A FRAMEWORK DESIGN FOR CONSTRUCTION WASTE MINIMIZATION IN MALAYSIA

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Honours) Civil Engineering

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

Malaysia's construction industry had shown rapid growth in the last decade. The recent construction industry is undertaking pressure to practice waste minimization due to the over-production of waste. This study focused on identifying an effective waste management plan by proposing a framework design for construction waste minimization. A mixed-method approach, involving qualitative and quantitative research, has been adopted as the mean of data collection by online questionnaire surveys. Factors such as the enforcement of regulations, recycling market development, operatives' consciousness and advanced methods were included. The data analysis was conducted through a combination of reliability analysis, Kruskal-Wallis test and descriptive statistics analysis by adopting Statistical Package for Social Science (SPSS) version 25. Key findings which emerged from this study revealed that the major construction waste was caused by conventional way of construction and improper site management. The most potential waste minimization strategies included Site Waste Management Plan (SWMP), Industrialized Building System (IBS) and Building Information Modelling (BIM). The framework presents a coherent approach for achieving sustainable waste minimization in construction companies.

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LIST OF SYMBOLS / ABBREVIATIONS

BIM	Building Information Modelling
BREEAM	Building Research Establishment's Environmental Assessment Method
CAD	Computer-Aided-Design
CIDB	Construction Industry Development Board
GBI	Green Building Index
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
IBS	Industrialized Building System
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
PAM	Persatuan Arkitek Malaysia
PVC	Polyvinylchloride
PWD	Public Work Department
SPSS	Statistical Package for Social Sciences
SWMP	Site Waste Management Plan
WRAP	Waste & Resources Action Programme
3R	Reduce, Reuse and Recycle

CHAPTER 1

INTRODUCTION

1.1 General Introduction

One of the main economic contributors to the Gross Domestic Product (GDP) in Malaysia is the construction industry. According to Vasudevan (2019), the continuous growth of the construction sector boosts Malaysia’s GDP to a new peak value reaching around RM140 billion in 2018 compared to the previous year reading of about RM138 billion. Besides generating such a high income, the rapid development of the construction industry comes along with environmental impacts. By referring to Saadi, Ismail and Alias (2016), Malaysia Solid Waste and Public Cleansing Management Corporation verified that the yearly construction waste generated is nearly 8 million tonnes. Along with the GDP progress, Malaysia’s waste generation rate is increasing at an alarming stage, pressuring the overloaded landfills (Noh and Mydin, 2017).

Begum, et al. (2007a) reported that in mid and southern Malaysia, 28.34% of landfills are industrial and construction waste. Although this issue had caught the attention of the media for a long time ago, the actual measures taken to control waste generation were not significant. In corresponding to Turkyilmaz, et al. (2019), the construction sector is expected to consume 40% of global energy usage, 16.7% of freshwater and 25% of globally-harvested timber whilst generating 13% to 30% of total waste around the world. Construction waste production occurs throughout the entire construction period, right from the planning stage until the last stage. The activities such as excavation, site clearance, roadwork, concreting, plumbing work and tiles laying at construction sites produce construction waste (Nagapan, et al., 2018). The implementation of improper waste management directs a lot of waste to landfills, including recyclable ones.

Despite the remarkably high construction waste generation rate, Malaysia’s waste management standards are inadequate to cope with the waste (Begum, et al., 2007a). Yusof (2006) reported that Malaysia’s landfill sites were occupied at a rate of beyond 3 500 m^3 per day. The reasons are such that the material storage and waste collection schemes are inefficient, the documentations of waste production information are outdated, the waste disposals are unsystematic and the operations of disposal location space are unproductive. Furthermore, the highly fragmented nature of the construction industry mainly focuses on fulfilling the clients’ requirements (Ajayi, et al., 2017). As compared to constraints such as cost and time, waste management usually gains limited attention from construction management (Hassan, et al., 2012). Since construction waste is usually highly contaminated and hard to be categorized, it would be challenging to dispose of, reuse or even recycle them.

Although constructions are usually recognized as non-environmental-friendly activities (Tam and Tam, 2006), the reasons for construction waste generation should be identified and the corresponding measures should be investigated. If efficient early-stage site management can be practised, it will reduce waste generation to the greatest extent while preventing the overburden of future waste management (Turkyilmaz, et al., 2019). The efforts to mitigate the waste problem shall consider the community wellness and environmental concerns. The operation of waste-free construction sites can control environmental impacts besides saving cost, material and space needed for waste management.

1.2 Importance of the Study

This study provides contextual waste minimization information to the construction industry stakeholders in performing a sustainable way of development. The results of this study should provide theoretical recommendations after refining the current guidelines and regulations to minimize construction waste. By suggesting preliminary outcomes of potential ways to minimize construction waste, economic benefits are offered to the construction corporations since they can maximise their future incomes in the long term. In addition to monetary paybacks, the implementation of effective waste minimization practice will achieve sustainable construction. Above and beyond preserving natural resources to avoid materials wastage, the environment is protected since the landfill demands are reduced. This study highlights effective construction waste minimization, which can lead to a more sustainable way of development. Besides constructing a building that is compliant with its design standards, the ecological system shall be respectfully taken care while enhancing the social welfare of the public.

1.3 Problem Statement

In Malaysia, the fast-moving expansion of the construction building industry varies from infrastructure to housing and industrial types. Due to the mounting construction leftover, waste control is becoming defective and inappropriate, leading to a severe waste production rate (Vasudevan, 2019). Along with the fast waste generation rate, illegal disposal issues and environmental burdens are counting up in this country.

According to Mallak and Ishak (2012), in the Klang Valley alone, there were above 52 unlawful dumpsites that were piled up by 933 000 kilogrammes of waste which polluted the environment with greenhouse emission and leachate. Referring to the case study done by Rahmat and Ibrahim (2007), construction wastes occupied up to 42% of 46 unlawful dumping spots in the Johor region alone. In Bandar Hilir Malacca, there were nearly 30 000 kilogrammes of illegal construction waste disposal near the tropical mangrove swamps (Nagapan and Rahman, 2014). It is undeniable that landfill is one of the handy ways to handle waste without spending a significant amount of money. However, the world has changed with the rise of resource exhaustion, global warming, pollutions and the growth of population exponentially. The construction industry is forced to bear higher responsibility and change the attitude towards environmental subjects. This issue is being pressurized by the progressively legislative business environment together with the increasingly educated and outspoken public (Teo and Loosemore, 2001).

The current research trend was found mostly focusing on physical waste management issues on the construction sites ranging from waste reduction and waste recycling to waste disposal (Dainty and Brooke, 2004; Mallak and Ishak, 2012; Gálvez-Martos, et al., 2018). The published researches seldom discussed the design practice outcome on construction waste generation, although most of them agreed that waste is primarily generated from the decision made during the design phase (Ekanayake and Ofori, 2004; Esa, Halog and Rigamonti, 2017a; Nagapan and Rahman, 2014; Magalhães, Danilevicz and Saurin, 2017). The critical role in designing out waste at the source was left to be insufficiently addressed. Most of the studies were just suggesting remedial actions to cope with the construction waste after it had been produced. These waste-related studies had primarily concentrated on waste management efforts during the construction stage or post-construction stage throughout the project's delivery when it was almost too late to avoid waste from generating (Ajayi, et al., 2017; Tam and Tam, 2006).

1.4 Aim and Objectives

This research aims to identify an efficient construction waste management plan for Malaysia's construction sector by proposing a framework design for construction waste minimization. The following objectives shall be achieved in progress to reach the aim as stated:

i. To offer contextual information regarding the construction waste issues in Malaysia.
ii. To identify current barriers to implement construction waste minimization.
iii. To highlight strategies and guidelines for effective construction waste minimization.

1.5 Scope and Limitation of the Study

The scope of this research focuses on the current trend and practice of the construction industry in Malaysia to reduce construction waste. Subsequently, the existing problems to perform proper construction waste management are distinguished. By investigating the reasons for inefficient waste management, the possible approaches to overcome these obstacles are finally proposed.

The limitation of this study is restricted to cover only waste generation of residential and commercial projects in Malaysia. Future researches could otherwise figure out the approaches to minimize the generation of waste in other civil engineering projects involving infrastructures. This study determines the construction management methods to minimize waste, but the comparative issues on the post-construction stage will not be addressed. Therefore, future studies are suggested to investigate the scope of waste reduction measures up to the post-construction period of the project development after the waste has been produced. Such studies will then improve the understanding of the strategic importance of construction waste mitigation at each stage.

1.6 Contribution of the Study

The findings presented in this study act as a relevant resource for comparative waste-related studies by providing first-hand useful pointers for decision-makers to enhance the quality of their decisions about waste management practice in Malaysia’s construction projects. Specifically, emphasis on the management strategies should focus on those with greater importance to maximise waste management efficiency. Additionally, the findings serve as valuable references for other economies trying to improve their waste management practice. Nevertheless, it should be emphasized that the management suggestions are yet to be finetuned accordingly to ensure the cases under study are within a specific context.

1.7 Outline of the Study

The outline of this study covered the introduction followed by the literature review and methodology in Chapter 1, 2 and 3 respectively. After obtaining the questionnaire responses, discussion of results was included in Chapter 4. The concluding Chapter 5 further finalized the outcome of this study.

Chapter 1 reviewed the general introduction of this topic of study related to the construction waste matters in Malaysia. This chapter also revealed the importance of the study and the problem statement of the construction waste issues. In response to the problem statement, this study’s aim and objectives were established with the provision of scope and limitation to constraint the study range.

Chapter 2 outlined the findings obtained from the review of the literature. The sources of construction waste were identified and the factors of the increasing construction waste production in Malaysia were discussed. It further clarified the advantages of minimizing construction waste in Malaysia. The current trend of construction waste management implemented in Malaysia was investigated. It also proposed possible measures to minimize construction waste in Malaysia. A brief overview of the statistical analyses was included in this chapter too.

Chapter 3 clarified the research methods adopted in this study. This topic introduced the standards of methodology typically applied in research studies. The process of data collection method for primary and secondary data were identified. It also covered the sampling process and design adopted in this study to figure out the sampling size and target respondents. The last section of this chapter discussed the data analyses selected, including reliability analysis, Kruskal-Wallis test and descriptive statistics analysis.

Chapter 4 presented the results of questionnaire surveys while analyzing the data obtained for this research. The questionnaire survey response rate and sociodemographic of the respondents were investigated. The findings were interpreted using the SPSS and explained based on the statistic tests.

Chapter 5 is the concluding chapter which declared the achievement of the research objectives. It also summarised the whole research findings while proposing recommendations for future researches.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Construction waste denotes the waste in solid form, excluding fluids and hazardous constituents, which are normally inert and produced from buildings projects such as residential, non-residential, roads and bridges (Chen, Li and Wong, 2002). These materials or products will be transported somewhere else or remained in the same location to serve other purposes. Usually, these items are damaged, in excess, not suitable for the specifications, or those inevitable construction by-products (Liu, et al., 2015).

Poon, et al. (2013) describe construction waste as inert materials that are soft, including soil and slurry, whereas the hard-inert ones are rocks and broken concrete. For non-inert waste materials, they are metals, wood, plastics and packaging components. Furthermore, Nagapan, et al. (2012) categorized waste into physical forms such as concrete, wood, metal and packaging materials, whereas non-physical wastes are such as overruns of budget and project delays. Construction waste is not limited to materials only, but it includes non-physical waste resulted from inadequate site planning and management (Esa, Halog and Rigamonti, 2017a). The definition of construction waste shall consider both material deficiency and extra work done which are not conducive, especially from the environmental and productivity viewpoints (Lu and Yuan, 2011).

The construction waste problem is not only happening in Malaysia but also in other countries. According to Tam, Le and Zeng (2012), there were about 23% of waste due to construction and demolition actions in Hong Kong. As for China, Ding, et al. (2016) revealed that nearly 40% of their municipal solid waste was accounted for the building construction events. Baldwin, et al. (2008) stated that construction waste took up 17% of annual waste in the United Kingdom, which equalled about 70 million tonnes. In Germany, the construction waste was estimated at 30 000 000 tonnes per year, whereas the demolition waste was about 14 000 000 tonnes per year (Lu and Yuan, 2011). In the United States of America, the contribution of construction waste to total landfill volume was up to 29% (Teo and Loosemore, 2001).

According to Liu, et al. (2015), construction waste minimization is defined as a design phase process of avoiding, eliminating or decreasing waste at its source before entering the waste stream. Source reduction is described as any mitigation measures within a process that controls the waste generation based on its source. As for recycling, the items that are supposed to be wasted are recovered and reused (Begum, et al., 2007b). The Waste & Resources Action Programme (WRAP, 2014) suggested that waste minimization consists of a series of clear-cut ways starting from designing waste out of a project and waste generation control throughout the construction stage. For enhancement of resource efficacy and consideration of the environmental effect, a proper waste minimization practice should be implemented systematically (Gálvez-Martos, et al., 2018). Besides reducing landfill demand and slowing down the exhaustion of limited natural resources, construction waste minimization is economical-wise contributing to the construction sector and the country's performance.

2.2 Sources of Construction Waste

According to Tam and Tam (2006), construction waste included demolished concrete from foundations, slabs, columns, beams, et cetera. Other significant elements of the waste comprised bricks and masonry, timber, glass, electric cable, pipe, rock and excavated soil. From the studies of Nagapan, et al. (2012), 30 construction sites in Malaysia were identified with six types of waste materials, comprising timber (69.10%), concrete (12.32%), metals (9.62%), bricks (6.54%), plastics (0.43%) and others waste (2%). In the construction stage of three apartment building sites in Korea, concrete took up the highest percentage of the construction waste amount (Kim, et al., 2019). As shown in Table 2.1, CIDB (2008) reported the construction waste composition discarded at Malaysia's landfill sites.

Table 2.1: Composition of Construction and Demolition Waste Disposed at Landfills (CIDB, 2008).

Component	Road Work Materials	Excavated Soil	Demolition Waste	Site Clearance	Renovation Waste
Soil/ sand	23	73.8	21.5	33	19.4
Rock/ Rubble	14.4	12.5	27.7	15	38.8
Concrete/ Mortar	16.9	1.2	10.8	4.6	7.4
Wood	0.6	0.9	10.5	13.3	7.1
Reinforced Concrete	14.2	0.4	5.8	0.9	7
Asphalt	24.7	0	0	0.2	0
Others (glass etc)	1.4	0.7	5.6	13.8	2.9
Bricks / tiles	0.8	0.4	12.1	1.4	9.6
Cement Contaminated	1.7	0.4	3.2	15.6	3.3
Slurry and mud	1.8	9.7	1.5	1	3.1
Ferrous metals	0.5	0	0.6	1	1.3
Non-ferrous metals	0	0	0.7	0.2	0.1
Total	100	100	100	100	100
Total quantity of C & D waste landfilled (%)	5.2	59.4	8.5	14.6	12.3

By referring to Table 2.1, the sources of construction waste generation which took up the landfill space are summarized in the pie chart in Figure 2.1. It shows that excavation waste is the primary source in the landfills, whereas road work waste is the least content.

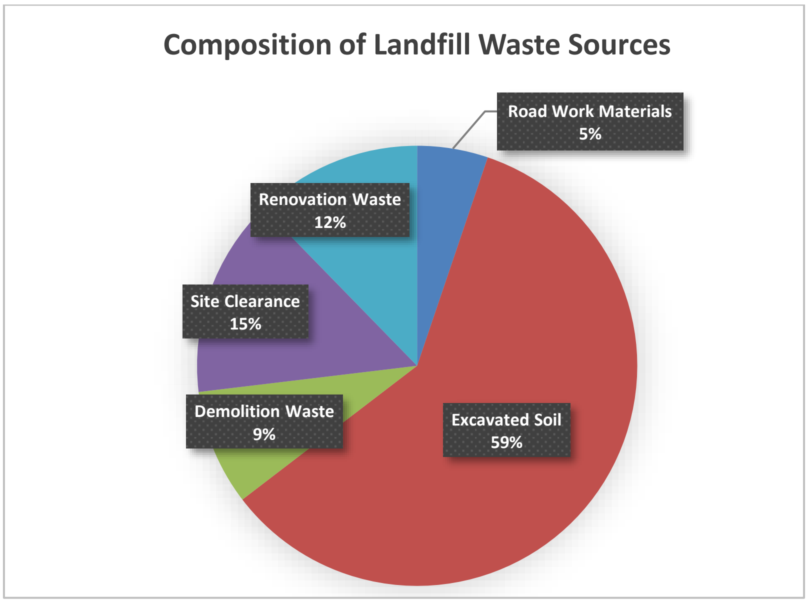


Figure 2.1: The Sources of Construction Waste in the Landfills (CIDB, 2008).

