RISK LEVEL OF FACTORS CAUSING CONSTRUCTION WASTE GENERATION THROUGHOUT CONSTRUCTION PROJECT LIFE CYCLE

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For my beloved mom and dad,
Khoriah Hj Ismail & Md. Akhir Chin
For their endless love, support and prayers.

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ABSTRACT

The construction industry has an adverse impact on the environment from the wastes generated during construction work. The amount of wastes generated increases yearly due to rapid economic growth worldwide which includes Malaysia. Due to waste generation, one of the major issues faced is the increase of illegal dumpsites. The illegal dumping may caused a risk to human health and environment. Thus, it calls for serious measures to regulate wastes generation. The waste is generated due to various factors throughout construction project life cycle (CPLC). For controlling purpose, it is very important to identify the generation factors and also to determine the level of risk from each factor. Hence, this study focuses on assessing the risk level of factors causing wastes generation throughout CPLC. Besides, it also proposes mitigation measures for the high risk factors. For assessing the risk level, a total of 33 factors that causes construction wastes generation that have been identified from literature review were considered. The assessment involved 15 experts who are experienced in handling construction projects. This investigation adopted two rounds of Delphi method in determining level of occurrence and severity of each factor in relation with different phases of CPLC. The experts were required to fill out the questionnaire set and the analysis on the gathered data from the questionnaire work was done using risk matrix. The result indicated that in the construction phase, majority of the identified factors occurred in this phase are critical due to having high risk level and most of them are categorised in Human Resource/Manpower (HRM) group. It is followed by finishing phase, design phase, and planning phase. However, in planning phase, the chances of wastes generation are minimal with no high risk factors. In order to control the construction wastes generation problem, mitigation measures for high risk factors were proposed. The findings of this study can be a useful guide for the practitioners in controlling construction wastes generation.

ABSTRAK

Industri pembinaan telah menyumbang kesan buruk terhadap persekitaran akibat daripada penjanaan sisa semasa kerja pembinaan. Jumlah penjanaan sisa kian meningkat setiap tahun disebabkan pertumbuhan ekonomi yang semakin pesat di seluruh dunia termasuk di Malaysia. Hal ini menyebabkan jumlah tapak pelupusan sampah secara haram semakin meningkat. Tapak pelupusan sampah yang berleluasa boleh mendatangkan risiko kepada kesihatan manusia dan alam sekitar. Oleh yang demikian, perhatian yang serius diperlukan bagi mengawal masalah ini. Penjanaan sisa boleh berlaku disebabkan pelbagai faktor di sepanjang kitaran hayat projek pembinaan (CPLC). Bagi tujuan pengawalan, ia adalah penting untuk mengenalpasti faktor-faktor penyebab penjanaan sisa dan juga menentukan tahap risiko bagi setiap faktor. Oleh itu, kajian ini fokus kepada menilai tahap risiko bagi faktor-faktor penyebab penjanaan sisa di sepanjang CPLC. Di samping itu, kajian ini juga mencadangkan langkah-langkah mengatasi untuk faktor-faktor yang berisiko tinggi. Untuk menilai tahap risiko, sebanyak 33 faktor penyebab penjanaan sisa pembinaan yang telah dikenalpasti daripada kajian literatur dipertimbangkan. Penilaian ini melibatkan 15 orang pakar yang berpengalaman dalam mengendalikan projek-projek pembinaan. Dua pusingan kaedah Delphi digunakan bagi menentukan tahap berlaku dan tahap impak setiap faktor bagi setiap fasa di sepanjang CPLC. Pakar-pakar diminta untuk mengisi borang soal selidik dan analisis yang dilakukan ke atas data yang diperolehi adalah dengan menggunakan matrik risiko. Keputusan mendapati bahawa dalam fasa pembinaan, sebahagian besar faktor-faktor yang dikenal pasti berlaku dalam fasa ini adalah kritikal kerana mempunyai tahap risiko yang tinggi dan kebanyakan faktor yang berisiko tinggi adalah dari kategori Sumber Manusia/Tenaga Kerja (HRM). Ia diikuti dengan fasa kemasan, fasa reka bentuk, dan fasa perancangan. Walau bagaimanapun, dalam fasa perancangan kemungkinan penjanaan sisa adalah minimum dan tiada faktor yang berisiko tinggi dalam fasa ini.

