A STUDY ON LIFE CYCLE COST (LCC) ANALYSIS OF RIGID PAVEMENT MAINTENANCE AND REHABILITATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

BY

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A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Built Environment)

Kulliyyah of Architecture and Environmental Design
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SEPTEMBER 2019

ABSTRACT

Life Cycle Cost (LCC) analysis has been recognized as one of the emerging methodologies in cost estimation that can evaluate and compares the cost-effectiveness of different rigid pavement maintenance and rehabilitation alternatives throughout its service lifespan. However, the main drawback of LCC implementation resides with the inferior acquisition of quality cost data inputs (i.e. data availability, accessibility, currency and reliability) to produce a comprehensive and reliable LCC output. In relation to rigid pavement maintenance and rehabilitation in the Malaysian construction industry, the objectives of this research are; i) to identify the most appropriate mathematical cost model that can be applied in the LCC analysis, ii) to assess the quality of cost data inputs with regard to its availability, accessibility, currency and reliability that can be used for LCC analysis, and iii) to evaluate the most appropriate strategies that can be carried out to improve the quality of cost data inputs for LCC analysis. In order to answer the research objectives, qualitative research strategy was adopted, which face-to-face interview was carried out with the respondents who have skills, knowledge or experience in the LCC analysis, or rigid pavement maintenance and rehabilitation works to get their opinions on the subject matter. The literature review also was adopted in this research to study the background of the research and to construct the interview questionnaire. The findings of this research established that the Net Present Value (NPV) is the most appropriate mathematical cost model to be used for LCC analysis of rigid pavement maintenance and rehabilitation. Nevertheless, this research also presents that the cost data inputs for LCC analysis are not ready and quality enough to be used for LCC analysis of rigid pavement maintenance and rehabilitation in the Malaysian construction industry. Thus, this research presents strategies that are considered very appropriate to be proposed in facilitating the cost estimators to elevate the quality of the cost data inputs for LCC analysis, which are; i) the responsible organizations (i.e., PWD, CIDB, MHA, etc.) and educational institution can do research collaborations to improve the LCC applications and the quality of cost data inputs to be used for LCC analysis of rigid pavement maintenance and rehabilitation, ii) there is also need for establishment of LCC specific team in the field of LCC analysis of rigid pavement maintenance and rehabilitation, and iii) the responsible organizations can impose every private agency and concessionaires to submit a well-organized data in order to develop a centralized database for LCC analysis of rigid pavement maintenance and rehabilitation in the Malaysian construction industry.

خلاصة البحث

كواحدة من المنهجيات الناشئة في تقدير التكلفة (LCC) لقد تم التعرف على تحليل تكلفة دورة الحياة التي يمكن أن تقيم وتقارن بين فعالية التكلفة لمختلف بدائل صيانة الرصيف الجامدة وإعادة التأهيل طوال في الحصول على مدخلات منخفضة LCC فترة خدمتها. ومع ذلك، يكمن العيب الرئيسي في تنفيذ التكلفة لبيانات الجودة (أي توفر البيانات وإمكانية الوصول إليها والعملة والموثوقية) لإنتاج مخرجات شاملة وموثوقة. فيما يتعلق بصيانة الأرصفة الصلبة وإعادة تأهيلها في صناعة البناء الماليزية، فإن LCC ، ب) LCC أهداف هذا البحث هي: أ) تحديد أنسب نموذج تكلفة رياضية يمكن تطبيقه في تحليل تقييم جودة مدخلات بيانات التكلفة فيما يتعلق بتوفرها وإمكانية الوصول إليها وعملتها وموثوقيتها التي ، ج) وتقييم أنسب الاستراتيجيات التي يمكن تنفيذها لتحسين جودة LCC يمكن استخدامها لتحليل من أجل الإجابة على أهداف البحث. وتم الاعتماد على LCC مدخلات بيانات التكلفة لتحليل إستراتيجية البحث النوعي، والتي أجريت مقابلة وجهاً لوجه مع المجيبين الذين لديهم مهارات أو معرفة أو ، أو أعمال صيانة وإعادة تأهيل الرصيف الجامدة للحصول على آرائهم حول LCC خبرة في تحليل الموضوع. كما تم اعتماد مراجعة الأدبيات في هذا البحث لدراسة خلفية البحث وبناء استبيان المقابلة. هو أنسب نموذج تكلفة رياضية ليتم (NPV) لقد أثبتت نتائج هذا البحث أن صافي القيمة الحالية لصيانة الأرصفة الصلبة وإعادة تأهيلها. ومع ذلك، يعرض هذا البحث أيضًا LCC استخدامه لتحليل LCC ليست جاهزة وجودة كافية لاستخدامها في تحليل LCC أن مدخلات بيانات التكلفة لتحليل لصيانة الأرصفة الصلبة وإعادة تأهيلها في صناعة البناء الماليزية. وبالتالي، يقدم هذا البحث استراتيجيات LCC مناسبة للغاية لاقتراحها في تسهيل مقدري التكلفة لرفع جودة مدخلات بيانات التكلفة لتحليل ، إلخ) MHA، CIDB، وهي: 1) يمكن للمنظمات المسؤولة (أي الأشخاص ذوي الإعاقة ، وجودة مدخلات بيانات LCC والمؤسسة التعليمية القيام بعمليات تعاون بحثية لتحسين تطبيقات هناك حاجة أيضًا لصيانة الأرصفة الصلبة وإعادة تأهيلها ، 2) LCC التكلفة لاستخدامها في تحليل لصيانة وإعادة تأهيل الرصيف الجامدة، 3) ويمكن LCC في مجال تحليل LCC إلى إنشاء فريق محدد للمؤسسات المسؤولة فرض كل وكالة خاصة وأصحاب الامتياز على تقديم بيانات منظمة بشكل جيد لصيانة الرصيف الصلب وإعادة التأهيل في صناعة LCC من أجل تطوير مركزية قاعدة بيانات لتحليل البناء الماليزية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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Mohd Fairullazi Ayob
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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ACKNOWLEDGEMENTS

