

INTEGRATION OF BUILDING MAINTENANCE COST MODEL INTO THE DESIGN STAGE

MD RASHIDUL ISLAM

UNIVERSITI TEKNOLOGI MALAYSIA

INTEGRATION OF BUILDING MAINTENANCE COST MODEL INTO THE
DESIGN STAGE

MD RASHIDUL ISLAM

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Built Environment and Surveying
Universiti Teknologi Malaysia

DECEMBER 2018

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.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. First and Foremost, praise to Allah, the Almighty, the greatest of all, on whom ultimately, we depend for sustenance and guidance.

I wish to express my sincere appreciation to my supervisor, Assoc. Prof. Sr Dr. Sarajul Fikri Mohamed, for encouragement, guidance, critics, and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Building Information Center (BIC), all the Lecturers and staff in the Faculty of Built Environment (FAB) and Universiti Teknologi Malaysia (UTM) for their valuable support and assistance throughout my MPhil program. My sincere appreciation also extends to all my friends and colleagues for their views and tips are useful indeed.

Last but not least, I would like to thank my family, my sister, my beloved parents for their always emotional support and confidence to me. Special thanks to my wife, Tasnia Hassan Nazifa, for her love, sacrifice, patience and continuous struggle towards the accomplishment of this study. I dedicate this work to my beloved parents and wife.

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 piawai (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 penyelenggaraan. 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 penyelenggaraan 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 mekanikal-elektikal-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

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF ABBREVIATIONS	xvi
	LIST OF APPENDICES	xvii
1	INTRODUCTION	1
	1.1 Research Background	1
	1.2 Problem Statement	4
	1.3 Research Questions	9
	1.4 Research Aim and Objectives	10
	1.5 Research Significance	10
	1.6 Research Scope	11
	1.7 Research Methodology	12
	1.8 Outline of the Thesis Organization	14
	1.9 Chapter Summary	15
2	LITERATURE REVIEW	16
	2.1 Introduction	16
	2.2 Building Maintenance	16

2.2.1	Types of Building Maintenance	17
2.2.2	Building Maintenance Cost	19
2.2.3	Sustainable Building Maintenance	21
2.3	Facilities Management	21
2.3.1	Role and Responsibilities	23
2.3.2	Scope of Facilities Management	23
2.3.3	Components	27
2.3.4	Present and Future Development	28
2.3.5	Development of FM in Malaysia	30
2.4	The Concept of Sustainable Facilities Management	35
2.5	The Strategic Role of FM in the Design Process	37
2.6	Integration of Design and Facilities Management	39
2.7	Benefits of Integrating FM in Design Phase	43
2.8	Factors Affecting Integration of FM in Design Phase	46
2.8.1	Clients Related Factors	47
2.8.2	Design Related Factors	47
2.8.3	FM Related Factors	48
2.9	Consequences of Limited Integration of FM	49
2.10	Building Design	50
2.10.1	Design Objectives	51
2.10.2	Sustainable Design	53
2.10.3	Disciplines of Systematic Building Design	54
2.10.4	Design Stages	55
2.10.5	Design Team	57
2.10.6	Design Defects in Architectural Design	61
2.10.7	Design Defects in Structural Design	68
2.10.8	Design Defects in Mechanical, Electrical and Plumbing (MEP) Design	72
2.10.9	Cost Implication of Design Defects	74
2.11	Effects of Design Quality on Facility Operation and Maintenance	76
2.11.1	Added Value of FM	83
2.12	Review of FM Conceptual Model	85
2.13	Gaps in the Literature	91

	2.14 Conceptual Model for the Study	93
	2.15 Chapter Summary	95
3	RESEARCH METHODOLOGY	96
	3.1 Introduction	96
	3.2 Research Philosophy	96
	3.2.1 Research Paradigm	97
	3.3 Research Methodology	99
	3.3.1 Research Approach	101
	3.4 Research Design	107
	3.4.1 Choice of Research Methods	107
	3.4.2 Research Methodology Adopted	109
	3.5 Research Development	111
	3.5.1 Literature Review	111
	3.5.2 Questionnaire Survey	111
	3.5.2.1 Validity	114
	3.5.2.2 Reliability	114
	3.5.2.3 Survey Instrumentation	115
	3.5.2.4 The Population of the Study	116
	3.5.3 Data Analysis	119
	3.6 Chapter Summary	124
4	DATA ANALYSIS AND DISCUSSION	125
	4.1 Introduction	125
	4.2 Survey Response Rate and Validity	125
	4.3 Survey Results and Analyses	127
	4.3.1 Respondents' Profiles	127
	4.4 Identify FM Operations and Maintenance Issues	133
	4.4.1 Integration of Maintainability Criteria in Design Phase	133
	4.4.2 Integration of Facility Manager in Design Phase	135
	4.5 Issues Increasing Maintenance Cost at Post-Occupancy Phase	136
	4.6 Difficulty Level of Building Components in Maintaining	139

4.6.1	Architectural Components	139
4.6.2	Structural Components	142
4.6.3	Mechanical, Electrical and Plumbing (MEP) Components	144
4.7	Design Consideration for Maintainability Checking at Design Phase	149
4.7.1	Factors Related to Architectural Design	149
4.7.2	Factors Related to Structural Design	151
4.7.3	Factors Related to MEP Design	152
4.8	Facilities Management Related Parameters	156
4.8.1	Importance of People Related Parameters	156
4.8.2	Importance of Process Related Parameters	158
4.8.3	Importance of Economy Related Parameters	159
4.8.4	Importance of Social Related Parameters	160
4.9	The Cost-Benefit of Integrating Design Factors and Design Parameters	161
4.10	Main Considerations in Designing the Building	164
4.11	Development of Maintenance Cost Model	166
4.11.1	Model Development Process	167
4.12	Chapter Summary	171
5	CONCLUSION AND RECOMMENDATIONS	173
5.1	Introduction	173
5.2	Conclusion	173
5.2.1	Type of Design Defects at the Post-Occupancy Phase	174
5.2.2	Design Parameters	175
5.2.3	Maintenance Cost Model for Cost-Effective Maintenance	176
5.3	Contribution to Knowledge	177
5.3.1	Theoretical Contributions	177
5.3.2	Contribution to Industry Practices	178
5.4	Research Limitations	179
5.5	Recommendations for Future Research	180

REFERENCES

182

Appendices A-B

207-217

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Definition of FM from the various development industry	22
2.2	Area of FM from the perspective of different authors and organizations	27
2.3	Development of facilities management in the context of Malaysia	33
2.4	Specific tasks of FM in building project	42
2.5	Barriers to integrating FM in design process	49
2.6	Objectives of the design decision	52
2.7	Sustainable building issues	53
2.8	Summary of design factors in increasing maintenance cost	73
2.9	Key performance indicators for FM services	81
2.10	Main components of the model	83
2.11	Identified various value parameters from FM model	88
2.12	Adopted design parameters	91
2.13	Gap analysis between previous studies and this research	92
3.1	Characteristics of four research paradigms	98
3.2	Comparison of the structured, semi-structured and unstructured interview	105
3.3	Research strategies with relevant situations	106
3.4	Structure of the questionnaire	113
3.5	Cronbach's alpha calculation from SPSS	115
3.6	Total population of the study	116
3.7	Analysis of the study area	119
3.8	Likert scale used in the questionnaire	120
3.9	Mean range for the scale of agreement level	121
3.10	Instrument adopted in the research	123

4.1	Total questionnaire responses	127
4.2	Demographic information of respondents'	132
4.3	Respondents' ratings of maintainability criteria in the design phase	134
4.4	Cronbach's alpha calculation from SPSS (Section B, Q 1)	135
4.5	Respondents' ratings of integrating facility manager in the design phase	136
4.6	Cronbach's alpha calculation from SPSS (Section B, Q 2)	136
4.7	Maintenance cost increasing issues	137
4.8	Cronbach's alpha calculation from SPSS (Section B, Q 3)	139
4.9	Assessment of building components affecting the maintenance cost	141
4.10	Overall group assessment of building components	148
4.11	The level of importance of building components based on rating	148
4.12	Cronbach's alpha calculation from SPSS (Section B, Q 4)	149
4.13	Assessment of architectural design factors affecting maintenance cost	150
4.14	Assessment of structural design factors affecting maintenance cost	152
4.15	Assessment of MEP design factors affecting maintenance cost	153
4.16	Overall group assessment of design factors	154
4.17	The level of importance of design factors based on rating	154
4.18	Cronbach's alpha calculation from SPSS (Section B, Q 5)	156
4.19	Assessment of maintenance related design parameters	157
4.20	Cronbach's alpha calculation for design parameters from SPSS	161
4.21	Cost-benefit of integrating design parameters	162
4.22	Factor consideration in designing the building	165