The pie chart in Figure 2.2 demonstrates the distribution of waste materials that contributed to the landfill volume. The waste components were summed up from their respective sources to produce an overview of items found in the landfill sites. The most significant construction waste material was soil followed by rock and rubble, concrete and mortar, wood, bricks and tiles, slurry mud and metals.

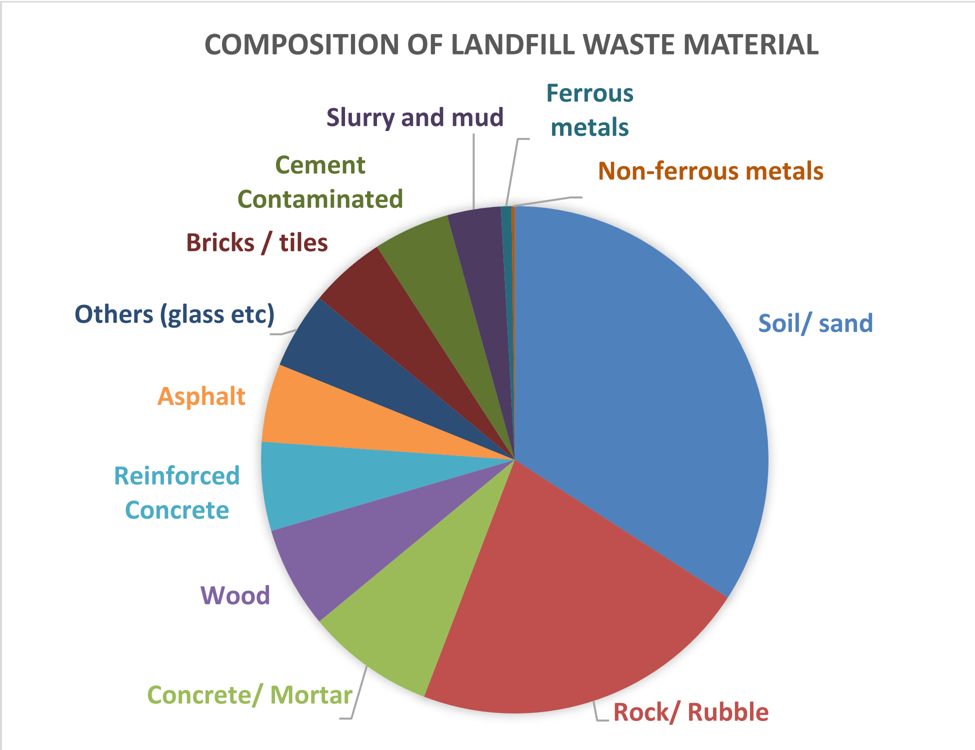


Figure 2.2: The Material Composition of Construction Waste in the Landfills (CIDB, 2008).

2.2.1 Soil

Soil waste is usually generated during the earthwork activities upon the commencement of the construction stage. In cut and fill, the amount of earth material to be cut and filled will never be equal. When there is a surplus of earth material, it will most probably be discarded. The earthwork planning depends mainly on the land topography and soil condition. The amount of soil waste produced will be significant, especially when the land has hilly and uneven topography which is not suitable for development. For poor soil condition, the soil material may be excavated to carry out soil improvement measures. The topsoil at the surface of earth cuts is usually unsuitable to be used in compacted earth fills. Thus, the soil will be ended up in the landfill. Although earthworks only take up the initial part of the construction phase, the massive changes to the existing land will generate enormous unused earth material.

2.2.2 Concrete

According to Gálvez-Martos, et al. (2018), if a new building is constructed, 18 kg to 33 kg of concrete was ended up as waste per meter square (m^2) of the built area. On the other hand, for every meter square (m^2) of demolition, about 840 kg of waste concrete was produced. Additionally, Vasudevan (2019) revealed that the concrete and aggregates waste might be generated due to improper handling of precast concrete members during transportation, wrong concrete mix, concreting errors and demolition. Lachimpadi, et al. (2012) suggested that on-site management for concrete or aggregates material was weakly monitored because they were readily available at a comparatively low price in Malaysia.

2.2.3 Timber

Since Malaysia mostly practices conventional construction methods, timber and plywood were mainly used as support structures during concreting work, momentary support in blockades and other additional supporting features (Lachimpadi, et al., 2012). Due to the low durability properties of wood, the amount of timber waste increases after exposure to bad rainy weather and lack of supervision plans to maximise their reuse possibility on formwork. The frequency of timber and plywood reusing or recycling at the construction sites is mostly governed by the construction material quality used on site. Timbers with better quality reduce the need to rectify for reusing purposes, whereas lower quality has a limited chance to be reused and is sooner or later disposed of at the landfills (Lachimpadi, et al., 2012).

2.2.4 Bricks

The production of brick waste is also relatively high since almost every construction will use brick, especially when building walls (Ahmad, et al., 2014). Brick waste is mostly generated during material storage, transportation and handling throughout the construction stages (Vasudevan, 2019). It is usually labour-intensive and costly to separate the potentially valuable facing bricks from the contaminants by hand sorting and cleaning (Tam and Tam, 2006). Therefore, most of the time, brick waste will not be reused or recycled but end up in landfill disposal since most of them are spoiled with mortar, rendering and plaster during demolition.

2.2.5 Metals

Metal waste includes rebar steel, wire meshes, mild steel sheets and other metal-based products (Lachimpadi, et al., 2012). They are mostly credited to the excess cut of steel bars, leaving the residues behind with unfeasible sizes and dimensions. Mistakes in cutting are even more frequent due to the variety of standardization and detailing for structural components (Mydin, Khor and Sani, 2014). Nevertheless, the proportion of metal waste is not as considerable compared to soil and concrete waste since it has a higher market value resulting in a tighter controlled mechanism on-site (Lachimpadi, et al., 2012). Moreover, the metal waste in the metal recycling sector is in high demand and hence its contribution to landfill waste is not too noteworthy.

2.2.6 Plastic

During loading, transportation and unloading, the possibility of materials damages is foreseeable. Thus, the fragile construction materials are usually well wrapped and protected with thick and waterproof plastic bubble wrap or plastic sealer (Ajayi, et al., 2017). These packaging materials on-site are resulting in too much plastic waste, possibly due to over-packaging. Polyvinylchloride (PVC) waste is produced from plumbing cutting, especially during the installation of drainage, sewerage and water reticulation system (Magalhães, Danilevicz and Saurin, 2017).

2.3 Factors of Generating Construction Waste

There are several reasons why construction waste minimization practices are not achieving widespread implementation in Malaysia. Table 2.2 summarizes the findings on the causes of construction waste generation all over a construction project lifecycle. The waste stream is viewed from different aspects such as contractual, design, procurement, site operation, labouring, transportation, residual, law and legislation.

2.3.1 Conventional Way of Construction

The studies from Maniam, et al. (2018) clearly showed that the conservative construction method created more waste than the modern construction method. According to Nagapan, et al. (2018), the current conventional construction trend used less prefabricated materials and insufficiently emphasizing modern construction ways. The conventional construction approach usually involves double handling of work which will reduce waste minimization efforts and consequently lead to higher material wastage. Conventional construction is more popular among the constructors as modern construction involving fabrication may uneconomically incur high cost in designing element moulds (Lachimpadi, et al., 2012). On top of that, technical constraints such as unskilful labour forces, irregular construction procedure and improper site management have caused the construction waste minimization knowledge involving off-site design to be more hardly applicable (Chi, et al., 2020).

2.3.2 Unsustainable Nature of Construction Industry

Esa, Halog and Rigamonti (2017) revealed that Malaysia's construction practitioners were used to linear economy-based exercises of the 'take-make-consume-dispose' concept. This standard of practice is mainly performed since the building materials are abundant and readily available at a comparatively low price, restricting waste minimization practices (James, 2014). Aini, Awang and Iranmanesh (2017) revealed that it would be an economic decision to dispose of the used products compared to proper waste management.

Vasudevan (2019) claimed that most industry players were used to the unsustainable nature of the construction sector, especially when it comes to unusable construction waste handling. Construction waste management can be hardly implemented due to the characteristics of construction plans such as project complexity, production background which is hostile and unpredictable, the disintegrated nature to procure buildings by each project company and the intense budget and schedule burdens (Teo and Loosemore, 2001; Yuan, 2013). According to Wang, et al. (2019), most clients would have less demand and interest to be concerned about the construction waste minimization design due to the constraint of budget and schedule. Employers with low primary funds may tend to allocate a limited budget to less important waste management, which will reduce the priority and importance of site waste management (Mydin, Khor and Sani, 2014).

2.3.3 Improper Design Documentation

Oyedele, Ajayi and Kadiri (2014) declared that the stages throughout the whole project lifespan were interdependent such that errors conducted in the prior stage would influence the following ones. According to Ajayi, et al. (2017) and Begum, et al. (2007b), waste generation was closely related to reworks when some crucial details were missing in the design documentation. The missing information will then affect the performance of a successful construction exercise. The contractors are said to be left with guesswork and mostly end up in waste production. When the design documentations are improperly done, the projects' buildability will be affected, especially in terms of its accuracy and detailing consideration, which will result in confusing design followed by the possibility of reworks (Ajayi and Oyedele, 2018a). Even though architects play their roles well in specifying design elements under the given conditions, they will still miss out on something in the detailed design documents, such as minor details of coordinating building products and materials, especially when there are changes in the design (Salgın, et al., 2017).

2.3.4 Design Change

Designers often argue that sorting out foreseeable design changes in a detailed manner at the early design stage is impracticable and irrelevant to their designing tasks (Bilal, et al., 2016). For the changes made in the design stage, Wang, Li and Tam (2014) suggested that the reasons are such as provisional design change as requested by the customers, insufficient experience of the designers, higher complexity on construction design standards, shortage of essential design data, incompetence to predict construction circumstances on-site and policy change. However, Al-Hajj and Hamani (2011) argued that the off-cut waste due to design-related incompetency was obviously beyond the contractors' responsibility but is within the control of the designers. The opposing stand of the designers and the contractors reflected the critical conflict to perform effective coordination and communication, especially at the design stage. This situation has caused the construction waste minimization effort to be more challenging. Liu, et al. (2015) suggested that the contractors' late involvement might partly influence the disagreement in the design stages to perform discussion on the practicality of waste reduction on-site.

2.3.5 Improper Site Management

Salgın, et al. (2017) pointed out that the improper way of storing material and protection measures contributed to materials wastage generation on site. The construction materials may be wasted if they are improperly stacked at any open space without an adequate shield. Bad weather circumstances such as rain may destroy the unprotected exposed bricks, blocks, cement bags and other construction materials. Hasmori, et al. (2020) stated that improper material handling would lead to breakage and loss of construction materials which lastly generating waste on-site.

2.3.6 Absence of Design-Based Tools

Ajayi and Oyedele (2018) mentioned that the current construction industry practice was lack of provisions to prepare a deconstruction plan even though building demolition waste comprised a remarkable fragment in the construction waste volume. The deconstruction plan is an important document for demolition as it promotes the diversion of waste to be ended up in landfills. Among the five spectrums to design waste out in construction projects, one is the scheming for deconstruction (WRAP, 2014). Bilal, et al. (2016) argued that one of the barriers to manage construction waste was the absence of design-based tools to design out waste. Hence, more time and effort are needed to plan waste management without computer-aided automated tools. Detailed and cautious building plans are needed to support deconstruction at the final lifecycle phase to decrease construction waste generation significantly. Gálvez-Martos, et al. (2018) also claimed that adopting well-planned deconstruction works would considerably reduce the deconstruction duration while increasing work efficiency and practicality.

2.3.7 Uncertainty of Legislations

Some researches pointed out that there was a lack of promotion and encouragement from the authorities to practice waste management in the construction sites (Papargyropoulou, 2011). Malaysia's prevailing guidelines and policies mostly dealt with the municipal waste generated from household and hazardous waste from industrial activities (Sa'adi, Ismail and Alias, 2015). The disconnections between policies and practices were due to insufficient implementation, lease enforcement and vagueness over the authorities' responsibilities (Papargyropoulou, 2011). The absence of established policies that comply with relevant legislation, rules and standards failed to commence a more explicit goal and impact in waste management (Saadi, Ismail and Alias, 2016). Even if the construction players intend to carry out a proper construction waste control, they have no accessible information and there is no one to guide them.

2.3.8 Immaturity of Waste Recycling Industry

Chi, et al. (2020) revealed that the recycling commerce for construction waste was immature such that the business to recycle construction waste was said to be a form of public welfare rather than a money-making trade. The application of construction waste recycling has many uncertainties, such as intense rules, high capital cost, irregular sources of recyclable items, under-developed market, comparatively low product value and other risk threats.

Table 2.2: Review of Literature on the Causes of Construction Waste Generation.

Category	Causes of Construction Waste Generation	References																	
		Teo and Loosemore, 2001	Bilal, et al., 2016	Akinade, et al., 2018	Liu, et al., 2015	Salgın, et al., 2017	Lachimpadi, et al., 2012	Ajayi, et al., 2017	Ajayi and Oyedele, 2018	Osmani, Glass and Price, 2008	Othuman Mydin, Khor and Sani, 2014	Wang, Li and Tam, 2014	Saadi, Ismail and Alias, 2016	Ekanayake and Ofori, 2004	Osmani, 2012	Ikau, Tawie and Joseph, 2013	Papargyropoulou, 2011	Ding, et al., 2018	Yuan, 2013
Contractual	• Contract documents errors							✓		✓				✓					
	• Incomplete contract documents									✓				✓					
	• Lack of early involvement by contractor				✓					✓									
Design	• Design changes		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓				✓	✓
	• Design complexity		✓		✓			✓	✓	✓		✓	✓	✓	✓				✓
	• Design and construction detail errors			✓	✓	✓		✓		✓									✓
	• Uncertain materials outline specifications			✓	✓					✓				✓					
	• Ineffective coordination and communication			✓	✓	✓						✓	✓		✓		✓		
	• Lack of design knowledge / experience	✓		✓				✓	✓	✓		✓		✓	✓			✓	
	• Lack of environmental awareness goal	✓	✓	✓				✓		✓		✓	✓	✓				✓	
	• Lack of design-based tools		✓	✓										✓			✓		✓
	• Improper design documentation			✓				✓	✓	✓				✓	✓			✓	
Procurement	• Ordering errors							✓	✓	✓			✓	✓					
	• Over allowances							✓	✓										
	• Equipment malfunction / poor material quality												✓	✓					

Table 2.2: (continued)

Category	**Causes of Construction Waste Generation**	**References**																	
		Teo and Loosemore, 2001	Bilal, et al., 2016	Akinade, et al., 2018	Liu, et al., 2015	Salgın, et al., 2017	Lachimpadi, et al., 2012	Ajayi, et al., 2017	Ajayi and Oyedele, 2018	Osmani, Glass and Price, 2008	Othuman Mydin, Khor and Sani, 2014	Wang, Li and Tam, 2014	Saadi, Ismail and Alias, 2016	Ekanayake and Ofori, 2004	Osmani, 2012	Ikau, Tawie and Joseph, 2013	Papargyropoulou, 2011	Ding, et al., 2018	Yuan, 2013
Site operation	• Improper on-site waste management										✓		✓			✓			✓
	• Inadequate material requisition						✓			✓				✓					
	• Lack of on-site material control					✓				✓	✓		✓	✓		✓			✓
	• Poor supervision										✓		✓						
	• Accidents due to negligence													✓					
	• Time pressure	✓														✓			
	• Inappropriate site storage space					✓				✓	✓		✓	✓		✓			✓
	• Inadequate material handling					✓				✓	✓		✓	✓					✓
Labouring	• Lack of knowledge					✓				✓	✓		✓						
	• Shortage of skilled workers					✓							✓						✓
	• Poor craftsmanship										✓								✓
	• Poor work ethics												✓	✓					
Transportation	• Damage during transportation						✓												
	• Site access difficulties during delivery											✓							
	• Insufficient protection during unloading					✓													

Table 2.2: (continued)

Category	Causes of Construction Waste Generation	References																	
		Teo and Loosemore, 2001	Bilal, et al., 2016	Akinade, et al., 2018	Liu, et al., 2015	Salgın, et al., 2017	Lachimpadi, et al., 2012	Ajayi, et al., 2017	Ajayi and Oyedele, 2018	Osmani, Glass and Price, 2008	Othuman Mydin, Khor and Sani, 2014	Wang, Li and Tam, 2014	Saadi, Ismail and Alias, 2016	Ekanayake and Ofori, 2004	Osmani, 2012	Ikau, Tawie and Joseph, 2013	Papargyropoulou, 2011	Ding, et al., 2018	Yuan, 2013
Residual	• Off-cuts from cutting materials						✓		✓	✓	✓								
	• Residual from cutting special dimensions									✓									
	• Packaging						✓			✓	✓		✓						✓
	• Low irritation of market benefit						✓						✓				✓		✓
Law and legislation	• Lack of government intervention											✓	✓		✓		✓		✓
	• Uncertain responsibilities of authorities												✓		✓		✓		
Others	• Readily available sources						✓												
	• Attitude and behaviour	✓		✓						✓		✓	✓	✓					✓
	• Effect of weather					✓				✓									
	• Theft													✓					

2.4 Benefits of Minimizing Construction Waste

2.4.1 Cost Reduction

According to Vasudevan (2019), it is verified that 5% to 10% of the utilized construction resources would transform into waste that drastically drags down the profits of the company. Thus, the adoption of construction waste control plays a vital role in decreasing the number of construction materials needed and controlling material requisition cost. Besides cutting down materials cost wastage, the non-physical cost is controlled by reducing the time taken to do on-site sorting, handling and managing waste (Waste & Resources Action Programme (WRAP), 2014). When there is less waste to be taken to landfills, transportation and disposal costs can be trimmed down significantly (Ding, et al., 2018).

