A COMPARATIVE STUDY OF CONSTRUCTION WASTE GENERATION RATE BASED ON DIFFERENT CONSTRUCTION METHODS USED IN CONSTRUCTION PROJECTS IN MALAYSIA

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DEDICATION

To my lovely mother and father, who gave me endless love, trust, constant encouragement over the years, and for their prayers.

To my sister, who gave me moral support in all forms, and motivates me always.

To my brothers, for their patience, support, love, and prayers.

To my friends, for their endless support.

This thesis is dedicated to them.

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ABSTRACT

In Malaysia, the huge generation of construction waste (CW) has led to negative impact on the environment. Limited data is available on quantification methods of CW in the country. The lack of quantification methods has resulted to the improper management of CW. The consequence of the improper CW management has shortened the lifespan of landfills. The aim of this study is to compare the construction waste generation rate between different construction methods. In order to obtain CW data in terms of volume and weight, the site visit (SV) method was carried out for a 3-month period. There are two types of SV methods applied in this study, namely direct measurement and indirect measurement. The data were collected from 12 social amenities projects at the construction stage which can be divided into the Conventional Construction Method (CCM), the Mixed Construction Method (MCM) and the Industrialised Building System (IBS). The waste (tonnes) obtained from each construction method is divided by gross floor area (m^2) to attain the Waste Generation Rate (WGR). Finally, the result of the study revealed that the WGRs for IBS, MCM and CCM are 0.018 tonne/m^2, 0.030 tonne/m^2 and 0.046 tonne/m^2 respectively. It can be concluded that the IBS method is the most effective method to reduce CW generation on site. This finding will be a contribution for construction players, policy makers and authorities in the country to promote IBS methods more rigorously.

ABSTRAK

Penjanaan sisa pembinaan (CW) yang tinggi telah memberikan impak negatif kepada alam sekitar di Malaysia. Data mengenai kaedah pengukuran CW adalah sangat terhad di negara kita. Kekurangan kaedah pengukuran telah membawa kepada pengurusan CW yang tidak teratur. Kesan daripada pengurusan CW yang tidak teratur, telah mengurangkan jangka hayat tapak pembuangan sampah. Tujuan penyelidikan ini adalah untuk membandingkan antara kadar penjanaan sisa pembinaan dengan kaedah pembinaan. Untuk mendapat data penjanaan CW dalam isipadu dan berat, kaedah melawat tapak (SV) telah dijalankan selama 3 bulan. Terdapat 2 jenis kaedah SV, iaitu pengukuran langsung dan pengukuran tidak langsung. Data telah dikutip daripada 12 projek ameniti sosial dalam peringkat pembinaan yang dibahagikan kepada Kaedah Pembinaan Konvensional (CCM), Kaedah Pembinaan Bercampur (MCM) dan Kaedah Pembinaan Industri (IBS). Berat sisa (tonne) yang didapat daripada setiap kaedah pembinaan telah dibahagikan dengan jumlah kasar keluasan lantai (m^2) untuk mendapat kadar penjanaan sisa (WGR). Akhirnya, dapatan kajian ini membuktikan bahawa WGR untuk IBS, MCM dan CCM adalah 0.018 tonne/m^2, 0.030 tonne/m^2 dan 0.046 tonne/m^2. Konklusinya, kaedah IBS adalah kaedah yang paling efektif berbanding dengan yang lain untuk mengurangkan CW di tapak. Kajian ini akan menjadi satu sumbangan bagi pemilik pembinaan, kerajaan dan juga pihak berkuasa di dalam negara untuk menggalakkan kaedah IBS dengan lebih baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

AWGR	-	Average waste generation rate
BQ	-	Bill of quantities
CIDB	-	Construction Industry Development Board
CITP	-	Construction Industry Transformation Programme
CCM	-	Conventional construction method
CPC	-	Central product classification
CSA	-	Classification system accumulation
CW	-	Construction waste
DM	-	Direct measurement
DO	-	Delivery order
FM	-	Field measurement
GRC	-	Generation rate calculation
IBS	-	Industrialised Building System
IM	-	Indirect measurement
MCM	-	Mixed construction method
RORO	-	Roll-on Roll-off
SV	-	Site visit
SWCorp	-	Solid Waste Corporation
UN	-	United Nation
VM	-	Variables modelling
WGR	-	Waste generation rate
WRAP	-	Waste and Resources Action Programme