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Cost of new projects and maintenance works	7
1.2	Thesis organisation	15
2.1	Type of maintenance	18
2.2	The scope of facilities management	26
2.3	A paradigm shift in facilities management	29
2.4	Budget allocation for FM in National Budget	31
2.5	Cost-benefit curve of extension of service life	37
2.6	Inherent gap created when coordinating the design process	39
2.7	Action flow of FM coordination buffering	42
2.8	Linking strategic level with operational level	44
2.9	Project life cycle and early involvement	45
2.10	Detailed building design divisions	55
2.11	Construction project life cycle	56
2.12	An integrated design team	57
2.13	Involvement of FM practitioners with integrated design team	58
2.14	The detailed flow of the design modification	59
2.15	Common operational issues	60
2.16	Signs of stains at the façade	62
2.17	Poor quality tiles	62
2.18	Damaged sharp wall edge	63
2.19	Plaster decay on an external wall	65
2.20	Hairline plaster crack	69
2.21	Cracks in slab and wall due to differential settlement	69
2.22	Estimated design defects costs for each designer type	75

2.23	Defect costs (%) by origin.	75
2.24	Schematic diagram of BSC	79
2.25	Business excellence criteria	80
2.26	Schematic diagram of capability maturity model	82
2.27	Existing FM profile in all sectors	84
2.28	Influencing factors of added value	86
2.29	Parameters in each model	90
2.30	Conceptual model for cost-effective maintenance practice	94
3.1	Relation of philosophical worldview, selected strategies and research method	97
3.2	Triangulation of quantitative and qualitative data	103
3.3	Framework for research design quantitative, qualitative and mixed methods approach.	104
3.4	Breadth and depth in “Question-Based” studies	108
3.5	Research methodology flowchart adopted in this study	110
3.6	Execution process of a questionnaire survey	112
3.7	Total respondents	117
4.1	Distribution of respondents by professional roles	128
4.2	Respondents’ highest level of academic achievement	128
4.3	Respondents’ age group breakdown	129
4.4	Respondents’ years of experience in the FM sector	130
4.5	Number of respondents based on the type of industry	130
4.6	Number of respondents based on involved employee	131
4.7	Number of respondents based on professional membership	132
4.8	RII value for design parameters	158
4.9	RII value for percent of cost savings	162
4.10	Integrated approach to FM in building life-cycle	163
4.11	Importance index of each factor	165
4.12	Maintenance cost model for cost-effective maintenance practice	170

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

APPENDIX NO.	TITLE	PAGE
A	Questionnaire	207
B	List of Publications	215

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.

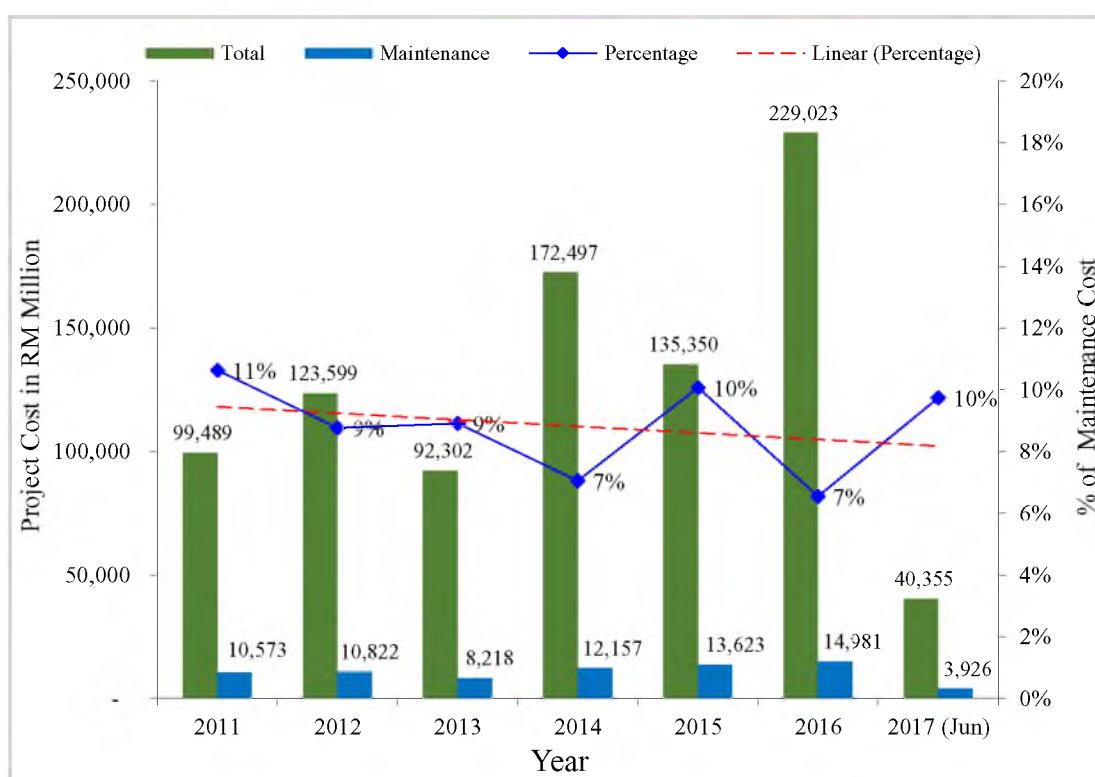


Figure 1.1 Cost of new projects and maintenance works (CIDB, 2018)

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 necessitates 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.

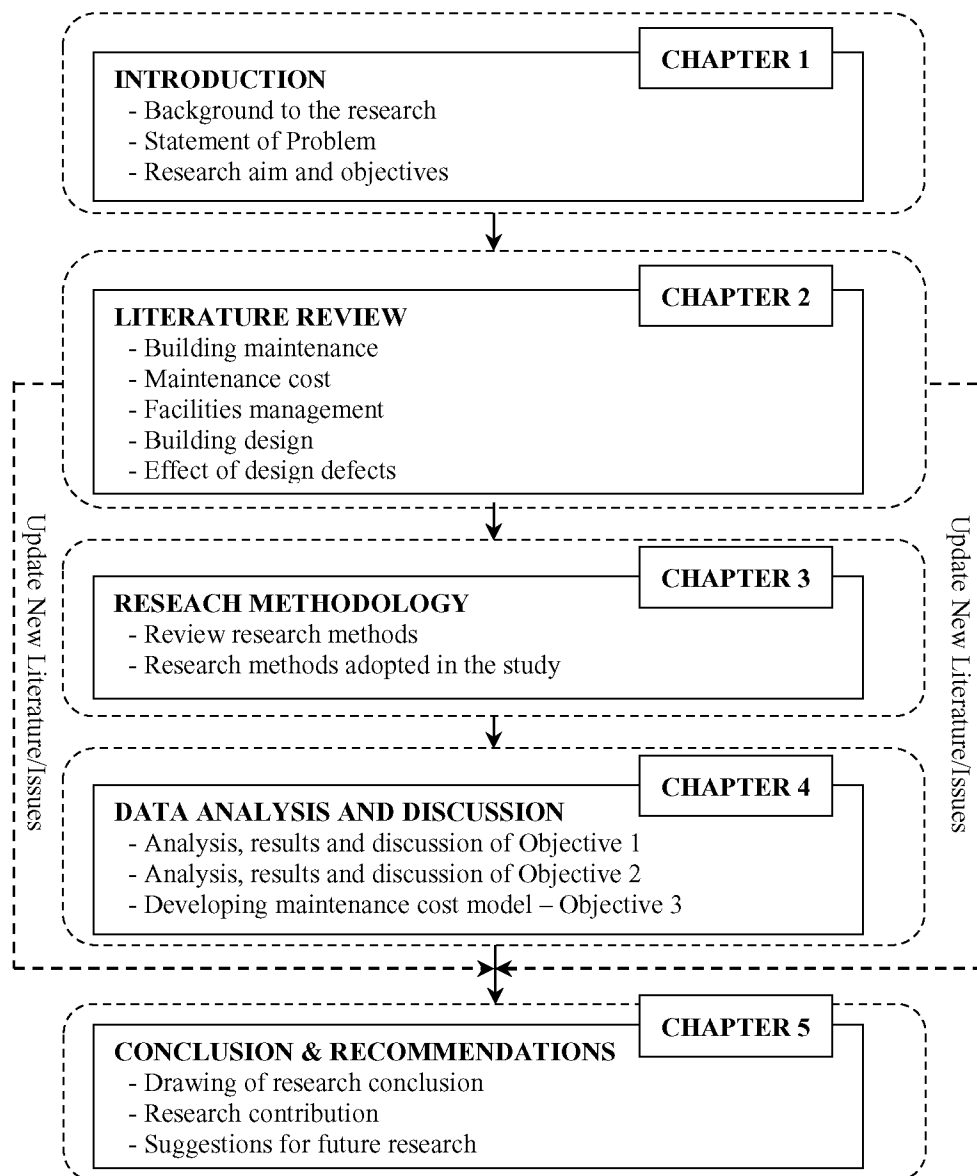


Figure 1.2 Thesis organisation

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.

