READINESS OF LIFE CYCLE COST (LCC) DATA INPUTS FOR LCC ANALYSIS OF NEW FLEXIBLE PAVEMENT CONSTRUCTION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

BY

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ABSTRACT

Most of the flexible pavement constructions in Malaysia are designed with a lifespan ranging between ten to fifteen years. The selection of quality design and effective construction method in the early design would minimize maintenance and rehabilitation works in the future. However, the literature study has identified that the traditional practice of clients in the Malaysian construction industry focuses on the cheapest construction cost but ignored the future cost. As a result of this, the clients may encounter difficulty to achieve long-term cost saving because the greater focus is given on the cheapest construction cost instead of the optimal total cost of road pavement throughout entire service life of flexible pavement. Life Cycle Cost (LCC) analysis is increasingly recognized as an important economic assessment technique to provide cost information to facilitate the clients in achieving potential cost savings. This study is carried out to discover the LCC practice in the Malaysian construction industry by investigating the quality and readiness of cost data inputs of LCC analysis of new flexible pavement construction in the Malaysian construction industry. The methodology employed for this study is qualitative research strategy that comprises of two approaches, which are literature review (secondary approach) and modified Delphi study (primary approach). The literature study has established that one of the barriers to the implementation of LCC practice in the Malaysian construction industry is the lack of available, accessible and reliable cost data that is required to be used as inputs for LCC analysis of new flexible pavement construction. The outcomes of the modified Delphi have shown that all the panellists have reached agreement that the cost data in the Malaysian construction industry are not readily available, accessible, current and reliable that can be used as inputs for LCC analysis of new flexible pavement construction. To overcome this problem, the majority of the modified Delphi panellists have established that there is a need to develop an appropriate methodology on how to identify, collect and record quality cost data in producing comprehensive and reliable LCC analysis of new flexible pavement construction in the Malaysian construction industry.

خلاصة البحث

تُصمم معظم إنشاءات الأرصفة المرنة في ماليزيا بعمر افتراضي يتراوح بين عشرة إلى خمسة عشرة سنة. يُقلل اختيار التصميم ذو الجودة العالية وأسلوب البناء الفعّال في المراحل الأولى من التصميم من الإصلاحات وأعمال إعادة التأهيل في المستقبل. على الرغم من ذلك، فإن الأبحاث أظهرت أن الممارسات التقليدية للعملاء في صناعة الإنشاءات الماليزية تركز على أرخص التكاليف الإنشائية وتتجاهل التكاليف المستقبلية. نتيجة إلى ذلك، فإن العملاء قد يُواجهون صعوبات في تحقيق توفير طويل المدى للتكلفة، لأن التركيز الأكبر يقع على تكلفة الإنشاءات الأرخص بدلًا من التكلفة الأفضل لرصيف الطريق طوال عمر الخدمة الافتراضي للرصيف المرن. لقد عُرِفَ تحليل تكلفة دورة الحياة (Life Cycle Cost) على نحو متزايد كأسلوب تقييم اقتصادي مهم يوفر معلومات التكلفة للتسهيل على العملاء لتحقيق توفير التكلفة الأمثل. وتم اتخاذ هذه الدراسة لاكتشاف ممارسة تكلفة دورة الحياة في صناعة الإنشاءات الماليزية عن طريق التحقيق في جودة وتهيؤ مدخلات بيانات تحليل تكلفة دورة الحياة لإنشاء أرصفة مرنة وجديدة في صناعة الإنشاءات الماليزية. كان المنهج المتبع في هذه الدراسة هو البحث الكيفي والذي يتكون من نهجين: استعراض الأدبيات (نهج ثانوي) ودراسة ديلفي المعدلة (نهج رئيسي). وأظهرت مراجعة الأدبيات أن أحد الأسباب المعيقة لتطبيق تكلفة دورة الحياة في صناعة الإنشاءات الماليزية هو عدم التوفر، وعدم سهولة الوصول لمعلومات التكلفة الموثوقة المطلوبة لاستخدامها كمدخلات في تحليل تكلفة دورة الحياة لإنشاء أرصفة مرنة جديدة. أما نتائج ديلفي المعدلة، فقد أظهرت أن جميع الأعضاء توصلوا إلى اتفاق واحد وهو أن معلومات التكلفة غير متوفرة في صناعة الإنشاءات الماليزية ولا تُعد سهلة الوصول إليها ولا موثوقة لاستخدامها كمدخلات لتحليل تكلفة دورة الحياة لإنشاء أرصفة مرنة جديدة. للتغلب على هذه المشكلة، فجميع أعضاء ديلفي المعدلة اتفقوا على أنه ثمة احتياج لتطوير منهجية مناسبة تخص كيفية تَبَيُّن، وتجميع، وتسجيل معلومات التكلفة ذات الجودة في إنتاج تحليل تكلفة دورة الحياة الشامل والموثوق به لإنشاء أرصفة مرنة جديدة في صناعة الإنشاءات 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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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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CHAPTER ONE

