INTEGRATION OF BUILDING MAINTENANCE COST MODEL INTO THE DESIGN STAGE

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I dedicate this dissertation to my beloved family;

To my precious parents for their continuous encouragement and unconditional support to me, may Allah provide them strength and health;

To my lovely wife for her advice and her patience

To my beloved sister;

It can never express my appreciation to my entire family and friends for their support, sacrifices, and prayers during this long journey.

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ABSTRACT

Maintenance of buildings and other assets are important in order to lengthen the lifespan of the buildings and to retain their good condition. Modern building has witnessed tremendous and progressive transformation in the use of complex design, innovative building materials and modern construction technologies. Thus, the resultant cumulative negative impact increases maintenance cost at post-occupancy phase is a recurrent problem within the construction sectors. In addition, lack of facilities management (FM) concepts and their limited integration in the design are among the problems. This research investigated the impact of design on maintenance cost performance of building projects by addressing the identified problems that include the assessments of design defects during post-occupancy phase, and parameters impact on maintenance and development of a maintenance cost model for building projects. A quantitative research approach that uses questionnaire survey was adopted for data collection. 71 questionnaires were distributed to FM organizations in Kuala Lumpur, Selangor and Johor Bahru of Malaysia. The retrieved administered questionnaires revealed a 43.67% (31) response rate. Collected data were analyzed using Statistical Package of Social Sciences (SPSS) to calculate the frequency, mean, standard deviation (SD), relative importance index (RII) and rank analysis. The empirical findings revealed that design errors, lack of maintenance plan and lack of understanding of FM significantly affected the maintenance cost. Thus, the most important design factors are inadequate working drawing details, incomplete working drawing and specification, inappropriate selection and specification of materials and non-availability of specific building materials in the market. Besides, "architectural design defects" and "structural components" are prevalent factors for increasing maintenance cost. In addition, eight design parameters rated as very important for cost model development are cost effectiveness, value of asset, environment, practiced culture, design adaptability, health and safety, client and end-user desires and responsibility. The research concludes by developing a maintenance cost model that integrates the statistically assessed thirty-seven design factors and ten design parameters. The defects in the design factors were categorized as architectural, structural and mechanical-electrical-plumbing (MEP). Finally, the study revealed that the integration of design factors and design parameters into a design stage is capable of reducing 15-20 percent maintenance cost in building projects. Therefore, this research is of practical significance to designers and facilities managers, as it will prompt the management of building facilities to focus on the most important factors affecting the maintenance cost, thereby reducing the total cost.