REFERENCES

- Abbas, E., Czwakiel, A., Valle, R., Ludlow, G., and Shah, S. (2009). The practice of sustainable facilities management: Design sentiments and the knowledge chasm. *Architectural Engineering and Design Management*, 5(1-2), 91-102.
- Abdullah, S., Razak, A.A., Hanafi, M.H. and Salleh, M.N. (2011). Managing Government Property Assets: The Main Issues from The Malaysian Perspective. *Journal of Techno-Social*, 3(1), 35-52.
- Ahzahar, N., Karim, N. A., Hassan, S. H., & Eman, J. (2011). A study of contribution factors to building failures and defects in construction industry. *Procedia Engineering*, 20, 249-255.
- Ajayi, A. A. (2016). *Change Management Capability Assessment Model for Construction Organizations*. Doctoral dissertation, Universiti Teknologi Malaysia.
- Akadiri, P. O., Chinyio, E. A., & Olomolaiye, P. O. (2012). Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. *Buildings*, 2(2), 126-152.
- Akintoye, A. (2000). Analysis of factors influencing project cost estimating practice. *Construction Management & Economics*, 18(1), 77-89.
- AL Mousli, M. H., & El-Sayegh, S. M. (2016). Assessment of the design–construction interface problems in the UAE. *Architectural Engineering and Design Management*, 12(5), 353-366.
- Alaloul, W.S., Liew, M.S. & Zawawi, N.A.W.A. (2016). Identification of coordination factors affecting building projects performance. *Alexandria Engineering Journal*. 1-10.
- Al-Hammad, A., Assaf, S. and Ai-Shihah, M. (1997). The effect of faulty design on building maintenance. *Journal of Quality in Maintenance Engineering*, 3(1), 1355-2511.

- Ali, A. S., Keong, K. C., Zakaria, N., Zolkafli, U., and Akashah, F. (2013). The effect of design on maintenance for school buildings in Penang, Malaysia. *Struct. Surv.*, 31(3), 194–201.
- Ali, A.S. (2009). Cost decision making in building maintenance practice in Malaysia. *Journal of Facilities Management*, 7(4), 298–306.
- Al-Kafrawi, M. S. (2011). Interview, Maintenance Manager at King Fahad University of Petroleum and Minerals, Maintenance Department, Dhahran, Saudi Arabia.
- Al-Khatam, J. A. (2003). Building maintenance cost. *Master of Engineering Report, College of Environmental Design, King Fahd University of Petroleum & Minerals*, Saudi Arabia, 1-66.
- Allen, P.J. and K Bennett. (2010). PASW statistics by SPSS: a practical guide: version 18.0.: South Melbourne, Victoria: Cengage Learning.
- Alshehri, A. R. (2016). *Quality management system for building maintenance*. Doctoral dissertation, Heriot-Watt University.
- Alshenqeeti, H. (2014). Interviewing as a Data Collection Method: A Critical Review. *English Linguistics Research*, 3(1), 39.
- Amaratunga, D. and Baldry, D. (2000) Assessment of facilities management performance in higher education properties *Facilities* 18(7/8), 293-301.
- Amaratunga, D., Haigh, R., Sarshar, M. and Baldry, D. (2002), Assessment of facilities management process capability: a NHS facilities case study, *International Journal of Health Care Quality Assurance*, 15(6), 277-88.
- Anand, K. B., Vasudevan, V., and Ramamurthy, K. (2003). Water permeability assessment of alternative masonry systems. *Build. Environ.* 38(7), 947–957.
- Andi & Minato, T. (2003). Design documents quality in the Japanese construction industry: Factors influencing and impacts on construction process. *International Journal of Project Management*, 21(7), 537–546.
- Anna-Liisa Lindholm (2005), Public Facilities Management Services in Local Government, International Experience, Master Thesis, Department of Surveying, Institute of Real Estate Studies, Helsinki University of Technology.
- Arain, F. M., Pheng, L. S. (2006). Developers' Views of Potential Causes of Variation Orders for Institutional Buildings in Singapore, *Architectural Science Review*, 49(1), 59-74.

- Arain, F., Sui, P., & Assaf, S. (2007). Consultant's prospects of the sources of design and construction interface problems in large building projects in Saudi Arabia. *Environmental Design Science*, 5(2), 15–37.
- Archer, B. (1968). The structure of the design process, in Moore, G. T. (Ed.) *Emerging Methods in Environmental Design and Planning*. MIT Press, Cambridge.
- Arditi, D., Elhassan, A., & Toklu, Y. C. (2002). Constructability analysis in the design firm. *Journal of construction engineering and management*, 128(2), 117-126.
- Aris, R. B. (2006). Maintenance Factors in Building Design. Master thesis, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia.
- Ashuri, B., Yarmohammadi, S., and Shahandashti, M. (2014), A critical review of methods used to determine productivity of mechanical, electrical, and plumbing systems coordination, *Proceedings of the Construction Research Congress*, American Society of Civil Engineers, May 19-21, Atlanta, Georgia, 777-786.
- Assaf, S. A., and Al-Hejji, S. (2006), Causes of delay in large construction projects, *International Journal of Project Management*, 24(4), 349-357
- Assaf, S., Al-Hammad, A.M and Al-Shihah, M. (1996). Effects of Faulty Design and Construction on Building Maintenance. *Journal of Performance of Constructed Facilities*. 23(3):175-181.
- Assaf, S., Hassanain, M. A., & Abdallah, A. (2018). Review and assessment of the causes of deficiencies in design documents for large construction projects. *International Journal of Building Pathology and Adaptation*. (In Press)
- Atkin, B., & Brooks, A. (2014). *Total facility management*. 4th Edn. John Wiley & Sons.
- Austin, S., Baldwin, A., Li, B., & Waskett, P. (1999). Analytical design planning technique: a model of the detailed building design process. *Design studies*, 20(3), 279-296.
- Austin, S., Newton, A., Steele, J., & Waskett, P. (2002). Modelling and managing project complexity. *International Journal of project management*, 20(3), 191-198.
- Awodele, O. A. (2012). Framework for Managing Risk in Privately Financed Market Projects in Nigeria. Unpublished PhD Thesis, Heriot – Watt University.

- Baaki, T. K., Baharum, M. R., & Ali, A. S. (2016). A review of sustainable facilities management knowledge and practice. In *MATEC Web of Conferences* (Vol. 66, p. 00075). EDP Sciences.
- Baba, W. and Buba, V. (2013), Evaluation of Factors Affecting Residential Building Maintenance in Nigeria: Users' Perspective, *Civil and Environmental Research*, 3(8), 2224-2235.
- Baharum, M., and Pitt, M. (2009). Determining a conceptual framework for green FM intellectual capital. *Journal of facilities management*, 7(4), 267-282.
- Banyani, M. A., & Then, S. S. (2010). A model for assessing the maturity of facility management as an industry sector. In *Proceedings of CIB W070 International Conference in Facilities Management*. 99-110.
- Barbarosoglu, B. V. (2018). *Early Detection of Maintainability Issues in MEP Systems Using BIM* (Doctoral dissertation, Illinois Institute of Technology).
- Barret, P. & Baldry, D. (2003). *Facilities management: towards best practice*. 2nd ed. Oxford: Blackwell Publishing.
- Bassioni, H.A., Price, A.D.F. and Hassan, T.M. (2004). Performance measurement in construction, *Journal of Management in Engineering* 20(2), 42-50.
- Bertola, P., & Teixeira, J. C. (2003). Design as a knowledge agent: How design as a knowledge process is embedded into organizations to foster innovation. *Design Studies*, 24(2), 181-194.
- Best, R. & De Valence. G. (Editors). (1999). *Building in value: pre-design issues*. New York: John Wiley & Sons.
- Bhatla, A., and Leite, F. (2012), "Integration framework of BIM with the last planner system". Proceedings of the 20th Annual Conference of the *International Group for Lean Construction*, International Group for Lean Construction, San Diego, USA.
- Brace, I. (2008). *Questionnaire Design: How to plan, structure and write survey material for effective market research*. 2nd ed: London: Kogan Page.
- Brackertz, N. (2006) Relating physical and service performance in local government community facilities *Facilities* 24(7/8), 280-91.
- Bröchner, J. (2003). Integrated Development of Facilities Design and Services. *Journal of Performance of Constructed Facilities* 17:1, 19-23.
- Brown, C. M & Nash, C. E. (1988). Planning an aquaculture facility - Guidelines for bioprogramming and design. *Aquaculture Development and Coordination*

- Programme. Report ADCP/REP/87/24, United Nations Development Programme, Food and Agriculture Organization of the United Nations. Rome.
- Bryman, A and E Bell. (2003). *Business research methods*: Oxford: Oxford University Press.
- BSI (1984). *BS 3811: 1984: Glossary of maintenance management terms in terotechnology*. London, UK: British Standards Institution (BSI).
- Cavana, R. Y., Delahaye, B. L., & Sekaran, U. (2001). *Applied business research: Qualitative and quantitative methods*. Australia, John Wiley & Sons.
- Chambers, R., & Clark, R. (2012). *An introduction to model-based survey sampling with applications*, Vol. 37. OUP Oxford.
- Chan, A.P.C. and Chan, A.P.L. (2004) Key performance indicators for measuring construction success *Benchmarking: An International Journal* 11(2), 203-21.
- Chandrashekar, A. & Gopalakrishnan B. (2008) Maintenance risk reduction for effective facilities management. *Journal of Facilities Management*, 6 (1), 52-68.
- Chanter, B. and Swallow, P. (2007). *Building Maintenance Management*. 2nd Ed. Oxford: Blackwell Publishing Ltd.
- Chew, M. Y. L. (2010). *Maintainability of Facilities for Building Professionals*. Singapore: World Scientific publishing Co. Pte. Ltd
- Chew, M. Y. L., and T. P. Ping (2003). *Staining of Facades*. Singapore:World Scientific Publishing.
- Chew, M. Y. L., N. De Silva, and S. S. Tan. (2004). Maintainability of Wet Areas of Non-Residential Buildings. *Structural Survey* 22 (1): 39–52
- Chong,W. K., and Low, S. P. (2006). Latent building defects: Causes and design strategies to prevent them. *J. Perform. Constr. Facil.*, 10.1061/ (ASCE) 0887-3828(2006)20:3(213), 213–221.
- Chotipanich, S. (2004) Positioning Facility Management. *Facilities*, 22 (13/14), 364-372.
- Chrissis, M.B., Konrad, M. and Shrum, S. (2003) *CMMI: Guidelines for Process Integration and Product Improvement*. Boston, Addison-Wesley,.
- Cigolini, R. D., Van der Zwan, J., Straub, A., Martinez, D., Aiello, G., Mazziotta, V., and Micale, R. (2009). Facility management, outsourcing and contracting overview. In *Recent Advances in Maintenance and Infrastructure Management*, 225-290. Springer.

