CAUSATIVE FACTORS OF CONSTRUCTION AND DEMOLITION WASTE GENERATION IN IRAQ CONSTRUCTION INDUSTRY

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DEDICATION

To the soul of my demised wife and also, to my lovely daughters, Ban and Huda.

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First of all, I am much more thankful for ALLAH SWT, for his special blessings over me. Even if I spend my whole life thanking his blessings, it is still very little effort to be thankful for his blessings. All my achievements thus far only because of him. Then, I would like to illustrate my heartfelt gratefulness to all those who have contributed to completing this project. I would like to express my gratitude to UTHM for giving me such a prestigious opportunity to take my Ph.D., which is an important step in my professional career and one of my UTHM.

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ABSTRACT

The construction industry has hurt the environment from the waste generated during construction activities. Thus, it calls for serious measures to determine the causative factors of construction waste generated. There are limited studies on factors causing construction, and demolition (C&D) waste generation, and these limited studies only focused on the quantification of construction waste. This study took the opportunity to identify the causative factors for the C&D waste generation and also to determine the risk level of each causal factor, and the most important minimization methods to avoiding generating waste. This study was carried out based on the quantitative approach. A total of 39 factors that causes construction waste generation that has been identified from the literature review were considered which were then clustered into 4 groups. Improved questionnaire surveys by 38 construction experts (consultants, contractors and clients) during the pilot study. The actual survey was conducted with a total of 380 questionnaires, received with a response rate of 83.3%. Data analysis was performed using SPSS software. Ranking analysis using the mean score approach found the five most significant causative factors which are poor site management, poor planning, lack of experience, rework and poor controlling. The result also indicated that the majority of the identified factors having a high-risk level, in addition, the better minimization method is environmental awareness. A structural model was developed based on the 4 groups of causative factors using the Partial Least Squared-Structural Equation Modelling (PLS-SEM) technique. It was found that the model fits due to the goodness of fit (GOF ≥ 0.36= 0.658, substantial). Based on the outcome of this study, 39 factors were relevant to the generation of construction and demolition waste in Iraq. These groups of factors should be avoided during construction works to reduce the waste generated. The findings of this study are helpful to authorities and stakeholders in formulating laws and regulations. Furthermore, it provides opportunities for future researchers to conduct additional research's on the factors that contribute to construction waste generation.

ABSTRAK

Industri pembinaan telah mencemari alam sekitar daripada sisa yang dihasilkan semasa aktiviti pembinaan. Justeru itu, langkah-langkah serius perlu diambil untuk menentukan faktor penyebab sisa pembinaan yang dihasilkan. Terdapat kajian terhad mengenai faktor-faktor yang menyebabkan pembinaan, dan perobohan (C&D) penjanaan sisa, dan kajian terhad ini hanya tertumpu kepada kuantiti sisa pembinaan. Kajian ini mengambil peluang untuk mengenal pasti faktor penyebab bagi penjanaan sisa C&D dan juga untuk menentukan tahap risiko setiap faktor penyebab dan kaedah peminimuman yang paling penting untuk mengelakkan penjanaan sisa. Kajian ini dijalankan berdasarkan pendekatan kuantitatif. Sebanyak 39 faktor yang menyebabkan penjanaan sisa binaan yang telah dikenal pasti daripada sorotan literatur telah dipertimbangkan yang kemudiannya dikelompokkan kepada 4 kumpulan. Kajian soal selidik yang telah ditambah baik oleh 38 pakar pembinaan (perunding, kontraktor dan pelanggan) semasa kajian perintis. Kaji selidik sebenar telah dijalankan dengan sejumlah 380 borang soal selidik, diterima dengan kadar respons sebanyak 83.3%. Analisis data dilakukan menggunakan perisian SPSS. Analisis ranking menggunakan pendekatan skor min mendapati terdapat lima faktor penyebab yang paling ketara iaitu pengurusan tapak yang lemah, perancangan yang lemah, kekurangan pengalaman, kerja semula dan kawalan yang lemah. Hasilnya juga menunjukkan bahawa majoriti faktor yang dikenal pasti berada di tahap berisiko tinggi, di samping itu, kaedah peminimuman yang lebih baik adalah kesedaran alam sekitar. Struktur model dibangunkan berdasarkan 4 kumpulan faktor penyebab menggunakan teknik Penganggaran Kuasa Dua Terkecil Separa- Permodelan Persamaan Berstruktur (PLS-SEM). Hasil kajian turut menunjukkan kebagusuaian padanan model (GOF $\geq$ 0.36= 0.658, sebahagian besar). Berdasarkan hasil kajian ini, sebanyak 39 faktor adalah relevan dengan penjanaan sisa pembinaan dan perobohan di Iraq. Golongan faktor ini perlu dielakkan semasa kerja-kerja pembinaan bagi mengurangkan sisa yang dihasilkan. Dapatan kajian ini sangat membantu pihak berkuasa dan pihak berkepentingan dalam menggubal undang-undang dan peraturan. Selain itu, ia memberi peluang kepada penyelidik pada masa hadapan untuk menjalankan penyelidikan tambahan atas faktor-faktor yang menyumbang kepada penjanaan sisa pembinaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

