STRUCTURAL MODELLING OF CAUSE AND EFFECT FACTORS OF CONSTRUCTION WASTE GENERATION IN MALAYSIAN CONSTRUCTION INDUSTRY

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DEDICATION

For my beloved father (Nagapan Subramaniam), mother (Pushpavalli Doraysamy),
wife (Jeyaletchumey Raman), children (Shamirha & Shanurha),
sister & brother-in-law (Sasikala & Raguraman),
uncle's family (Anandan & Sandramogan)
for their support and prayers.

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ABSTRACT

Construction industry contributes significantly in improving socio-economic development of a country. However, this industry faces serious problems of construction waste generated worldwide including Malaysia. Construction waste is results from various factors which are necessary to identify for reducing the waste generated in construction project. Hence, this study focused on developing a structural model of construction waste generation and determining the most important group that contributes to construction waste generation. The questionnaire consisted of 77 causative factors which then clustered into 7 groups and 13 effects factors of construction waste which are clustered into 3 groups. These factors and assigned groups were validated by 30 construction personnel (contractors, consultants and clients) during the pilot study. The actual survey was conducted with a total of 302 questionnaires were received by respond rate of 60%. The data analysis is carried out using SmartPLS software. A structural model of construction waste generation was developed based on 7 groups of causative factors and 3 groups of effect factors using Partial Least Squared-Structural Equation Modelling (PLS-SEM) technique. It was found that the model is fit due to the R^2 value of 0.451 ($R^2 \geq 0.26$ = substantial). The model identifies that all 10 groups are significant with t-value ≥ 2.58 from bootstrapping process of 5000 random samples. The model indicates that Handling of Materials and Equipment group has the highest impact on construction waste generation. Finally, this finding was validated by 22 construction practitioners who agreed that Handling of Material and Equipment group of factors contributes the highest amount of construction waste generation at site. This group of factors should be avoided during construction works to reduce the waste generation. The findings of this study are contributed to understand clearly the cause and effect factors of construction waste generation in Malaysia.

ABSTRAK

Industri pembinaan adalah penyumbang yang ketara di dalam peningkatan pembangunan sosio-ekonomi sebuah negara. Walau bagaimanapun, industri ini menghadapi masalah yang serius bagi isu penjanaan sisa pembinaan di seluruh dunia termasuk Malaysia. Sisa pembinaan dihasilkan daripada pelbagai faktor yang perlu dikenalpasti untuk mengurangkan penjanaan sisa di projek pembinaan. Oleh itu, kajian ini telah fokus kepada membangunkan satu model struktur penjanaan sisa pembinaan dan menentukan kumpulan yang paling signifikan kepada penjanaan sisa pembinaan. Soal selidik terdiri daripada 77 faktor penyebab yang diklasterkan kepada 7 kumpulan dan 13 faktor kesan sisa pembinaan yang diklusterkan kepada 3 kumpulan. Semua faktor dan kumpulan yang ditentukan ini telah disahkan oleh 30 pekerja pembinaan (kontraktor, perunding dan pelanggan) semasa kajian rintis. Kajian sebenar telah dijalankan dengan 302 borang soal selidik yang telah diterima dengan kadar respon sebanyak 60%. Analisis data dilakukan dengan menggunakan perisian SmartPLS. Satu model struktur penjanaan sisa pembinaan telah dibangunkan berdasarkan 7 kumpulan faktor penyebab dan 3 kumpulan kesan dengan mengunakan teknik *Partial Least Squared-Structural Equation Modelling (PLS-SEM)*. Ia mendapati bahawa model tersebut adalah baik kerana nilai R^2 adalah 0.451 ($R^2 \geq 0.26$ = *substantial*). Model tersebut telah kenalpasti bahawa semua 10 kumpulan adalah signifikan dengan nilai-t $\geq$ 2.58 daripada proses *bootstrapping* bagi 5000 sampel rawak. Model tersebut telah menunjukkan bahawa kumpulan Pengendalian Bahan dan Peralatan mempunyai impak tinggi kepada penjanaan sisa pembinaan. Akhirnya, penemuan ini telah disahkan oleh 22 pengamal pembinaan yang bersetuju bahawa kumpulan Pengendalian Bahan dan Peralatan merupakan faktor penyumbang tertinggi bagi penjanaan sisa pembinaan di tapak. Faktor-faktor bagi kumpulan ini harus dielakkan semasa kerja pembinaan supaya penjanaan sisa pembinaan dapat dikurangkan. Penemuan kajian ini menyumbang kepada memahami dengan jelas faktor penyebab dan kesan penjanaan sisa pembinaan di Malaysia.