INTRODUCTION TO THE RESEARCH

1.1 INTRODUCTION

This research reports a study on the investigation of data inputs in Life cycle cost (LCC) analysis of new flexible pavement construction in the Malaysian construction industry. In this chapter, the researcher provides the readers with the following introductory sections, which include:

i. Statement of the research problem
ii. Aim and objectives of the research
iii. Significance of the research
iv. Scope of the research
v. Organization of the research
vi. Papers in support of this thesis

1.1 STATEMENT OF THE RESEARCH PROBLEM

Road infrastructures are very important assets in the trade and transportation system, which act as an enabler to generate excellent growth to the economic and social to the countries (Goh and Yang, 2009; Nurul Wahida, 2010; Nasradeen and Zulkiple, 2013; Zarabizan, Syuhada & Aminah, 2013). Road infrastructures have become the most important means for 96% of transported goods and passengers in Malaysia (Sufiyan & Zulakmal, 2009 as cited in Putera Zal Hafizin, 2015).

The Government of Malaysia has invested a large amount of money for the construction of road infrastructures (Nurul Wahida, 2010; Nasradeen and Zulkiple,

2013; Zarabizan, Syuhada & Aminah, 2013). According to the Construction Quarterly Statistical Bulletin 2017, the Government of Malaysia has spent RM9, 803.34 million between January 2017 and June 2017 for the construction of infrastructure projects (CIDB, 2017). However, in the Bulletin published by the Construction Industry Development Board (CIDB), the information provided does not properly specify the amount spent for infrastructure projects and whether it belongs to the building works, civil engineering works or road pavements (i.e. flexible and rigid pavements). Furthermore, according to the report from Malaysia Productivity Corporation (2016), there are two main projects that have contributed to the development of road infrastructure projects in Malaysia, which are the Construction of the West Coast Highway and the Construction of the People's Highway from Machang to Kuala Krai, Kelantan in year 2014. In addition, the Government of Malaysia has announced the increase of total length of road networks from 137,200km to 230,300km, between year 2010 and 2015 that has been stated in Tenth Malaysia Plan (2010-2015) with the objectives are to increase the total length of road networks and to enhance the connectivity between rural and urban areas to basic social amenities such as health, education, and public services. For this reason, it is important to ensure that the road infrastructure is continuously in a good condition and able to provide quality services to users. The Government of Malaysia has entrusted few respective agencies, i.e. the concession companies (e.g. SPRINT, PLUS Expressway Berhad, IJM Corporation Berhad, etc.) Malaysia Highway Authority, State Public Works Department and facility management companies (e.g. Global Facilities Management Sdn Bhd, Savills Malaysia's Facilities Management, SGS Malaysia, etc.) to maintain, monitor and administer road networks in Malaysia (Highway Planning Unit, Ministry of Works & Malaysia Highway Authority, 2013, as cited in Zarulazam & Evdorides, 2013).

In Malaysia, there are two types of road pavements, which are flexible and rigid pavements (Mathew & Rao, 2007; Haritsehrawat, 2012; Pavement Interactive, 2012; The Constructor, 2015; Wan Imran, 2015). The flexible pavement is constructed mainly in five different layers, which include subgrade, sub-base, road base, binder course and wearing course (Kibukwo, 2013; Public Works Department, 2013; The Constructor, 2014). Rigid pavement on the other hand, is constructed mainly with three different layers, which include subgrade, base or sub-base and concrete slab (Public Works Department, 2013; The Constructor, 2014). However, this study will focus on the LCC estimation with specific reference to new flexible pavement construction, which is well known for having lower initial capital cost, but higher maintenance cost as compared to rigid pavement (Wan Imran, 2015).