Dalam usaha untuk mengawal masalah penjanaan sisa pembinaan, langkah-langkah mengatasi bagi faktor yang berisiko tinggi telah dicadangkan. Hasil kajian ini dapat menjadi panduan kepada pihak industri dalam mengawal penjanaan sisa binaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AI	-	Average Index
CPLC	-	Construction Project Life Cycle
CWDCS	-	Construction Wastes Disposal Charging Scheme
C&D	-	Construction and Demolition
DEL	-	Delivery/Procurement
EQP	-	Equipments
EXT	-	External/Unpredictable
GHG	-	Green House Gas
HRM	-	Human Resource/Manpower
IBS	-	Industrialized Building System
ICT	-	Information, Communication, and Technology
MAT	-	Material
PCM	-	Project and Contract Management
RIBA	-	Royal Institute of British Architects
SPSS	-	Statistical Package for the Social Sciences
WGR	-	Wastes Generation Rate
WMP	-	Wastes Management Plan
α	-	Cronbach's Alpha Coefficient

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Construction is an imperative industry that plays a vital role in the socio-economic growth of a country. It provides necessary infrastructure and physical structure for activities such as commerce, services, and utilities (Khan, Liew, & Ghazali, 2014). Besides that, it also generates employment opportunities and enhances the nation's economy by creating foreign and local investment opportunities (Wibiwo, 2003). However, the industry is facing the problem of construction wastes generation. As reported by Kartam et al. (2004), based on statistics and assumptions, a total of Construction and Demolition (C&D) wastes production was estimated to be 1.6 million ton/year. According to Ferguson et al. (1995), over 50% of the wastes in a typical United Kingdom landfill is contributed by construction wastes. Bossink & Brouwers (1996) indicated that9% of the totally purchased materials ended up as wastes. Furthermore, Masudi et al. (2011) stated that wastage level for major materials in some projects in Malaysia may reach up to 10%.

This generation of wastes has negative impact to the environment, cost, productivity, time, social, and economy of the industry (Kozlovská & Spišáková, 2013; Marzouk & Azab, 2014; Osmani, 2012; Wang, Kang, & Tam, 2008). In addition, production of wastes may weaken the efficiency, effectiveness, value, and profitability of construction activities (Augustine, 2011). Thus, the risk of generation of construction wastes needs to be proactively managed.

There are various factors that contribute to generation of construction wastes. These factors pose different levels of risk in wastes generation. Various researchers have identified factors that contribute to wastes generation. As an example: A study conducted in Sri Lanka revealed that the domestic construction industry workforce is ignorant of the flow of activities that generated wastes (Senaratne & Wijesiri, 2008). In Malaysia, it was found that there were five significant factors that caused generation of construction wastes in this country. The factors are poor site management or supervision, lack of experience, inadequate planning and scheduling, mistakes and errors in design, and mistakes during construction (Nagapan, Rahman, & Asmi, 2012a). In addition, contractors and consultants agreed that three most important factors that contribute to generation of material wastes at construction site are rework contrary to drawings and specification, design changes and revision, and wastes from uneconomical shapes (Adeweyu & Otali, 2013).

A number of study highlighted that construction wastes are effectively generated during the whole Construction Project Life Cycle (CPLC) from start until completion of construction work (Kozlovská & Spišáková, 2013; Osmani, Glass, & Price, 2008). It may be generated during planning, design, procurement, and construction phase (Bossink & Brouwers, 1996; Ekanayake & Ofori, 2004; Wahab & Lawal, 2011). While, several studies highlighted that construction wastes is commonly generated during design and construction phase (Osmani, Glass, & Price, 2006; Panos & Danai, 2012).