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CHAPTER 1

INTRODUCTION

1.1 Research background

The construction industry plays an important role in promoting the growth of the economy to achieve the target of plausible development in Malaysia (Mah, Fujiwara, & Ho, 2016). Construction waste refers to unwanted substances generated during the construction period and renovation of structures (Yeheyis *et al*., 2016).

As the construction of infrastructure and buildings increases, the amount of construction waste (Vivian *et al.*, 2011). A huge amount of waste produced from these activities, including concrete, wood, and metals, are disposed of in landfills (Nagapan *et al.*, 2012).

The general components in construction waste are inert materials (e.g., concrete, timber, metal, bricks, etc.), which cause small damage to the environment. Proper measurement of construction waste is vital to initiate effective management at both project level and regional level (Bergsdal *et al.*, 2007).

Construction waste quantification is paramount in the construction management field. As the generation of the construction waste increases and becomes uncontrolled in Malaysia, waste management becomes more difficult. The proper quantification of construction waste would help the respective authorities to understand the current environment of construction waste generation.

Different construction methods can influence construction waste generation. This theory has been proven by many researchers. The practices of CCM, MCM and IBS implementation on site need to be identified to determine whether it affects waste generation in the Malaysian construction industry.

1.2 Problem statement

The Malaysian construction industry is saturated with various types of problems ranging from safety issues, worker's affairs and poor-quality control. One of the most famous issues emphasised by local researchers is construction waste management at Malaysian construction sites. Serious issues have resulted from the construction waste generated in different cities worldwide (Mah *et al.,* 2016). Despite the fact the problem has long become the attention of the media, measures to control waste generation have been limited (Nagapan *et al.,* 2013).

Construction waste in landfills is a burden to the environment and a costly issue for solid waste management (Dolan *et al.,* 1999). These wastes have the potential to affect the well-being of humans and the environment (Arslan *et al.,* 2012). The spotlight turned towards construction waste only after environmental implications arose (Tomas, 2015). Both the environmental and economic sustainability of countries has been affected by the generation of construction waste (Marzouk & Azab, 2014).

Very limited data pertaining to construction waste generation in Malaysia exists (Mahayuddin *et al.,* 2013). According to Mah (2016), there is no printed and credible construction waste data related to construction waste materials. In addition, Malaysia still lacks research studies on construction waste generation (Noor *et al.,* 2013). These reasons have become the primary motivation for construction waste generation rates to be investigated in this study.

Construction waste generation is affected by a few factors in the construction field. The factors include improper management, less awareness and rules and regulations. According to Mahayuddin (2013), construction waste generation also depends on the construction methods and materials utilised at construction sites. This statement is strengthened more by Mohamed & Mohamed (2016) who stated that construction waste varies along with different building structures and methods of construction. In addition, not many studies comparing construction waste generation rate with construction methods in Malaysia have been carried out.

A limited number of CW generation rate data is the motivating factor for local researchers to explore this field further. Besides that, the findings of this study would also contribute to the existing body of knowledge of the current construction industry, especially on the relationship between construction methods and construction waste generation rates.

1.3 Research questions

Based on the problem statement, the research questions are formulated as follows:

i. What are the construction methods used in the construction field?
ii. What is the construction waste generation rate at construction projects in Malaysia?
iii. How does the construction method affect construction waste generation in terms of waste generation rate?

1.4 Research aim and objectives

This study aims to compare the construction waste generation rate between different construction methods for on-going construction projects in Malaysia. To achieve this aim, the objectives of this study are developed as below:

i. To identify the current construction methods practiced at a construction site.
ii. To quantify construction waste generation rate for each construction method.
iii. To compare the construction waste generation rate among different construction methods.