C&D	Construction and demolition wastes
GDP	Gross domestic product
USEPA	United state environmental protection agency
OSC	Off-site construction
PLS-SEM	Partial least squares structural equation modeling
IBS	Industrial building systems
BIM	Building industrial management
MMC	Modern method of construction
OSM	Off-site manufacturing
OSP	Off-site production
GOF	Goodness of fit

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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 the necessary infrastructure and physical structure for activities such as commerce, services, and utilities. Besides that, it also generates employment opportunities and enhances the nation's economy by creating foreign and local investment opportunities (Low & Ong 2014; Asgari, *et al.*, 2017).

It has long been proven that the construction sector is one of most important most successful industries globally and remains so with the continuation of the development process, especially in developing countries. Despite this success, industry produces significant quantities of waste known as construction and demolition (C&D) waste, which is a major challenge in some countries, because treatment of this waste is costly. A vast amount of C&D waste is detrimental to the environment, social well-being and economy of a country if it is poorly handled (Saadi, *et al.*, 2016; Husnain *et al.*, 2017; Meng *et al.*, 2018). According to "*Global Waste Management Outlook*" prepared by United Nations Environmental Programme (UNEP), and "*International Solid Waste Association (ISWA)"*, construction waste generated by areas such as construction industry, and other industries makes up seven to ten billion tons of waste annually. Almost 85% of waste generated worldwide is disposed to landfills and level of waste re-use and recycling of waste is critically low (UNEP, 2015). A significant amount of industrial waste is created by the construction industry, which is generally categorized as construction & demolition waste C&D,

which has become a concern of governments and, consequently of construction companies (Jin *et al.*, 2019; Ferronato *et al.*, 2019).

Construction industry is estimated to be accountable for using around two-fifths of the world's energy and materials flow, one-sixth of fresh water reserves and one-quarter of global wood harvest (Thongkamsuk *et al.*, 2017), while contributing to 13–30% to total waste generated worldwide (Giannis *et al.*, 2017). The exact Figures regarding the share of C&D waste in total solid waste (SW) stream can be very high and also vary significantly among different countries, for example, in Europe, 25-30% in 2016 (EC Waste, 2019); in Hong Kong, 23% in 2014 (EPD Statistics Unit, 2015); in the United Arab Emirates, 80% in 2010 (Rogers, 2011); and, in Singapore, 59% in 2011 (Giannis *et al.*, 2017). The high speed of urbanization entails the increased demand for housing and transportation; therefore, the volume of C&D waste continues its increase (Mistri, 2015). Figure 1.1 shows the huge amount of C&D waste in Iraq generated by construction activities.

Figure 1.1: C&D waste generation in Iraq (Babylon city)

Unfortunately, in Iraq, the share of C&D waste in total solid waste (SW) is inaccurate and unavailable, in the majority of years, and also varies widely across cities; For instance, in 2005 it was 1,111,788 tons/year (Abdul-Amir, 2014), in 2013 it was 11,315,000 tons/year Mustafa *et al.*, (2017), at 2014 the amount of waste decrease to

8,272,0 tons/year, in 2015 it was 14,349,428 tons/year. According to the Central Statistical Organization-Iraq (Iraqi ministry of planning), the waste of C&D in 2016 was 14,545,692 tons/year Central Statistical Organization - Iraq (2017), in 2017 it is 15,138,812 tons/year Central Statistical Organization - Iraq (2018), in 2018 it was16,841,963 tons/year Central Statistical Organization - Iraq (2019), except for three governorates which are Nineveh, Anbar, and Salah al-Din out of control from 2014 to 2018. figure 1.2 shows the amount of C&D for governorates of Iraq

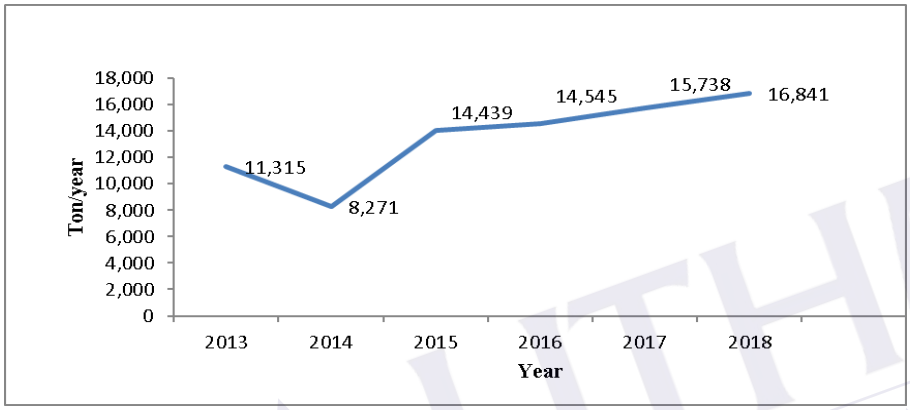

Figure 1.2: Shows the amount of C&D waste in governorates of Iraq

Reference to Figure 1.2 shows the amount of construction waste from the governorates of Iraq from 2013 to 2018, with the exception of the three governors of Nineveh, Anbar, and Salah al-Din. This amount of waste is a result due to increased demand for housing development, Iraq reconstruction plan, commercial buildings, and infrastructure improvement. The aim of the table was to estimate the huge amount of construction debris generated in Iraqi cities that need to be addressed.