2.4.2 Environmental Sustainability

By practicing proper construction waste management, the volume of waste sent to landfills will be greatly decreased and the illegal waste dumping rate will drop (Ding, et al., 2018). The management to control construction waste shall improve the environmental benefits by decreasing the land space occupation for landfill waste. Furthermore, reducing construction waste disposal to the landfill will reduce environmental damage by controlling greenhouse gas emissions (Xu, et al., 2019). When the building materials supplies are unnecessary, a lesser amount of energy and water will be required to manufacture and transport those materials while emission of greenhouse gasses is reduced (Yusof, 2006). Moreover, an increasing construction waste recycling rate will stimulate the demand for recycled materials. It will then promote recycling practice throughout the waste production economy and indirectly act as environmental protection (Waste & Resources Action Programme (WRAP), 2014).

2.5 Implementation of Construction Waste Management in Malaysia

According to Papargyropoulou (2011), waste control in Malaysia had been a matter of worry for some period due to its inadequate management. Chen (2015) reported that the construction waste picked up by contracted waste management companies was only 15%. In contrast, the remaining 85% was left uncollected.

In Malaysia, conventional construction projects seemed to implement less efficient waste management strategies (Mydin, Khor and Sani, 2014). Maniam, et al. (2018) revealed that Malaysia's construction industries were majorly relying on conventional construction methods that generate higher construction waste than the modern construction method such as Industrialized Building System (IBS). According to Begum, et al. (2007b), the most ordinary practice of waste minimization in the Malaysian construction industry is buying those durable materials which can be repaired and refilled. However, the material storage and handling on site are still unproductive. There are redundant materials due to ordering mistakes and low quality of materials which may be thrown away and contributing to the waste generation rate (Vasudevan, 2019).

With the rising construction waste production rate, increasing pressure is imposed on the readily overstretched waste management infrastructure in Malaysia. As reported by Aini, Awang and Iranmanesh (2017), the Malaysian government highlighted construction waste management to lessen the environmental burden by launching the National Green Policy in 2009 and establishing a Green Building Index (GBI) assessment for environmental practices. Besides that, Saadi, Ismail and Alias (2016) revealed that The National Strategic Plan for Solid Waste Management was initiated in 2005 as guidance on how to implement solid waste management in Peninsular Malaysia. Although there were quite a number of policies and proposals substantiating the waste management in Malaysia’s construction industry, the reality was still challenging due to the insufficient enforcement and doubtful obligations of the authorities (Papargyropoulou, 2011; Saadi, Ismail and Alias, 2016).

In order to encourage construction waste control, the respective authorities tried to reward the parties who efficiently performed construction waste management while providing punishment for the disobeyers (Esa, Halog and Rigamonti, 2017b). In 2005, The IBS Score was introduced in Malaysia by the government through the Construction Industry Development Board (CIDB) to indicate the implementation level of IBS in any of the construction projects. However, this scoring system has not transformed into legal means and enforcement to ensure compliance from every construction project (CIDB, 2005).

As a developing country, Malaysians' current awareness level is low on the importance of waste management and waste is generally recognised as inevitable. According to Esa, Halog and Rigamonti (2017b), the existing standard form of contracts in Malaysia, such as Persatuan Arkitek Malaysia (PAM) Contract 2006 and Public Work Department (PWD) Form 203 (Revision 1/2010) insufficiently calling attention to the implementation of appropriate construction waste management. Therefore, the authorities should enhance waste-related regulations to line up with the "Strategic Recommendation for Improving Environmental Practices in Construction Industry" initiated by CIDB Malaysia (CIDB, 2008).

2.6 Measures to Minimize Construction Waste

Construction waste minimization schemes can be classified into planning and controlling (Ekanayake and Ofori, 2004). An appropriate waste minimization practice dealing with planning outlines shall start from the early stage, which involves design work, construction schedule, laying out of site and procurement. The effort of controlling shall consider material delivery and management, upkeep of machinery, waste handling methods, book-keeping of onsite material tradings and even up to the labour force training. The possible measures in terms of planning and control are discussed in the following subtopics. The possible measures to minimize construction waste recommended from the literature reviews are summarised in Table 2.3.

2.6.1 Site Waste Management Plan (SWMP)

The SWMP establishes a framework to estimate and note down the construction waste types and quantities expected to be produced throughout the project construction. A series of suitable measures will be recommended to decrease the construction waste amount sending to landfills (WRAP, 2014). For example, in Malaysia, the framework called Green Building Index certification was used. It is a set of standards design appraisal system related to environmentally sustainable practice to cultivate waste management in construction industries. Similar frameworks for sustainable building assessment procedure are such as the Leadership in Energy and Environmental Design (LEED), Green Building Rating System in the United States, Building Research Establishment's

Environmental Assessment Method (BREEAM) rating system in the UK, Green Mark in Singapore and Green Star in Australia (Papargyropoulou, 2011).

By referring to the studies from Gálvez-Martos, et al. (2018), initially at the design stage, SWMP produced a first cost estimation to find out the potential savings. Later on, planning is done based on removal, separation, storage, transportation and handling of waste materials. Throughout the pre-development phase, the possible waste stream further identifies the waste prevention methods, reuse and recycling possibilities by evaluating their potential on-site application. The regions for waste and materials stored within site should be well distinguished. The waste containers should be located relatively close to the point of waste generation. Training and promotion of the SWMP should be made consistently and the documentation files should always be updated.

During the implementation stage, the waste manager should bear the responsibility to share the plan with the participating site staff and external stakeholders who take part in the site activities. According to EPA (2012), the waste manager should be authorised to assign the responsibility for waste prevention to coordinate with those participating parties such as the contractors, vendors, service providers and suppliers. It is important to initiate and sustain the habit of on-site record tracking, audit performance and goal establishment, especially regarding the construction waste matter. The waste manager should be well-trained in applying the best method to segregate and store construction waste on-site.

2.6.2 Circular Economy Concept

According to Akinade and Oyedele (2019), the circular economy approach encouraged the enclosed material lifecycle via the recycling economy and reuse practice. This concept considers whole production work phases to minimize waste and reduce resource demand while achieving sustainable development. By considering the project lifecycle as a whole from conceptual, design, construction, service, renovation and lastly demolition, the efficiency of construction waste control would be directly or indirectly affected (Osmani, Glass and Price, 2008). The circular economy concept in the construction industry is shown in Figure 2.3.

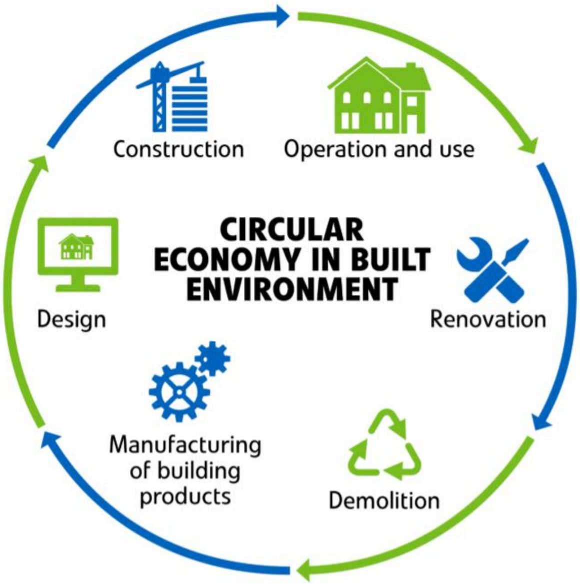


Figure 2.3: Circular Economy Concept in Construction (Tikkanen, 2019).

When the circular economy applies, the life cycle assessment (LCA) methodology is taken into account. The LCA may analyse data flow and investigate the handling processes of construction waste to minimize waste production and control resource demand throughout the construction phase. The transformation from the traditional linear 'take-make-waste' concept to the circular model should promote sustainable development (Akinade and Oyedele, 2019). Besides the project lifecycle, Lu and Yuan (2011) suggested that the material lifecycle helped to track the material process and find out the potential waste areas to be enhanced. The circular economy concept should not be limited to the 3R principle of reduce, reuse and recycle. Esa (2017) suggested that the inclusion of Re-imagine and Re-design elements increased resources efficiency after re-examining the construction process and designing out of waste.

Esa, Halog and Rigamonti (2017a) proposed a framework following a 3-layer method, namely micro-, meso-, and macro-level. For the micro-level, the researchers highlighted the transformation of the conventional construction method to a more modern method such as using prefabrication material to ease the source material control. At the meso-level, the constructors should be well aware of the requirement to carry out proper construction waste management by clearly stating the relevant clauses and sections of waste management-related laws in the agreements. Finally, the macro-level applies efficient construction waste management to ensure sufficient supervision, coordination and communication throughout the construction process.

2.6.3 Building Information Modelling (BIM)

Due to the fragmented and dynamic nature of the construction industry, it is normal to conduct uncountable errors. When these errors happen, it would require reworking amendment and affecting the project cost besides generating extra construction waste (Ajayi, et al., 2017). Thus, Heigermoser, et al. (2019) proposed that BIM should come in place to provide a collaborative decision-making platform to enable information sharing when stimulating models and managing projects.

As published in the studies from Vasudevan (2019), BIM relied on 3-Dimensional (3D) technologies by using computer-aided-design (CAD) software that could integrate all the processes involved in the construction lifecycle and permit the trading of information in digital forms among the projects' participants. BIM facilitates planning and scheduling, simultaneously allowing clashes identification in the early project stage (Turkyilmaz, et al., 2019). By superimposing 2D designs in the 3D visualised space of the project modules, the software provides sufficient information proven to be precise and reliable throughout the entire life of building information assessments. Using a computer-aided tool should significantly minimize human errors that are usually performed due to negligence or inappropriate analysis (Vasudevan, 2019).

Furthermore, the advance-equipped features in BIM tools could detect waste-related costs and materials in construction projects to enable early planning in waste reduction (Ajayi, et al., 2017). BIM expediates the cost and materials computation that a quantity surveyor usually does at a much faster speed and shorter duration (Vasudevan, 2019). Besides avoiding immediate clash and estimating the waste-related cost, BIM application can improve coordination and exchange project related information. The stakeholders would have a much accessible path towards reliable data and information to predict the likely causes of waste generation (Razkenari, et al., 2020).

BIM could improve digital illustration, promote collaboration in construction, and enhance building information storage and sharing (Ajayi and Oyedele, 2018b). By ensuring the building information is up to date throughout its lifecycle, BIM could enrich the end life of building deconstruction and increase the reusability of building elements. BIM application would improve the constructors' knowledge regarding the design and documentation due to their early-stage contribution and participation (Ajayi, et al., 2017). BIM is a potential tool that could be employed in a virtual computational setting in which designers and contractors could utilise different design and construction options in a glance to perform construction waste minimization (Salgın, et al., 2017).

Moreover, BIM addresses the ordering issues such as over-estimation, under-estimation and over-allowance in schedule and specifications documents to control the amount of on-site construction waste production. In similar studies, an inadequate specification was considered the main reason for construction waste generation (Nagapan, et al., 2018; Osmani, 2015; Yates, 2013; Pheng, Shang and Peter, 2016). Therefore, it is important to accurately prepare the documents related to design and specifications with the aid of BIM to avoid waste arising from imperfect design documentation (Ajayi, et al., 2017b). Figure 2.4 shows that the application of BIM for design, construction, operation and maintenance.

Figure 2.4: General Overview of BIM (Koutsogiannis, 2020).

2.6.4 Reduce, Reuse, Recycle (3R)

In order to apply waste hierarchy principles, proper waste management planning includes the reduction of generated waste quantity and maximization of reused or recycled items (WRAP, 2014). In construction waste management, the reduce method seems to be the most beneficial, economical and sustainable way not to produce waste at the early project design stage (Turkyilmaz, et al., 2019; Salgın, et al., 2017). Lu and Yuan (2011) summarized that waste reduction could be achieved by government legislation, design, effective waste management plan, low-waste technologies and proper attitudes of the contractors.

Even though the construction site operates in such a sustainable manner, complete waste elimination is impossible and unavoidable waste will still exist (Hasmori, et al., 2020). Therefore, reuse is the most desirable preference after reduction since it does not require complicated processing and the energy usage is not too much. Lachimpadi, et al. (2012) defined reuse as an action to use identical materials within the same construction site above one time for a similar purpose, whereas recycling was defined as to use construction waste at a different site for a similar or different function. Ling and Leo (2000) suggested that the construction materials for reuse or recycle included formworks, tiles, bricks, concrete, aggregates, soil and sand. Turkyilmaz, et al. (2019) suggested that crushed concrete was reusable as a sub-base while constructing roads or reused as aggregate, asphalt, drainage and cover material.

For non-reusable waste, they could be sorted for recycling to decrease the significance of construction waste in landfill amount (Nagapan and Rahman, 2014). The surplus cost to transfer resources and produce energy could be cut down through recycling while reducing the demand for new material resources (Lu and Yuan, 2011). However, recycled materials only seem to be attractive when they have a lower price and higher quality than virgin materials (Tam and Tam, 2006). Gálvez-Martos, et al. (2018) stated that recycled construction materials usually produced downgraded products that were only applicable for unbound purposes, such as sub-base fillings for roads or secondary resources to manufacture new concrete. It is undeniable that the recycling effort is challenging since the recycled substances are competing with the abundantly available, low cost and better-quality virgin resource materials.

2.6.5 Industrialized Building System (IBS)

IBS is a way to construct buildings, whereby the components used are factory-made and on-site assembled. Various building components are manufactured in an under control factory environment before being transported to the construction sites for assembly (Ajayi, et al., 2017). This modern method is adopting prefabrication of building components and offsite construction, which can significantly cut down construction leftovers since the usage of rebars, timber formworks and in-situ concrete casting is unnecessary (Chen, Li and Wong, 2002).

Jaillon, Poon and Chiang (2009) suggested that prefabrication and modular application could reduce up to 84.7% of construction waste. Tam, et al. (2005) also mentioned that prefabrication technology could decrease 52% of construction project waste. Moreover, quantitative advantages of using prefabricated materials were predicted to substitute 70% on-site finishing task, decreases 74% to 87% timber waste and 51% to 60% of concrete waste (Turkyilmaz, et al., 2019). Lu and Yuan (2011) declared that IBS involving prefabrication in a factory environment was more favourable than conventional construction to reduce waste. The reason was that the upstream processes of offsite prefabrication only generate waste at a rate of around 2% by weight.

2.6.6 Design Standardization and Dimensional Coordination

A significant number of studies found a close relationship between construction waste generation and design errors or design changes (Bilal, et al., 2016; Akinade, et al., 2018; Liu, et al., 2015; Salgın, et al., 2017). Therefore, one of the most efficient methods to combat this issue is by standardizing and coordinating the designs dimensions of the building components. When the design dimensions are coordinated with denoted standard materials, building constructability will be more practical while unnecessary offcuts leading to waste are greatly reduced.

Ajayi, et al. (2017) suggested that construction waste control could be done by standardizing the building forms, layout and using full-height doors based on available commercial sizes in the market. According to Dainty and Brooke (2004), standardization and dimensional coordination of building components could be achieved by using standard doors and windows. The structural and design grid should be coordinated and planned in terms of their dimensions and units. Moreover, if the layout of the tiles could be optimised as well, waste generated by the construction activities could be significantly reduced while the construction work could be carried out more smoothly. In terms of the site topography, excavation waste could be prevented if the buildings are designed in response to the natural existing ground formation (Yuan, 2013).

2.6.7 Design Documentations Assurance and Appropriateness

The design change is one of the main contributors to construction waste since it requires amendments to the design due to design errors, budget constraints or owners' requirement (Ekanayake and Ofori, 2004). The studies from Osmani, Glass and Price (2008) argued that wrong decisions made in the early design stages was a fundamental driver of waste and could result in significant implications on-site. The completeness and accuracy of design documents are nevertheless affecting project buildability but also important to ensure its comprehensiveness and accuracy to avoid mistakes that could cause reworks (Ajayi and Oyedele, 2018a). Besides that, the presentation of the design documents should be in a uniform detailing language and format so that project participants involved have no problem in understanding the proposed design.