Therefore, it can be concluded that construction wastes may be generated by various factors and it may occur in the whole of CPLC. It also contributes to a lot of negative impacts either to the project, environment or life. Thus, reducing wastes at the source is the most effective measure in wastes management (Masudi et al., 2011). By identifying the risk level of the factors and proposing the mitigations of the risky factors, it may help the practitioners to figure out the best way to control this problem.

1.2 Problem Statement

Production of construction wastes is directly related with the increasing demand of infrastructure projects, residential development projects, and other facilities which are required to improve the level of Malaysians' living conditions (Begum, Satari, &

Pereira, 2010; Nasaruddin & Ravana, 2008). Out of these projects, the construction of residential building contributes the largest amount of construction wastes (Begum & Pereira, 2011; Foo et al., 2013).

According to Oh (2014) in The Star daily publication in March 2014, Solid Wastes Management and Public Cleansing Corporation highlighted that in 2007, Kuala Lumpur generated 1.04 million metric tonnes of construction wastes per year and this amount is expected to increase to 1.34 million metric tonnes a year by 2020. However, these wastes were not properly handled by the construction parties involved. Research studies have indicated that dumping of construction wastes in landfill is a common practice in Malaysia (Foo et al., 2013; Nagapan et al., 2012a).In 2007, a study conducted by Rahmat & Ibrahim (2007) showed that 42% of the wastes were dumped illegally in the district of Johor Bahru Tengah, Johor. The study also found 46 illegal dumping sites in the district and most of them were located near the road side. A study in the Klang Valley found only 20% of C&D wastes were disposed at legal landfills while others were disposed at illegal landfills or private lands (Begum & Pereira, 2011). There are also a number of contractors that disposed material wastes through open burning especially timber and packaging wastes, and also by burying concrete wastes (Masudi et al., 2011).

The wastes then pose a threat to the environment and society if they are not handled properly. Thus, it is important to control the source of construction wastes generation. Before it can be controlled, it is vital to identify the factors that contribute to wastes generation. Previous studies had identified factors that caused construction wastes generation (Ikau, Tawie, & Joseph, 2013; Masudi et al., 2011; Nagapan, Rahman, & Asmi, 2012b). However, not much emphasis was given in assessing the relative risk level of these factors towards construction wastes generation, which is very important for proper planning and development of strategies in controlling the factors. This has motivated the author to conduct this research in identifying the risk level of various causative factors that occurs in CPLC phases and propose mitigations of risky factors, which can serve as a useful guide for the practitioners in controlling the construction wastes generation.

1.3 Aim and Objectives

The aim of this research is to assess the risk level of factors causing construction wastes generation throughout CPLC. In order to achieve this aim, three objectives have been established namely:

1) Identifying major factors causing construction wastes along the CPLC.
2) Determining the risk level of factor causing construction wastes along the CPLC.
3) Proposing mitigation of the risky factors.

1.4 Scope of Study

The scope of this research is limited to construction-related companies in Peninsular Malaysia. Data collection involves questionnaire survey using the Delphi method. The survey is start conducted in the early of 2014. The targeted respondents are the clients, consultants, and contractors whom are registered with CIDB between Grade 5 and 7. Respondents are selected among those who have more than ten years of working experience in the construction industry. Construction wastes are limited to material wastes only.

1.5 Research Methodology

This study is carried out based on the qualitative and quantitative mode of research. It involves a comprehensive literature review from past researches to identify the factors causing construction wastes generation. Based on that, a questionnaire is developed to determine the factors occurrence and severity with respect to the various phases of a construction project. The investigation for the developed questionnaire is carried out using the Delphi method to assess the level of occurrence and severity of the factors causing wastes generation for the construction industry in Malaysia. The data are then analyzed using the average index and risk matrix to identify the risk level of each factor. Mitigations of the risky factors are proposed based on literature review.

1.6 Thesis Organization

This thesis is divided into five chapters as follows:

Chapter 1: This chapter describes the need of this study. It contains study background, problem statements, objectives, scope of study, research methodology, and thesis organization.