- Clark, M. L. (2009). The emergence and transformation of positivism, In S. Nuccetelli, O. Schutte, O. Bueno (Ed) a companion to latin American philosophy: Wiley-Blackwell.
- Clevenger, C. And Haymaker, J. (2012) The value of design strategies applied to energy efficiency. *Smart and Sustainable Built Environment*, 1 (3), 222 – 240.
- Cnuddle, M. (1991). Lack of quality in construction—Economic loss. Proc., 1991 European Symp. on Management, Quality and Economics in Housing and other Building Sectors, Lisbon, Portugal, 508–515.
- Colander, C. (2003) Designing the customer experience. *Building Research and Information*, 31 (5), 357-366.
- Conti, T.A. (2007) A history and review of the European Quality Award Model, *The TQM Magazine* 19(2), 112-28.
- Cornick, T. (1991) Quality Management for Building Design. Butterworth, Rushden.
- Cresswell, J. P. (2011). Designing and Conducting Mixed Methods Research. Los Angeles: Sage.
- Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice*, 39(3), 124-130.
- Creswell, J.W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches: NY, Sage Publications, Inc.
- Creswell, J.W. and Plano Clark, V. L. (2007). Designing and Conducting Mixed Methods Research. Thousand Oaks, London and New Delhi: Sage Publications.
- Cullen, L. (2007). Human factors integration – Bridging the gap between system designers and end-users: A case study. *Safety Science*, 45, 621-629.
- Czaja, R and C.R. Blair. (2005). Designing Surveys: A Guide to Decisions and Procedures: Thousand Oaks: Sage, Pine Forge Press.
- Das, S., Chew, M. Y. L., & Poh, K. L. (2010). Multi criteria decision analysis in building maintainability using analytical hierarchy process. *Construction Management and Economics*, 28(10), 1043-1056.
- David, F.R. (2005) *Strategic Management: Concepts and Case Studies*, 10th ed., NJ Pearson, Englewood Cliffs,.
- Dawson, S., & Goulding, J. S. (2017). Shaping tomorrows-built environment: driving innovation through higher education engagement. *Welcome to delegates IRC 2017*, 587.

- De Silva, N. (2011). Promoting the facilities management profession in the project development phase of high-rise buildings in Sri Lanka. *Built-Environment Sri Lanka*, 9(1–2), 37–44
- De Silva, N. and Ranasinghe, M. (2010). Maintain ability risks of condominiums in Sri Lanka. *Journal of Financial Management of Property and Construction*, 15(1), 41-60.
- De Silva, N., Dulaimi, M. F., Ling, F. Y. Y., and Ofori, G. (2004). Improving the maintainability of buildings in Singapore. *Build. Environ.*, 39(10), 1243–1251.
- de Vries, J. C., de Jonge, H., & van der Voordt, T. J. (2008). Impact of real estate interventions on organisational performance. *Journal of Corporate Real Estate*, 10(3), 208-223.
- Den Heijer, A. C. (2011). *Managing the University Campus: Information to support real estate decisions*: PhD Thesis, Eburon Uitgeverij BV.
- Diakaki, C., Grigoroudis, E., Kabelis, N., Kolokotsa, D., Kaltitzakis, K., and Stavrakakis, G. (2010). A multi-objective decision model for the improvement of energy efficiency in buildings. *Energy*, 35(12), 5483–5496.
- DIN 276-1, Building costs – Part 1: Building construction, DIN – German Institute for Standardization, 2008.
- Ding, G. K. C. (2008) Sustainable construction – the role of environmental assessment tools. *Journal of Environmental Management*, 86 (3), 451-464.
- Dixit, M. K., & Venkatraj, V. (2017). Integrating Facility Management Functions in Building Information Modeling (BIM): A Review of Key Issues and Challenges. *IRC 2017*, 597.
- Doleman, R. G. (2013). A study of facility management knowledge classification for the effective stewardship of existing buildings. PhD Thesis, Edith Cowan University.
- Duffy *et al.*, (1995). *The Review of the Profession, Stages Two and Three*, RIBA, London.
- Edum-Fotwe, F.T., Egbu, C. and Gibb, G.F. (2003). Designed facilities management needs into infrastructure projects: case from a major hospital. *Journal of Performance of Constructed Facilities*, 17(1).
- Edvardsson, B. and Ohlsson, J. (1996) Key concepts for new service development. *The Service Industrial Journal*, 16 (2), 140-164.

- Eisenhardt, K. M. (1989). Building theories from case study research. *The Academy of Management Review* 14: 532-550.
- Eizzatul, A.S., Hishamuddin, M.A. & Suwaibatul Islamiah, A.S. (2012). A Review of the Effect of Building Design on Maintenance Management. Paper presented at 3rd *International Conference on Business and Economic Research*, ISBN: 978-967-5705-05-2, 12-13 March 2012, Golden Flower Hotel, Bandung, Indonesia, 648-662.
- El-Haram, M. A., & Agapiou, A. (2002). The role of the facility manager in new procurement routes. *Journal of Quality in Maintenance Engineering*, 8(2), 124-134.
- Elmualim, A., Czwakiel, A., Valle, R., Ludlow, G. & Shah, S. (2009). The practice of sustainable facilities management: design sentiments and the knowledge chasm. *Architectural Engineering and Design Management*, 5 (1-2), 91-102.
- Environment and Heritage (2011). Building a Conceptual Model. Viewed from: <http://www.environment.nsw.gov.au/4cmas/buildconceptmodel.htm>. Accessed on 20/06/2016.
- Ercoskun, K. and Kanoglu, A. (2003). Bridging the gap between design and use processes: Sector-based problems of a CRM oriented approach. *EuropIA International Conference: E-Activities and Intelligent Support in Design and the Built Environment*. 9. Istanbul, 21-27.
- Erdener, E. (2003). Linking Programming and Design with Facilities Management. *Journal of Performance in Constructed Facilities*, February, 4-8. Erlandson.
- Fähnrich, K. P., & Meiren, T. (2007). Service engineering: state of the art and future trends. In *Advances in services innovations* (pp. 3-16). Springer, Berlin, Heidelberg.
- Fatayer, F. A. A. (2012). *A framework for the involvement of the maintenance manager during the design development and review stages*. Doctoral Dissertation, King Fahad University of Petroleum and Minerals, Saudi Arabia.
- Fellows, R. F. and Liu, A. M. (2015). *Research methods for construction*. Oxford: John Wiley & Sons.
- Femi, O. T. (2014). Effects of faulty design and construction on building maintenance. *International Journal of Technology Enhancements and Emerging Engineering Research*, 2(5), 59-64.

- Fewings, P. (2005). *Construction project management: An integrated approach*, UK: Taylor and Francis.
- Fitz-Gibbon, C.T. (1990) *Performance Indicators, Multilingual Matters*, Clevedon, PA.
- Flores-Colen, I., de Brito, J. And de Freitas, V.P. (2008). Stain in facades' rendering – diagnosis and maintenance techniques' classification, *Construction and Building Materials*, 22, 211-221.
- FM LINK (2013) 20:20: The evolution of facilities management over the past eight years. [Internet]. *Facilities Management Magazine: FM World*. Available from:
<http://www.fmlink.com/article.cgi?type=Magazine&title=20%3A20%20Vision&pub=FM%20World&id=43788&mode=source>.
- Forcada, N., Macarulla, M., Gangoilells, M., & Casals, M. (2014). Assessment of construction defects in residential buildings in Spain. *Building Research & Information*, 42(5), 629-640.
- Formoso, C. T., Tzotzopoulos, P., Jobim, M. S., & Liedtke, R. (1998). Developing a protocol for managing the design process in the building industry. In *6th Annual Conference of the International Group for Lean Construction, Guarujá, SP*.
- Foster, B. (2011), BIM for Facility Management: Design for Maintenance Strategy. *Journal of Building Information Modelling*, 18-19.
- Fowler, F. J. (2014). *Survey research methods*. Vol. 1: Sage publications.
- Fraser, K. (2014). Facilities management: the strategic selection of a maintenance system. *Journal of Facilities Management*, 12(1), 18-37.
- Gabrielli, J. (2010) *Architecture. Whole Building Design Guide*, National Institute of Building Science, Washington, DC., USA.
- Ganisen, S., Nesan, J., Mohammad, I. S., Mohammed, A. H., & Kanniyapan, G. (2015). Facility management variables that influence sustainability of building facilities. *Jurnal Teknologi*, 75(10), 27-38.
- Ganiyu, A. Y. (2015). *A Framework for the Establishment of Building Services Standard Method of Measurement in Malaysia* (Doctoral dissertation, Universiti Teknologi Malaysia).
- Gatlin, F. (2013). Identifying & Managing Design and Construction Defects'. *Insight from Hindsight*, (5), 1-11.