ABSTRAK

Penyelenggaraan bangunan dan aset lain adalah penting untuk memanjangkan jangka hayat bangunan dan mengekalkan bangunan dalam keadaan yang baik. Reka bentuk bangunan moden telah menyaksikan pembangunan yang hebat dan transformasi yang progresif dalam penggunaan bahan binaan yang inovatif dan teknologi pembinaan moden. Oleh itu, impak negatif terkumpul yang dihasilkan meningkatkan kos penyelenggaraan merupakan masalah yang berulang dalam industri pembinaan. Di samping itu, kekurangan konsep pengurusan fasiliti dan integrasi teknik pengurusan fasiliti (FM) yang terhad adalah antara masalah yang dihadapi. Kajian ini mengkaji impak reka bentuk terhadap prestasi kos penyelenggaraan projek bangunan dengan menangani masalah yang dikenal pasti termasuk penilaian kecacatan reka bentuk semasa pasca penghunian, penilaian impak parameter terhadap penyelenggaraan dan pembangunan model kos penyelenggaraan untuk projek pembinaan. Pendekatan kuantitatif yang menggunakan kajian soal selidik digunakan bagi tujuan pengumpulan data. 71 soal selidik telah diedarkan kepada organisasi FM di Kuala Lumpur, Selangor dan Johor Bahru, Malaysia. Soal selidik yang dijalankan menunjukkan 43.67% (31) kadar tindak balas. Data yang dikumpul telah dianalisis menggunakan perisian Pakej Statistik Sains Sosial (SPSS) untuk mengira kekerapan, min, sisihan piawaian (SD), indeks kepentingan relatif (RII) dan analisis kedudukan. Dapatan empirikal menunjukkan bahawa kecacatan reka bentuk, kekurangan pelan penyelenggaraan dan kekurangan pemahaman terhadap FM memberi kesan terhadap kos penyelenggaraan. Oleh itu, faktor reka bentuk yang paling penting adalah butiran lukisan yang tidak mencukupi, lukisan dan spesifikasi kerja yang tidak lengkap, pemilihan dan spesifikasi bahan yang tidak sesuai dan tidak ada bahan binaan khusus di pasaran. Selain itu, kesilapan reka bentuk seni bina dan struktur komponen adalah faktor yang lazim untuk meningkatkan kos penyelengaraan. Di samping itu, lapan parameter reka bentuk yang sangat penting untuk pembangunan model kos adalah keberkesanan kos, nilai aset, alam sekitar, budaya, kebolehsuaian reka bentuk, kesihatan dan keselamatan, keinginan pelanggan dan pengguna akhir dan tanggungjawab. Kajian ini menyimpulkan dengan membangunkan model kos penyelengaraan yang mengintegrasikan 37 faktor reka bentuk dan sepuluh parameter reka bentuk secara statistik. Kesilapan dalam faktor reka bentuk dikategorikan sebagai kecacatan reka bentuk seni bina, kecacatan reka bentuk struktur dan kecacatan reka bentuk makanikal-elektrikal-paip (MEP). Akhir sekali, kajian ini menjelaskan bahawa integrasi faktor reka bentuk dan parameter reka bentuk dalam fasa reka bentuk mampu mengurangkan 15-20 peratus kos penyelenggaraan dalam projek pembinaan. Oleh itu, kajian ini penting kepada pereka bentuk dan pengurus fasiliti kerana ia akan mendorong pengurusan fasiliti bangunan untuk memberi tumpuan kepada faktor-faktor yang lebih penting yang mempengaruhi kos penyelenggaraan dan seterusnya dapat mengurangkan jumlah kos.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIA	-	American Institute of Architects
BIFM	-	British Institute of Facilities Management
CIB	-	Chartered Institute of Building
CIDB	-	Construction Industry and Development Board
FM	-	Facilities Management
HVAC	-	Heating, Ventilation and Air Conditioning Institute
IEM	-	Institute of Engineers Malaysia
IFMA	-	International Facility Management Association
KPI	-	Key Performance Indicators
MAFM	-	Malaysian Association of Facilities Management
MEP	-	Mechanical, Electrical, and Plumbing
MYR	-	Malaysian Ringgit
RIBA	-	Royal Institute of British Architects
RICS	-	Royal Institution of Chartered Surveyors

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Presently, Malaysia is being considered in the intermediary phase of development and industrialization whereby many construction mega-projects development is in progress (Mydin *et al.,* 2014). For the economic development of a country, the construction industry has a wide-ranging connection with the rest of the economy, for example, the manufacturing industry and financial services industry. This industry is responsible for building the nation's physical infrastructure, providing transportation services, housing facilities, business and various educational and commercial institutions. Over the past decade, the Malaysian construction industry has contributed significantly to the economy as an enabler of growth to other industries, more specifically construction industry contributes to national economy 3-5% (Alaloul *et al.*, 2016).

The global Architecture, Engineering, and Construction (AEC) markets are forecasted to grow at a rate of 5.50% from 2016 to 2021. United Kingdom (UK) construction industry is predicted to be worth US$208 billion by 2020 and growth is expected to stay at around 3% (Dixit and Venkatraj, 2017). Within the same period Qatar, Mexico and Indian construction industries are anticipated worth US$59 billion, US$144.90 billion and US$563.40 billion respectively. The Construction Industry Development Board (CIDB) of Malaysia reported that in 2015 this industry spent US$28.72 billion, US$32 billion in 2016 and evaluated that it would be US$70 billion in 2018 (CIDB, 2018). Furthermore, CIDB stated construction industry is continuing

double-digit growth, nearly 12.7% since 2011. Building construction is considered to be an essential element of the construction industry in Malaysia and it shapes around 64.6% of the overall construction work (Alaloul *et al.,* 2016). Allocation for new housing projects is US$550 million in 2018. There are many projects that have been constructed such as commercial buildings, residential buildings, public buildings and industrial buildings. The project of public buildings includes educational buildings, hospital buildings and government buildings (Mydin *et al.*, 2014).

