benefit of incorporating maintainability criteria in building material selection

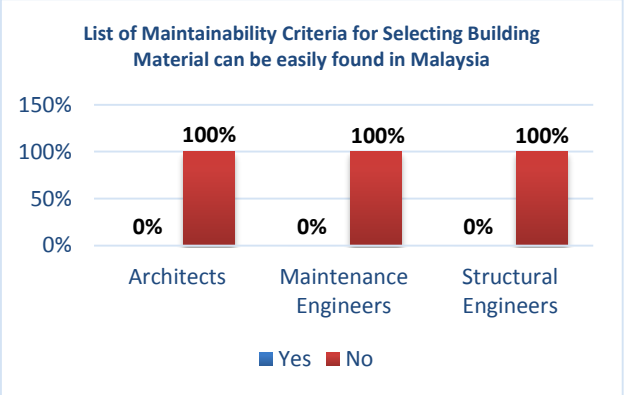


Figure 3 List of maintainability criteria for selecting building material can be easily found in malaysia

In general, the figures indicate that:

i) Ninety-three percent of the practitioners in Malaysia say that incorporating maintainability criteria in building material selection are important.
ii) Ninety-five percent of the practitioners in Malaysia say that incorporating maintainability criteria in building material selection is beneficial for the improvement of building maintainability.
iii) All the practitioners in Malaysia say that the list of maintainability criteria for selecting building materials is not available in Malaysia.

7.2 The Knowledge of Practitioners on Implementing Maintainability Criteria in Building Material Selection Process

The Figure 4 and 5 below demonstrate the knowledge of the practitioners in Malaysian construction industry on implementing maintainability criteria in building material selection. The questions dealing with the knowledge of practitioners could be divided into 2 categories:

i) Knowledge on maintainability aspect of building material.
ii) Knowledge on what is the maintainability criteria that needed for building material selection.

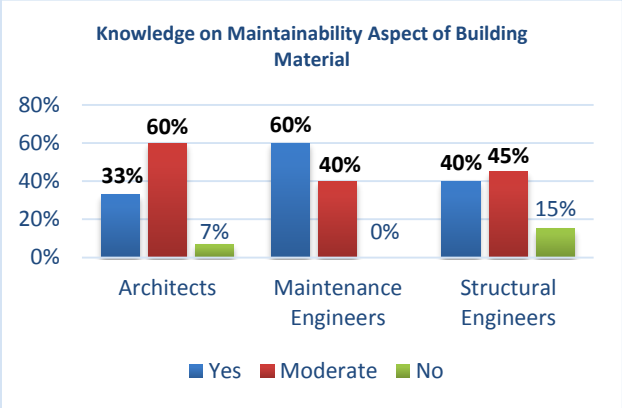


Figure 4 Knowledge on maintainability aspect of building material

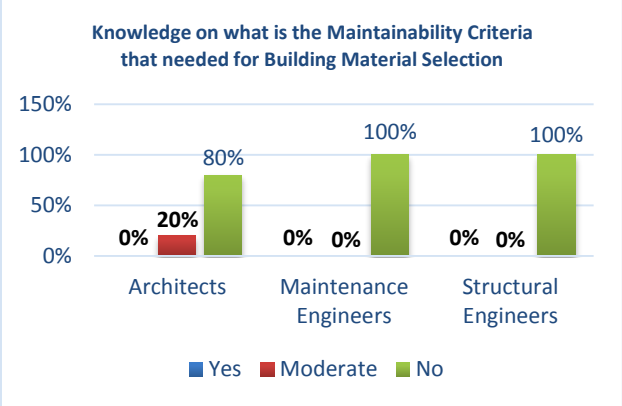


Figure 5 Knowledge on what is the maintainability criteria that needed for building material selection

In general, the figures indicate that:

i) Forty-eight percent of the practitioners in Malaysia have moderate knowledge on maintainability aspect of building material.
ii) Ninety-three percent of the practitioners in Malaysia have less knowledge on what are the maintainability criteria that needed for building material selection.

7.3 The Current Practise on Building Material Selection for Building Projects in Malaysia

The Figure 6 and 7 below demonstrate the current practise on building material selection for building projects in Malaysia. The questions dealing with the building material selection process on current project could be divided into 2 categories:

i) Do you consider maintainability criteria during selecting building material for your project?
ii) Do you or your members in your company get input from the maintenance unit when selecting building material?