First and foremost, all praises to Allah S.W.T. for His greatness and for giving me ideas and strength in preparing and completing this thesis.

A special thanks to my dedicated supervisor, Asst. Prof. Ir. Dr. Mohd Fairullazi Ayob for consistently giving endless guidance, encouragement and leadership during his time supervising me. Not to forget to thank my former co-supervisor, Prof. Sr. Dr. Khairuddin Abdul Rashid for the useful comments, remarks and engagement through the learning process of this master thesis.

For always staying by my side, I must express my very profound gratitude to my lovely parents, Ahmad Jasmi Don and Rohani Hassan and my family members, especially my sister and my brother, Siti Zubaidah and Muhamad Fairuz, and not to forget Bro Khairy and Sis Emme Eryanie, this thesis is a gift for all of you. Plus, I really appreciate assistance and companionship from my fellow MSBE peers, Khalisah, Baiti, Wahidah, Ain and my beloved friends, Zaitun, Amira, Aisyahs and others for comforting as well as forever motivating throughout my years of study. This accomplishment would not have been possible without them and may Allah reward them with far more rewarding gifts.

Last but not least, I wish to express my appreciation and thanks to those who provided their time, effort and support for this project. I would also like to thank the respondents who were involved in the data collection for this research project. Without their passionate participation and inputs, the data collection process could not have been successfully conducted.

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LIST OF ABBREVIATIONS

ASR	Alkali-silica reaction
ASTM	American Society for Testing and Materials
BAM	Board of Architects Malaysia
BEM	Board of Engineers Malaysia
BIM	Building Information Modelling
BNM	*Bank Negara Malaysia* (Central Bank of Malaysia)
BQSM	Board of Quantity Surveyors Malaysia
BS	British Standard
BS ISO	British Standard and International Organization for Standardization
BSI	British Standard Institution
Caltrans	California Department of Transportation
CAPEX	Capital expenses
CBS	Cost breakdown structure
CIDB	Construction Industry Development Board
CPR	Concrete Pavement Repair
CRCP	Continuously Reinforced Concrete Pavement
CSR	Central Spine Road
DBKL	*Dewan Bandaraya Kuala Lumpur* (Kuala Lumpur City Hall)
DCP	Dynamic Cone Penetrometer
DMI	Distress Manifestation Index
DOSM	Department of Statistics Malaysia
DPB	Discounted payback
DT	Destructive test
ECER	East Coast Economic Region
EPU	Economic Planning Unit
et al.	(et alia); and others
etc.	(et cetera); and so forth pages that follow
EUAC	Equivalent Uniform Annual Cost
ft.	feet
FWD	Falling Weight Deflectometer
FWHA	Federal Highway Administration
HDM-4	Highway Development and Management
i.e.	That is
IRI	International Roughness Index
IRR	Internal rate of return
JPCP	Jointed Plain Concrete Pavement
JRCP	Jointed Reinforced Concrete Pavement
KKH	*Kos Kitaran Hayat* (Life Cycle Cost)
km	kilometre
LCC	Life Cycle Cost
m	meter
MHA	Malaysian Highway Authority
mm	millimetre
n.d.	no date
N3C	National Construction Cost Centre
NATO	North Atlantic Treaty Organization
NCHRP	National Cooperative Highway Research Program
NDT	Non-destructive test
NPV	Net Present Value
NPW	Net Present Worth
NS	Net Saving
NSE	North-South Expressway Project
OPEX	Operation expenses