1.5 Research scope

The study is limited due to certain restriction to ensure a valid research path. The scopes are as follows:

Table 1.1: Research Scope

Scope of location	Peninsular Malaysia; Kuala Lumpur (1), Terengganu (4), Kedah (4), Pinang (2) and Perak (1).
Data collection period	3 months
Waste collection criteria	Well organized, orderly sorted and neatly collected
Types of project	Social amenities
Data collection method	Site visit

The total number of sites studied was 12. The number of sites was based on the availability of waste. This is due to the consistency of the data. Besides, only the construction wastes of these 12 sites were well organised. Construction waste categorisation on site is vital for this study. CW without proper sorting was ignored. The period of data collection was 3 months. This timeline was due to the continuous availability of CW on site. This period is popular among local researchers in Malaysia who conduct studies in the same field. Data which was not obtained during this continuous period was ignored.

The type of project chosen for this study was social amenity projects. This will contribute to the body of knowledge for existing studies in Malaysia as limited studies available focus on this type of project. All these projects were at the construction stage and duration where most of the sites selected had practical completion within the period from October 2017 to August 2018.

The methodology applied in this research was the site visit method. This method was proposed and developed in different ways by multiple researchers worldwide. This method was adapted according to the nature of construction in Malaysia as it varies according to country. The site visit method can be classified as direct measurement and indirect measurement. Both were applied in this study.

1.6 The significance of the research

This research is important to identify the amount of construction waste produced by construction projects and the waste generation rate in Malaysia. In addition, the construction methods used in Malaysia vary according to project management. Thus, by comparing the construction waste generation rate with the construction method, the output results in the method that produces the least waste can be identified. This outcome will indirectly assist in determining construction waste reduction strategies and management in future. For the construction industry, effective construction method implementation can be identified through this study, especially for waste management. Besides, it is also a big contribution to the country in accordance with the requirements of the Construction Industry Development Board (CIDB) under CITP (Construction Industry Transformation Programme) which aims to reduce irresponsible waste during construction.

1.7 Summary

This chapter concludes that the construction industry in Malaysia is emerging day by day as it plays an important role in the development of the country. Simultaneously, construction waste production is increasing from day to day. Despite the focus on infrastructure development, immediate action must be taken to reduce construction waste in Malaysia. These problems may lead to bigger issues such as improper waste management in future if proper attention is not given.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section contains studies related to construction waste quantification in Malaysian construction projects. Throughout this chapter, construction waste quantification, type of construction methods and construction projects will be explained. This review is important to gain a better understanding of the topic undertaken.

2.2 Definition

Waste is characterised as a material which is gotten rid through disposal or is intended for disposal. Construction waste consists of different forms during the extraction of raw materials, where they are processed into intermediate and final products, and final product consumption (Eusuf *et al.*, 2012).

Activities such as building activities, road and rail development, maintenance and excavation create construction wastes. Meanwhile, Ekanayake & Ofori (2004) stated that construction waste refers to any medium separated from the earth's existing medium which should have been moved to somewhere else from the construction site or utilised at the place due to malfunction, overabundance or mismatch with specifications. In addition to that, construction waste is interpreted as unwanted materials from construction, renovation, etc. It is also described as excess and damaged substances generated during construction work (Ponnada & P, 2015). Table 2.1 shows the definition of construction waste provided by various authors worldwide.

Table 2.1: Construction waste definition by different authors

No.	References	Construction Wastes Definition
1.	Ghosh et al. (2016)	An eliminated substance which emerges from construction and renovation activities including land excavation, construction, site clearance, roadwork, and building remodel.
2.	Gayakwad & Sasane, (2014)	Waste which arises from construction, and renovation activities and malfunctioned products and substance generated in the course of construction work or used temporarily during the course of on-site activities.
3.	Jr & Manukau, (2014)	Discarded materials generally considered to be not water-soluble and non-hazardous in nature, including, but not limited to, steel, glass, brick, concrete, asphalt roofing material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a structure as part of a construction project or from the renovation of a structure, and including rocks, soils, tree remains, trees, and other vegetative matter that normally results from land clearing or land development operations for a construction project, including such waste from construction of structures at a site remote from the construction project site
4.	Arslan et al. (2012)	Mixture of inert and non-inert materials arising from construction, excavation, renovation, refurbishment, roadwork and other construction-related activities
5.	Zia & Devadas, (2007)	comprising of unwanted materials generated during construction
6.	Ekanayake & Ofori, (2004)	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.
7.	Formoso et al. (2002)	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.