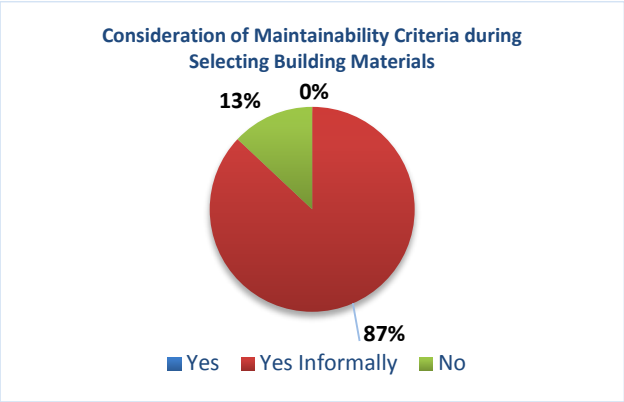


Figure 6 Consideration of maintainability criteria during selecting building materials

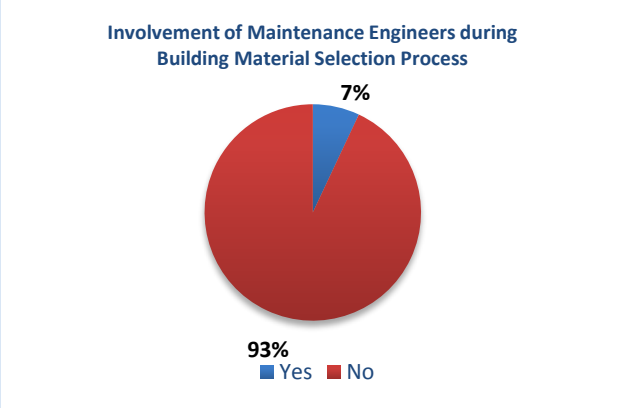


Figure 7 Involvement of maintenance engineers during building material selection process

In general, the figures indicate that:

i) Eighty-seven percent of architects in Malaysia consider maintainability criteria informally during selecting building material in their project.
ii) Ninety-three percent of architects in Malaysia does not get input from the maintenance unit when selecting building material.

7.4 Discussion

It is strongly suggested by the survey that most of the practitioners in the Malaysian construction industry perceive maintainability assessment in building material selection as significant. In terms of the knowledge on maintainability aspect in building material, it is clearly demonstrated by the survey that sixty percent of the maintenance engineers have knowledge on maintainability aspect of building material. Meanwhile, only thirty-three percent of architects and forty percent of structural engineers have knowledge on the maintainability aspect of building material. However, architects, maintenance engineers and structural engineers have less knowledge on what are the maintainability criteria that needed for building material selection. As maintainability is still at its infancy in Malaysia, the extremely low level of knowledge of the practitioners on what are the maintainability criteria needed in building material selection is understandable. In terms of current practice, around eighty-seven percent of architects in Malaysia consider maintainability criteria in building material selection informally which means that they do not have standardised list on maintainability criteria that needed for building material selection. Moreover, ninety-three percent of architects do not consult with maintenance unit during the building material selection process. The preliminary survey results not only support the literature review, they also show that practitioners are not familiar with maintainability criteria in building material selection.

8.0 FACTORS THWARTING THE IMPLEMENTATION OF MAINTAINABILITY ASPECTS IN BUILDING MATERIAL SELECTION

The lack of awareness and knowledge on maintainability as part of the effort to select building material are the main reasons for building deteriorates very fast in the post occupancy stage. However, there are no clear factors in past studies that thwart the implementation of maintainability criteria in building material selection process. Therefore, this article has taken some of the factors from Akadiri [36] and used it for this article. The factors thwarting the implementation of maintainability aspects in building material selection are:-

i) Lack of information on maintainability criteria for building material selection [31].
ii) Uncertainty in the liability for the final works [36].
iii) Environment concern [37].
iv) Building code restriction [36].
v) Lack of tools and data to compare material alternatives [36].
vi) Perception of extra cost and time being incurred [36].
vii) Aesthetically less pleasing [36].
viii) Limited availability & reliability of suppliers [36].
ix) Low flexibility [36].
x) Unwillingness to change the conventional way of specifying [36].

The validity of these factors was tested in a recent survey involving 20 architects, 20 maintenance engineers and 20 structural engineers in Klang Valley,

Malaysia. The result of the survey is as shown in Table 1.