p.	page
PAM	Malaysian Institute of Architects
PCC	Portland Cement Concrete
PCI	Pavement Condition Index
PFI	Private Finance Initiative
Ph.D	Doctor of Philosophy
PIARC	World Road Association (Permanent International Association of Road Congresses)
PLUS	*Projek Lebuhraya Utara Selatan*
PMS	Pavement Management System
PROPEL	*Projek Penyelenggaraan Lebuhraya Berhad*
PV	Present value
PWCIC	Public Work Cost Information Centre
PWD	Public Works Department
R&D	Research and development
RATOL	Rates Online
RCI	Riding Comfort Index
RCR	Riding Comfort Rating
Resp.	Respondents
RICS	Royal Institution of Chartered Surveyors
RISM	Royal Institution of Surveyors Malaysia
SD	Standard deviation
SDI	Surface Distress Index
SPB	Simple Payback
sq. ft.	square feet
U.S.	United States

CHAPTER ONE

INTRODUCTION TO THE RESEARCH

1.1 INTRODUCTION

The focus of the study is Life Cycle Cost (LCC) cost data input requirements for the maintenance and rehabilitation of rigid pavement. This chapter illustrates the introductory elements of the research, which include:

i. Background study
ii. Problem statement
iii. Research gap
iv. Research questions
v. Aim and objectives of the research
vi. Scope and limitation of the research
vii. Significance of the research
viii. Organization of the research
ix. Papers in support of this thesis

1.2 BACKGROUND STUDY

The impact of road infrastructures on society and the environment has been the object of scrutiny investigation in recent time. In Malaysia, physical road infrastructures such as roads and highways are imperative for providing social access to employment, health, education, and daily activities in order to stimulate the social and economic function in society (Ramachandran, 2017). Due to its imperative function, road infrastructures in Malaysia are undergoing rapid development that has improved nationwide linkages in achieving better connectivity. As a part of the social obligation to its citizen, the government of Malaysia has invested RM2 billion for the construction of new Pan-Borneo Highway and RM934 million for the construction of rural roads in Malaysia to improve accessibility in Sabah and Sarawak (Mohamed Radhi & Hamid, 2018). A recent report by Economic Planning Unit indicates The National Road Development Index, which is used to measure the level of road development in Malaysia, has risen from 1.42 to 2.29 in the year 2010 to 2015 as a result from this investment (Eleventh Malaysia Plan (2016-2020), Economic Planning Unit, 2015). This positive indicator reflects the Government's commitment to ensuring the road infrastructures as public assets are adequate for public access to help the nation grow and develop.

However, although the Malaysian government has allocated an immense amount of money to construct new roads and highways, the quality and performance of existing roads throughout its service lifespan are still relatively low compared to the developed nation (Mohd Yunus, 2017; Wan Omar, 2015). The drawback of this situation leads to increasing future cost of maintenance and rehabilitation. A recent report stated that a road maintenance company's outstanding order book has been amounting at staggering RM4.2 billion up to 2026 and is projected to grow continuously from the 2018 financial year onwards (Mohammed, 2018). The effect of this situation is substantial, as it may further hamper economic and urban growth in the long run. Thus, addressing this problem requires proper mitigation strategies to prolong its useful service life (Mohamed, 2010; World Road Association (PIARC), 2014).

One of such strategies is the usage of the more resistant type of pavement such as rigid pavement. In general, road infrastructure in Malaysia can be divided into two main types, which are flexible pavement and rigid pavement. The benefits of rigid pavement over flexible pavement resides with its ability to provide longer service life with a lower requirement for maintenance as it is constructed from higher quality and more durable materials (Khan & Harwalkar, 2014). However, due to its higher associated cost (Mohod & Kadam, 2016) and complicated construction method (Suanmali & Ammarapala, 2010) compared to the flexible pavement, the implementation of rigid pavement is quite limited. The effect of this situation leads in its deployment on only selected roads especially in Malaysia rural areas and high traffic flow expressway (i.e. North-South Expressway) (Public Works Department, 2014; Yaacob, 2018).