In this study, construction waste can be defined as any materials that are eliminated, unwanted or disposed of during construction activities which result from excess or non-use products.

2.3 Type of construction waste

Construction wastes can be categorised into physical waste and non-physical waste (Nagapan *et al.*, 2013). Physical waste is defined as materials which are lost, spoiled, cannot be repaired, cannot be used or losses during construction activities. Meanwhile, non-physical wastes are related to cost overrun and delay in construction projects (Nagapan, 2012). The main solid wastes found at construction sites are gravel, concrete, asphalt, bricks, tiles, plaster, masonry, wood, metal, paper and plastics (Hurley, 2003). Franklin Associates (1998) explained that construction waste from building sites typically consists of trim scraps of construction materials, such as wood, sheetrock, masonry, and roofing materials.

Table 2.2 shows the categories of waste classified by different authors. By referring to this table, construction waste materials can be filtered. The materials include timber, concrete, bricks and blocks, metal, packaging material, ceramic and tiles, glass, soil and aggregate, plastic material, asphalt and tar, cardboard, gypsum board and mixed waste. In Malaysia, Nagapan et al. (2013) have sorted construction waste into six main categories namely concrete, timber, metals, bricks, packaging wastes, ceramic and tiles. Table 2.2 shows six types of construction waste. Therefore, this study also focused specifically on these construction wastes.

Table 2.2: Typical construction waste

References	Country	Construction Wastes					
		Concrete	Timber/Wood	Steel/Metal	Packaging Waste	Ceramic and Tiles	Mixed
Mah et al. (2016)	Malaysia	*	*	*		*	*
Cho et al. (2015)	Korea	*	*	*	*		*
Bakshan et al. (2015)	Lebanon	*	*	*	*	*	*
Button et al. (2014)	Canada	*	*	*			*
Foo et al. (2013)	Malaysia	*	*	*	*		
Bergsdal et al. (2007)	Norway	*	*	*	*		
Assari et al. (2004)	Malaysia	*	*	*	*		*
Franklin Associates, (1998)	United States	*	*	*	*		*
Bossink & Brouwers, (1996)	Netherlands	*	*	*		*	

2.3.1 Concrete

Concrete is considered as the basis of the urban environment. Apartments and office blocks are primarily constructed using concrete. Basically, concrete is a mixture of aggregate (gravel, stone and sand), cement and water (Mulders, 2013). Concrete exists at a construction site in two forms – reinforced concrete and foundations (non-reinforced concrete) (Ponnada & P, 2015). The construction of both substructures and superstructures of buildings and other infrastructures is conducted using concrete as the generally used component. Poon (2004) identify that the material wastage in construction is mainly due to the excessive order of concrete when compared with the amount required, mostly in the case of ready mix concrete supply. identified that material wastage in construction is mainly due to the excessive use of concrete, mostly in the case of ready-mixed concrete supply. Additionally, poor planning, project delays and inefficient material handling processes by contractors can lead to material wastage.

2.3.2 Wood

The usage of wood in the construction industry can be both long-term and temporary. Structural elements (pillars and beams) and building envelope components (frames/panels, windows, and doors) belong to the long-term category (Parisi *et al.,* 2018).

The second largest component of construction waste after concrete is wood. It contributes around 20-30 percent of construction waste from buildings (Leblanc, 2018). Wood waste contributes to a significant portion of building construction waste (Hossain & Poon, 2018). According to the California Integrated Waste Management Board (2008), the primary constituents of wood wastes are used in lumber, trim, shipping pallets, and other kinds of wood debris from construction activities. The main cause of wood wastes is natural deterioration (Poon, 2004), especially during demolition activities.