- Georgoulis, S.W. (2008) Facility management: a profession at risk. MA thesis, Arizona State University, Tempe, AZ.
- Ghasson, S. (2003). A low-cost maintenance approach to high rise buildings. *Journal of Facilities*, 23, 315 – 322.
- Goh, S. C., Elliott, C., & Richards, G. (2015). Performance management in Canadian public organizations: findings of a multi-case study. *International Journal of Productivity and Performance Management*, 64(2), 157-174.
- Gray, C., & Hughes, W. (2001). *Building design management*. UK: Routledge.
- Griffin, J. J. (2003). Life cycle cost analysis: A decision aid. In *Life cycle costing for construction*, 147-158). Routledge.
- Guba, E.G. and Y.S. Lincoln. (1994). "Competing paradigms in qualitative research." *Handbook of qualitative research 2*: 163-194.
- Hahn, H. A. (2013). The conundrum of verification and validation of social science-based models. *Procedia Computer Science*, 16, 878-887.
- Han, S., Love, P., and Peña-Mora, F. (2013). A system dynamics model for assessing the impacts of design errors in construction projects. *Mathematical and Computer Modelling*, 57(9), 2044-2053.
- Hart, T. A., & Sharfman, M. (2015). Assessing the concurrent validity of the revised Kinder, Lydenberg, and Domini corporate social performance indicators. *Business & Society*, 54(5), 575-598.
- Hassanain, M. A. (2005). Guidelines for the design of water and sewage systems in buildings. *J. Archit. Eng.*, 10.1061/(ASCE) 1076-0431 (2005)11:4(117), 117–121.
- Hassanain, M. A., Adewale, B., Al-Hammad, A. M., & Sanni-Anibire, M. O. (2017). Factors affecting building services coordination during the design development and review stages. *Built Environment Project and Asset Management*, 8(1), 64-77.
- Hassanain, M. A., Al-Hammad, A. M., & Fatayer, F. (2014a). Assessment of architectural defects attributed to lack of maintenance feedback to the design team. *Architectural Science Review*, 57(2), 132-138.
- Hassanain, M. A., Fatayer, F., & Al-Hammad, A. M. (2014b). Design phase maintenance checklist for water supply and drainage systems. *Journal of Performance of Constructed Facilities*, 29(3), 04014082.

- Hassanain, M. A., Fatayer, F., & Al-Hammad, A. M. (2015a). Design-phase maintenance checklist for electrical systems. *Journal of Performance of Constructed Facilities*, 30(2), 06015003.
- Hassanain, M., Al-Hammad, A.-M., & Fatayer, F. (2014c). Assessment of defects in HVAC systems caused by lack of maintenance feedback to the design team. *Architectural Science Review*, 8628, 1–8.
- Hassanain, M., Al-Hammad, A.-M., & Fatayer, F. (2015b). Design phase maintenance checklist for structural durability. [Data set]. ISEC Press. <https://doi.org/10.14455/isec.res.2015.36>.
- Hauptfleisch, A. C., & Verster, J. J. P. (2011, June). Facilities management: Proposals for practice improvement and development support through educational programmes in South Africa. In Management and Innovation for a Sustainable Built Environment MISBE 2011, Amsterdam, The Netherlands, June 20-23, 2011. CIB, Working Commissions W55, W65, W89, W112; ENHR and AESP.
- Haynes, B., and Price, I. (2004). Quantifying the complex adaptive workplace. *Facilities*, 22(1/2), 8-18.
- Hernandez, G., Seepersad, C. C. and Mistree, F. (2002) Designing for Maintenance: A game theoretic approach. *Engineering Optimization*, 34, 561–577.
- Hertwich, E. G., and Peters, G. G. (2009). Carbon footprint of nations: A global, trade-linked analysis. *Environmental science & technology*, 43(16), 6414–6420.
- Hien, W. N., Poh, L. K., & Feriadi, H. (2003). Computer-based performance simulation for building design and evaluation: The Singapore perspective. *Simulation & Gaming*, 34(3), 457-477.
- Hochbaum, D. (2009) Dynamic evolution of economically preferred facilities. *European Journal of Operational Research*, 193, 649-659.
- Hodges, C. P. (2005). A facility manager's approach to sustainability. *Journal of Facilities Management*, 3(4), 312-324.
- Horgen, T. (1999). Excellence by design: Transformation of workplace and work practice. New York: Wiley.
- Hsu, I.-C. & Sabherwal, R., (2012). Relationship between Intellectual Capital and
Downloaded by Suffolk University At 14:54 23 January 2018 (PT) Knowledge Management: An Empirical Investigation. *Decision Sciences*, 43(3), 489–524.

- Hwang, B.-G., and Yang, S. (2014). "Rework and schedule performance: A profile of incidence, impact, causes and solutions." *Engineering, Construction and Architectural Management*, 21(2), 190-205.
- Hyde, T. M. (2000). Recognising Deductive Processes in Qualitative Research. *Qualitative Market Research: An International Journal*, 3(2), 82-89.
- Ihsan, B., & Alshibani, A. (2018). Factors affecting operation and maintenance cost of hotels. *Property Management*, (just-accepted), 00-00.
- Ilesanmi, A. O. (2010). Post-occupancy evaluation and residents' satisfaction with public housing in Lagos, Nigeria. *Journal of Building Appraisal*, 6, 153–169.
- Ishak, N. H., A. H. Chohan, and A. Ramly. (2007). Implications of Design Deficiency on Building Maintenance at Post-Occupational Stage. *Journal of Building Appraisal* 3 (2): 115–124.
- Islam, R., Mohamed, S. F., Bjørberg, S., Misnan, M. S., & Yusof, Z. M. Towards a Framework to Integrate Facilities Management Cost Effective Parameters in Design Process. *International Journal of Engineering and Technology*, 9(6), 4515-4526.
- Jalaei, F., Jrade, A., & Nassiri, M. (2015). Integrating decision support system (DSS) and building information modeling (BIM) to optimize the selection of sustainable building components. *Journal of Information Technology in Construction (ITcon)*, 20(25), 399-420.
- Jandali, D., & Sweis, R. (2018). Assessment of factors affecting maintenance management of hospital buildings in Jordan. *Journal of Quality in Maintenance Engineering*, 24(1), 37-60.
- Jaunzens, D., Warriner, D., Garner, U. and Waterman, A. (2001). Applying Facilities Expertise in Building Design. Construction Research Communication Ltd, London.
- Jawdeh, H. M. (2013). *Improving the integration of building design and facilities management* (Doctoral dissertation, University of Salford).
- Jawdeh, H., Wood, G., and Abdul-Malak, M. A. (2010). Altering design decisions to better suit facilities management processes. *Proceedings, International Conference for Enhanced Building Operations, Kuwait Institute for Scientific Research, Kuwait*.
- Jensen, P. A. (2008). The origin and constitution of facilities management as an integrated corporate function. *Facilities*, 26 (13), 490 – 500.

- Jensen, P. A. (2009) Design Integration of Facilities Management: A Challenge of Knowledge Transfer. *Architectural, Engineering and Design Management*, 5, 124-135.
- Jensen, P. A. (2011) Organisation of facilities management in relation to core business. *Journal of Facilities Management*, 9 (2), 78–95.
- Jensen, P. A., & van der Voordt, T. (2016). Towards an integrated value adding management model for FM and CREM. *WBC16 Proceedings*, 4, 332-344.
- Jensen, P. A., Nielsen, K., & Nielsen, S. B. (2008). *Facilities Management best practice in the nordic countries: 36 cases*: Centre for Facilities Management–Realdania Research.
- Jensen, P., van der Voordt, T., Coenen, C., von Felten, D., Lindholm, A.-L., Balslev Nielsen, S., Pfenninger, M. (2012). In search for the added value of FM: what we know and what we need to learn. *Facilities*, 30(5/6), 199-217.
- Jensen, P., van der Voordt, T., Coenen, C., von Felten, D., Lindholm, A.-L., Balslev Nielsen, S., Riratanaphong, C., and Pfenninger, M. (2012). In search for the added value of FM: what we know and what we need to learn. *Facilities*, 30(5/6), 199-217.
- Jin, X. H., Doloi, H., Gao, S. Y., (2007). Relationship-Based Determinants of Building Project Performance in China. *Construction Management and Economics* 25, 297-304.
- Josephson, P. E. (1998). Defects and Defect Costs in Construction-A study of seven building projects in Sweden. Working Paper, Department of Management of Construction and Facilities, Chalmers University of Technology, Sweden.
- Josephson, P. E., and Hammarlund, Y. (1999), The causes and costs of defects in construction: A study of seven building projects. *Automation in Construction*, 8(6), 681–687.
- Kalantari Hematabadi, S.S. (2014). *Toward an economic design process: enhancing building performance through better integration of facility management in the design process*. Doctoral dissertation, TX A&M University, College Station, TX.
- Kalantari, S., Shepley, M. M., Rybkowski, Z. K., and Bryant, J. (2017). "Designing for operational efficiency: facility managers' perspectives on how their knowledge can be better incorporated during design." *Architectural Engineering and Design Management*, 13(6), 457-478.