Most of the flexible pavement constructions in Malaysia are designed with a lifespan between ten to fifteen years (Zakaria & Hassan, 2005 as cited in Wan Imran, 2015). The main factors affecting the design life of flexible pavement are quality of materials, traffic loading, technology and thickness of flexible pavement layers (Vasudevan & Hidayu, 2014; Nogorska, Nagorski & Blazejowski, 2015). For example, the flexible pavement structure will deteriorate before the end of its design life when the thicknesses of each flexible pavement layers are designed to be too thin. Hence, a major road maintenance work is required to rehabilitate this deteriorated road pavement (Vasudevan & Hidayu, 2014). It is not a misconception to state that the selection of design alternatives and construction methods during planning and design stage of the road pavement will give impact to the future operation and maintenance cost (Vasudevan & Hidayu, 2014; Wennstrom, 2014). Besides that, the clients may encounter difficulty to achieve long-term cost saving if the sole focus is given on the cheapest construction cost instead of the optimal total cost of road pavement

throughout design lifespan (Goh & Yang, 2009). The total cost is defined as the total expenses of all direct and indirect costs in acquiring and operating product or services over an anticipated lifespan (Oxford University Press, 2018; Encyclopaedia Britannica, 2018). The total cost of pavement consists of initial capital cost, maintenance and rehabilitation cost as well as salvage cost. It is very important to connect initial capital cost with future costs such as maintenance and rehabilitation cost as well salvage cost in the investment decision-making process at the very early stage of the project to achieve the best value for money over the investment.

Life Cycle Cost (LCC) analysis is an economic assessment technique that is used to estimate the total ownership cost of assets or facilities i.e. roads, buildings, electricity, telecommunication, water supplies and etc. However, this study will emphasize on the estimation of LCC analysis of road pavement which includes initial capital cost, maintenance cost, rehabilitation cost, salvage cost, and financial cost over the anticipated lifespan. Life cycle cost (LCC) analysis is increasingly recognized as an important economic assessment technique to provide the cost information which can help the client to develop economical strategies since the clients and government agencies require optimum maintenance cost of roads and highways infrastructure (Rangaraju, Amirkhanian & Guven, 2008; Wan Imran, 2015). In addition, LCC analysis is a cost management tool to compare the overall long-term economic efficiency between the available competing alternatives in the construction, operation, maintenance and rehabilitation work of flexible pavement over an anticipated lifetime to identify potential cost savings (Boussabaine & Kirkham, 2006, Davis Langdon Management Consulting, 2006; BS ISO 15686-5, 2008, Davis Langdon, 2010 as cited in Mohd Fairullazi, 2014).

According to the Tenth Malaysian Plan (2011-2015), the Government of Malaysia has encouraged the adoption of LCC practice in the procurement process to assist the Government and clients to achieve the best value for money on the public investment made in building and infrastructure projects (Economic Planning Unit, 2010). In the recent Eleventh Malaysia Plan (2016-2020), the Government of Malaysia has asserted again that LCC should be practised in the Malaysian construction industry, specifically in the maintenance of road and rail infrastructure networks to ensure that the road and rail infrastructure networks are in good working performance condition and quality performance over the maximum service lifespan (Economic Planning Unit, 2015). Hence, it is not a misapprehension to state that LCC analysis has been recommended as an economic assessment technique to facilitate the Malaysian Government in designing the best value for money procurement strategies to achieve the most cost-effectiveness on public investment, particularly in building, road and rail infrastructure networks in Malaysia.

The LCC analysis process can be categorized into three main phases; i.e. data inputs, conversion and outputs (BSI IS0 15686-5, 2008; Kelly and Hunter, 2009; NATO Research and Technology Organisation. 2009; Rist, 2011 as cited in Mohd Fairullazi, 2014). For this study, the quality data refers to cost data inputs of LCC analysis. Cost data is the important inputs of LCC analysis that should be identified and measured by the cost estimators in the early stage of the project (Fuller, 2009 & Davis Langdon, 2010 as cited in Mohd Fairullazi, 2014). In the estimation of LCC analysis, there are several types of mathematical cost model have been recommended i.e. Simple Payback, Discount Payback method (DP), Net Present Value (NPV), Equivalent Uniform Annual Cost (EUAC), Internal Rate of Return (IRR) and Net saving (Guven, 2006; Schade, 2007; BS ISO 15686-5, 2008; Nor Azizah and Zainal

Abidin, 2010; Babashamsi et al., 2016). Each of these mathematical cost models requires different type of cost data for the estimation of LCC analysis. Therefore, it is very important to identify appropriate and quality cost data to be used as inputs in these mathematical cost models. Previous study has reported that there are four key quality of data input requirements required for producing a reliable and comprehensive LCC analysis, as follows (Mohd Fairullazi and Khairuddin, 2011a, 2011b, 2013 ; Mohd Fairullazi, 2014 p. 2; Mohd Fairullazi et al., 2017):

i. **Availability** of cost data indicates the level of data certainty (Davis Langdon Management Consulting, 2007; Gross and AEA, 2008; BS ISO 15686-5, 2008; BSI, 2008; NATO Research and Technology Organisation, 2009 as cited in Mohd Fairullazi, 2014; p. 2; Goh et al., 2010).