2.3.3 Steel/Metal

In the construction industry, metals are the most valuable material. Metals can be classified as ferrous or non-ferrous. Reinforced concrete bars and reinforced masonry are made up of the most essential component which is a reinforcement bar (Rai, 2005). Steel reinforcement bars are also common materials. The main causes of rebar wastage are due to the careless cutting by labourers and improper estimation of dimensions. Poon (2004) confirmed that damages during storage and rusting also contribute to the volume of wastes.

2.3.4 Packaging waste

Packaging waste is one of the contributors of construction waste, and cardboard is mainly generated during electricity works. Of the environmental impacts caused by a product, 80% is defined during the construction stage, including the impact of the packaging needed to deliver that product on site (Pericot, 2017).

2.3.5 Ceramic and tiles

Ceramic and tiles are generated from naturally existing materials containing clay minerals in high proportion. Following a process of dehydration and controlled firing at temperatures between 700ºC and 1000ºC, these minerals acquire the characteristic properties of fired clay (Juan & Medina, 2010). These ceramic wastes are also part of construction waste.

2.3.6 Mixed waste

One of the most common types of construction waste generated in the construction industry is mixed waste. Generally, mixed waste consists of all the wastes which are not sorted according to category. These wastes cannot be separated into its own category.

REFERENCES

Arslan, H., Coşgun, N., & Salgın, B. (2012). Construction and Demolition Waste Management in Turkey.

Assari, A.S., Halim, H. B. A., & Isa, M. H. (2004). A study on construction and demolition waste from buildings in Seberang Perai. In *Proceeding of 3rd NationalConference in Civil Engineering,Copthorne Orchid, Tanjung Bungah, Malaysia* (pp. 3–8).

Badir, Y.F., Kadir, M. R. A., & Ali, A. A. (1998), "Theory of classification on Badir-Razali building system classification", Bulletin of Institution of Engineers, Malaysia, October.

Badir, Y. F., Kadir, M. R. A., & Hashim, A. H. (2002). Industrialized Building Systems Construction in Malaysia. *Journal of Architectural Engineering*, *8*(1), 19–23. http://doi.org/10.1061/(ASCE)1076-0431(2002)8:1(19)

Bakshan, A., Srour, I., Chehab, G., & El-Fadel, M. (2015). A field based methodology for estimating waste generation rates at various stages of construction projects. *Resources, Conservation and Recycling*, *100*, 70–80. http://doi.org/10.1016/j.resconrec.2015.04.002

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2006). A benefit-cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Conservation and Recycling*, *48*(1), 86–98. http://doi.org/10.1016/j.resconrec.2006.01.004

Bergsdal, H., Bohne, R. A., & Bratteb, H. (2007). Projection of construction and demolition waste in Norway. *Journal of Industrial Ecology*, *11*(3), 27–39. http://doi.org/10.1162/jiec.2007.1149

Bjerregaard, M., Shaw, H., & Kohler, N. (2008). CONSTRUCTION AND DEMOLITION WASTE. *Centre for Science and Environment*, *161*, 45–49.

Bossink, B. A. G., & Brouwers, H. J. H. (1996). Construction Waste: Quantification and

Source Evaluation. *Journal of Construction Engineering and Management*, *122*(1), 55–60. http://doi.org/10.1061/(ASCE)0733-9364(1996)122:1(55)

Button, A., Lee, W., Marshall, D., Dawood, Z., Maclellan, S., Umali, H., & Pagsuyoin, S. (2014). Management of Construction and Demolition Waste in the Region of Waterloo, *00*(c), 53–56.

California Integrated Waste Management Board. (2008). Retrieved April 20, 2018, from California Integrated Waste Management Board: www.ciwb.ca.gov

Cho, K., Jeon, H., Lee, M., An, J., & Choi, D. (2015). A Study on Estimation of the Amount of Construction Wastes Using Construction Material Costs in Korea, *96*(Irtt), 9–13.

CIDB (2003) IBS Survey 2003 - A Survey on the Usage of Industrialised Building System in Malaysian Construction Industry, Construction Industry

CIDB. (2016). *Construction Industry Transformation Programme 2016-2020*. Kuala Lumpur: CIDB Malaysia.