- Kamarazaly, M. A. (2014). Challenges in strategic facilities management: analysis of problems faced by university facilities managers in New Zealand and Australia. Doctoral dissertation, Massey University, New Zealand.
- Kamaruzzaman, S.N. and Zawawi, E.M.A. (2010), Development of facilities management in Malaysia, *Journal of Facilities Management*, 8(1), 75-81.
- Kamaruzzaman, S.N., Myeda, N.E., Pitt, M. (2013), Performance levels of high-rise private office buildings maintenance management in Malaysia. *Eksploatacja I Niezawodnosc- maintenance and reliability*, 15(2), 111-116.
- Katchamart, A. (2013). *Profiling value added position in FM: DTU Management Engineering*. PhD Thesis, Delft University of Technology.
- Kauppila, O., Mursula, A., Harkonen, J., & Kujala, J. (2015). Evaluating university–industry collaboration: the European Foundation of Quality Management excellence model-based evaluation of university–industry collaboration. *Tertiary Education and Management*, 21(3), 229-244.
- Kaya, S., & Alexander, K. (2006). Classifying client-side FM organisations in the United Kingdom: Why my in-house FM organisation is dissimilar to competitors and others. *Journal of Facilities Management*, 4(2), 86-98.
- Kelly, J. (2004). A proposition for a construction research taxonomy, edited, 1-3.
- Kelly, M. J. (2009). Retrofitting the existing UK building stock. *Building Research Information*, 37(2), 196–200.
- Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*: 3rd Ed. John Wiley & Sons.
- Kiong, N.B., and Akasah, Z.B. (2012). Analysis of building maintenance factors for IBS precast concrete system: a review. *International Journal of Engineering Research and Applications*, 2 (6), 878-883.
- Kulatunga, U., Liyanage, C. and Amaratunga, D. (2010) Performance measurement and management in facilities management. *Facilities*, 28 (5/6).
- Kumar, R. (2011). *Research methodology : a step-by-step guide for beginners* (3rd ed.). London: Sage.
- Kutucuoglu, K. Y., Hamali, J., Irani, Z., & Sharp, J. M. (2001). A framework for managing maintenance using performance measurement systems. *International Journal of Operations & Production Management*, 21(1/2), 173-195.

- Lam, K.C. (2007). Design for Maintenance from the Viewpoint of Sustainable Hospital Buildings. *The Australian Hospital Engineer*, 30(1), 30-34.
- Lateef, O. A. (2009). Building maintenance management in Malaysia. *Journal of Building Appraisal*, 4(3), 207-214.
- Lee, A.L. (1991). Integrating positivist and interpretive approaches to organisational research. *Organisation Science* 2 (4): 342-365.
- Lee, J.H. (1996). *Statistical deterioration models for condition assessment of older buildings*, unpublished PhD thesis, Wayne State University, Detroit, MI.
- Lindholm, A.-L. (2008) A constructive study on creating core business relevant CREM strategy and performance measures, *Facilities*, 26 (7/8), 343-58.
- Lindholm, A.-L. and Aaltonen, A. (2012) *Green FM as a way to create value*. Chapter 12 in: Jensen et al. eds. *The Added Value of Facilities Management – Concepts, Findings and Perspectives*. Centre for Facilities Management - Realdania Research, DTU Management Engineering, and Polyteknisk Forlag 195-204.
- Liu, R. and Issa, R.R.A (2013) Issues in BIM for Facility Management from Industry Practitioners Perspectives, *Journal of Computing in Civil Engineering*, 411 - 418.
- Liu, Y. (2006). A forecasting model for maintenance and repair costs for office buildings (Doctoral dissertation, Concordia University).
- Loosemore, M. and Hsin, Y.Y. (2001), Customer-focused benchmarking for facilities management, *Facilities* 19(13/14), 464-75.
- Lopez, R., & Love, P. E.D. (2012). Design error costs in construction projects. *Journal of Construction Engineering and Management*, 138(5), 585–593.
- Lopez, R., Love, P. E., Edwards, D. J., & Davis, P. R. (2010). Design error classification, causation, and prevention in construction engineering. *Journal of performance of constructed facilities*, 24(4), 399-408.
- Love, P. E. D., Lopez, R., Kim, J., & Kim, M. (2014). Influence of organizational and project practices on design error costs. *Journal of Performance of Constructed Facilities*, 28(2), 303–310.
- Love, P. E., & Li, H. (2010). Quantifying the causes and costs of rework in construction. *Construction Management & Economics*, 18(4), 479-490.
- Love, P. E., Edwards, D. J., & Smith, J. (2013). Systemic life cycle design error reduction model for construction and engineering projects. *Structure and Infrastructure Engineering*, 9(7), 689-701.

- Lowe, R. (2007). Addressing the challenges of climate change for the built environment. *Building Research Information*, 35(4), 343–350.
- Manzini, E. (2009) Viewpoint: New design knowledge. *Design Studies*, 30, 4- 12.
- Mark, S., Philip, L., & Adrian, T. (2009). Research methods for business students. *Harlow: Prentice Hall*.
- Marshall, C. and Rossman, G. B. (2011). *Designing Qualitative Research*. 5th Edition, Thousand Oaks, CA, Sage.
- Martin, C. S. and Guerin, D. A. (2006). Using research to inform design solutions. *Journal of Facilities Management*, 4 (3), 167-180.
- May, D., and Pinder, J. (2008). The impact of facilities management on patient outcomes. *Facilities*, 26(5/6), 213-228.
- Mazarella, F. (2011). Interior Design, Whole Building Design Guide. Washington, DC: National Institute of Building Sciences.
- McAuley, B, Hore, A, West, R & Wall, J (2012). The Economic Case for Early Adoption of Facilities Management', *International Conference on Facilities Management, Procurement Systems and Public Private Partnership: Delivering Value to the Community*, University of Cape Town, South Africa, 23-25 January.
- McAuley, B. (2016). *Identification of Key Performance Tasks to Demonstrate the Benefit of Introducing the Facilities Manager at an Early Stage in the Building Information Modelling process on Public Sector Projects in Ireland*. Doctoral Dissertation, Dublin Institute of Technology.
- McGaghie, W. C., Bordage, G. and J. A. Shea (2001). Problem Statement, Conceptual Framework, and Research Question. Retrieved on January 5, 2017 from <http://goo.gl/qLIUFg>.
- McLennan, P. (2000). Intellectual capital: future competitive advantage for facility management. *Facilities* 18(3/4):168-171.
- McLeod, S. A. (2014). The Interview Method. Retrieved from www.simplypsychology.org/interviews.html
- McMurray, A., R.W. Pace and D. Scott. (2004). *Research: A common sense approach*: Social Science Press.
- Meng, X. (2013). Involvement of Facilities Management Specialists in Building Design: United Kingdom Experience. *Journal of Performance of Constructed Facilities*, 27(October), 500–507.

- Meng, X. (2014). The role of facilities managers in sustainable practice in the UK and Ireland. *Smart and Sustainable Built Environment*, 3(1), 23-34.
- Meng, X., & Minogue, M. (2011). Performance measurement models in facility management: a comparative study. *Facilities*, 29(11/12), 472-484.
- Merritt, F. S., & Ricketts, J. T. (2001). *Building design and construction handbook* (Vol. 13). New York, NY: McGraw-Hill.
- Mertens, D. M. (2015). *Research and Evaluation in Education and Psychology: Integrating Diversity with Quantitative, Qualitative, and Mixed Methods*. 4th Edition, Thousand Oaks, CA, Sage Publications.
- Miles, M. B., and Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook* (2nd ed.). California: Sage Publications.
- Mirdeeliana, A. (2012), Customers Satisfaction Towards Maintenance Management in a Government Hospital Building in Malaysia in 1st *International Conference on Innovation and Technology for Sustainable Built Environment* 2012, 16-17 April 2012, Perak, Malaysia, 403-411.
- Mohamed, S. F. (2006). Improving Construction Site Management Practices Through Knowledge Management. Unpublished PhD. Thesis, Department of Civil and Building Engineering, Loughborough University, Leicestershire LE11 3TU, UK.
- Mohamed, S. F. (2010). Research Methodology Workshop: Latest Research Tools and Techniques. CRIOCM 2010 15th International Symposium on Advancement of Construction Management and Real Estate Towards Sustainable Development of International Metropolis, 6th August 2010.
- Mohammed, M. A., & Hassanain, M. A. (2010). Towards improvement in facilities operation and maintenance through feedback to the design team. *The Built & Human Environment Review*, 3, 72-87.
- Mohd-Noor, N., Hamid, M. Y., Abdul-Ghani, A. A., & Haron, S. N. (2011). Building maintenance budget determination: an exploration study in the Malaysia government practice. *Procedia Engineering*, 20, 435-444.
- Monga, A. and Zuo, M. J. (1998). Optimal system design considering maintenance and warranty. *Computers and Operations Research*, 25 (9), 691-705.
- Moore, M., & Finch, E. (2004). Facilities management in South East Asia. *Facilities*, 22(9/10), 259-270.