With the increase in the supply of buildings, the amount invested in building maintenance is also increasing. For instance, there was an increase of 29 percent in the number of maintenance contracts awarded from 2013 to 2015 (CIDB, 2018). In 2013, 1337 maintenance contracts were awarded, while the number increased to 1725 in 2015. In terms of value, investment in maintenance was about US$3.40 billion in 2015, which represents about 10 percent of the total construction cost. In 2016, it had increased to US$3.745 billion. This highlights a 10.15 percent increase in allocation to the sector as compared to 2015. Therefore, building maintenance is becoming a major activity because enormous resources are being committed as the government is recognising the need for building maintenance. This will probably be the most concern in the years ahead, as buildings require maintenance to be able to perform efficiently. British Standard 3811:1984 defined maintenance as the combination of all technical and associated administrative actions intended to retain an item in or restore it to a state in which it can perform its required function. Buildings are assets, if proper maintenance is invested in a building, the value will improve. Further, the needs for maintenance works will be expected to increase, since it is not always cost-effective to demolish or rebuild new facilities to replace existing ones.

The growing significance of building maintenance has also generated an increasing interest in developing maintenance management procedures to reduce the maintenance budget of buildings in Malaysia. As an illustration, it was concluded that the fundamental problem is ineffective maintenance management (Femi, 2014). Rahman and Salim (2013) indicated there are three primary issues in maintenance: deficient budgetary, incompatible management and poor building detailing and design. Defects in building emerge through inappropriate design specification and

construction and it will be responsible for an impact to maintenance management. Presently, for project success most crucial factor is defects in design perceived by both owners and contractors and have a tremendous impact on later expenditures like at post occupancy stage.

Since May 2007, the issue of building defects in Malaysia is continued reporting in the media (Rahman *et al.*, 2012; Ahzahar *et al.*, 2011; Samad *et al.*, 2013). For example, pipe leakages halted the operations at Immigration Headquarters in 2007, poor condition of the ceiling panels in the Kuala Lumpur Court Complex (the second biggest court in the world) in 2007 and cornice in the main lobby crashed at the State Legislative Assembly building in 2008 (Lateef, 2009). According to a survey report, defects in design is the major risk in Kuwait, Japan, United States of America (USA) and Hong Kong construction industry too (Lopez and Love, 2012).

Aris (2006) mentioned that 20 percent of the annual cost of building maintenances in the UK are due to design defects. An empirical analysis in various types of building by Zhou (2014) also identified that annual maintenance cost is 20 percent. A study by Love *et al.* (2014) shows that maintenance cost can be increased 14.20 percent due to faulty design decisions. The cost of building design and construction are very little compared with the total cost of a building. A study performed by Tan *et al.* (2018) shows that 85% of the lifecycle cost of a building occurs during the operation and maintenance phase. Ohara (2009) also revealed by his study that maintenance cost is 83% or 4-5 times than construction cost.

Hence, the significance of maintenance and its position in the world's diverse industries can be seen in progressive developments of manufacturing, refineries, mining and building. Kamaruzzaman *et al.* (2013) signifies the role of maintenance as the major driver of economic growth. In many countries, it represents almost 50 percent of the total turnover of the construction industry (Lateef, 2009). Ihsan and Alshibani (2018) reports that building maintenance accounts for over half the building industry's total output, and for over two-third of the contracts let. In this respect, the maintenance of buildings needs to be more systematically controlled. Therefore, the role of facilities management (FM) continues to expand, as more demands are made

by users regarding the economic and functional efficiency of the buildings. Jensen (2009) asserts fast growing profession FM assists to optimize the capital investment and supports to enjoy long life better services in the cost effective way of built-environment. Therefore, buildings that require effective maintenance, otherwise they become a burden to clients, users and the general public. In addition, an extensive increase in investment is likely to be needed in the very near future to rectify defect, decay and deterioration.

Reducing the impact of the design factors that affect maintenance cost is therefore very important. This research seeks to identify the design factors affecting maintenance cost and rank these factors in order of importance with a view to achieve cost-effective maintenance.

1.2 Problem Statement

Over the last two decades, the built environment has witnessed great development and progressive transformation in terms of use of innovative building materials and modern construction technologies (Hassanain *et al.,* 2017). Rapid advancement in technology and the increased competition in modern economies have forced building industry to create efficient supporting services system to achieve long-term building functionality and successful building operation. Consequently, this has required complex and sophisticated support systems to fulfill the needs of the modern building facilities and intended end-users. Development of this modern structure attributed to surging initial investment up to fifty percent (50%) of the total building cost i.e. capital and operational (Jaunzens *et al.*, 2001). The role of maintenance in modern building is becoming ever more important with companies adopting maintenance as a profit-generating business element (Kutucuoglu *et al.,* 2001).