Table 1 The factors thwarting the implementation of maintainability aspects in building material selection

Factors	Mean
Lack of information on maintainability criteria for building material selection	4.00
Perception of extra cost being incurred	4.00
Perception of extra time being incurred	3.93
Lack of tools and data to compare material alternatives	3.67
Low flexibility	3.60
Environment concern	3.60
Uncertainty in the liability for the final works	3.53
Limited availability & reliability of suppliers	3.53
Problem in assessing information	3.40
Unwillingness to change the conventional way of specifying	3.33
Building code restriction	3.33
Aesthetically less pleasing	3.27

The result shows that 'Lack of Information on Maintainability Criteria for Building Material Selection' and 'Perception of Extra Cost' is the most critical factor that thwarts the implementation of maintainability aspects in building material selection in Malaysia. Factors that include 'Unwillingness to change', 'Building Code Restriction' and 'Aesthetically less pleasing' scored less than other factors and this factors have less significant impact on the implementation of maintainable building material selection in Malaysia.

9.0 THE NEED FOR AWARENESS AND KNOWLEDGE ON MAINTAINABILITY CRITERIA IN BUILDING MATERIAL SELECTION

Practitioners in the construction industry alike need to get closer to the maintainability inputs during material selection. It has been highlighted by practitioners that implementing maintainability in building material selection raises issues pertaining to lack of information, extra cost and time and above all, not stated as a requirement in any contract or policy. However, the complete cycle of the benefit should be clearly put into perspective. Though gaining profit is undoubtedly the main goal, learning from the experience of maintaining previous buildings will promote continuous improvement of the buildings that we build. This in return will lead to the elevation of satisfaction, improvement of work efficiency, increased building performance, and of course luring more projects for the builders.

Practitioners also state that in spite of understanding the concept of maintainability, they are unfamiliar with the methodology. Most maintainability studies are carried out as academic research and have been widely deliberated in journals and conferences. However, in the practical world of building design, most organisations have not established a list of maintainability criteria for building material selection decision making. Thus, it is imperative for a study to be undertaken to develop a theoretical framework of maintainability criteria that need to be included in building material selection, what methodology to be used, and how to process the maintainability data into workable information, acting as a guideline for the practitioners in the Malaysian construction industry upon adopting maintainability criteria as a tool for building material selection. Learning from the extensive literature about maintainability, benchmarking maintainability practices in other countries, and deriving the most suitable maintainable material selection framework in our own context will be of utmost assistance to shed light to the practitioners on how to implement maintainability aspects in building material selection for continuous performance improvement of the buildings that they deliver.

The findings for this study are illustrated in Figure 8.

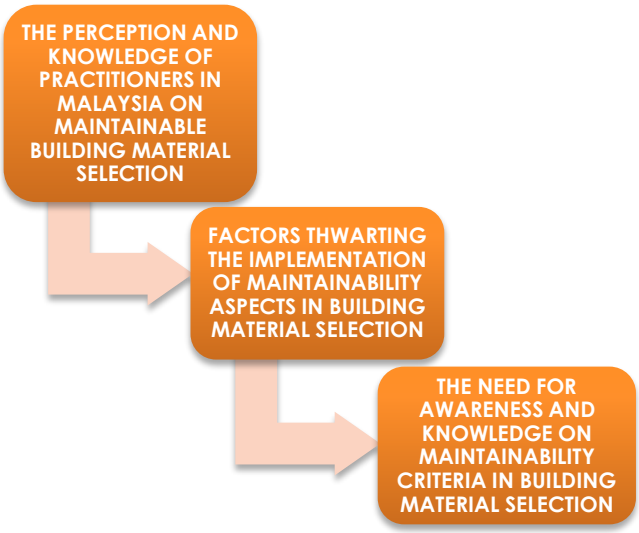


Figure 8 The findings of this study

10.0 CONCLUSION

This paper has discussed the need for awareness and knowledge among practitioners in the construction industry on maintainability in material selection. The results from the pilot survey discussed earlier clearly indicate that the construction industry needs a paradigm shift to become more aware and interested to learn from maintaining previous building which leads to high maintenance cost. The literature findings have been articulated about the need to foster maintainability aspects as an essential part of the building material selection process. Adopting maintainability principles enables practitioners in the construction industry to establish a functional building with less maintenance in the post occupancy stage. Various researchers and practitioners have acknowledged the significant building performance improvements that can be achieved by fostering maintainability principles in building material evaluation as a standard practice in the construction industry. However, maintainability is a mere tool to provide essential information for improved building performance. Without the awareness and knowledge of maintainability, continuous improvement of building maintenance will only be an idea to be achieved. There is a knowledge gap on what are the maintainability criteria for building material selection and further studies on developing a theoretical framework for maintainability criteria of building material selection, what mechanism to be used, how it is to be implemented, who should be involved, etc., are inevitably needed.

Acknowledgement

The authors would like to express their sincere appreciation to University Technology Malaysia.

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