In order to avoid make-do waste resulted from the late elemental design information provision, designs are expected to be produced and handed over on time (Koskela, 2004). If the construction strictly adheres to the preliminary version of project drawings, the design change could be lesser or even totally avoided in the phase of construction. The freeze design documents with sufficient specifications could ensure certainty of the construction activities performed to avoid mistakes that could lead to reworks (Ajayi, et al., 2017). Adequate schedules and specifications documents are vital to prevent over-estimation or under-estimation when ordering materials while ensuring less waste generation (Ajayi and Oyedele, 2018a).

2.6.8 Incentive Reward or Penalty Program

The material control system offers a practical means for the project managers to deal with site material resources and encourage the workers to reuse the materials extensively before dumping them as waste. Tam and Tam (2006) claimed that the administrative or operators would achieve effective construction waste practice only when the construction company declares a custom-made waste management program compliant with their respective business models.

According to Chen, Li and Wong (2002), the incentive reward program could be implemented using bar-code technology. The bar-code method application provides instantaneous and latest materials dealing with statistics among the person in charge of storage and the workers. With the aid of the global positioning system (GPS) and geographic information system (GIS), it automatically tracks and traces real-time information of the site construction materials, historical log amount of used materials, monitor materials usage and online transmit materials data (Yuan, 2013). Therefore, the workers are motivated by the performance-based financial rewards in decreasing on-site generation of avoidable waste materials.

Furthermore, the authorities should impose a tariff, so-called the landfill or waste disposal charging scheme on those who utilize the public landfills through construction waste disposal (Lu and Yuan, 2011). By applying this kind of ‘polluter pays principle’, the policymakers could stimulate the modern way of environment legislation whereby the contaminators bear their environmental responsibilities respectively (Duran, Lenihan and O’Regan, 2006). Researches revealed that the legislative instructions and controls should take money matters into considerations to grant economic drivers on contractors in conducting a proper waste control (Hao, Hills and Tam, 2008; Lu and Yuan, 2012; Poon, et al., 2013; Gálvez-Martos, et al., 2018; Osmani, 2012). The government’s policies and laws are key factors to promote social growth, develop market nature and most importantly, to manipulate the community attitudes and behaviours (Wang, et al., 2019).

2.6.9 Logistic Management

Site logistic management should efficiently plan purchase orders of materials, site materials transfer and warehouse storages (Al-Hajj and Hamani, 2011). In conventional practice, most of the materials were kept upon arrival on the construction sites. This stockpiling method would require double handling, which increases materials damage risk, waste generation rate and costs (Gálvez-Martos, et al., 2018). All over the different stages of the construction projects, the materials have to be estimated accurately to reduce the probability of waste generation from ordering too many materials and leaving them behind (Begum, et al., 2007b). Moreover, unsuitable site routes to deliver material restrict on-site movement and give rise to the problems of breaking materials and consequently contributing to waste sources (Dainty and Brooke, 2004). Thus, planning should be done for material purchase, delivery until their storage and handling to avoid wastage of materials due to breakages, human error, improper handling and weather (Ajayi, et al., 2017c). Figure 2.5 shows the general view of logistics systems at construction sites which involve ancillary storage, secure storage and just-in-time delivery.

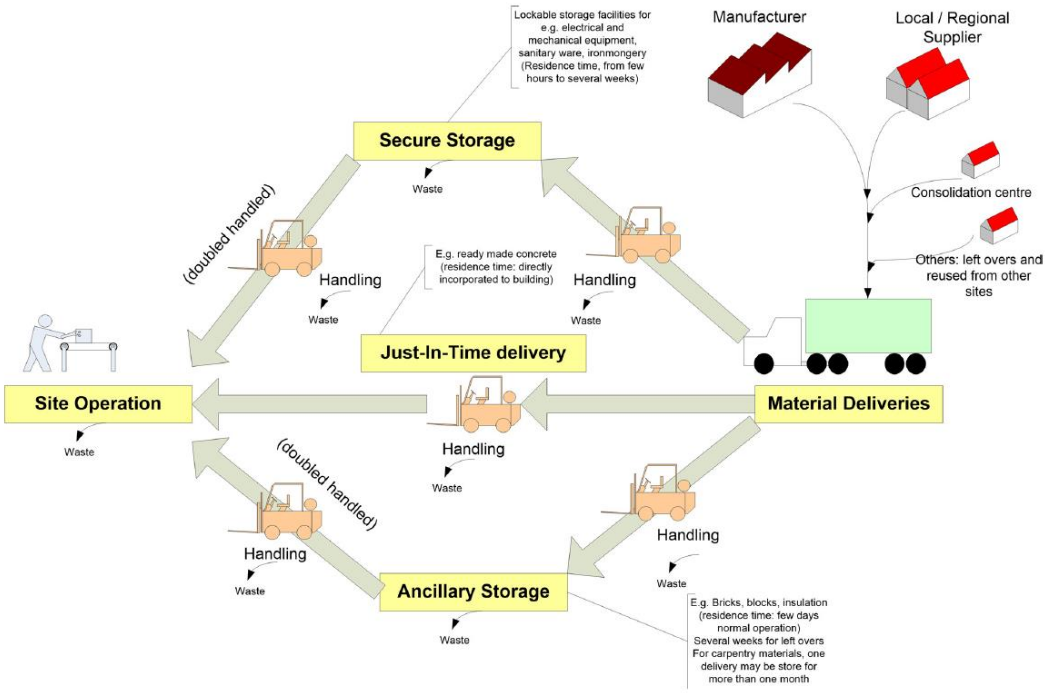


Figure 2.5: Overview of Logistic Supply to the Construction Sites (Gálvez-Martos, et al., 2018).

According to Gálvez-Martos, et al. (2018), the supplies of specially designed construction components or products materials are usually from the manufacturers, suppliers, urban consolidation centres or its construction company. Ancillary storage is used to buffer the materials supply such as bricks, blocks and timbers to smoothen the site operation. These materials are usually centrally located at the materials storage facilities and left for several weeks up to one month. At the specific delivery session, spaces should be made available for reservation on-site (Won, Cheng and Lee, 2016). Secure storage serves a similar role, but with better security to safeguard valuable materials such as ironmongery, ceramics and sanitary ware. The residence time for secure storage items ranges from a few hours up to several weeks. The third mode is just-in-time delivery which establishes the desired system for bulky materials supply such as ready-mix concrete (Gálvez-Martos, et al., 2018). These materials would only be delivered when needed, thereby avoiding long site storage duration which would increase the risk of premature damage (Ajayi, et al., 2017b). Won and Cheng (2017) asserted that the right time of the right amount of construction materials should come into first consideration so that these just-in-time-delivered materials could directly be incorporated into the buildings.

Table 2.3: Review of Literature on the Construction Waste Minimization Strategies.

Strategies	**Applicability**	(Nagapan and Rahman, 2014)	(Tam and Tam, 2006)	(Teo and Loosemore, 2001)	(Bilal, et al., 2016)	(Akinade, et al., 2018)	(Xu, et al., 2019)	(Liu, et al., 2015)	(Salgın, et al., 2017)	(Lachimpadi, et al., 2012)	(Ajayi, et al., 2017b)	(Ajayi and Oyedele, 2018a)	(Osmani, Glass and Price, 2008)	(Wang, Li and Tam, 2014)	(Saadi, Ismail and Alias, 2016)	(Osmani, 2012)	(Lu and Yuan, 2011)	(Ikau, Tawie and Joseph, 2013)	(Ding, et al., 2016)	(Turkyilmaz, et al., 2019)	(Gálvez-Martos, et al., 2018)	(Ajayi, et al., 2017c)	(Chen, Li and Wong, 2002)	(Papargyropoulou, 2011)	(Ajayi, et al., 2017c)	(Yuan, 2013)
Planning	• Logistic management												✓		✓						✓				✓	
	• Waste scenario planning													✓							✓					
	• Early involvement of contractor							✓			✓	✓										✓				
	• Pre-design meetings of key stakeholders											✓														
	• Detailed specifications to avoid over-ordering										✓															
Design	• Standardize dimension and units				✓						✓	✓		✓								✓	✓		✓	
	• Designing out waste				✓		✓	✓								✓		✓	✓		✓					
	• Ensure design freeze before starting construction							✓			✓	✓										✓				
	• Early distribution of design documents										✓														✓	
	• Ensure simplicity and clarity of detailing				✓	✓	✓				✓	✓														
Site Waste Management Plans (SWMP)	• Identify possible waste stream				✓		✓									✓					✓	✓		✓	✓	✓
	• Allocate areas for waste storage																	✓			✓	✓			✓	✓
	• Update documentation regularly				✓							✓									✓			✓		
	• Training of the workers			✓														✓		✓	✓	✓	✓			✓
	• On site waste management														✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2.3: (continued)

Strategies	Applicability	References																								
		(Nagapan and Rahman, 2014)	(Tam and Tam, 2006)	(Teo and Loosemore, 2001)	(Bilal, et al., 2016)	(Akinade, et al., 2018)	(Xu, et al., 2019)	(Liu, et al., 2015)	(Salgın, et al., 2017)	(Lachimpadi, et al., 2012)	(Ajayi, et al., 2017b)	(Ajayi and Oyedele, 2018a)	(Osmani, Glass and Price, 2008)	(Wang, Li and Tam, 2014)	(Saadi, Ismail and Alias, 2016)	(Osmani, 2012)	(Lu and Yuan, 2011)	(Ikau, Tawie and Joseph, 2013)	(Ding, et al., 2016)	(Turkyilmaz, et al., 2019)	(Gálvez-Martos, et al., 2018)	(Ajayi, et al., 2017c)	(Chen, Li and Wong, 2002)	(Papargyropoulou, 2011)	(Ajayi, et al., 2017c)	(Yuan, 2013)
Circular Economy	• Consider whole project lifecycle					✓	✓					✓						✓								
	• Consider material lifecycle																	✓								
	• Apply Life Cycle Analysis (LCA)					✓	✓										✓	✓								
	• Transform into modern construction method										✓															
Building Information Modelling (BIM)	• Improve planning and scheduling					✓	✓	✓						✓						✓						
	• Forecast waste related cost and materials				✓		✓	✓	✓											✓						
	• Identify clashes					✓		✓	✓		✓									✓						
	• Update information throughout lifecycle				✓	✓	✓		✓																	
	• Promote information sharing				✓	✓	✓	✓	✓		✓									✓						
	• Improve design coordination and time management					✓	✓	✓	✓		✓	✓								✓						✓
	• Improve design documentation					✓		✓			✓	✓														
	• Store large data volume				✓		✓																			
	• Support decision making				✓	✓		✓																		
	• Monitor construction progress							✓	✓																	

Table 2.3: (continued)

Strategies	**Applicability**	(Nagapan and Rahman, 2014)	(Tam and Tam, 2006)	(Teo and Loosemore, 2001)	(Bilal, et al., 2016)	(Akinade, et al., 2018)	(Xu, et al., 2019)	(Liu, et al., 2015)	(Salgın, et al., 2017)	(Lachimpadi, et al., 2012)	(Ajayi, et al., 2017b)	(Ajayi and Oyedele, 2018a)	(Osmani, Glass and Price, 2008)	(Wang, Li and Tam, 2014)	(Saadi, Ismail and Alias, 2016)	(Osmani, 2012)	(Lu and Yuan, 2011)	(Ikau, Tawie and Joseph, 2013)	(Ding, et al., 2016)	(Turkyilmaz, et al., 2019)	(Gálvez-Martos, et al., 2018)	(Ajayi, et al., 2017c)	(Chen, Li and Wong, 2002)	(Papargyropoulou, 2011)	(Ajayi, et al., 2017c)	(Yuan, 2013)
Reduce, Reuse, Recycle	• Reduction through design									✓		✓			✓					✓		✓			✓	
	• On-site sorting													✓					✓	✓			✓			✓
	• Reuse material for same or new function										✓									✓						
	• Reuse and recycling									✓	✓	✓		✓	✓		✓	✓	✓	✓		✓			✓	✓
Industrialized Building System (IBS)	• Factory built component									✓		✓	✓					✓								
	• On-site assembly										✓	✓		✓												
	• Offsite prefabrication					✓				✓	✓	✓	✓	✓				✓	✓	✓	✓	✓			✓	✓
Incentive and penalty based	• Implement on-site monitoring of material usage																						✓			
	• Financial reward based on workers' performance			✓									✓	✓				✓					✓			✓
	• Landfill tax / waste disposal charge																	✓	✓							✓
	• Enforce legislative regulation	✓	✓										✓	✓	✓			✓	✓	✓	✓			✓		✓
Demolition	• Produce disassembly and deconstruction plan					✓					✓	✓									✓					
	• Use of modular system that support disassembly										✓															
	• Use joint system instead of the usual gluing and nailing										✓									✓						

2.7 Statistical Analysis

Data reliability is related to the variation level of responses representing the dissimilarities among the respondents. In order to check the internal reliability on scales and indices of variables, Cronbach's alpha was applied. For Likert scale questions, descriptive statistics analysis compute the counts and percentages to evaluate the mean rankings of the variables represented (Gamage, 2011). A non-parametric test is an ideal statistical analysis technique for the data measured by nominal and ordinal scales, which assesses whether there are statistically significant differences between the variables without assuming the underlying population distribution (Zezhou, et al., 2019). The commonly used non-parametric techniques are the Mann-Whitney U Test and Kruskal-Wallis Test. The Mann-Whitney U Test compares two independent groups, whereas the Kruskal-Wallis Test examines the differences within three groups and above. For this study, the significant difference comparisons involve more than two groups. Hence, the Kruskal-Wallis Test for multiple independent samples is more appropriate to determine whether the values of particular variables differ between two or more groups (Gamage, 2011).

2.8 Summary

Generally, the literature review in this chapter revealed the different sources of construction waste in Malaysia and the main factors of construction waste generation. Besides that, it elaborated on the advantages of construction waste minimization in terms of monetary and environmental perspectives. Furthermore, it discussed the current implementation trend of construction waste management in Malaysia. Next, the possible strategies to minimize construction waste were explained in detail in the subtopics. The corresponding construction waste minimization measures were summarized with their respective sources of reference. Lastly, the statistical analyses were compared before suggesting the most relevant tests to be adopted in this study.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This study includes a literature review on barriers in applying construction waste measures in Malaysia and suggestions on applying waste minimization methods in the construction industry. An outline of possible construction waste minimization methods was recommended by investigating the construction waste management aspects from the existing research, observing the apparent practices and merging them into a framework proposal for Malaysia's construction industry. The questionnaire determined the suggested strategies for construction waste minimization while testing Malaysian constructors' commitment to the construction waste management plan in real projects.

3.2 Standards of Methodology

A well-organized research methodology was established to accomplish the research aim and objectives. Both qualitative and quantitative methods were applied in this study as shown in Figure 3.1. Qualitative research was done by reviewing literature and further to be supported by validation via quantitative questionnaires.

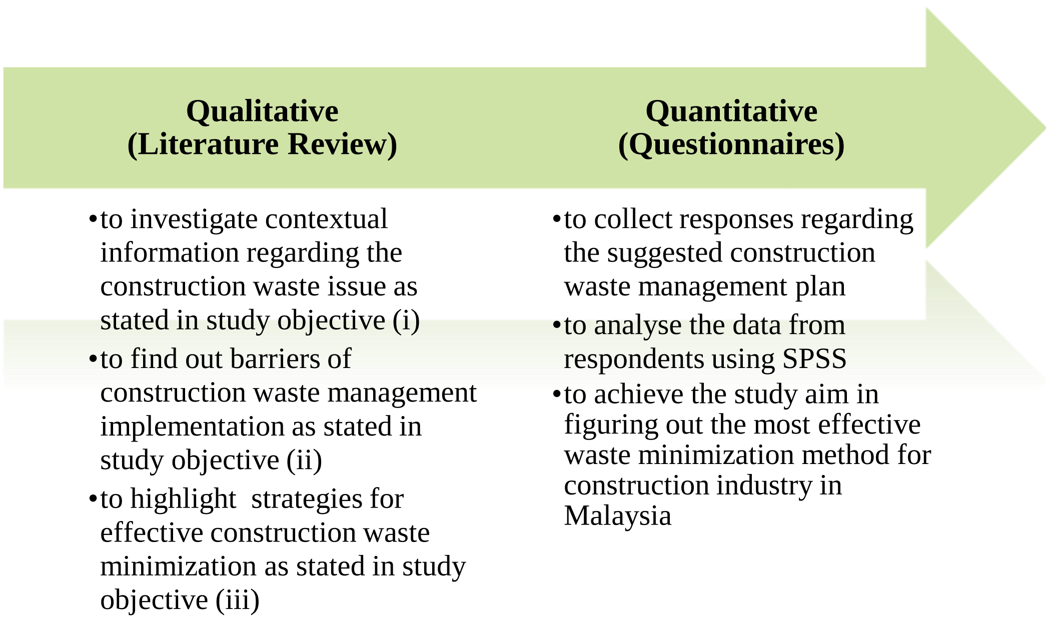


Figure 3.1: Summary of Methodology Adopted.