Dajadian, S. A., & Koch, D. C. (2014). Waste Management Models and Their Applications on Construction Sites. *International Journal of Construction Engineering and Management*, *3*(3), 91–98. http://doi.org/10.5923/j.ijcem.20140303.02

Dolan, P. J., Lampo, R. G., & Dearborn, J. C. (1999). Concepts for Reuse and Recycling of Construction and Demolition Waste. *US Army Corps of Engineers*, 1–137.

Ekanayake, L. L., & Ofori, G. (2004). Building waste assessment score: Design-based tool. *Building and Environment*, *39*(7), 851–861. http://doi.org/10.1016/j.buildenv.2004.01.007

Eusuf, M. A., Ibrahim, M., & Islam, R. (2012). The Construction and Demolition waste in Klang Valley, Malaysia. *Journal of the Malaysian Institute of Planner*, *X*, 99–124.

Foo, L. C., Abdul Rahman, I., Asmi, A., Nagapan, S., & Khalid, K. I. (2013). Classification and quantification of construction waste at housing project site. *International Journal of Zero Waste Generation*, *1*(1), 1–4. Retrieved from http://www.zwgm.org/index.php/zerowastejournal/article/view/4

Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material Waste in Building Industry: Main Causes and Prevention. *Journal of Construction*

Engineering and Management, *128*(4), 316–325. http://doi.org/10.1061/(ASCE)0733-9364(2002)128:4(316)

Franklin Associates. (1998). Characterization of Building related Construction and Demolition Debris in the United States. Pairie Village, KS: Techlaw Inc.

Ganiron, T. U. J. (2015). Recycling Concrete Debris from Construction and Demolition Waste. *International Journal of Advanced Science and Technology*, *77*, 7–24. http://doi.org/http://dx.doi.org/10.14257/ijast.2015.77.02

Ganiron, T. U. J., Roopu, T., & Manukau, T. O. (2014). Investigation on the Physical Properties and Use of Lumampao Bamboo Species as Wood Construction Material, *72*, 49–62.

Gayakwad, H. P., & Sasane, N. B. (2014). Construction and Demolition Waste management in India, (June), 712–715.

Ghosh, S. K., Haldar, H. S., Chatterjee, S., & Ghosh, P. (2016). An Optimization Model on Construction and Demolition Waste Quantification from Building. *Procedia Environmental Sciences*, *35*, 279–288. http://doi.org/10.1016/j.proenv.2016.07.008

Hafezi, M.H., & Ismail, A. (2011). Interaction between bus stops location and traffic on bus operation. J. Appl. Mech. Mater. Adv. Transport., 97- 98(2011): 1185-1188.

Hafizan H. S., Abdul Aziz, H., Johari, I., & Adlan, M. N. (2015). Quantification of Concrete Waste Generated in Housing Construction Sites via Site Sampling: Development of a Multiple Linear Regression Model. *Applied Mechanics and Materials*, *802*(2), 676–681. http://doi.org/10.4028/www.scientific.net/AMM.802.676

Haron, N.A., Hassim, S., Razali, M. K. A., & Jaafar, S. (2005). Building Cost Comparison Between Conventional and Formwork Building Cost Comparison Between Conventional and Formwork System. *Jurnal Teknologi*. http://doi.org/10.3844/ajassp.2005.819.823

Hossain, U., & Poon, C. S. (2018). Comparative LCA of wood waste management strategies generated from building construction activities. *Journal of Cleaner Production*, *177*, 387–397. http://doi.org/10.1016/j.jclepro.2017.12.233

Hurley, J. (2003). Construction, innovation and global competitiveness: How to SMART Waste the construction industry. *10th International Symposium.* London: CRC Press

LLC.

Ismail, R., Hafezi, M. H., & Nor, R. M., (2013). Perception towards Public Amenities in Malaysia, *6*(18), 3410–3414.

Juan, A., & Medina, C. (28 September 2010). Re-use of ceramic wastes in construction. In *Ceramic Materials* (p. 228). Rijeka: Sciyo.