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LIST OF SYMBOLS AND ABBREVIATIONS

CW	-	Construction Waste
CIDB	-	Construction Industry Development Board
PLS-SEM	-	Partial Least Square-Structural Equation Modelling
SEM	-	Structural Equation Modelling
KPKT	-	Urban Wellbeing, Housing and Local Government
EPU	-	Economic Planning Unit
PPSPPA	-	Solid Waste and Public Cleansing Management Corporation (*Perbadanan Pengurusan Sisa Pepejal dan Pembersihan Awam*)
CIOB	-	The Chartered Institute of Building
JKR	-	Public Works Department (*Jabatan Kerja Raya*)
Ir.	-	Professional Engineer
UTHM	-	*Universiti Tun Hussein Onn Malaysia*
PSA	-	*Politeknik Sultan Salahuddin Abdul Aziz Shah*
PMU	-	*Politeknik Mukah Sarawak*
csv.	-	Comma Separated Value
AVE	-	Average Variance Extracted
CR	-	Composite Reliability
GDP	-	Gross Domestic Product
RM	-	*Ringgit Malaysia*
BE	-	Bachelor of Engineering
Q^2	-	Predictive Relevancy
CV Red	-	Cross Validated Redundancy
CV Com	-	Cross Validated Communality

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CHAPTER 1

INTRODUCTION

1.1 Background

In Malaysia, construction development is growing rapidly since last few decades. Together with social development, construction sector has contributed significantly to Gross Domestic Product (GDP) of the country. The construction growth trend in GDP since 2004 is illustrated in Figure 1.1.

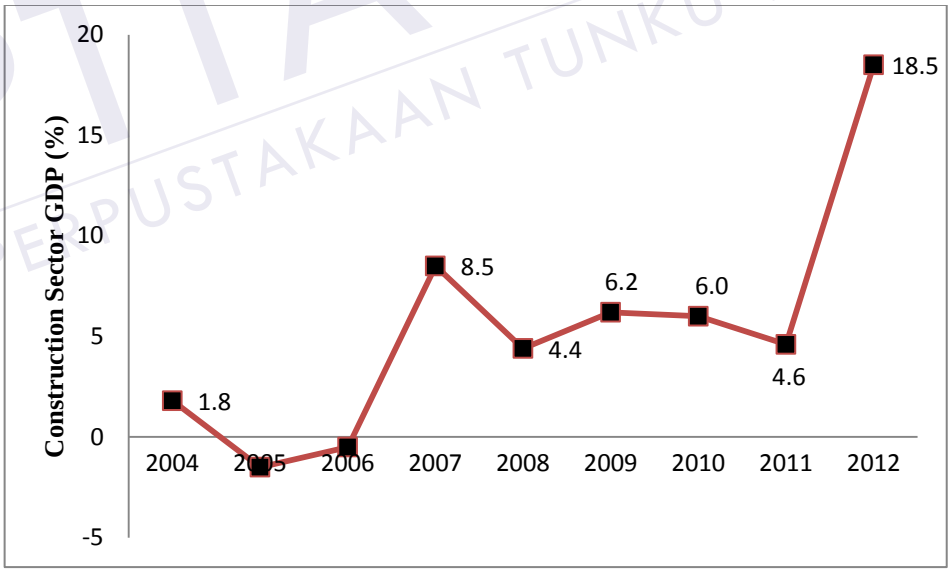

Figure 1.1: Construction Sector Growth Trend from 2004 to 2012
(Khan *et al.*, 2014 & CIDB, 2013a)

Figure 1.1 shows that, in year 2012, Malaysian construction sector registered an impressive GDP growth of 18.5% that is far surpassing the 4.6% in 2011. This growth is due to the huge amount invested for construction development projects

under 10th Malaysia Plan (2011-2015) with the allocation of RM230 billion (EPU, 2011).