On the other hand, Zhu *et al.* (2017) describe modern building is designed to fulfill the greater building standards and the impact of this on the maintenance practice is more remarkable than any other time, in terms of cost, time and service. Nowadays, standard design practices are not pretty enough for multidisciplinary problems solving,

thus, designers need to be proficient about the relationship amongst individuals. The absence of this, high intake of design defects appear that increase the non -value adding demolition and repetitive work ultimate consequence in increasing maintenance cost (Wan and Kumaraswamy, 2012).

Cost of maintenance is going up rapidly in many countries i.e. China, Hongkong, Saudi Arabia, Nigeria and USA (Barbarosoglu, 2018). The cause of the increasing cost of maintenance can be one or more of the following factors: building type and characteristics, user factors, implementation of maintenance management and government policies. Al-Khatam (2003) conducted a study on the factors affecting the cost of maintenance in buildings. It was concluded that the major causes for high cost of maintenance in buildings are: faulty design and construction, absence of local material standards and specifications, concern about the initial cost by owners, poor supervision and management of maintenance projects, poor scheduling and absence of standardized maintenance contracts. Baba and Buba (2013) assessed factors affecting maintenance cost in residential building and revealed that lack of preventive maintenance, the use of substandard materials, design defects and faulty workmanship were the most significant factors. Errors and omissions in design documentation and changes initiated by the client and end-user are the major causes of increasing maintenance cost (Love and Li, 2010).

The defective design need for continuous maintenance (Rahman and Salim, 2013). Wong and Chan (2014) demonstrated that 58% of building defects causes of faulty design, 35% from operation and establishment, 12% from poor materials and 11% from unforeseen clients' necessities. The impacts of design defects on maintenance can be described as follows: maintenance budget will increase, striving in repairing and maintenance recurrence will multiply. Typically, maintenance principles rarely considered during design and construction stages. As a result, defects appear on the buildings due to quality and types of used materials and completed construction method. Austin *et al.* (2002) showed the design coordination and contractors are not able to convey quality construction work without the backing of good and clear working design.

Femi (2014) stated that most of building defects were the result of faulty design and construction and this led to increase maintenance work. The issue of design defects and its effect on maintenance also was studied by Ali *et al.* (2013). Their solution was to benefit from the maintenance inputs during the design phase for the ease of maintenance to decrease design defects. Ofori *et al.* (2015) concluded that faulty designs, lack of maintenance plan and unavailability of skilled labour to undertake maintenance operations and poor financial support for maintenance work were the most influential factors to increase maintenance cost. These factors are a real threat to the structural and functional state of the building and consequently, this would lead to rapid deterioration. Based on that, maintenance should be taken into consideration within the design phase and emphasize the focus on producing appropriate design documentation. Therefore, the study focuses on classifying the design defects and evaluating their impact on maintenance cost of building projects.

Maintenance cost consists of building structures repair, technical equipment repair and outdoor installation repair (DIN 18960, German Institute for Standardization, 2008). ÖNORMB 1801-2 (Austrian Standard Institute, 2011) is presented main components of maintenance cost in the following: cost of preventive maintenance cost, repair cost and renovation cost. Many associations or consultancies also published components of maintenance costs. For example, International Facilities Management Association (IFMA) divided it into following elements: exterior building maintenance, interior systems maintenance, replacement cost, janitorial cost and indirect cost (administration and management, overhead and cost of lost revenue). However, FM cost constitutes a major portion of the total operational and maintenance cost. According to IFMA, FM cost associated with maintenance cost, replacement cost, janitorial cost, cost of moves, indirect cost, utility cost, life-safety cost, support and project cost (security, space planning, employee amenities) and financial indicator (lease, fixed asset, operation, etc).

The significance of reducing building maintenance cost has continued to grow. According to Tan *et al.* (2014), this cost in the USA market is forecast to advance 5.6 percent per year to nearly US$95 billion in 2011. In contrast, this percentage in Malaysia is 8% and Malaysian government counted a large amount of currency for

repair, maintenance and renovation work, as shown in Figure 1.1 (CIDB, 2018). In terms of value, maintenance cost was about MYR8.218 billion in 2013, which represents about 9 percent of the total construction cost. In 2016, it had increased to MYR14.981 billion. This highlights 82.30 percent increase in allocation to the sector within four years. In one research Lee (1996) described that in the last decade up to 50% of the construction budget was spent for repair and maintenance work in building construction industry in the USA but now this situation changed, and expenses reduced to 25% (Ali, 2009). This indicates that the repair and maintenance sector is important in the USA.