Kaming, P., Olomoliye, P., Holt, G., & Harris, F. (1997). Factors Influencing Craftsmen's Productivity in Indonesia. *International Journal of Project Management*, 21-30.

Kasvar, K. (2017). Cost Implication Analysis of Concrete and Masonry Waste in Construction Project. *Pertanika Journal Science and Technology*, 177-184.

Lachimpadi, S. K., Pereira, J. J., Taha, M. R., & Mokhtar, M. (2012). Construction waste minimisation comparing conventional and precast construction (Mixed System and IBS) methods in high-rise buildings: A Malaysia case study. *Resources, Conservation and Recycling*, *68*, 96–103. http://doi.org/10.1016/j.resconrec.2012.08.011

Lau, H. H., Whyte, A. A., & Law, P. L. (2008). Composition and characteristics of construction waste generated by residential housing project. *International Journal of Environmental Research*, *2*(3), 261–268.

Liu, J., & Wang, Y. (2013). Cost Analysis of Construction and Demolition Waste Management : Case Study of the Pearl River Delta of China . *he Open Construction and Building Technology Journal*, 251-263 .

Mah, C. M., Fujiwara, T., & Ho, C. S. (2016). Construction and demolition waste generation rates for high-rise buildings in Malaysia. *Waste Management & Research*. http://doi.org/10.1177/0734242X16666944

Mahayuddin, S. A., Pereira, J. J., Badaruzzaman, W. H. W., & Mokhtar, M. B. (2006). Construction Waste Index for Waste Control in Residential House Project. *SB 10 New Zealand*, 1–7.

Mahayuddin, S. A., & Zaharuddin, W. A. Z. W. (2013). Quantification of Waste in Conventional Construction. *International Journal of Environmental Science and Development*, *4*(3), 296–299. http://doi.org/10.7763/IJESD.2013.V4.357

Marzouk, M., & Azab, S. (2014). Environmental and economic impact assessment of construction and demolition waste disposal using system dynamics. *Resources,*

Conservation and Recycling, *82*, 41–49. http://doi.org/10.1016/j.resconrec.2013.10.015

Masudi, A. F., Hassan, C. R. C., Mahmood, N. Z., Mokhtar, S. N., & Sulaiman, N. M. (2012). Waste quantification models for estimation of construction and demolition waste generation: a review. *International Journal of Global Environmental Issues*, *12*(2/3/4), 269. http://doi.org/10.1504/IJGENVI.2012.049378

Masudi, A., & Hassan, C. (2011). Construction Waste Quantification and Benchmarking: A study in Klang Valley, Malaysia. *Chemical Engineering*, *5*, 909–916.

Mohamed, U. F., & Mohamed, D. A. (2016, January 1). A Glance on Construction Solid Waste Management in Khartoum. *International Journal of Science, Engineering and Technology Research (IJSETR)*, *5*(1), 101-116.

Muhaidin, N. H., & Chan, H. B. (2018). The comparison of construction waste produced by conventional method against IBS: A case study in Pulau . *Advances in Civil Engineering and Science Technology*, 6.

Mulders, L. (2013). High quality recycling of construction and demolition waste in the Netherlands, 20.

Mydin, M. O., Khor, J., & Sani, N. M. (2014). Approaches to Construction Waste Management in Malaysia. *MATEC Web Conferences 17, 01014* (p. 7). EDP Sciences.

Mydin, M. O., Sani, N. M., & Phius, A. (2014). Investigation of Industrialised Building System Performancein Comparison to Conventional Construction Method . *MATEC Web of Conferences 10* (p. 6). EDP Sciences.

Nagapan, S., Rahman, I. A., & Asmi, A. (2012). Construction Waste Management: Malaysian Perspective. *The International Conference on Civil and Environmental Engineering Sustainability IConCEES 2012*, *2*(October 2016), 1–11.