Chapter 2: This chapter elaborates on related literature through the published research work. It includes the definition, wastes generation scenarios, handling the wastes, and factors causing construction wastes generation. Besides that, the phases in CPLC are discussed.

Chapter 3: This chapter describes how this research is carried out. It explains the technique of data collection and the way to analyze them.

Chapter 4: The survey results will be illustrated in this chapter. It includes the factors of wastes generation throughout CPLC, level of occurrence, severity, and risk of the factors causing generation construction wastes throughout the CPLC. At the end of this chapter, the mitigation measures of high risk factors are presented.

Chapter 5: This chapter presents the conclusion of the study. It also presents some recommendations for future study and limitations that arise while this study was conducted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides literature reviews that are related to this study. It is to gain an overview of the current study and to provide a theoretical basis in refining the research methodology and also the analysis approach for the current work. In this chapter, risk management in construction projects, the definitions of construction wastes, issues related to wastes generation, wastes management, impacts, and factors causing construction wastes generations are reviewed. In addition, the concept of four phases of CPLC is also discussed.

2.2 Risk Management in Construction Project

Project success can be defined by fulfilling the project objectives on the cost, time and quality. However, to achieve project success, it is subjected to various risks due to the unique features of construction activities, such as long period, complicated processes, abominable environment, financial intensity, and dynamic organizational structures (Zou, Zhang, & Wang, 2007; Akintoye & MacLeod, 1997). In addition, Husin, Ismail, & Memon (2013) stated that the construction industry is always faced with chronic problems such as time overrun, cost overrun, wastes generation, imposing negative impacts to the environment, and excessive resource consumption. Thus, risks in construction project have to be given serious attention so that the project is successfully accomplished.

Risk can be defined as a combination of the probability and the severity, and also the exposure of all hazards in the construction activity (Jannadi & Almishari, 2003). In managing risk, a systematic way is required to look into the areas of risk and consciously determining how to treat the risk. It is a management tool that aims at identifying sources of risk and uncertainty, determining their impact, and developing appropriate management responses (Uher, 2003). A process of risk management has been divided into three consecutive stages as stated by Perera et al. (2014) and KarimiAzari et al. (2011) which are;

i. risk identification,
ii. risk analysis and
iii. risk response, where risk response has been further divided into four actions, i.e. retention, reduction, transfer, and avoidance

For risk identification and risk analysis, it specifies and predicts the likelihood and adverse impacts of risks; whereas for risk response, it is concerns on the measures taken by project management to reduce the probability and effects of risks (Perera et al., 2014).

Risk identification is a significant step in the risk management process, as it attempts to identify the various risks affecting a construction project. In this stage, risk factors that influence the project are detected, classified and documented (Gohar, Khandazi & Farmani, 2012). Source of the knowledge for risk identification phase is vital to the success of this stage and should elicit the viewpoints of experts with extensive experience in directly dealing with similar construction projects (Ruthankoon & Ogunlana, 2003). In this study, risk identification was accomplished through literature review and pilot study. A total of 33 factors causing construction waste generation were identified through literature review. Then, the identified factors were classified into four phase of CPLC through pilot study. From that, it presented one factor in planning phase, five factors in design phase, 32 factors in construction phase and nine factors in finishing phase.

Risk analysis is important as it estimate risk by identifying the undesired event, the likelihood of occurrence of the unwanted event, and the consequence of such event. It involves measures which produce the estimation of significance level of the individual risk factors to the project, so as to produce the estimation of the risk of the potential factors to project success (KarimiAzari et al., 2011).