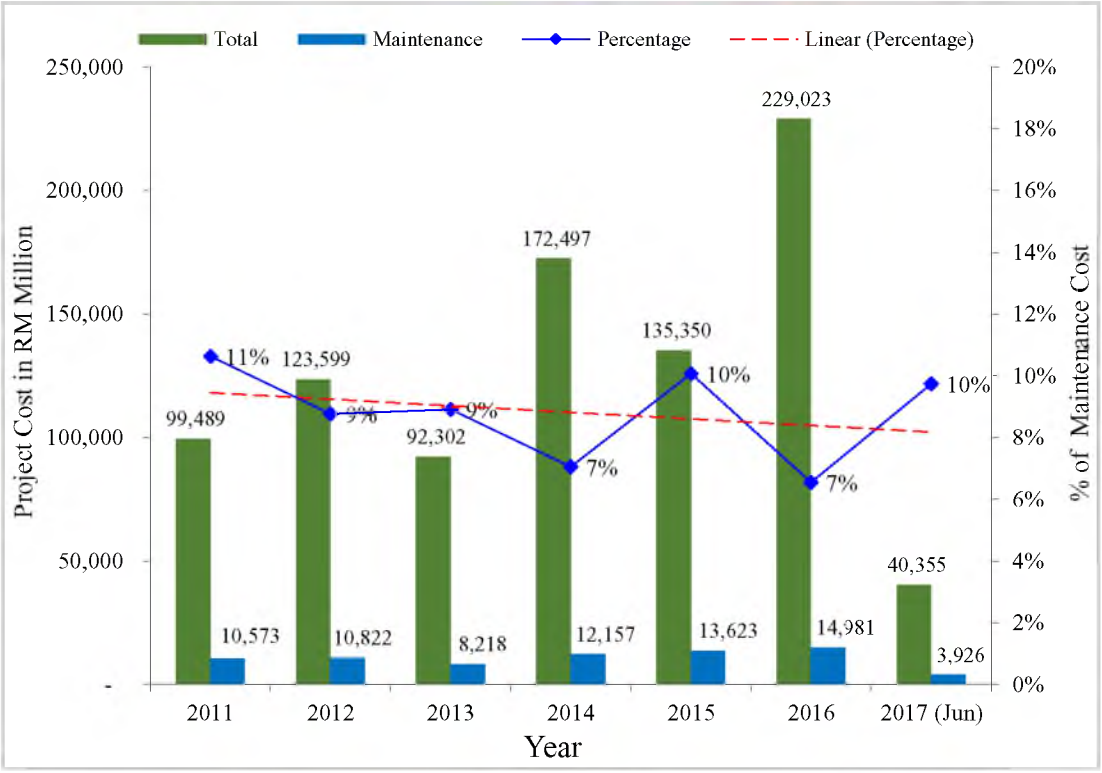

Figure 1.1 Cost of new projects and maintenance works (CIDB, 2018)

Barret and Baldry (2003) expressed that lack of FM integration and communication gap between the design phase and construction phase affect the maintenance work. Ercoskun and Kanoglu (2003) added facilities management and design are seen as two different processes whereby the former starts on with the commencement of the construction process and the latter engages in post-construction practices. The separation of design from the post-construction processes has resulted in many problems, such as the lack of constructability, operability, maintainability and

serviceability for designed facilities (Meng, 2013). Hassanain *et al.* (2017) identified and evaluated the causes of maintainability issues at post-occupancy phase. They were errors conducted during the design of the project, lack of coordination between the construction and maintenance group, lack of quality control measures during the installation of systems and lack of feedback from the maintenance group to the design team. Moreover, Jensen (2009) considers that one of the drawbacks in the building industry is the inadequate knowledge attained from facilities' operational and maintenance experiences. Jaunzens *et al.* (2001) mention that the overall integration of FM knowledge and requirements in design were still rarely acknowledged by the designers.