1.3 PROBLEM STATEMENT

While selecting the construction method is vital in determining the overall quality of road pavement, cost also plays a vital criterion for successful project execution and future maintenance work. Due to road infrastructures complexity involving a nation-wide system with the different geotechnical and meteorological condition, a comprehensive methodology of cost calculation is needed before the execution of any road development.

Life Cycle Cost (LCC) can be defined as an economic assessment technique that applies mathematical method to estimate total ownership costs of the asset which associates the initial capital cost with the operation costs, maintenance costs, replacement costs, financial costs, and salvage cost over an anticipated life (Ayob, Abdul Rashid, Bidi, & Ahmad Jasmi, 2017; BS 8544, 2013; BS ISO 15686-5, 2008; Goh, 2011; Wan Hassan, Zakaria, & Ismail, 2014b). In literature, LCC analysis is one of the emerging methodologies in cost calculation to determine the costing at the initial stage of infrastructure's development and feasibility of the project development until project completion. It acts as a mechanism that permits transportation organizations to measure the differential costs of alternative investment options for a given project (Ramachandran, 2017). This also includes the evaluation for pavement types selection, the initial quality and performance of pavement design, and the financial impact on the road agency and the road users. The versatility of LCC analysis is imperative, as it can also be used to examine the most cost-effective maintenance strategies in preserving the existing road pavement projects (Babashamsi, Md Yusoff, Ceylan, Md Nor, & Jenatabadi, 2016a). Furthermore, it is also has been highlighted in the Strategy A2 in Chapter 7 of the Eleventh Malaysia Plan (2016-2020), where maintaining the roads in good condition is essential for ensuring the effectiveness of the road network, and functions as required standards throughout its lifespan (Economic Planning Unit, 2015).

However, the accuracy and reliability of LCC analysis estimation are highly dependent on the quality of available data inputs (Heralova, 2017; Mahamid, 2013). Data inputs are the vital information which required to compute the LCC analysis using the mathematical cost models. There are various types of data inputs for LCC analysis. However, the main focus of this research is on the cost data inputs. As stated by the World Road Association (PIARC) (2013), cost data is the most important criteria in a pavement management organization to produce better decisions for pavement management. In this sense, the quality of the cost data inputs used in the LCC estimation including the agency cost data, road user cost data, and financial cost data are depended on the ability of the data to give accurate information to be incorporated into LCC analysis practice. It is also crucial to implement LCC analysis during the early stage of the feasibility study before undertaking any road infrastructure project. The advantage of performing a feasibility study helps the stakeholders to determine whether the project is suitable to be constructed (Heralova, 2017) after considering associated costs and its impact on society and the environment. While conducting LCC estimation during the feasibility stage is essential, there are some significant difficulties arise in this stage. Such concerns involved the lack of data availability, deficiency of preliminary information, unavailability of road work cost database and the shortage of current cost estimation methods for road infrastructure (Heralova, 2017).

On the other note, maintenance can be described as works carried out to maintain the road condition to its required functional state of operation (Chang, Rodriguez, Yapp, & Pierce, 2018). Maintenance works are generally performed to maintain the condition of the pavement and extend its performance whereas repair works act as remedial works which to restore the damaged or distressed pavement to their normal operating condition (Adnan, Mohd Fauzi, Rahmat, & Supardi, 2012). In Malaysia, the degraded pavement begins to show signs of defect, which requires repair as part of the pavement maintenance works (Adnan et al., 2012; Wan Omar, 2015). Typically, the repairing work involves only the surface of the pavement without taking into account the structural works. On the other hand, rehabilitation works are more extensive, which involves the structural strength enhancement to extends the service life of the pavement. Thus, the rehabilitation works require a substantially more extended period to carry out and more costly (Chang et al., 2018; Wan Omar, 2015). Besides that, upgrading works are also categorized as one of the rehabilitation works, which involve the structure of the pavement (Sahari, 2018).

From this study perspective on the rigid pavement maintenance and rehabilitation, the remedy of this concern requires LCC analysis to be at an assured