3.2.1 Qualitative Research

An intensive literature review was done by referring to reliable databases such as Scopus, ScienceDirect, Wiley Online Library and Elsevier without limiting the publication years of the resources. Keywords used for searching the databases and journal repositories include effective and efficient construction waste management plans, construction waste minimization approaches, construction waste control and prevention, building design-related waste, the origin of construction waste and construction design documentation.

The main purpose of the literature review was to simplify some methods to control construction waste and formulate a provisional list containing mostly adopted actions in minimizing construction waste. While filtering out the resources, brief reviews were conducted on the titles and abstracts of the papers. The findings were separated into few folders based on the preferred waste management method, the origin of the countries and the respective aims of those researches. In order to explore more sources of studies, the cross-referencing examination was done to find out more additional papers to be read. Those reference citations of the chosen papers were screened to check whether they belonged to the scope. Those considered most relevant were then be selected for further studies.

Comparative studies were made to obtain insight into the latest norms of waste management policies implemented in Malaysia compared to other developed countries. The gaps of respective studies were identified after reviewing various published papers and journals that were reliable. Previous researches related to waste minimization subjects and elements were highlighted by considering their extensiveness and trustworthiness from the literature review. The findings from the literature studies were discussed and presented before concluding the study with implication for practice. The overall process to conduct the literature review is shown in Figure 3.2.

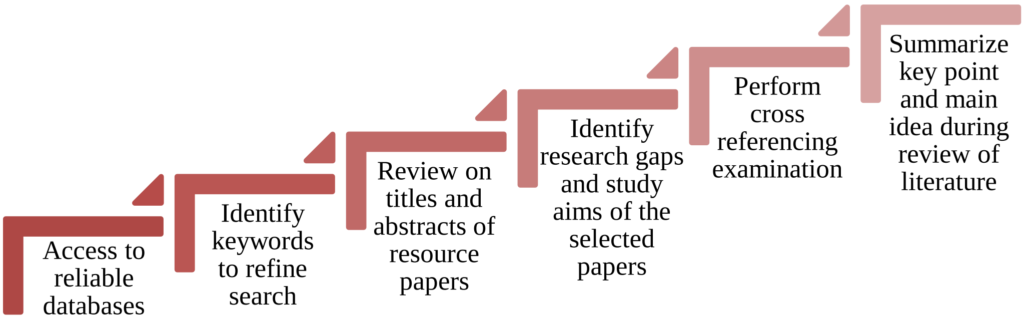


Figure 3.2: Procedures while Conducting Literature Review.

3.2.2 Quantitative Research

The quantitative method to collect data is widely adopted to obtain crucial factors with sample data from different perspectives when conducting an empirical study (Begum, et al., 2007a; Ahmad, et al., 2014; Yates, 2013). Samples were selected from the parties involved in building construction ranging from the consultants to the contractors in Malaysia. This questionnaire aimed to collect a sufficient amount of responses from Malaysia's construction industry players through online survey forms. The online method was preferable to the face-to-face interviews in corresponding to the circumstances of pandemic Covid-19. Moreover, data collection through online survey forms reflected higher accuracy by preventing human compilation errors during result analysis.

3.2.2.1 Questionnaire Design

Before entering the main section of the questionnaire, there was a statement to introduce the study aim and intentions while assuring the respondents' confidentiality. The questionnaire was designed for construction professionals to determine the reliability and significance of each option. The questionnaire was set using close-ended questions by providing multiple choice answers to be selected by the respondents. The closed-ended questions were preferred to allow a more straightforward presentation to the respondents while saving their time answering the questions.

The questionnaires consisted of three sections namely Section A, Section B and Section C. Section A inquired about the respondents' sociodemographic including gender, age, working experience, education level, job position and company. Multiple choice answers were provided and the respondents were required to select the most relevant option. In Section B, the waste-related status and policies of the respondents' company were requested. The informants were asked to rate the importance of elements in construction projects. In addition, they had to express their satisfactory level on construction waste management in Malaysia and reveal whether their company adopted any construction waste management system. Section C was intended to collect opinions on the most possible and effective construction waste minimization strategies after considering the waste generation factors.

The research instrument adopted in this study was the data collection tool using an online questionnaire form. The possible factors of construction waste generation and measures to mitigate this problem in Malaysia were highlighted in the questionnaire content. The respondents were required to rate the options based on a five-point Likert scale as shown in Table 3.1. Rating of 5 means the most significant, whereas the rate of 1 means the least significant (Ekanayake and Ofori, 2004). The responses from questionnaires were compiled and investigated through the SPSS. Based on the survey data collection, the mean importance ratings were calculated and tested statistically to conclude their significance.

Table 3.1: Five-point Likert Scale Used in Questionnaire Survey (Ekanayake and Ofori, 2004).

Ratings	Indication
1	Strongly Disagree
2	Disagree
3	Neither Agree nor Disagree
4	Agree
5	Strongly Agree

3.3 Data Collection Method

Data collection is a process to collect and investigate information based on the study interest in an orderly pattern to get responses from the research questions, test hypotheses and finally examining the findings (Kabir, 2016). There are two categories of research data collection, namely primary data and secondary data.

According to Ajayi (2017), primary data is the first time collected information by the researchers, whereas secondary data is the repetitive data gathered or generated by others. The differences between primary and secondary data are summarized in Table 3.2.

Table 3.2: Differences between Primary and Secondary Data.

	Primary Data	**Secondary Data**
Definition	First-hand data from respective researchers	Non-first-hand data cited from others work
Publication	Not published	Published
Manipulation of data	No	Yes
Reliability and validity	Higher	Lower
Accessibility	Limited sources	Easily accessible
Process	Time-consuming and complicated	Fast and simple
Availability	Raw format	Refined format
Sources	Experiment, survey, questionnaire, interview, observation	Books, newspaper, articles, databases, published data

In this study, primary data was obtained from the questionnaire survey, whereas the method to collect secondary data was from published journals, articles, websites and conference papers.

3.4 Sampling

While conducting research, it is impossible to collect responses from every one of the populations. In order to meet the research purpose, part of the population was selected through sampling to choose a sufficient number of respondents out of the huge population. Sampling is the selection process of the representatives from a population while finding out the parameters or features of the entire population. The sampling process for this study is shown in Figure 3.3.

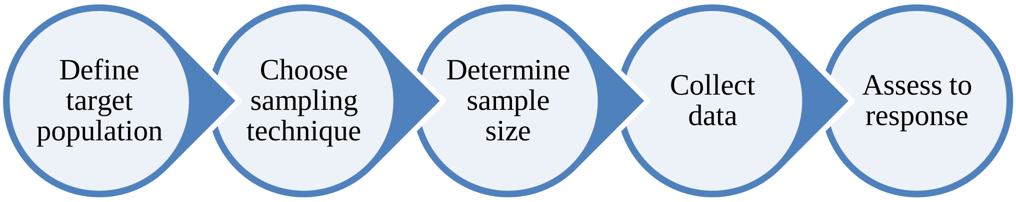


Figure 3.3: Sampling Process Adopted in this Study.

3.4.1 Sampling Design

Generally, sampling methods could be classified into two types namely probability sampling or non-probability sampling. The former is also recognised as random sampling or representative sampling (Datta, 2018). This means that every unit in the population has an equal chance to be investigated and the likelihood to be selected is known (Blackstone, 2012). Probability sampling has the utmost freedom from prejudice but it is a costly sampling technique especially in terms of time and energy (Taherdoost, 2016). Conversely, non-probability sampling is also recognised as non-random sampling (Datta, 2018). The sample selection will be made from the subjective judgment of the researchers. Although this sampling technique does not need to be representative, a well-defined basis is still required to include some individuals as compared to the others (Taherdoost, 2016).

In this study, convenience sampling classified as non-probability sampling was applied to select the respondents. This sampling technique was preferred since the respondents were more readily available, convenient and not costly (Taherdoost, 2016). Convenience sampling overcame many limitations while conducting this research as there was not much time available and the population involved was too huge. Since the parties involved in construction industries are too general and hard to be estimated, the application of probability sampling is less suitable.

3.4.2 Sampling Size

The sample size has to be suitable to avoid sampling errors or biases. This selected sample size should not only consider the proportions of the research population that are being sampled, but it should comply with the population complexity, research aim and types of statistical operation to be used in the data analysis (Taherdoost, 2016). While conducting survey research, the sample size determines how the sample values come close to the population values. A smaller size of the sample will require larger population differences to reach statistical significance. In contrast, a greater sample size will decrease the probability of drawing the wrong conclusion. However, the sensitivity of the sample size beyond a particular point will magnify the required cost and effort.

The research scope in this research was limited to the Malaysian construction players. By referring to the report from Lai (2020), about 30 000 industry players in Malaysia dealt with the scope of construction skills, supervision and management. The appropriate sample size of this research was found by Slovin's Formula. In the formula, a 10% tolerance of error was accounted for the possibility of mistake done while selecting the represented part of the population for Malaysian construction industry players (Soo, 2019). Slovin's formula is presented in Equation 3.1.

$$n = \frac{N}{(1 + Ne^2)} \tag{3.1}$$

where

n = size of sample

N = size of population

e = margin of error

The margin of error is related to the confidence interval where 10% margin error indicates that in 90% of the time, the reflection of the sample on population values is probably true. Valtierra-Pacheco (2017) revealed that the sampling could accept 1% to 10% margin of error depending on the desire of the researcher. In this research, 10% of margin error was assumed because the population size was too large and the possibility of constructing errors was relatively high. By applying Equation 3.1 with 10% margin error and 30 000 population size, the sample size in this research was calculated as 99.67. Thus, 100 respondents were needed to complete this survey.

3.4.3 Targeted Respondents

These targeted respondents could be anyone who participated in the construction industry ranging from consultancy, main contractor, sub-contractor, site personnel, site supervisor, site engineer, et cetera. These individuals were not limited based on their gender, age, race, working experience and education level. This study allowed significant differences between the categories of respondents. Due to the time and budget constraint, the respondents were from a non-specified category and their responses were collected to increase the significance of their representative in the targeted population of Malaysian construction players.

3.5 Data Analysis Method

Computer-aided software simplified data manipulation and demonstration besides allowing the analytical process to be more replicable, explicit and extensive (Gamage, 2011). Thus, this study adopted the analytical SPSS software tool to generate reliable statistical results from the quantitative responses as supportive evidence for this research. All completed feedback surveys were downloaded from the online Google Form, exported in excel format and entered into the SPSS.

Before further analysing the statistics, prior data screening and filtering were conducted. The missing values in the feedback forms were discovered, unqualified informants were excluded and the outliers were detected (Ajayi and Oyedele, 2018a). For a more convenient data analysis, each variable from the questionnaire was coded with specific numbers in the SPSS software. As soon as the data input was done, the data ‘cleaning’ process was carried out to verify valid data entry execution. In preventing double entry discrepancies, the accuracy was double-checked by keying in the data for the second time (Osmani, Glass and Price, 2008). The statistical analyses adopted in this research are reliability analysis, Kruskal-Wallis test and descriptive statistics analysis, as shown in Table 3.3.

Table 3.3: Statistical Analyses of the Questionnaire.

Test	Description	Application
Reliability	Cronbach’s coefficient alpha (α) with a higher value indicates greater reliability.	Section B - Q11 Section C - Q12 Section C - Q13
Kruskal-Wallis	Test for significant difference across more than two groups of respondents.	Section A - Q6 Section B - Q7
Descriptive statistics analysis	Identify the mean rating of the variables before declaring the corresponding rankings.	Section B - Q7 Section B - Q11 Section C - Q12 Section C - Q13

3.5.1 Reliability Analysis

The reliability of the sample data obtained will determine the quality of the questionnaire since it is affecting the trustworthiness of outcomes (Wang, et al., 2019). Consequently, Cronbach’s alpha reliability analysis was carried out with the SPSS software to evaluate the internal consistency of variables included in the survey and to justify the appropriateness of the analysis criteria (Ajayi and Oyedele, 2018a). Reliability analysis was conducted to verify the survey components and the corresponding Likert scale, whether they systematically reflect the study intentions (Akinade, et al., 2018). When the Likert scale was used in a questionnaire, the Cronbach’s alpha reliability analysis was recommended by Ajayi and Oyedele (2018b) to test the dependability of data. With the aid of SPSS software, Cronbach’s alpha reliability coefficients (α) were calculated for the variables accordingly. Generally, Cronbach’s alpha value must be at least 0.5 to be accepted in the study (Ong, 2020). According to Akinade, et al. (2018), α higher than 0.8 portrays good internal consistency, which validates that the information obtained is interconnected and the scales used are dependable (Esa, 2017).

3.5.2 Kruskal-Wallis Test

Kruskal-Wallis test is a non-parametric assessment related to the null hypothesis that could measure different perspectives on certain hypotheses involving one or two groups of informants (Ajayi, et al., 2017c). This test was adopted to investigate whether the respondents' career positions influence their ranking pattern about the elements in construction projects. The Kruskal-Wallis test reflects the significant difference regarding the perception of the importance of construction sector components across different professions. The grouping variables are the respondents' occupation, while the testing variables are those construction sector elements to be tested (Ajayi and Oyedele, 2018a). According to Ajayi, et al. (2017a), in the Kruskal-Wallis test, a p-value under 0.05 indicates significant perspective deviation between the involved parties about the affected variable, whereas a p-value beyond 0.05 shows insubstantial disparity among the groups.

3.5.3 Descriptive Statistic Analysis

In order to find out the relative significance of a group of statistical variables, statisticians usually employed the measure of central tendency such as descriptive statistical analysis of mean testing (Ajayi, et al., 2017c). The descriptive analysis applied in this study was to ascertain the causes of construction waste generation and key strategies to promote construction waste minimization. The questionnaire variables were investigated by employing ranking analysis and factor analysis facilitated by SPSS (Yuan, 2013). According to the mean rankings obtained from the Likert scale, the relative importance of the variables was declared through their ratings. In this circumstance, the variable is more significant if it has a higher mean value.

3.6 Summary

This chapter mainly discussed the methodologies and work plan for this research. Both qualitative and quantitative methods were adopted while conducting the research. The qualitative research method included literature reviews, whereas the quantitative research method involved data collection from questionnaire surveys. The sampling method was explored from the viewpoints of sampling design, sampling size and targeted respondents. The data collected for this research was then analysed and interpreted using reliability analysis, Kruskal-Wallis test and descriptive statistics analysis. The overview of the research process is shown in Figure 3.4. The findings from these tests are further discussed in the following chapter.