According to Meng (2013) three perspective sources (client, design and FM) are identified as barriers to integrate FM in the design process. The main barrier caused by client organizations is that most clients are cost constrained, capital cost driven and short-term focused. Finally, there is a lack of awareness of the whole life concept of buildings and lack of awareness of early FM involvement. Similar to the client, the design team often does not recognize the long-term benefits from early FM involvement. Other barriers from the design organisations are underestimation of FM, separation of facilities design from building design and low priority to functionality. From the FM perspective, lack of adequate knowledge and experience of FM practitioners become a barrier to their involvement in the design process. Jensen (2009) indicated that FM has limited participation in the design team and considered as not equivalent associates in the design process. Their integration in building design process cannot be explored except move out from this kind of understanding. Femi (2014) concluded that incorporation of facility manager in the design process lead to avoid repetition of faulty design.

There are many studies in literature focusing on the identification of causes and effects of design in maintenance practice all over the world, including Erdener (2003) in the USA; Jensen (2009) in Denmark; Ali *et al.* (2013) and Yap *et al.* (2017) in Malaysia; Meng (2013) in the UK; Tan *et al.* (2014) in Hong Kong; Bu Jawdeh (2013) in the Gulf countries and Hassanain *et al.* (2017) in Saudi Arabia. Very little or no efforts are focused to research in the area of categorization and assessment of design

defects to effectively manage building projects. Design defects have direct negative impacts on cost overrun and schedule delays, disputes and rework (Sun *et al.*, 2009). However, several of the generic models developed can facilitate design process (Mohammed and Hassanain, 2010; Das and Chew, 2011; Love *et al.*, 2013 and Mutalib *et al.*, 2018) but cannot be adopted as a basis for systematic assessment of design defects.

Therefore, these gaps in the literature are addressed in this research project. This study focuses on developing a model for the involvement of design factors and design parameters during the design stage of building projects, aiming at increasing the benefits and supporting cost-effective maintenance practice. Development of the model necessities the identification and assessment of the design defects raised by the facility manager during the design stage which will have significant impacts on building maintainability in the future. Moreover, this research findings will be a suitable reference for all stakeholders in building projects to make sure a fruitful usage of design, especially for upcoming building projects in Malaysia.

1.3 Research Questions

Existing literature reveals fast development of the construction business in Malaysia is requesting a cost-effective maintenance practice in building projects. In the point of view, the research needs to answer the following questions:

a. What types of design defects affect the building maintenance cost?
b. What are the relevant design parameters to be considered in practicing of cost-effective maintenance?
c. How can all professionals utilize the identified design parameters to promote cost-effective maintenance practice?

To answer these questions, the research aim and objectives were hence formulated.

1.4 Research Aim and Objectives

The research aims to develop a maintenance cost-model for cost-effective maintenance practice through improving building design. To achieve this aim following three objectives are set for this research:

a. To identify the type of design defects at the post-occupancy stage.
b. To establish maintenance related design parameters of building design for cost-effective maintenance practice.
c. To develop a maintenance cost model to reduce maintenance cost by prioritizing the design defects and design parameters.

1.5 Research Significance

Cost-effective maintenance practice has become a crucial principle to be pursued throughout the life-cycle of a building project, particularly during the post-occupancy phase. Building projects are very important to keep these in a condition in which they perform their functions as designed. The efficiency, performance, lifespan and appearance of any building can be affected by faulty design decisions. The ultimate effect is on maintenance cost due to design defects.

This study investigates the design factors that would increase maintenance cost in the building projects. Through scrutinising and identifying the potential design factors, this study provides valuable information linked with cost-effective maintenance practice. By conducting this research, the designer will improve the quality of the design by recognizing the design faults and avoiding them. The contractor will improve the quality of work and minimize time delay and expenditure on repair work. Finally, the owner will minimize maintenance cost and the substantial life of the building will increase.

The outcome of this study is a maintenance cost model for reducing the maintenance cost at the post-occupancy stage. The integration of this model into the

design stage will also decrease the complexities of unplanned maintenance activities in buildings. This model will help all stakeholders to identify knowledge deficiencies and skill gaps for continuing education and training. Facility managers will benefit from this research through a better understanding of the design defects that can motivate and enhance their daily practices.

This study adds to the body of knowledge pertaining to the maintainability concept in the building projects, particularly in regard to the design enhancement approach. The findings of this research will directly assist in reducing design defects and promote the implementation of cost-effective maintenance practice. This research also establishes the maintenance cost-model for future study adopting sustainability concept in the building life-cycle.

1.6 Research Scope

This research focuses on the design defects, it is regarded as the key enabler to increase building maintenance cost at post-occupancy phase. The scope of this research is limited to the construction industry, which involves the FM sector. In order to ensure a focused and robust research, FM is considered in relation to building maintenance.