Even though the rapid development of construction provides facilities which are needed by people but it also contributes to negative impact to economy, social and environment (Noor *et al.*, 2013; Azis *et al.*, 2012; Llatas, 2011). The waste generated from construction activities has been increasing over the years and giving negative effect to environment. The waste generation has resulted in the increasing of illegal dumping activity (Katz & Baum, 2011) and shortage of landfill space *(*Ann *et al*., 2013). Thus, it is important to take actions for avoiding construction waste generation.

1.2 Problem Statement

Like other countries, Malaysia is also facing a serious problem of waste generation in the construction industry (Noor *et al*., 2013; Hassan *et al*., 2012; Aadal *et al*., 2013). This waste generation is due to the increasing demand for major infrastructure projects, commercial buildings and housing development (Begum *et al*., 2010; Mokhtar & Mahmood, 2008). It has resulted in creating a number of illegal dumping site nationwide (Wei, 2012; Sharifah & Zainal, 2014). The waste generation is caused by various factors which need to be identified for avoiding the waste.

Unfortunately, Malaysia does not have accurate data of construction waste flows and factors causing the waste generation on-site or off-site (Begum *et al*., 2007). The same problem was also highlighted by foreign researchers (Yuan & Shen, 2011; Lu & Yuan, 2011b; Azis *et al*., 2012). In order to overcome this issue, Construction Industry Development Board of Malaysia (CIDB) and National Solid Waste and Public Cleansing Corporation (PPSPPA) have encouraged researchers to conduct research works in construction wastes area (Hamid, 2011; Taha, 2012). Unfortunately only a few researchers have studied the issue of construction waste in Malaysia. However, most of these studies focused on quantifying the amount of construction waste generation and less attention is given on developing relationships model for cause and effect factors of construction waste generation.

Hence, this study focuses on identifying factors of construction waste generation and developing a structural model of cause and effect factors of construction waste generation for Malaysian construction industry.

1.3 Research Questions

Based on the problem statement of the study, the research questions are formulated to help researcher into achievable objectives. This research focuses on the following research questions:

i. What are the cause and effect factors of construction waste?
ii. What is the main factor of the cause and effect factors of construction waste?
iii. How to develop a relationships model between the factors and construction waste generation?

1.4 Aim and Objectives

The aim of this study is to develop a relationship model of cause and effect factors of construction waste generation for Malaysian construction industry. In order to achieve this aim, the objectives of this study are:

i. Identifying cause and effect factors of construction waste.
ii. Determining hierarchically the cause and effect factors of construction waste.
iii. Developing structural model of cause and effect factors of construction waste.

1.5 Scope of the Research

This study focuses on identifying the cause and effect factors of construction waste generation through factual perception of the construction practitioners. The target respondents are focuses to contractors, consultants and clients. These three categories of respondent are the major players in Malaysia construction industry (Yong &

Mustaffa, 2011). Contractors who involved in the study are registered with Construction Industry Development Board (CIDB) of Malaysia. There are seven categories of contractors from smallest contractor G1 (less than RM 200,000) until the largest contractor G7 (above than RM 10 million). Consultant who is working in Malaysia construction project is identified during direct visitation to their office/site. Client who has participated in the survey is from government body such as Public Work Department (JKR) and Solid Waste Management and Public Cleansing Corporation (PPSPPA). The gathering of data involves only quantitative method using structured questionnaire distributed throughout Malaysia. Since the research focuses for Malaysia construction industry, all the respondents involved are only from Malaysia.

1.6 Thesis Structure

This study focuses on developing a structural model of cause and effect factors of construction waste generation for Malaysian construction industry. The thesis of this study is divided into 6 chapters as stated below:

Chapter 1: This chapter discusses the need of this study. It contains background, problem statement to summarize the main research questions and objectives of the study.

Chapter 2: This chapter contains the review of published research works for the related study on construction waste factors and effects.

Chapter 3: This chapter explains research plan and the methodology adopted for this research work. It presents details of analyzing approaches used for data analysis together with the data collection technique.

Chapter 4: This chapter discusses the univariate analysis results including identifying and determining hierarchically the cause and effect factors of construction waste generation. It also highlights the most top factor of cause and effect of construction waste generation in Malaysia construction industry.

Chapter 5: This chapter explains the multivariate approaches of structural equation modelling (SEM) analysis. It also includes the development of structural

model of cause and effect factors of construction waste generation using PLS-SEM approaches and as well as explains the course of validating the model's output.