- Morris, T. (2006). *Social work research methods: Four alternative paradigms* thousand oaks: Sage.
- Mosey, D. (2009). *Early contractor involvement in building procurement: Contracts, partnering and project management*, Wiley-Blackwell, Oxford, U.K.
- Muhey, S. (2012). *Facility Management Model for Maintenance and Repair for Office Buildings*. Doctoral dissertation, Concordia University, Canada.
- Mustaffa, S.A.H., Adnan, H. and Jusoff, K. (2008), "Facilities management challenges and opportunity in the Malaysian property sector", *Journal of Sustainable Development*, 1(2), 79-85.
- Mutalib, A. F., Sapri, M., & Sipan, I. (2018). An assessment model of FM organisational performance. *Facilities*, 36(3/4), 212-226.
- Mydin, M. O., Salim, N. A., Tan, S. W., Tawil, N. M., & Ulang, N. M. (2014, January). Assessment of significant causes to school building defects. In *E3S Web of Conferences* (Vol. 3). EDP Sciences.
- Myeda, N. E., & Pitt, M. (2014). Facilities management in Malaysia: Understanding the development and practice. *Facilities*, 32(9-10), 490-508.
- Naoum, SG. (2006). *Dissertation research and writing for construction students*: Butterworth-Heinemann.
- Neely, A. and Bourne, M. (2000) Why measurement initiatives fail *Measuring Business Excellence* 4(4), 3-6.
- Neuman, W. L. (2006). Analysis of qualitative data. *Social research methods: Qualitative and quantitative approaches*, 457-489.
- Neuman, W., and Kreuger, L. W. (2012). *Social Work Research Methods: Qualitative and Quantitative Applications*. Boston: Allyn and Bacon.
- Newton, L.A. and Christian, J. (2006). Impact of Quality on Building Costs. *Journal of Infra Structure Systems*, 199-206
- Nkala, S. M. (2016). *Defining early facilities management involvement using the concepts of performance management*(Doctoral dissertation). University of the Witwatersrand, Johannesburg.
- Nutt, B. (2000), Four competing futures for facility management, *Facilities*, 18(3/4). 124-132.
- Ofori, I., Duodu, P., & Bonney, S. (2015). Establishing factors influencing building maintenance practices: Ghanaian perspective. *Journal of Economics and Sustainable Development*, 6(24), 184-193.

- Ogungbile, A. J., & Oke, A. E. (2015). Assessment of facility management practices in public and private buildings in Akure and Ibadan cities, south-western Nigeria. *Journal of Facilities Management*, 13(4), 366-390.
- Ohara, S. and Asada, T. (2009). *Japanese project management* – Hackensack, NJ: World Scientific.
- Olaniyi, O. O. (2017). *Development of a facilities management framework for sustainable building practices in Nigeria*. Doctoral dissertation, University of Central Lancashire.
- Olatunji, A. and Sher, W. (2009). Process problems in facilities management: An analysis of feasibility and management indices. International Postgraduate Research Conference. 9. The Lowry, Salford Quays, Greater Manchester.
- ÖNORM B 1801-2, Project and object management in construction – Part 2: Follow-up costs for constructions, Austrian Standards Institute, 2011.
- Oyedele, L. and Tham, K. W. (2007) Clients' assessment of architects' performance in building delivery process: Evidence from Nigeria. *Building and Environment*, 42, 2090–2099.
- Pallant, J. (2010). *SPSS survival manual: A step by step guide to data analysis using SPSS*: Open University Press.
- Patton, M. Q. (2002). *Qualitative Evaluation and Research Methods-3rd edition*: Thousand Oaks, Calif.: Sage.
- Paumgarten, P. V. (2003) The business case for high performance green buildings: Sustainability and its financial impact. *Journal of Facilities Management*, 2 (1), 26 – 34.
- Peansupap, V., & Ly, R. (2015). Evaluating the impact level of design errors in structural and other building components in building construction projects in Cambodia. *Procedia Engineering*, 123, 370-378.
- Peltier, J. W., Zahay, D., & Lehmann, D. R. (2013). Organizational learning and CRM success: a model for linking organizational practices, customer data quality, and performance. *Journal of Interactive Marketing*, 27(1), 1-13.
- Pesola, O. (2017). Differences between real estate maintenance costs in Scandinavia, Middle East, China and Spain-The savings potential through facility management software. Master Dissertation, Aalto University, Finland.
- Phadtare, M. T. (2010). Developing Balanced Scorecard: Case of three construction firms of small size. *Journal of Asia-Pacific Business*, 11(2), 135-157.

- Pitt, M. & Tucker, M. (2008) Performance measurement in facilities management: driving innovation? *Property Management*, 26 (4), 241-254.
- Plaut, J. M., Dunbar, B., Wackerman, A., and Hodgins, S. (2012). "Regenerative design: the LENSES Framework for buildings and communities." *Building Research & Information*, 40(1), 112-122.
- Politis, Y., Litos, C., Grigoroudis, E. and Moustakis, V.S. (2009) A business excellence model for the hotel sector: Greek hotels *Benchmarking: An International Journal* 16(4), 462-3.
- Price, S., Pitt, M. and Tucker, M. (2011) Implications of a sustainability policy for facilities management organizations. *Facilities*, 29 (9), 391 – 410.
- Project Guidance (2009) WBDG [Internet]. National Institute of Building Science. Available from: <http://www.wbdg.org/design/index.php>
- Project Management Institute (2008). A guide to the project management body of knowledge, 4th Ed., Project Management Institute, Newtown Square, PA.
- Pryke, S., and Smyth, H. (2006). The management of complex projects: A relationship approach, Blackwell, Oxford, U.K.
- Pulaski, M. H., and Horman, M. J. (2005). Organizing constructability knowledge for design. *Journal of Construction Engineering Management*, 8(911), 911–919.
- Putnam, C. And Price, S. (2004) High-performance facilities engineering: Preparing the team for the sustainable workplace. *Journal of Facilities Management*, 3 (2), 161 – 172.
- Rahman, H., Wang, C., Wood, L. C., & Khoo, Y. M. (2012). Defects in affordable housing projects in Klang Valley, Malaysia. *Journal of Performance of Constructed Facilities*, 28(2), 272-285.
- Rahman, S. B. A. & Salim, N. A. A. (2013) A Study on Design Defects Affecting Maintenance. 5th *Undergraduate Maintenance and Facilities Management Conference 2013*,
- Raman, M. (2009). Mitigating climate change: What America's building industry must do. Design intelligence, (<http://www.di.net/articles/mitigating-climate-change-what-americas-building-industry-must-do/>) (Apr. 8, 2015)
- Ramly, A. (2006). A link between design and maintenance. *Journal of Building Engineers*, 81 (5).
- Ramsey, C. G., and Sleeper, H. R. (2008). Architectural Graphic Standards, Student ed. NJ: John Wiley & Sons.

- Ransley, J. and Ingram, H. (2001). What is "good" hotel design? *Facilities*, 19 (1/2), 79-86
- Remeli, S. (2014). *Enhancing Building Services Cost Management Knowledge Among Quantity Surveyors* (Doctoral dissertation, Universiti Teknologi Malaysia).
- Riratanaphong, C. (2014). *Performance measurement of workplace change: in two different cultural contexts*: Delft University of Technology.
- Riratanaphong, C., & van der Voordt, T. (2015). Measuring the added value of workplace change: performance measurement in theory and practice. *Facilities*, 33(11/12), 773-792.
- Rondeau, E.P., Brown, R.K. and Lapidés, P.D. (2006). *Facility Management*, Hoboken, NJ: John Wiley & Sons.
- Roslan, Q., Ibrahim, S. H., Affandi, R., Nawi, M. N. M., & Baharun, A. (2016). A literature review on the improvement strategies of passive design for the roofing system of the modern house in a hot and humid climate region. *Frontiers of Architectural Research*, 5(1), 126-133.
- Ross B, Lopez-Alcala M, Small III A. A. (2006) Modeling the private financial returns from green building investments. *Journal of Green Building*, 2 (1), 97–105.
- Rounce, G. (1998). Quality, waste and cost considerations in architectural building design and management. *International Journal of Project Management*, 16(2), 123-127.
- Rowley, J. (2002). Using Case Studies in Research. *Management Research News*, 25(1), 16-27.
- Royal Institute of British Architects (RIBA) (2013), *RIBA Plan of Work 2013 Overview*, London: RIBA Publishing.
- Samad, A., Basari, H. & Wahab, Y.A. (2013). Building Maintenance Management Preliminary Finding of a Case Study in Icym. *Middle-East Journal of Scientific Research*, 17(9), 1260–1268.
- Sambasivan, M. and Yau, S.W. (2007), Causes and effects of delays in Malaysian construction industry, *International Journal of Project Management*, Vol. 25 No. 5, pp. 517–526.
- Sapp, D. (2009). *Facilities operation and maintenance. Whole Building Design Guide*. Washington: National Institute of Building Sciences.