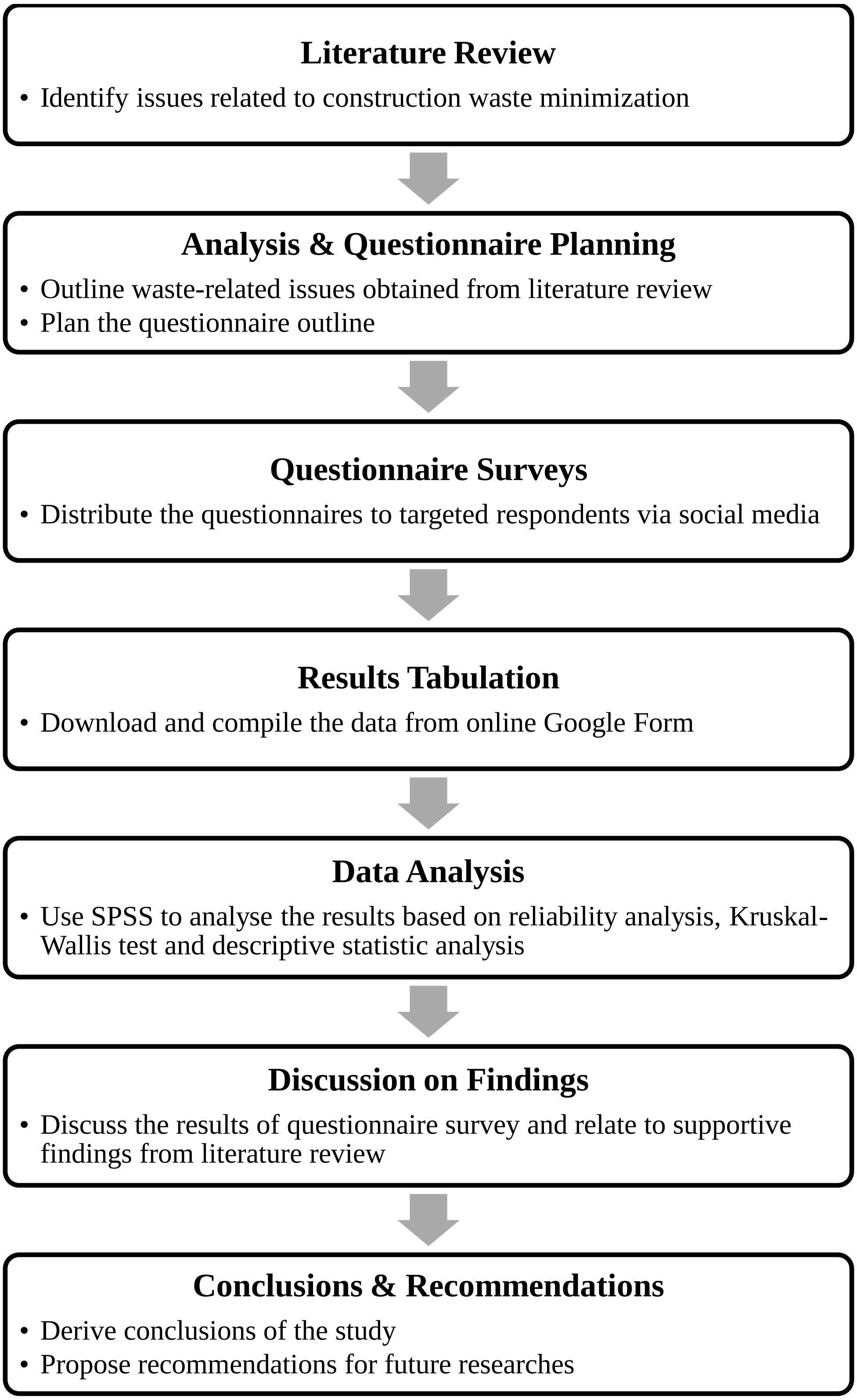


Figure 3.4: Overview of the Research Process.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

By targeting the construction players as the sampling frame of this study, typical postal questionnaires that limit the feedback rate was replaced by convenient online survey forms. This is to prevent ambiguity of questions beyond the respondents' competences while targeting only Malaysian construction practitioners to supply the required research data (Osmani, Glass and Price, 2008).

This chapter reveals the outcomes obtained from the questionnaire surveys. The survey response rate and sociodemographic of the respondents were analysed in the following sections. The result analyses regarding the construction waste-related background information were discussed as well. A laborious statistical analysis procedure was done to the survey responses to ascertain the construction waste generation factors and highlight the strategies to reduce construction waste. The statistical analysis comprised reliability analysis, Kruskal-Wallis test and descriptive statistics analysis.

4.2 Questionnaire Survey Response Rate

There were a total of 279 sets of questionnaires sent via Facebook, LinkedIn, WhatsApp and E-mail. The completion rate of this survey was 40.14%, indicating that only 112 respondents could properly respond to the survey. Besides non-replied surveys, some invalid responses were due to the respondents' working background out of Malaysia. Moreover, some of their career basis was not founded in the construction field but more on interior design architecture. Hence, six received feedback forms were discarded, remaining 106 valid responses for the result computation (37.99%). The summarized data of the questionnaire survey is presented in Table 4.1.

Table 4.1: Questionnaire Survey Data Summary.

Data Collection	Count	Percentage
Total questionnaires distributed	279	-
Total responses received	112	40.14%
-Discarded responses	6	2.15%
-Total valid responses	106	37.99%

4.3 Sociodemographic of Respondents

Generally, the survey respondents possessed professional information and rich experience in the construction industry (Wang, et al., 2019). Thus, their feedbacks practically reflected issues regarding the construction waste scheme in Malaysia.

The respondents involved 3 architects, 19 quantity surveyors, 4 managers, 4 site leaders, 55 civil and structural engineers, 15 site supervisors, 2 trainees, 2 designers and 2 lecturers. Most of the informants had a relatively close background to building and construction, while 7.55% of respondents held project managerial positions. 66.04% of informants received tertiary education and 34.91% of them were typically experienced experts in construction since they had above five years of working experience. The demographic distribution of the participants is shown in Table 4.2.

Table 4.2: Sociodemographic of the Respondents.

Parameter	Category	Frequency	Percentage (%)
Gender	Male	70	66.04
	Female	36	33.96
Age	25 and below	35	33.02
	26 - 30	40	37.74
	31 - 35	17	16.04
	36 - 40	4	3.77
	41 - 45	5	4.72
	46 - 50	2	1.89
	Above 50	3	2.83
Academic Qualification	Primary Education	0	0.00
	Secondary Education	2	1.89
	Tertiary Education	70	66.04
	Postgraduate Qualification	34	32.08
Working Experience	5 years and below	69	65.09
	6 - 10 years	22	20.75
	11 - 15 years	8	7.55
	Above 15 years	7	6.60
Nature of Organization	Developers	11	10.38
	Contractors	41	38.68
	Consultants	49	46.23
	Government Agencies	2	1.89
	Education	3	2.83
Profession	Architect	3	2.83
	Quantity Surveyor	19	17.92
	Manager	4	3.77
	Site Leader	4	3.77
	Engineer	55	51.89
	Site Supervisor	15	14.15
	Trainee	2	1.89
	Designer	2	1.89
	Lecturer	2	1.89

4.4 Reliability Analysis

A total of three questionnaire surveys were analysed with the Cronbach's alpha coefficient reliability test using SPSS. It is commonly interpreted that the reliability coefficient (α) beyond 0.5 is acceptable and α greater than 0.8 portrays good internal consistency (Akinade, et al., 2018; Gamage, 2011). As revealed in Table 4.3, the Cronbach's alpha coefficient values for 'factors to encourage waste management practice', 'causes of construction waste generation' and 'proposed strategies to minimize construction waste' were above 0.5, suggesting overall acceptable reliability of the hypothetical model.

Table 4.3: Results of Cronbach's Alpha Coefficient Reliability Test.

Variables	**Cronbach's Alpha**
Factors to encourage waste management practice	0.672
Causes of construction waste generation	0.805
Proposed strategies to minimize construction waste	0.841

4.5 Background Information

This section looks into the background information of respondents' views on their satisfactory level of current waste management practice in Malaysia. It further investigated the presence of the waste management system in the respondents' current company. After knowing the current waste-related policies, the respondents' opinion on the necessity to practice waste management was explored. The respondents were also required to rate the factors encouraging the implementation of a waste management system. After examining the causes of construction waste generation, those possible strategies to minimize construction waste would also be inspected in the following section.

4.5.1 Satisfactory of Current Waste Management Practice in Malaysia

Figure 4.1 discloses the operatives' satisfactory level towards construction waste management, which indicated that they realised the undesirable waste management in Malaysia's construction industry. However, their goodwill seemed to be hindered by the absence of a managerial pledge towards the waste reduction issues (Teo and Loosemore, 2001).

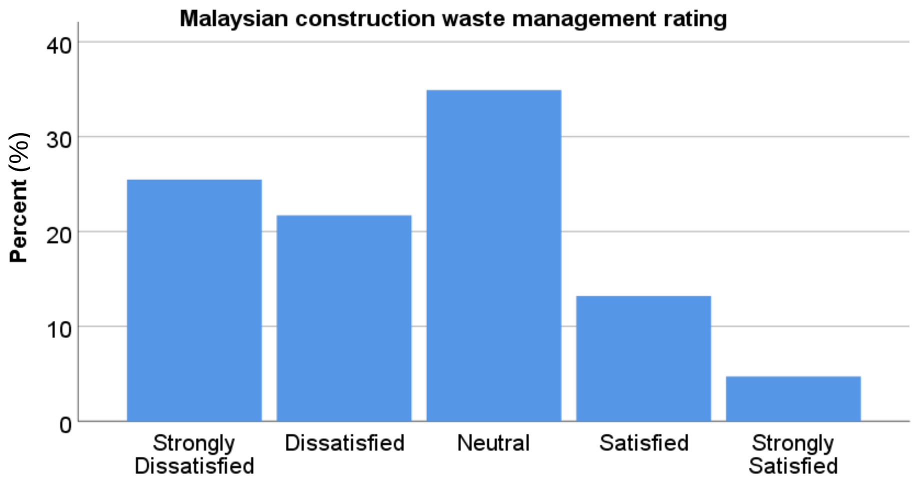


Figure 4.1: Satisfactory Level on Current Waste Management in Malaysia.

According to Ajayi, et al. (2017a), project stakeholders always prioritise those events that could contribute to their performance indices. It is reasonable from a common point of view whereby the project participants do not typically need to minimize construction waste as it does not significantly produce any visible input in terms of monetary returns. Thus, the current implementation of construction waste minimization in Malaysia is still in the infancy stage, with most of the respondents informing low employment of waste reduction efforts in their companies.

4.5.2 Presence of Waste Management System in Current Company

The norm of the current waste management system in the respondents' companies was summarized in Figure 4.2. It revealed that not much efforts were introduced to control and minimize construction waste. Indeed, only 9.43% of the respondents' companies were practicing waste management plan in their operation. The most adopted practice (7.55%) was waste recycling and reuse, while only 0.94% was applying lean construction or design-based software. Conversely, 90.57% of the informants acknowledged that they had never considered any waste minimization plan in their companies' projects.

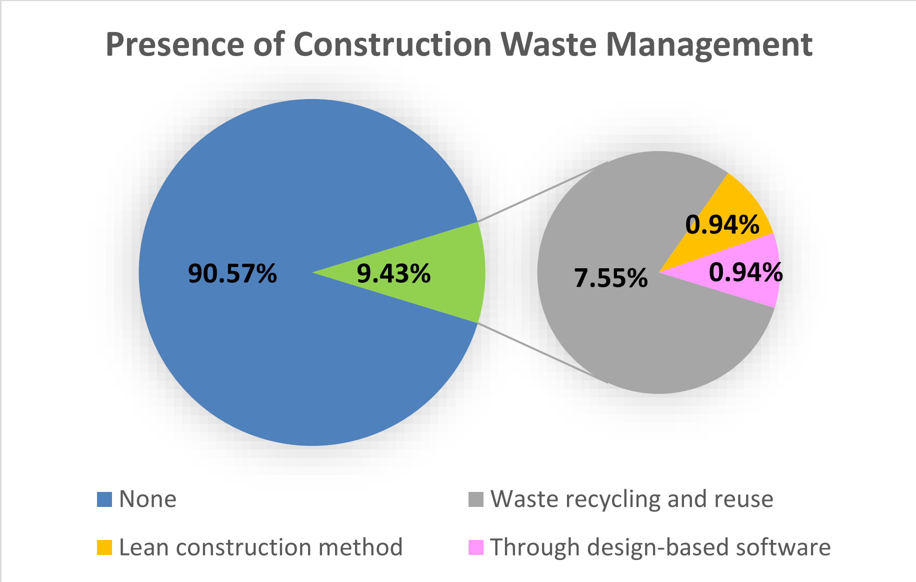


Figure 4.2: Pie Chart of Construction Waste Management Status.

In terms of waste minimization duties, the result appeared somewhat contradictory but not surprising since up to 90% concurred that they had never conducted any waste management plan. Only less than 10% of the respondents reported that they implemented a waste management system based on reuse and recycling, not including the reduction method. This phenomenon suggested that most construction players only considered waste during and after site operations but rarely took waste into account since the early design planning stages. This outcome was echoed by the researches from Ekanayake and Ofori (2004), Esa, et al. (2017b) and Nagapan and Rahman (2014) that revealed the waste management strategies were more focusing on post-waste generation rather than pre-waste generation.

4.5.3 Necessity of Waste Management Plan

The previous findings revealed that construction waste minimization hardly gained attention due to low consideration in project contracts. Project duration, cost and quality usually turn up to be the peak efficiency index for benchmarking construction projects achievement (Ajayi, et al., 2017c). Figure 4.3 shows the informants' rating on the necessity to implement a waste management plan. It indirectly disclosed their understanding of construction waste management tendency to improve overall construction projects, especially in material cost-saving (Ajayi, et al., 2017c).

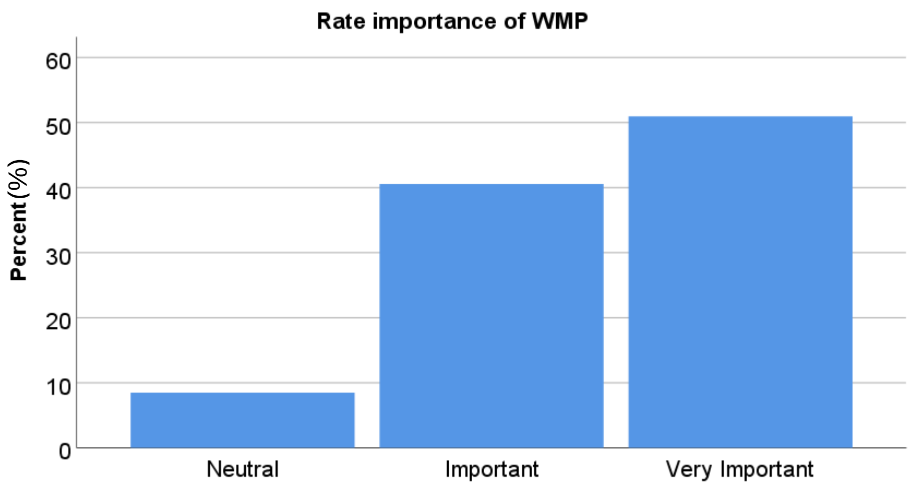


Figure 4.3: Rating on the Importance of the Waste Management Plan.

Notwithstanding current practice in Malaysia's construction industry to curb waste generation, many informants still corresponded that waste management issues must be outspoken. Since most construction companies had no detailed policy for construction waste minimization, it explained why the respondents suggested it was crucial to enhance company waste management (Udawatta, et al., 2015). In fact, construction waste reduction could remarkably avoid overrun of budget and time since more than half of them indicated that the waste management plan was extremely critical to be adopted.

Even though the relative importance of waste minimization is foreseeable by the construction players, projects duration and budget pressures had restricted their attempts to do so. Additionally, their usual working procedures were not meant to facilitate waste reduction policies (Teo and Loosemore, 2001). If the waste production rate was considered, it was challenging to prioritise waste management and other project goals simultaneously. Therefore, managerial level operators should demonstrate their commitment by supplying the necessary resources to reduce construction waste while promoting a conducive environment for effective waste management (Teo and Loosemore, 2001). The formation of clearly communicated company project policies is important to allow construction practitioners to comprehend waste performance standards.

4.5.4 Factors to Encourage Waste Management Practice

As shown in Table 4.4, all five factors receive mean values above 3.5. Thus, they were perceived as crucial to encourage productive construction waste management (Ajayi, et al., 2017c).

Table 4.4: Factors to Encourage Construction Waste Management Practice.

Factors to encourage waste management practice	**Mean ranking**	**Rating**
Law and legislation	4.10	1
Cost reduction	4.04	2
Improve the company's public image	3.81	3
Improve health and safety work conditions	3.76	4
Increase commitment to environmental sustainability	3.51	5

*Remark: Larger mean ranking indicates a higher significance level

The mean ranking revealed that 'law and legislation' was the most significant factor to encourage waste management practice. It indicated that in order to enhance the current construction waste management condition, the prime effort should pay particular attention to foster a well-developed regulatory environment for construction waste management. The regulations to guide the industry practitioners about proper waste control should be investigated and proposed (Ajayi, et al., 2017c). This factor emphasized the critical role of a regulated environment in stimulating the progress of construction waste management. The findings were corresponding to many previous studies revealing that nurturing an under-controlled environment was the key point to improve construction waste management as implemented in the United Kingdom (Osmani, 2012), German (Gálvez-Martos, et al., 2018), Hong Kong (Lu and Yuan, 2011) and China (Ding, et al., 2016). In a sense, an under-controlled regulated environment was very crucial for successful construction waste management. Many aspects of waste management were greatly affected by the promulgation of governmental macro-policies. For example, rules and regulations enforcement, the maturity of waste recycling market and supportive financial incentives launched for construction waste minimization. (Yuan, 2013).

It was not a surprise that 'cost reduction' was ranked secondly. It verified the 'cost' as the essential element to be considered in construction projects. The other factors to encourage construction waste management were to ‘improve the company’s public image’, ‘improve health and safety work conditions’ and ‘increase commitment to environmental sustainability’. This indirectly revealed that ‘environmental’ was always rated as the last consideration, resulting in the current construction waste handling in Malaysia. Likewise, the results indicated that construction operatives usually favoured economic profit over environmental sustainability, probably due to the organization’s economy-oriented culture (Wang, et al., 2019).