This study involves the FM organisations from the states of Kuala Lumpur, Selangor and Johor. They are also registered member in both Construction Industry Development Board (CIDB) of Malaysia and Malaysian Association of Facilities Management (MAFM). CIDB is a principal government authority for the development of the construction industry and MAFM is only leading professional institution for FM professionals in Malaysia.

Kuala Lumpur, Selangor and Johor state were considered the best choice for this research due to their strategic importance. For instance, according to the latest statistic from CIDB of Malaysia, more than two-third (66.79%) of the country's total project value is within these three states (CIDB, 2018). They are chosen as the

heartland of Malaysia's commercial and industrial activities (Yong and Mustaffa, 2013). Moreover, there are total 202 FM organisations identified in the category of G4 to G7 (CIDB, 2017). Kuala Lumpur, Selangor and Johor cover 66.33% of the population of FM organisations in all Malaysia regions with the quantity of 134. This study is limited to only G7 FM organisations within these three states as the main sampling group for data collection because they are most concentrated with FM activities.

Most of the respondents had extensive experience and held decision-making roles in their respective organisation, such as directors, engineers, facility managers and quantity surveyors. According to Fellows and Liu (2015), a mix of respondents with different backgrounds is important in order to minimize the possibility of bias. Therefore, it was expected that consensus among the respondents would represent the reliable and high-quality information for this study.

1.7 Research Methodology

Researchers must decide on the methodological approach to finding the solutions to the research problem or research questions being addressed (Fellows and Liu, 2015). A study should have a detailed research design which can be used as a framework for the data collection and observations. The research design involves a systematic plan to coordinate a research project to ensure the efficient use of resources, and to guide the researcher in the use of suitable research methods.

In this research, the quantitative research approach is adopted because of the nature of the objectives and data required. This approach is mostly preferred because it is more focused with specific issue or phenomenon and answer precise research question (Neuman, 2006). However, adopting quantitative approach is based on the need to obtain quality data from large participants without bias.

The questionnaire survey was used as the main data collection technique in this research to accomplish the aim and objectives. Surveys are adopted based on the fact

that it is faster when compared with other methods and is comparatively less expensive (Naoum, 2006). After the questionnaire was drafted and developed, a pilot test was conducted to ensure the questionnaire's clarity, comprehensiveness and acceptability. In addition, the feedback obtained is an opportunity to improve the questionnaire, fill in any gaps and calculate the time required to complete the exercise (Fellows and Liu, 2015).

In this study, the questionnaire survey was conducted in order to identify the most important design defects and maintenance related design parameters. Subsequently, develop a maintenance cost-model for reducing maintenance cost at the post-occupancy stage. The targeted population for the research was FM organisations from CIDB and MAFM within Kuala Lumpur, Selangor and Johor Bahru. However, all the respondents were directly related with the building maintenance and were all chosen as the research population. Therefore, because the population is sufficiently small, they were all considered as the sample size for the research (Fellows and Liu, 2015).

The instrument adopted for data collection is the self-administered five-point Likert scale questionnaire. However, all validly completed questionnaire returned were used for the analysis. The collected data were analysed using different statistical methods namely: mean, standard deviation (SD), relative importance index (RII) and rank analysis. Before adopting these methods for the analysis, collected raw data from the questionnaire were translated into numbers and arranged them into a statistical software package of "SPSS version 24" database. Details of the methodology approach is described in chapter three.

The implementation of the above key research methodologies in this research assists in defining appropriate processes to answer the research questions and to achieve the research objectives.

1.8 Outline of the Thesis Organization

This research comprising with five chapters, this thesis continues to chapter 2, describes the literature review. Building maintenance, facility management and building design discipline are discussed throughout by providing definition, details service provided by each discipline, design defects and its effect. Also highlights the importance of FM and design integration. Outline of this thesis is shown in Figure 1.2.

Chapter 3 describes this thesis methodology based on the choice of philosophy. Its frameworks the research design and choose the research approach, specifically, the questionnaire-based survey was considered suitable for examining the research question. Moreover, every designated method to guide the technique of data collection and analysis to execute the process.

Chapter 4 represents the data analysis and results of the questionnaire survey with adopted suitable data sampling and instrumentation afterward synthesizes the major findings obtained from a questionnaire survey.