- Sarasoja, A., & Aaltonen, A. (2012). Green FM as a way to create added value. *The added value of facilities management: concepts, findings and perspectives.*, Denmark: Polyteknisk Forlag.
- Sarpin, N. (2015). *Developing people capabilities for the promotion of sustainability in facility management practices* (Doctoral dissertation, Queensland University of Technology).
- Sarshar, M., Haigh, R., Finnemore, M., Aouad, G., Barrett, P., Baldry, D. and Sexton, M. (2000) SPICE: a business process diagnostics tool for construction projects *Engineering, Construction and Architectural Management* 7(3), 241-50.
- Schwarz, E.C., Hall, S. and Shibli, S. (2010) *Sport Facility Operations Management: A Global Perspective*, London: Butterworth-Heinemann.
- Seeley, I.H. (1987). *Building Maintenance*, 2nd Ed. New York: Palgrave.
- Sekaran, U. (2003). *Research methods for business: A skill-building approach*. NYC: John Willey Sons.
- Shari, Z. (2011). Development of a sustainability assessment framework for Malaysian office buildings using a mixed-methods approach. Doctoral dissertation, The University of Adelaide.
- Shehu, Z., & Akintoye, A. (2010). Major challenges to the successful implementation and practice of programme management in the construction environment: A critical analysis. *International Journal of Project Management*, 28(1), 26-39.
- Shen, W., Shen, Q., & Xiaoling, Z. (2012). A user pre-occupancy evaluation method for facilitating the designer-client communication. *Facilities*, 30(7/8), 302-323.
- Shohet, I.M. (2006), Key performance indicators for strategic healthcare facilities maintenance, *Journal of Construction Engineering and Management*, 132(4), 345-52.
- Sillanpää, E. and Junnonen, J-M (2012) Factors affecting service innovations in FM service sector. *Facilities*, 30 (11/12), 517-530.
- Silva-Afonso, A., and Russo, C. (2010). Deconstruction of building systems of water supply and drainage. Proc., *Int. Symp. on Water Supply and Drainage for Buildings*, International Council for Research and Innovation in Building and Construction (CIB), Rotterdam, Netherlands.
- Smith, M., R. Thorpe and A. Lowe. (2008). *Management Research*: London: Sage.

- Smyth, R. (2004). Exploring the Usefulness of a Conceptual Framework as a Research Tool: A Researcher's Reflections. *Issues in Educational Research*, 14.
- Sohi, A. J. (2015). *Maintainability Issues in Building Design and Operation* (Doctoral dissertation). Illinois Institute of Technology.
- Song, L., Mohamed, Y., and AbouRizk, S. M. (2009). Early contractor involvement in design and its impact on construction schedule performance. *Journal of Management Engineering*, 25(1), 12–20.
- Stewart, A. (2003) An investigation of the suitability of the EFQM Excellence Model for a pharmacy department in NHS Trust *International Journal of Health Care Quality Assurance* 16(2), 65-76.
- Strauss, A.L. and J. Corbin. (1998). Basics of qualitative research: Technique and procedures for developing grounded theory (2nd ed.), Canada: Sage.
- Sullivan, K., Georgoulis, S. W. and Lines, B. (2010) Empirical study of the current United States facilities management profession. *Journal of Facilities Management*, 8 (2), 91 – 103.
- Takim, R. and Adnan, H. (2008). Analysis of Effectiveness Measures of Construction Project Success in Malaysia. *Asian Social Science (CCSE)*. 4 (7), 2008.
- Tan, A. Z. T., Zaman, A., & Sutrisna, M. (2018). Enabling an effective knowledge and information flow between the phases of building construction and facilities management. *Facilities*, 36(3/4), 151-170.
- Tan, Y., Shen, L., Langston, C., Lu, W., & CH Yam, M. (2014). Critical success factors for building maintenance business: a Hong Kong case study. *Facilities*, 32(5/6), 208-225.
- Tay, L. and Ooi, J.T.L. (2001). Facilities management: a 'Jack of all trades'? *Facilities*, 19(10), 357-362.
- Teicholz, E. ed. (2001). *Facilities Design and Management Handbook*. New York, McGraw-Hill.
- Tladi, K. (2012). *Evaluating the facility manager's role in project design* (Doctoral dissertation, Faculty of Engineering and the Built Environment, School of Construction and Economics Management, University of the Witwatersrand, Johannesburg).
- Tucker, M., and Masuri, M. R. A. (2016). The rationale to integrate facilities management into the development process. *Property Management*, 34(4), 332–344.

- Turner, R. (2008) *Handbook of Project Management*, 4th ed., Gower, Aldershot.
- van der Voordt, T., & Jensen, P. A. (2014). Adding Value by FM: an exploration of management practice in the Netherlands and Denmark. *European Facility Management Conference, EFMC 2014, Berlin, Germany*. 1-11.
- Van der Zwart, J. (2014). *Hospital real estate management in a changing context*. PhD-thesis, Delft University of Technology.
- van Meel, J., Martens, Y., & van Ree, H. J. (2010). *Planning office spaces: a practical guide for managers and designers*. London: Laurence King.
- W. Paul Vogt, (2007). *Quantitative Research Methods for Professionals*. Published by Pearson Education, Inc.
- Waas, T. et al. (2010) University research for sustainable development: definition and characteristics explored. *Journal of Cleaner Production*, 18 (7), 629-636.
- Walker, A. (2002) *Project Management in Construction, 4th Edition*. Oxford: Blackwell Publishing.
- Wan, S. K. M., and Kumaraswamy, M. M. (2012), "Improving building services coordination at the pre-installation stage", *Engineering, Construction and Architectural Management*, 19(3), 235-252.
- Wang, N., Wei, K., & Sun, H. (2013). Whole life project management approach to sustainability. *Journal of Management in Engineering*, 30(2), 246-255.
- Way, M. (2006). Soft landings: A fresh scope of service that ensures users and clients get the best out of a new building. *Journal of Facilities Management*, 4(1), 23-39.
- Waziri, B. S. (2016). Design and construction defects influencing residential building maintenance in Nigeria. *Jordan Journal of Civil Engineering*, 10(3).
- Wilkinson, D. and Birmingham, P. (2003). *Using research instruments: A guide for researchers*. London: Psychology Press.
- Wong, F. W., Lam, P. T., & Chan, E. H. (2009). Optimising design objectives using the Balanced Scorecard approach. *Design Studies*, 30(4), 369-392.
- Wong, I., & Chan, A. (2014). How to Quantify Quality Architectural Design from the Aspect of Building Maintenance. In *ICCREM 2014: Smart Construction and Management in the Context of New Technology*, 1472-1479).
- Wongrassamee, S., Gardiner, P.D. and Simmons, J.E.L. (2003), Performance measurement tools: the Balanced Scorecard and the EFQM Excellence Model, *Measuring Business Excellence*, 7(1), 14-29

- Wood, B. (2011). Maintenance integrated design and manufacture of buildings: Toward a sustainable model. *Journal of architectural engineering*, 18(2), 192-197.
- Wright, K. B. (2005). Researching Internet-based populations: Advantages and disadvantages of online survey research, online questionnaire authoring software packages, and web survey services. *Journal of computer-mediated communication*, 10(3).
- Yap, J. B. H., Low, P. L., & Wang, C. (2017). Rework in Malaysian building construction: impacts, causes and potential solutions. *Journal of Engineering, Design and Technology*, 15(5), 591-618.
- Ye, G., Jin, Z., Xia, B., and Skitmore, M. (2014). "Analyzing causes for reworks in construction projects in China." *Journal of Management in Engineering*, 31(6), 04014097.
- Yin, R.K. (2014) *Case Study Research: Design and Methods: 5th Edition*. California: Sage Publications.
- Yip, C. P. and C. S. Poon. (2009). Cultural shift towards sustainability in the construction industry of Hong Kong. *Journal of Environmental Management* 90 (11): 3616-3628.
- Yiu, C.Y. (2008), A conceptual link among facilities management, strategic management and project management, *Facilities*, 26(13/114), 501-511.
- Yong, Y.C. and Mustaffa, N.E. (2013), Critical success factors for Malaysian construction projects: An empirical assessment, *Construction Management & Economics*, 31(9), 959–978.
- Zawawi, E. M. A., Kamaruzzaman, S. N., Abdul Samad, Z. A., & Myeda, E. N. (2010). A quick survey on maintenance management practice in Malaysian building industry. *In Proceedings of 1st Regional Symposium on sustainable construction material and building system (SUCOMBS)*. 229-236.
- Zhou, L. (2014). *International Benchmarking in Facility Management – Comparison of Different National Benchmarking Pools*. Doctoral Dissertation, Graz University of Technology, Austria.
- Zhu, L., Shan, M., & Hwang, B. G. (2017). Overview of Design for Maintainability in Building and Construction Research. *Journal of Performance of Constructed Facilities*, 32(1), 04017116.