ii. **Accessibility** of cost data is defined as the ease of access to obtain cost data from variable data sources within known background for the estimation of LCC analysis (Ren & Zhang, 2007; Schade, 2007; BSI, 2008; Ashworh, 2010 as cited in Mohd Fairullazi, 2014; p. 2).

iii. **Currency** of cost data means the most recent and advanced data that are updated frequently either on monthly or yearly basis for producing reliable LCC analysis (Khairani, 2009; Department of Statistic Malaysia, 2010 as cited in Mohd Fairullazi, 2014; p.2; Free Dictionary, 2015).

iv. **Reliability** of cost data refers to the consistency of data which implies how comparable the data to the actual value arrived from similar and repetitive methods under the same research situation (Annex 31, 2001; Neuman, 2003, Ashworth, 2004, Creswell & Clark, 2007; King, 2007, CRES & Kikira, 2009 as cited in Mohd Fairullazi, 2014; p.2).

Nevertheless, based on the comprehensive review of the literature, there is no previous study that has investigated the quality and readiness of cost data as inputs for LCC analysis of new flexible pavement construction in the Malaysian construction industry. Numerous studies have revealed that one of the major hurdles of implementing LCC practice in estimating the total cost of road pavement is the lack of availability and accessibility to a reliable cost data as inputs for LCC analysis of new flexible pavement construction (Singh and Tiong, 2004; Langdon, 2010; Tinni, 2013; Babashamsi, 2016).

Most published cost data in the Malaysian construction industry are historical data, which are collected from the previous projects in the past (Siti Hamisah et al., 2007; Masoud, 2009; Masoud et al., 2010; Mohd Fairullazi, 2011, 2012 as cited in Mohd Fairullazi, 2014). Based on the review of literature, the historical cost data can be used by various data users and organizations by measuring the currency degree of data inputs for LCC analysis i.e. "Very current", "Current" and "Less current" data (Mohd Fairullazi, 2014). Very current data is indicated as the most recent data that are updated on a weekly, monthly or yearly basis. Current data is the data that is frequently updated on a certain period of basis where the data is updated once in a couple of years but less than 5 years. Meanwhile, less current data refer to historical data which are collected from the previous study i.e. the data that are published more than 5 years. The historical data can be used in the estimation of LCC analysis by referring to similar characteristics of the projects as well as reporting the rationales of using them in the projects (Mohd Fairullazi, 2014; Fuller, 2016). However, it was difficult to directly use the historical data in estimating the total cost of certain road projects since different road projects have different models, manufacturers and technological advancements (Wennstrom, 2014). In addition, it could cause a

misleading information to LCC analysis and makes the LCC output tends to become erroneous, unreliable and show differences from the actual costs (Siti Hamisah et al., 2007, Masoud, 2009, Masoud et al., 2010 as cited in Mohd Fairullazi, 2014). Based on the comprehensive literature study, there is no proper and complete LCC database that has been developed specifically for new flexible pavement construction in the Malaysian construction industry, which can be referred by the cost estimators to carry out LCC analysis of new flexible pavement construction. Hence, many cost estimators have to make an assumption in the LCC analysis of road pavement and justify the rationales of using the assumptions to ensure the reliability of cost data used in LCC analysis can be achieved (Mohd Fairullazi, 2014).

A technical agency of the Public Works Department (PWD) has published a LCC guideline entitled "Garis Panduan Kos Kitaran Hayat (2012)" [Guideline of Life Cycle Cost (2012)]. The objective of this guideline is to provide procedures and methodology that can facilitate the cost estimators to carry out LCC analysis for the new construction of public building and road projects in the Malaysian construction industry. This guideline also helps clients and cost practitioners in making the best decision to achieve the most optimum life cycle cost of investment made in building and road projects (PWD, 2012). Based on the comprehensive review of PWD guideline, the guideline only provides fundamental LCC methodology on how to estimate the total cost of public projects but it does not provide procedure on how to collect a comprehensive and quality cost data that are required for LCC analysis of new flexible pavement construction. This procedure is significant to be included in this guideline to assist the cost estimators to the right practice of LCC in producing comprehensive and reliable LCC analysis of new flexible pavement construction.