4.6 Kruskal-Wallis Test

Reducing cost, shortening duration, enhancing quality, safety assurance and environmental sustainability are five main project scopes in almost every construction projects (Tam, Le and Zeng, 2012). The Kruskal-Wallis test reflected the significant difference regarding the perception of the importance of construction sector components across different professions.

4.6.1 Importance Ratings of Elements in Construction

The findings complied with the previous researches, whereby the most important project goals were to minimize construction expenses and reduce construction time (Dania, Kehinde and Bala, 2007; Nagapan, et al., 2012; Lu, et al., 2017). Meanwhile, ‘safety’ awareness was found to be surprisingly popular and highly rated in recent times. For ‘environmental’ consideration, it appeared to be the least important construction project element as expected. The importance ratings for the elements are shown in Table 4.5.

Table 4.5: Importance Ratings of Elements in Construction.

Elements	**Mean ranking**	**Rating**
Cost	2.17	1
Time	2.33	2
Quality	2.92	3
Safety	3.12	4
Environmental	4.46	5

*Remark: Smaller mean ranking indicates more important elements

4.6.2 Decisions Regarding Null Hypotheses

As shown in Figure 4.4, the Kruskal-Wallis coefficient proposed that only one of the elements was rated otherwise (P < 0.05) by the respondents across their professions. The remaining variables with P-Value above 0.05 concluded that the combination of perception from all the respondents did not influence the general dependability of the findings. In the meantime, the only factor with differing insight was the 'cost', which has a P-Value of 0.003.

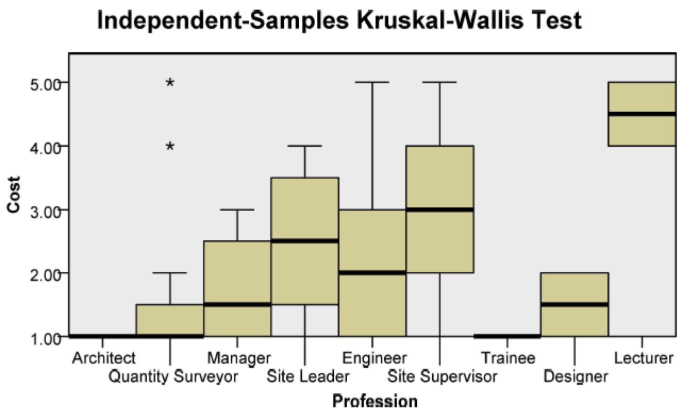
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Cost is the same across categories of Profession.	Independent-Samples Kruskal-Wallis Test	.003	Reject the null hypothesis.
2	The distribution of Time is the same across categories of Profession.	Independent-Samples Kruskal-Wallis Test	.171	Retain the null hypothesis.
3	The distribution of Quality is the same across categories of Profession.	Independent-Samples Kruskal-Wallis Test	.406	Retain the null hypothesis.
4	The distribution of Safety is the same across categories of Profession.	Independent-Samples Kruskal-Wallis Test	.597	Retain the null hypothesis.
5	The distribution of Environmental is the same across categories of Profession.	Independent-Samples Kruskal-Wallis Test	.246	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 4.4: Kruskal Wallis Test Result for Variables across Professions.

Figure 4.5 demonstrated a further probe about the rating pattern for 'cost' across the various professional groups. It showed that the 'cost' was rated as the most important element (1^{st}) by architects, quantity surveyors, managers, engineers, trainees and designers; site leaders and supervisors rated 'cost' as a moderately important element (3^{rd}); lecturers rated 'cost' as the least important element (5^{th}). This disparity portrayed the level at which each group of participants perceived the importance of 'cost' in considering construction projects.

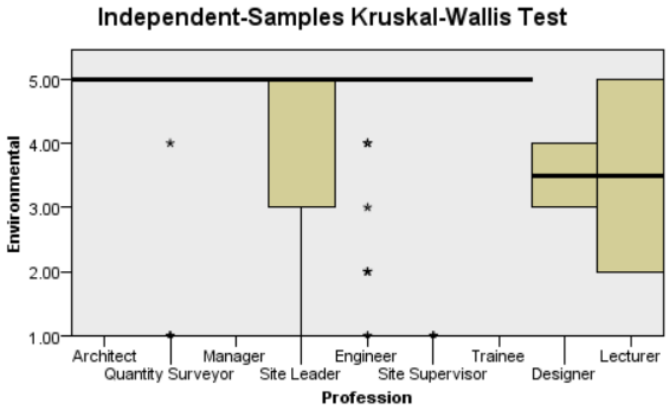


Total N	106
Test Statistic	22.908
Degrees of Freedom	8
Asymptotic Sig. (2-sided test)	.003

Figure 4.5: Kruskal Wallis Test Model View for ‘Cost’ across Professions.

Among the five main construction project scopes ranking, the only factor with differing insight among the professions was ‘cost’, which showed a P-Value of 0.003. This finding discovered that most of the site-based team members believed that ‘cost’ input was less considerable than those non-site-based team members. Despite the opposing insight between site-based staff and non-site-based staff in rating the element, ‘cost’ remained the topmost consideration in the construction industry.

As compared to the ‘environmental’ factor, the perception across the professions showed less significant statistical difference since the P-Value was 0.246 ($P > 0.05$). This indicated that no matter which position the construction players held, most of them had the same opinion showing the least ‘environmental’ concern in their projects. Generally, either site-based staff or non-site-based staff rated ‘environmental’ as the least important element for consideration which complied with the present norms for the absence of a construction waste management plan in the construction companies. However, the ‘environmental’ perspective from the respondents who belonged to educator background differed as shown in Figure 4.6. It was acceptable due to their contextual to promote sustainable construction method as endorsed from an educational viewpoint.



Total N	106
Test Statistic	10.277
Degrees of Freedom	8
Asymptotic Sig. (2-sided test)	.246

Figure 4.6: Kruskal Wallis Test Model View for 'Environmental' across Professions.

4.7 Descriptive Statistics Analysis

The descriptive statistics analysis was adopted to rate the significance of waste generation factors and key strategies to minimize construction waste. Within this circumstance, a higher mean ranking specified a greater significance level of the individual factors and measures. It relied on the importance index of the Likert scale varying from 1 to 5, whereby 1 represented strongly disagree while 5 represented strongly agree.

4.7.1 Causes of Construction Waste Generation

The questionnaire surveys allowed respondents to rate eight variables contributing to the construction waste generation on a scale from 1 (non-waste cause) to 5 (major waste cause) (Osmani, Glass and Price, 2008). The results were presented in Table 4.6.

Table 4.6: Causes of Construction Waste Generation.

Causes of waste generation	Mean ranking	Rating
Conventional way of construction	4.21	1
Improper site management	3.99	2
Immaturity of waste recycling industry	3.99	2
Unsustainable nature of industry	3.95	4
Design change	3.94	5
Improper design documentation	3.65	6
Uncertainty of legislation	3.47	7
Lack of design-based tools	3.30	8

*Remark: Larger mean ranking indicates a higher significance level.

The survey showed consensus that the 'conventional way of construction' was granted the highest attribute of construction waste generation. Moreover, 'improper site management' and 'immaturity of waste recycling industry' shared the second ranking of waste contribution factors. The fourth cause of construction waste production was the 'unsustainable nature of construction industry' followed by 'design change' and 'improper design documentation'. Moreover, construction practitioners believed that 'uncertainty of legislation' was 7th-rated as the cause of construction waste, whereas the 'lack of design-based tools' was last-rated as the construction waste production factor.

4.7.2 Proposed Strategies to Minimize Construction Waste

Informants were required to rate the suggested construction waste minimization strategies through the 5-point Likert scale, whereby 1 indicated 'not recommended' and 5 indicated 'highly recommended'. Table 4.7 showed the results obtained for the proposed strategies to reduce construction waste.

Table 4.7: Proposed Construction Waste Minimization Strategies.

Construction waste minimization strategies	**Mean ranking**	**Rating**
Site Waste Management Plan (SWMP)	4.24	1
Industrialized Building System (IBS)	4.10	2
Building Information Modelling (BIM)	3.99	3
Incentive reward or penalty program	3.85	4
Design documentations assurance and appropriateness	3.82	5
Design standardization and dimensional coordination	3.77	6
Circular Economy Concept	3.76	7
Reduce, Reuse, Recycle (3R)	3.75	8
Logistic management	3.75	8

*Remark: Larger mean ranking indicates a higher significance level.

Most respondents suggested the ‘Site Waste Management Plan (SWMP)’ proposal as the strongly recommended way to minimize construction waste. Secondly, the strategy endorsed was ‘Industrialized Building System (IBS)’ followed by ‘Building Information Modelling (BIM)’. Additionally, the results revealed that the implementation of ‘incentive reward or penalty program’ could control the construction waste generation rate. In term of design, more than one-fifth of the respondents claimed that ‘design documentations assurance and appropriateness’ and ‘design standardization and dimensional coordination’ as the crucial considerations to decrease construction waste generation. The informants recommended implementing the ‘circular economy concept’ in controlling construction waste production with a mean ranking of 3.76. Lastly, the method of ‘reduce, reuse, recycle (3R)’ and ‘logistic management’ share the same mean ranking of the least recommended method to reduce construction waste.

4.7.3 Relationship between Waste-Related Causes and Strategies

After revealing the underlying causes of construction waste generation, current attitudes towards construction waste minimization should be improved. Before adopting waste reduction strategies in construction projects, those waste causes were yet to be overcome and comprehended. For a better view of comparison, the findings were tabulated as shown in Table 4.8.

Table 4.8: Ratings for Waste Generation Causes and Minimization Strategies.

Waste Generation Causes	**Rating**	**Waste Minimization Strategies**
Conventional way of construction	1	Site Waste Management Plan (SWMP)
Improper site management	2	Industrialized Building System (IBS)
Immaturity of waste recycling industry		
Unsustainable nature of construction industry	3	Building Information Modelling (BIM)
Design change	4	Incentive reward or penalty program
Improper design documentation	5	Design documentations assurance and appropriateness
Uncertainty of legislation	6	Design standardization and dimensional coordination
Lack of design-based tools	7	Circular Economy Concept
-	8	Reduce, Reuse, Recycle (3R)
		Logistic management

The informants’ response on construction waste factors concluded that ‘conventional ways of construction’ was the foremost concern of waste production. They also declared that ‘improper site management’ as the main obstacle that impeded construction waste minimization. Conversely, the respondents launched a clear hierarchy by ranking ‘Site Waste Management Plan (SWMP)’ as the foremost approach that could drive waste minimization. Papargyropoulou (2011) supported this by stating that SWMP provided a practical and sustainable resources framework to manage construction waste. It helped improving resources’ efficacy before disposal while mitigating environmental concerns on illegal landfill and haphazard dumping. In fact, waste management involves a broad range of activities regarding on-site coordination, labour assignments, equipment handling, materials delivery, compliance of building design and improvement on resource productivity (Yuan, 2013). Saadi, et al. (2016) further defined construction waste management as a tool to identify the possible waste streams, address waste generation rates and achieve good waste-related practice.

They also acknowledged the adoption of modern construction methods with the concept of ‘Industrialized Building System (IBS)’ and ‘Building Information Modelling (BIM)’ as the critical factors to design out waste at the early stage. The waste analytics function in BIM software could forecast and reduce waste through interactive visualization before making design-based decisions on waste minimization (Akinade, et al., 2018). Improving coordination and sufficient information exchange through the software helped prevent immediate clashes, thereby expecting and avoiding probable waste causes (Ajayi and Oyedele, 2018a). The IBS system was promoted by Wang, et al. (2014), who quantified that modular construction design could decrease waste generation since prefabrication allowed early manufacturing in factories and it was suitable to be performed in a densely-populated city. Since IBS allows easy and quick installation with relatively less cutting and fitting works, waste products could be reduced significantly.

In addition, respondents shared a common view that the 'unsustainable nature of construction industry' led to significant waste production on-site. It directed to the consensus among informants that the 'incentive reward or penalty program' was by far the effective method to drive changes in unsustainable construction. This was agreed by Chen, et al. (2002), who described the adoption of motivational incentive schemes on rewards and penalties related to site resources handling could control waste production effectively. Yuan (2013) also revealed that without proper control and reward programme in monitoring waste-related issues, construction practitioners were less cautious while handling the building materials, and hence increasing wastage of reusable materials such as reinforcement bars, cement and timber pieces. Udawatta, et al. (2015) declared that administrative key points on economic viability were strengthened by incentives instead of individual preferences, especially in waste-related management implementation. The agreement on incentive reward or penalty program suggested that amplified financial measures and reward schemes were more efficient to encourage waste minimization than the voluntary approaches.

From a strategic perspective, the waste cause regarding 'design change' promoted the mean ranking for the 'design standardization and dimensional coordination' approach in waste minimization. Therefore, the construction project entity should conduct a considerable market review and prediction, enhance the design plan, choose competent design elements, continuously monitor drawings accuracy and prevent massive design changes throughout the construction process (Hu, 2011). This stand was further supported by Ajayi and Oyedele (2018a) whereby coordinating design dimensions and specifications of standard materials helped to prevent unnecessary off-cuts leading to waste. Moreover, standardized and coordinated materials can maximise the reusability of the items before ending the lifecycle of the resource, as promoted by the perceptions of ‘circular economy concept’. If a design change is inevitable, the project resources and activities should be cautiously rescheduled while properly informing those changes to all project stakeholders (Ajayi, et al., 2017c). As to control the construction waste production, it is significant to include flexibility of buildings in design so that any necessary amendment and variation in spatial configuration should only produce minimum waste.

Furthermore, some respondents considered that waste most probably arose from the ‘improper design documentation’ and therefore, ‘design documentations assurance and appropriateness’ was initiated as one of the proposed approaches to reduce construction waste. This complied with the study from Akinade, et al. (2018), stating that the design documentation could track building construction progress, monitor performance of building components and avoid any operational inadequacies while responding to the clients’ detailed requests. Proper documentation helped to enhance design coordination, improve time management and develop engineering competences to evade significant human errors that could increase wastage of materials (Ajayi and Oyedele, 2018a). This outcome buttressed the previous findings, which proposed that the major waste production in a construction project was due to deviated design documents (Ajayi, et al., 2017c). Any unintended modification from formerly prepared design documents would lead to demolition and material wastage before reworks for new construction. This minor practice related to design documentation was crucial to prevent waste accumulation while controlling construction projects budget and duration.

It was surprising to see that ‘reduce, reuse, recycle (3R)’ obtained a bottom-ranked mean value of 3.75 together with ‘logistic management’. As discussed earlier, several studies established the advantages of applying 3R in building construction, particularly to reduce construction waste (Lu, et al., 2017; Tam and Tam, 2006; Lachimpadi, et al., 2012; Ling and Leo, 2000). However, it was worth noting that the implementation of 3R was not popular in Malaysia’s construction projects. One of the reasonable justifications for this condition was the ‘immaturity of waste recycling industry’ in Malaysia, which caused 3R to be the least suggested way to minimize construction waste. As mentioned in the study by Umar, et al. (2016), Malaysia's recycling sector facilities were not well developed or integrated. Hence the construction operatives encountered difficulties in obtaining relevant information and approaching those recyclers. This judgement was echoed by the study from Hasmori, et al. (2020), stating that government involvement was critical to promote a widely applied recycling program in the construction industry. Therefore, Ajayi, et al. (2017a) suggested maximizing on-site material reuse by the obligatory establishment of waste targets or waste minimization project goals for those project stakeholders.

It was also astonishing to observe that 'logistic management' was regarded as a less significant measure, sharing a mean value of 3.75 with 'reduce, reuse, recycle (3R)'. Nevertheless, current literature portrayed a consensus to promote logistic management as an effective way to minimize construction waste. A notable study by Gálvez-Martos, et al. (2018) discovered that best management practice on material use referred to logistics arrangement. It optimises material usage by reducing the quantity of raw materials stockpiled on site to lower the possibility of wastage. Ajayi and Oyedele (2018b) also confirmed that planning materials logistics was a strategical means to monitor materials ordering and purchasing, storage of materials, schedule of inbound and outbound materials or waste, variation control and delivery arrangement. According to Ajayi, et al. (2017a), waste minimization needed a reasonable approximation of resources required at each projects phase to eliminate over-ordering and leftover issues while eliminating the main factors of waste production. Ajayi, et al. (2017) further claimed that well planned logistic system on-site prevented double handling of materials to avoid materials breakage and succeeding waste production.