Referring to waste generated in the process of dismantling, repair, and/or construction of buildings, the conventional preferred way of C&D waste management in most countries is disposal to designated landfills. It should be noted that the disposal to landfill is associated with costs, the largest and most visible ones being transportation costs and landfill tipping fees (Khandelwal *et al.*, 2018) for example, the collection and sanitary landfill disposal costs for lower-mid income countries (such as Iraq) being in the range of 15–40 USD, while for high-income countries being in the range of 85–250 USD (Jia *et al.*, 2018).

Various concerns on environmental pollution and rapid depletion of natural resources as well as sustainability programs being implemented have urged many other

countries to set aside the approach of landfill disposal and rather consider alternative ways for more efficient waste management such as: applying life cycle assessment to municipal solid waste management especially in European and some Asian countries for waste disposal reduction (Khandelwal *et al.*,2018), reducing illegal waste via C&D models using system dynamics and grey model theory (Jia *et al.*, 2018), and mixing inorganic construction wastes containing CaO (e.g., waste gypsum) to Portland cement in appropriate proportions to promote recycling and thus to reduce disposal (Kim *et al.*, 2018). On the contrary, companies are seeking more efficient ways of waste management most often in terms of economical sustainability more than in their urban environments (UNEP, 2017).

Among middle east countries, construction industry has been experiencing rapid growth in Iraq since 2003. Construction sector has been one of driver of economic growth in Iraq, while the research that has been carried out in the area of industrial and municipal construction waste management practices in Iraq is quite limited and a few published research related to C&D waste generation could have been found (Abdulameer, 2014; Khaleel *et al.*, 2018). Environmental Code of Republic of Iraq is the main directive that regulate the waste management including construction and demolition waste management (Al-ageeli *et al.*, 2016). Besides, issued in 2006 by "*Ministry of Health and Environment"*, Program of Modernization of Municipal Solid Waste Management aiming at improving management and control of municipal solid waste system also deals with the issues, management and regulations linked to the country-wide construction waste management practices (Khaleel *et al.*, 2018).

Although the primary focus is on addressing the damage to the environment caused by these streams of waste, this represents significant economic losses. In this context, the effective management of these wastes in order to reduce their environmental and economic impacts is one of the most important issues of the twenty-first century. This is because the most beneficial, most economical, and most environmentally sustainable approach within the waste management hierarchy is to prevent/minimize waste Nikmehr *et al.*, (2017). Consuming natural resources and increasing waste production require solutions to protect the quality of the natural and built environments. For these solutions to be effective waste management methods must be developed to prevent economic and environmental losses, it is important to prevent/reduce construction waste in the construction industry. To achieve this target, various site management strategies have been developed throughout the world. there

are several methods used to reduce waste generation such as BIM, IBS, policy and regulation, environmental awareness, training and information, construction waste management approach, etc. in managing construction waste. Although it is a completely new approach, it is gradually gaining recognition among construction professionals.

The industrialized building system (IBS) is one in which all building components, such as walls, slabs, beams, columns, and staircases, are mass-produced in a factory or on the job site under strict quality control and with minimal waste. As early as the 1960s, industrialized building systems (IBS) were introduced into the construction industry Nikmehr *et al.,* (2017). Our construction industry is facing challenges due to a shortage of skilled labor and the high cost of construction. As a result, the concept of construction using IBS is proposed in order to reduce our reliance on intensive labor work and construction waste generation. Therefore, this study aims to identifying causative factors and minimization methods to reducing/preventing construction waste in construction activities (Amu & Adesanya, 2016).

BIM technology is a technological development that can be very useful in construction waste management. However, BIM is an emerging technology. It is envisaged that the construction waste that is generated consciously and/or unconsciously during the construction process can be minimized by the possibilities of technology. At this point, it is thought that BIM technology, which can create the whole project on a digital interface, can be utilized with a systemic approach. One of the dynamic sectors where technological developments are put into practice as quickly as possible is undoubtedly the construction sector, although it is still slow compared to some sectors where industrialized production is carried out. The results of the race to follow innovations in order to make a difference in the competitive conditions of the world are followed with interest in architecture and the construction world Akinade *et al.,* (2018). BIM is one of the technological developments that has been increasingly seen in recent years in the acceleration of adoption by construction project stakeholders, which are closely related to the construction industry. As the most comprehensive of the existing conditions, BIM can be thought of as a new project management concept that allows all participants to stimulate and share data on a single model (Hasmori *et al.,* 2020).

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