Nagapan, S., Rahman, I. A., Asmi, A., & Adnan, N. F. (2013). Study of site's construction waste in Batu Pahat, Johor. *Procedia Engineering*, *53*, 99–103. http://doi.org/10.1016/j.proeng.2013.02.015

Nagapan, S., Rahman, I. A., Asmi, A., Hameed, A., & Zin, R. M. (2012). Identifying Causes of Construction Waste - Case of Central Region of Peninsula Malaysia. *International Journal of Integrated Engineering, Vol. 4 No. 2 (2012) p. 22-28*, *4*(2), 22–28.

Nagapan, S., Rahman, I. A., Asmi, A., Memon, A. H., & Latif, I. (2012). Issues on construction waste: The need for sustainable waste management. In *CHUSER 2012 - 2012 IEEE Colloquium on Humanities, Science and Engineering Research* (pp. 325–330). http://doi.org/10.1109/CHUSER.2012.6504333\

Noor, R. M., Mohd Ridzuan, A. R., Endut, I. R., Noordin, B., Shehu, Z., & Ghani, A. H. A. (2013). The quantification of local construction waste for the current construction waste management practices: a case study in Klang Valley. *2013 IEEE Business Engineering and Industrial Applications Colloquium (BEIAC)*, 183–188. http://doi.org/10.1109/BEIAC.2013.6560110

OECD. (2002, March 17). *Glossary of Statistical Terms*. (OECD) Retrieved December 17, 2018, from https://stats.oecd.org/glossary/detail.asp?ID=2326

O'Sullivan, A., Sheffrin, S.M. (2003). Economics. In *Principles in Action* (p. 474). Upper Saddle River: NJ: Pearson Prentica Hall

Parisi, A., Vargas, L., Cirelli, S., & Montelongo, A. (2018). Factors influencing temporary wood waste generation in high-rise building construction. *Waste Management*, *78*, 446–455. http://doi.org/10.1016/j.wasman.2018.05.057

Pericot, N. G. (2017). Packaging waste reduction in construction sites: eco-redesign of cardboard boxes. *Waste Recycling Research 2017;* , 4.

Ponnada, M. R., & P, K. (2015). Construction and Demolition Waste Management – A Review. *International Journal of Advanced Science and Technology*, 19-46.

Poon, C.S., Yu, A.T.W., See, S.C., Cheung, E., (2004). Minimizing demolition wastes in Hong Kong public housing projects. Constr. Manage. Econom. 22 (8), 799–805

Rai, D. C. (2005). Evaluation of Properties of Steel Reinforcing Bars for Seismic Design.

Saez, P. V., Porras-Amores, C., & Merino, M. D. R. (2014). New quantification proposal for construction waste generation in new residential constructions. *Journal of Cleaner Production*, *102*, 58–65. http://doi.org/10.1016/j.jclepro.2015.04.029.

Vivian W.Y., T. (2011). Rate of Reusable and Recyclable Waste in Construction. *The Open Waste Management Journal*, *4*(1), 28–32. http://doi.org/10.2174/1876400201104010028

Wahi, N., & Zin, R. M. (2018). Problems and Issues of High Rise Low Cost Housing in Malaysia Problems and Issues of High Rise Low Cost Housing in Malaysia.

http://doi.org/10.1088/1757-899X/341/1/012027

Wu, Z., Yu, A. T. W., Shen, L., & Liu, G. (2014). Quantifying construction and demolition waste: An analytical review. *Waste Management*, *34*(9), 1683–1692. http://doi.org/10.1016/j.wasman.2014.05.010

Yeheyis, M., Hewage, K., Alam, M. S., Eskicioglu, C., & Sadiq, R. (2016). An overview of construction and demolition waste management in Canada : A lifecycle analysis approach to sustainability, (February 2012). http://doi.org/10.1007/s10098-012-0481-6

Yuan, H., & Shen, L. (2011). Trend of the research on construction and demolition waste management. *Waste Management*. http://doi.org/10.1016/j.wasman.2010.10.030

Zia, H., & Devadas, V. (2007). Municipal solid waste management in Kanpur, India: obstacles and prospects. *Management of Environmental Quality: An International Journal*, *18*(1), 89–108. http://doi.org/10.1108/14777830710717749