There are two approaches used in risk analysis, which are quantitative risk analysis and qualitative risk analysis (Ehsan et al., 2010). Quantitative analysis involves more sophisticated techniques and methods to investigate and analyze construction project risks. Additionally, this analysis represents risks in mathematical form to quantify them in terms of performance in quality, time and cost (Morledge, Smith, & Kashiwagi, 2006). Quantitative risk analysis attempts to estimate the frequency of risks and the magnitude of their consequences by different methods such as the sensitivity analysis, decision tree analysis, the cost risk analysis, and Monte Carlo simulation (Mahendra, Pitroda, & Bhavsar, 2013; Ehsan et al., 2010; Modarres, 2006)

Qualitative risk analysis assesses the impact and likelihood of the identified risks and develops prioritized lists of the risks for further analysis or direct mitigation. A common qualitative approach is the precedence diagramming method, which uses ordinal numbers to determine priorities and outcomes. Another way of employing qualitative approach is to make a list of the processes of a project in descending order, calculate the risks associated with each process and list the controls that may exist for each risk (Ehsan et al., 2010). A risk matrix (or a probability/impact matrix) also is a tool commonly used in qualitative risk analysis (Mahendra et al., 2013; Zhou & Leung, 2012; Modarres, 2006). It is a table that contains several regions that indicate risk level based on the scale of probability and scale of impact or severity. Risks are qualitatively assessed according to the region it mapped. In this study, the risk levels for the factors that have been identified were assessed by using risk matrix which has been explained in section 3.5.3.

Once the risks of a project have been identified and analyzed, appropriate **risk response** strategies must be adopted to cope with the risks in the project implementation. The treatment measures on each risk are based on the nature and impact of the risk (Zou et al., 2007). As mentioned by Mahendra et al. (2013), risk response can be done by several methods including risk avoidance, risk transfer, risk mitigation/reduction, risk exploit, risk share, risk enhance, risk acceptance, and contingency plan. In this study, to response the risk, mitigation measures for the risky factor were proposed. The mitigation measure may reduce the probability and/or impact of an adverse risk event to an acceptable level of risk. Taking early action to reduce the probability and/or impact of a risk is often more effective than attempting to repair the damage after the risk has passed (Mahendra et al., 2013).

Basically, eliminating construction risks seems hardly doable (Siew & Abdul-Rahman, 2013). However, risk management should be applied into any construction project at the initial stage of the project to get maximum benefit in managing the risk. This is because, the awareness of the risks and appropriate strategies for dealing with the risks are imperative and contributes to the success of the projects (Zou et al., 2007).

2.3 Construction Wastes

There are a lot of researches in construction wastes generation that have been carried out in various countries. It includes the types of construction wastes, factors causing construction wastes, the impacts, and the way of handling the wastes. This subtopic comprises the definition of construction wastes, construction wastes generation in other countries, wastes management, and the impact of the wastes.

2.3.1 Definition

Construction wastes have been defined in various ways. Skoyles & Skoyles (1987) stated that construction wastes is 'a material which needed to be transported elsewhere from the construction site or used on the site itself other than the intended purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process'. In Hong Kong, the definition of construction wastes was established by Hong Kong Polytechnic (1993) as 'by-product generated and removed from construction, renovation, and demolition work places or sites of building and civil engineering structures'. In another research, construction wastes was defined as 'any material apart from earth materials, which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process' (Ekanayake & Ofori, 2004). Based on the Solid Wastes and Public Cleaning Management Act 2007 (Act 672), construction solid wastes are 'any type of solid wastes that is produced from any construction activities or demolition or including accomplishment, arrangement, renovation or modification'.

According to Poon et al. (2013), construction waste is a mixture of inert and non-inert materials arising from various construction activities like excavation, demolition, construction, renovation, and roadwork. Based on all highlighted definitions, it should be understood that construction wastes is in the form of materials losses while the construction project was being carried out.

However, according to new production philosophy, Koskela (1992) stated that construction wastes ‘includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but does not add value to the product. This was then was supported by Formoso, Isatto, & Hirota (1999) whom defined construction wastes as ‘any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered as necessary in the production of a building’. This means that, besides material wastes; time, cost, and process wastes also can be described as wastes. It can be generated due to any inefficiency of activities such as waiting time, over production, and processing but do not add any value to the project. However, this research only focuses on construction material wastes. Although construction wastes generation contributes to high economic losses than material wastes (Formoso et al., 1999), the most important thing that we have to be concerned with is the adverse impact on the environment (Masudi et al., 2011) which is contributed by material wastes. Table 2.1 summarizes the various definitions given for construction waste.

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