Chapter 6: The final chapter discusses the conclusion of the results achieved from this study with direction for future works to benefit the construction industry for controlling the construction waste factors of a project.

CHAPTER 2

CAUSE AND EFFECT FACTORS OF CONSTRUCTION WASTE

2.1 Introduction

This chapter provides an overview of the types, issues and factors of construction waste generation. Based on literature review the cause and effect factors are linked into a theoretical model. This model is addressing a gap in construction waste domain for Malaysia construction industry. This study explores the relationships of cause and effect of factors of construction waste generation.

2.2 Construction Industry

Construction industry plays a significant role in helping the development of a country to achieve developed nation status by the year 2020 (Islam & Ismail, 2010; Khan *et al.*, 2014). Therefore to fulfil the development process, high number of construction projects are being planned and constructed in the 10th Malaysia Plan (2011-2015) (CIDB, 2013b). Table 2.1 shows the total number and amount of construction projects are being registered in Construction Industry Development Board, Ministry of Works, Malaysia.

Table: 2.1: Construction Projects Registered under CIDB

Year	Total Numbers of Projects	Total Project Value (RM million)	Source
2009	7,039	74,913.65	CIDB, 2011
2010	7,124	87,286.46	CIDB, 2011
2011	7,359	97,034.17	CIDB, 2012
2012	7,542	122,720.59	CIDB, 2013b

From Table 2.1, it can be perceived that the trend of construction project numbers and its value are increasing from 2009 to 2012. Currently, numerous mega construction projects are ongoing in Malaysia such as Kuala Lumpur International Airport 2 (KLIA 2) project with RM 997,227,000.00 (Habibullah *et al.*, 2012), and Electrified Double Track Project (EDTP), Ipoh - Padang Besar project with RM 12.485 billion (Gamuda, 2014). Due to this rapid development in the construction sector, the construction industry faces the problem with construction waste generation. According to Nasaruddin & Ravana (2008) and Begum *et al*. (2010), the construction waste generation is increasing every year in Malaysia. This problem is a crucial challenge for the construction industry.

According to Ofori (2000), construction industry in developing country needs to take challenges in reducing waste generation which was to land disposal and also need to find an environmental-friendly way of minimizing the waste. This is because the generated waste leads to negative impact on the environment (Papargyropoulou *et al.*, 2011; Winkler, 2010). Hence, the construction waste such as time and cost overrun also reduces the overall projects performance in the construction industry (Alwi *et al.*, 2002b).

2.3 Type of Construction Waste

Waste is considered as unwanted material (Ferguson *et al*., 1995) which is a by-product of human and industrial activity that has no residual value (Serpell & Alarcon, 1998). It is also considered as losses which are resulted from activities that consume direct or indirect costs but do not add value to the end product (Koskela, 1992). For construction waste, it is generated due to construction activities which

include design works, planning, procurement, execution, renovation and also demolition. Currently, construction industry is facing severe problem due to construction waste generation that increase rapidly (Foo *et al*., 2013) worldwide such as in United States and Europe (Serpell *et al*., 1995), Singapore (Hwang & Yeo, 2011), Sri Lanka (Senaratne & Wijesiri, 2008) and Malaysia (Azis *et al*., 2012).

Construction waste has resulted in consumption of resources in excess than the necessary need to execute a service (Freitas, 1995 cited in Branco, 2007). It has a significant impact on environment and social aspects of life and also causing economic loss. Construction waste can be clustered into two types namely the physical and non-physical waste.

2.3.1 Physical Waste

Physical construction waste is defined as waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, building renovation and repair of damaged buildings. Some researchers define physical waste as solid waste which comprises sand, bricks, blocks, steel, concrete debris, tiles bamboo, plastics, glass, wood, paper, vegetation and other organic materials (Katz & Baum, 2011; Hao *et al*., 2008; Bossink & Brouwers, 1996). These wasted materials are usually deposited at landfills. Figures 2.1-2.4 show the examples of physical waste at construction site.

Figure 2.1: Wastage of Cement at Construction Site

Figure 2.2: Packaging Waste at Construction Site

Figure 2.3: Metal Waste at Construction Site

Figure 2.4: Bricks Waste at Construction Site

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