Finally, this thesis concludes with chapter 5 that underlining the research findings as well as involvement to knowledge and recommends a guideline for implementation of further research.

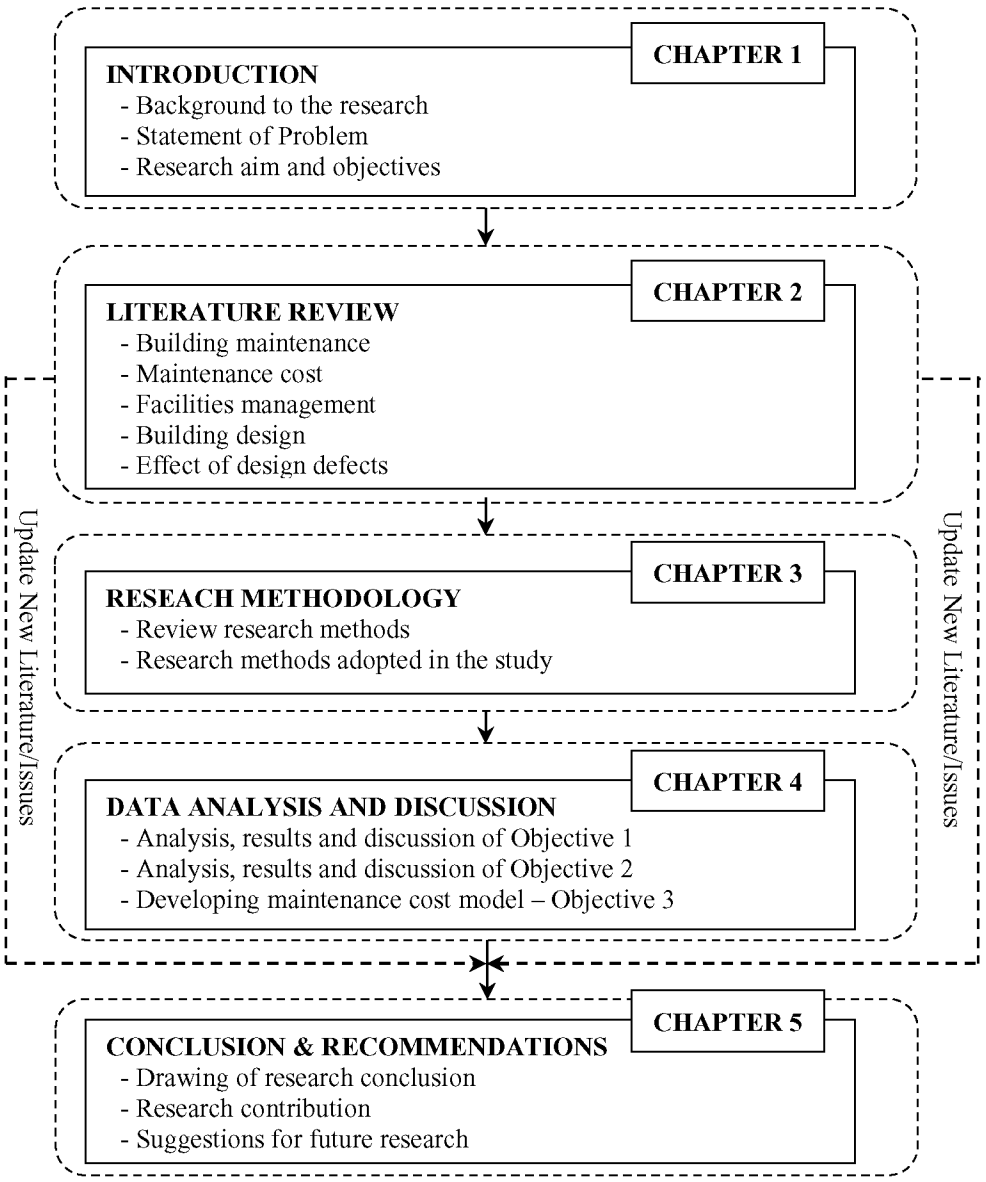

Figure 1.2 Thesis organisation

1.9 Chapter Summary

This chapter provided an overview of the research background and the problem statement regarding the facility manager's efforts in the building maintenance. The effect of design defects at post-occupancy phase was highlighted. The objectives of this research were then articulated based on the research questions. This was followed by research significance, research scope and overview of research methodology. Finally, an overview of the thesis structure was presented to show how the chapters are interconnect. The next chapter presents the literature review.

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