Although 'uncertainty of legislations' in Malaysia was 7th-rated as the construction waste generation cause, the mean ranking of 3.47 was more than the neutral score (i.e., 3.0) and shall not be ignored (Zezhou, et al., 2019). This was supported by the findings from Papargyropoulou (2011), stating that coordination inefficiency in the Malaysian waste management infrastructure and existing policies were preventing the promotion of sustainable activities. Wang, et al. (2019) proclaimed that the authorities' supervision directly influenced construction players' behaviours towards waste management. It was undeniable that existing construction industry standards and specifications in Malaysia failed to offer sufficient technical guidance and relevant limitations in the construction industry, especially in waste management practice. In this regard, our government should speed up the construction of a legal scheme, clarify the duty of each dominant player in the industry, provide guidance on the construction waste recycling implementation and encourage the reuse of waste. Meanwhile, Hu (2011) implied the importance to formulate a consistent standard of allowable waste production to include significant waste handling assessment criteria for the construction enterprise management.

4.8 Summary

The chapter presented the results and findings obtained from the questionnaire surveys. Firstly, it detailed the response rate and sociodemographic of the respondents, followed by a test to affirm the reliability of the statistics collected. Next, it investigated the background information regarding the construction waste status in Malaysia. Furthermore, the data composed from the questionnaire survey was tested through the Kruskal-Wallis test to observe the effect of the respondents' job positions on the ranking pattern of the variables in construction projects. The final test adopted descriptive statistics analysis to rank the waste causes and waste minimization strategies based on the mean importance index.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study detailed the core findings from an empirical survey designated to investigate the framework design for construction waste minimization in Malaysia. Based on an in-depth literature review, nine strategies have been formulated. These measures were further studied by administering a survey to Malaysia’s construction industry practitioners to identify the ranking of the above-mentioned measures. It is worth noting that some approaches such as the ‘reduce, reuse and recycle (3R)’ and ‘logistic management’ are perceived as non-critical by the informants, even though they had been commonly acknowledged as recommended measures to reduce construction waste in some other researches. This is perhaps attributable to particular contexts of implementing those waste control strategies in Malaysia. Several factors were discussed regarding their influence on the efficiency to minimize construction waste. As such, recognition and apprehension of the interrelated variables are practical and necessary to improve the overall waste management system.

5.2 Research Findings

This study aims to figure out an effective construction waste management plan for Malaysia’s construction sector by proposing a framework design for construction waste minimization. The findings revealed that most construction players in Malaysia agreed to put extra effort into waste management based on their current practice.

Although most respondents recognised construction waste as an important issue, they acknowledged that waste minimization was less prioritised in project development and building designs. It is interesting to note that waste control was not considered the main activities of the construction progress, whereby most of the respondents’ companies were not implementing any waste-related plan in their projects. Accordingly, the industry players held a vital role to look into waste production besides the project budget and timeline in construction operation.

Respondents declared that the principal waste production was during on-site activities rather than design stages. This statement was compounded through the insight of informants that rated major waste causes as a consequence of ‘conventional way of construction’ and ‘improper site management’. Additionally, the respondents also agreed that other obstacles were causing the waste minimization efforts to be more challenging, namely, ‘immaturity of waste recycling industry’, ‘unsustainable nature of construction industry’, ‘design change’, ‘improper design documentation’, ‘uncertainty of legislation’ and ‘lack of design-based tools’. Despite the construction players’ willingness to perform waste management duties, the existing waste management consideration in the industry failed to support them effectively. Thus, Malaysian construction industry players were encouraged to recommend stakeholders regarding the economic payback and ecological advantages of proper construction waste management. In that way, the construction operatives would be convinced to commence waste reduction practice and enhance overall design practice towards waste minimization.

This study employed a mixed-method approach after reviewing extensive literature about the possible waste cause and waste minimization strategies. After this, the questionnaire survey was carried out with the participation of the construction professionals to investigate their perceptions regarding construction waste management. Based on the literature review, the factors found out were then embedded into a survey to assess the viewpoints from the targeted population. The outcomes obtained from a series of responded data analyses revealed the rating of the potential framework in waste minimization varying from ‘Site Waste Management Plan (SWMP)’, ‘Industrialized Building System (IBS)’, ‘Building Information Modelling (BIM)’, ‘incentive reward or penalty program’, ‘design documentations assurance and appropriateness’, ‘design standardization and dimensional coordination’, ‘circular economy concept’, ‘reduce, reuse, recycle (3R)’ and ‘logistic management’.

This study revealed that the current construction waste management status in Malaysia was generally unsatisfying. Thus, the framework design to minimize construction waste was recognised as the potential means to achieve the expected waste performance in Malaysia’s construction sector. This study had notable inferences for construction waste research and application in a realistic industry to explore critical approaches capable of influencing construction waste minimization. This is particularly essential since the construction sector is one of the major contributors to landfill waste.

Instead of the typically fragmented tactic, this study proposed the requirement for an integrated approach starting from the early design phase until the entire project delivery stage. The result highlighted the possible potentials of a proper SWMP to initiate an effective waste control process. It also offered a basis to develop a modern IBS construction method and BIM-based management tools. Accordingly, this study provided an in-depth overview for the developers of the design-based software regarding the factors to encourage wider adoption of computer-aided waste management for this industry.

The study similarly implied that modern methods of construction design such as IBS had great potential to reduce construction waste production from construction sites. The application of prefabrication methods could lead the construction industry closer to the manufacturing level since their enhanced collaboration significantly reduces construction errors and waste. In this manner, it would similarly help to produce more accurate and complete design documents, which apparently control the waste intensity of the construction field. This study provided greater insights and verification of the findings from the questionnaire surveys. Based on this study, the following recommendations were concluded.

5.3 Research Recommendations

The results of this study act as a relevant resource for comparative waste-related studies. The participants of the questionnaire surveys were drawn from Malaysia only. The outcomes should then be interpreted and applied within the same context attributable to the difference in laws and regulation, construction methods and weather conditions. In future studies, the transferability and comprehensiveness of this study findings shall be explored before applying in other countries. In such a way, this study outcome is providing a fundamental reference source for comparative waste-related studies.

Moreover, this research gathered data from randomly picked respondents who might not entirely represent Malaysia's construction players.

Therefore, in future research, the distribution of the targeted respondents may be limited for each category to reflect the average view of their respective representatives.

For the rating questions, the weightage of the features was founded on the informants' insight regarding the respective importance level of these factors. The derived weightage from 5-point Likert scales was not absolutely reliable since all the respondents assigned different values to the scale points provided. Hence, interviews are suggested to be carried out to verify the outcomes obtained from the questionnaire surveys.

This study was conducted to establish proper waste management practice to reduce waste production from construction activities significantly. It provided soft measures to be practised in construction waste management application regardless of the detailed construction skills and techniques.

REFERENCES

Ahmad, A.C., Husin, N.I., Zainol, H., Tharim, A.H.A., Ismail, N.A. and Wahid, A.M.A., 2014. The construction solid waste minimization practices among Malaysian contractors. *MATEC Web of Conferences*, 15, pp.1–9.

Ajayi, S.O. and Oyedele, L.O., 2018a. Critical design factors for minimising waste in construction projects: A structural equation modelling approach. *Resources, Conservation and Recycling*, 137, pp.302–313.

Ajayi, S.O. and Oyedele, L.O., 2018b. Waste-efficient materials procurement for construction projects: A structural equation modelling of critical success factors. *Waste Management*, 75, pp.60–69.

Ajayi, S.O., Oyedele, L.O., Akinade, O.O., Bilal, M., Alaka, H.A. and Owolabi, H.A., 2017a. Optimising material procurement for construction waste minimization: An exploration of success factors. *Sustainable Materials and Technologies*, 11, pp.38–46.

Ajayi, S.O., Oyedele, L.O., Akinade, O.O., Bilal, M., Alaka, H.A., Owolabi, H.A. and Kadiri, K.O., 2017b. Attributes of design for construction waste minimization: A case study of waste-to-energy project. *Renewable and Sustainable Energy Reviews*, 73, pp.1333–1341.

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A. and Owolabi, H.A., 2017c. Critical management practices influencing on-site waste minimization in construction projects. *Waste Management*, [online] 59, pp.330–339. Available at: <http://dx.doi.org/10.1016/j.wasman.2016.10.040>.

Ajayi, V.O., 2017. *Distinguish betweenPrimary Sources of Data and Secondary Sources of Data*. [online] Benue State University. Available at: <https://www.researchgate.net/publication/320010397_Primary_Sources_of_Data_and_Secondary_Sources_of_Data>.

Akinade, O.O. and Oyedele, L.O., 2019. Integrating construction supply chains within a circular economy: An ANFIS-based waste analytics system (A-WAS). *Journal of Cleaner Production*, [online] 229, pp.863–873. Available at: <https://doi.org/10.1016/j.jclepro.2019.04.232>.

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A. and Arawomo, O.O., 2018. Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. *Journal of Cleaner Production*, 180, pp.375–385.

Al-Hajj, A. and Hamani, K., 2011. Material waste in the UAE construction industry: Main causes and minimization practices. *Architectural Engineering and Design Management*, 7(4), pp.221–235.

Baldwin, A.N., Shen, L.Y., Poon, C.S., Austin, S.A. and Wong, I., 2007. Modelling design information to evaluate pre-fabricated and pre-cast design solutions for reducing construction waste in high rise residential buildings. *Automation in Construction*, 17, pp.333–341.

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H., 2007a. Factors and values of willingness to pay for improved construction waste management - A perspective of Malaysian contractors. *Waste Management*, 27(12), pp.1902–1909.

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H., 2007b. Implementation of waste management and minimisation in the construction industry of Malaysia. *Resources, Conservation and Recycling*, 51(1), pp.190–202.

Bilal, M., Oyedele, L.O., Akinade, O.O., Ajayi, S.O., Alaka, H.A., Owolabi, H.A., Qadir, J., Pasha, M. and Bello, S.A., 2016. Big data architecture for construction waste analytics (CWA): A conceptual framework. *Journal of Building Engineering*, 6, pp.144–156.

Blackstone, A., 2012. Chapter 7 Sampling Who or What ? In: *Sociological Inquiry Principles: Qualitative and Quantitative Methods*. pp.1–25.

Chen, Z., Li, H. and Wong, C.T.C., 2002. An application of bar-code system for reducing construction wastes. *Automation in Construction*, 11, pp.521–533.

Chi, B., Lu, W., Ye, M., Bao, Z. and Zhang, X., 2020. Construction waste minimization in green building: A comparative analysis of LEED-NC 2009 certified projects in the US and China. *Journal of Cleaner Production*, [online] 256, p.120749. Available at: <https://doi.org/10.1016/j.jclepro.2020.120749>.

CIDB, 2008. Guidelines on Construction Waste. *Guidelines on Construction Waste*, p.42.

Dainty, A.R.J. and Brooke, R.J., 2004. Towards improved construction waste minimisation: a need for improved supply chain integration? *Structural Survey*, 22(1), pp.20–29.

Dania, A.A., Kehinde, J.O. and Bala, K., 2007. A study of construction material waste management practices by construction firms in Nigeria. *Proceedings of the 3rd Scottish Conference for Postgraduate Researchers of the Built and Natural Environment*, pp.121–129.

Datta, S., 2018. *Concept of sampling methods and different types of sampling*. [online] Research Gate. Available at: <https://www.researchgate.net/publication/327891202_Sampling_methods>.

Ding, Z., Yi, G., Tam, V.W.Y. and Huang, T., 2016. A system dynamics-based environmental performance simulation of construction waste reduction management in China. *Waste Management*, [online] 51, pp.130–141. Available at: <http://dx.doi.org/10.1016/j.wasman.2016.03.001>.

Ding, Z., Zhu, M., Tam, V.W.Y., Yi, G. and Tran, C.N.N., 2018. A system dynamics-based environmental benefit assessment model of construction waste reduction management at the design and construction stages. *Journal of Cleaner Production*, [online] 176, pp.676–692. Available at: <https://doi.org/10.1016/j.jclepro.2017.12.101>.

Duran, X., Lenihan, H. and O'Regan, B., 2006. A model for assessing the economic viability of construction and demolition waste recycling - The case of Ireland. *Resources, Conservation and Recycling*, 46(3), pp.302–320.

Ekanayake, L.L. and Ofori, G., 2004. Building waste assessment score: Design-based tool. *Building and Environment*, 39(7), pp.851–861.

EPA, 2012. *Construction Waste Management Plan*. [online] United States. Available at: <http://www.epa.ie/licences/lic_eDMS/090151b2804be3ba.pdf>.

Esa, M.R., 2017. *Moving towards Sustainable Construction in Malaysia: A Holistic Model for Construction and Demolition (C&D) Waste Management*. The University of Queensland.

Esa, M.R., Halog, A. and Rigamonti, L., 2017a. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *Journal of Material Cycles and Waste Management*, 19(3), pp.1144–1154.

Esa, M.R., Halog, A. and Rigamonti, L., 2017b. Strategies for minimizing construction and demolition wastes in Malaysia. *Resources, Conservation and Recycling*, [online] 120, pp.219–229. Available at: <http://dx.doi.org/10.1016/j.resconrec.2016.12.014>.

Gálvez-Martos, J.L., Styles, D., Schoenberger, H. and Zeschmar-Lahl, B., 2018. Construction and demolition waste best management practice in Europe. *Resources, Conservation and Recycling*, [online] 136, pp.166–178. Available at: <https://doi.org/10.1016/j.resconrec.2018.04.016>.

Gamage, I.S.W., 2011. *A Waste Minimisation Framework for the Procurement of Design and Build Construction Projects*. Loughborough University.

Hao, J.L., Hills, M.J. and Tam, V.W.Y., 2008. The effectiveness of Hong Kong’s Construction Waste Disposal Charging Scheme. *Waste Management and Research*, 26(6), pp.553–558.

Hasmori, M.F., Zin, A.F.M., Nagapan, S., Deraman, R., Abas, N., Yunus, R. and Klufallah, M., 2020. The on-site waste minimization practices for construction waste. In: *Materials Science and Engineering*. pp.1–11.

Hassan, S.H., Ahzahar, N., Fauzi, M.A. and Eman, J., 2012. Waste Management Issues in the Northern Region of Malaysia. *Social and Behavioral Sciences*, [online] 42(July 2010), pp.175–181. Available at: <http://dx.doi.org/10.1016/j.sbspro.2012.04.179>.

Heigermoser, D., García, B., Soto, D., Leslie, E., Abbott, S., Kim, D., Chua, H., Gmbh, H.E. and Main, F., 2019. BIM-based Last Planner System tool for improving construction project management. *Automation in Construction*, [online] 104(May), pp.246–254. Available at: <https://doi.org/10.1016/j.autcon.2019.03.019>.

Hu, Y., 2011. Minimization management of construction waste. *ISWREP 2011 - Proceedings of 2011 International Symposium on Water Resource and Environmental Protection*, 4, pp.2769–2772.

Ikau, R., Tawie, R. and Joseph, C., 2013. Initial findings on perspectives of local contractors on waste minimization barriers and incentives on construction sites. *BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium*, pp.506–509.

Jaillon, L., Poon, C.S. and Chiang, Y.H., 2009. Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste Management*, [online] 29(1), pp.309–320. Available at: <http://dx.doi.org/10.1016/j.wasman.2008.02.015>.

James, K.C.H., 2014. *A Framework Design for Construction Waste Minimization and Recycling in Malaysia*. University Technology Petronas.

Kabir, S.M.S., 2016. *Methods of data collection*. [online] Available at: <https://www.researchgate.net/publication/325846997_METHODS_OF_DATA_COLLECTION/citation/download>.

Kim, Y.C., Zhang, Y.L., Park, W.J., Cha, G.W., Kim, J.W. and Hong, W.H., 2019. Analysis of waste generation characteristics during new apartment construction—considering the construction phase. *International Journal of Environmental Research and Public Health*, 16(18), pp.1–16.

Koskela, L., 2004. Making-do the eighth category of waste. In: *Conference or Workshop Item*. [online] pp.1–10. Available at: <https://www.researchgate.net/publication/44389510_Making_do_-_the_eighth_category_of_waste>.

Koutsogiannis, A., 2020. *BIM software guide: Information is the key to success*. [online] Available at: <https://www.letsbuild.com/blog/bim-software-guide>.

Lachimpadi, S.K., Pereira, J.J., Taha, M.R. and 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*, [online] 68, pp.96–103. Available at: <http://dx.doi.org/10.1016/j.resconrec.2012.08.011>.

Lai, Y.Y., 2020. *CIDB allocates RM70m for programmes to enhance construction industry | The Edge Markets*. [online] Available at: <https://www.theedgemarkets.com/article/cidb-allocates-rm70m-programmes-enhance-construction-industry> [Accessed 2 Aug. 2020].

Ling, Y.Y. and Leo, K.C., 2000. Reusing timber formwork: Importance of workmen's efficiency and attitude. *Building and Environment*, 35(2), pp.135–143.

Liu, Z., Osmani, M., Demian, P. and Baldwin, A., 2015. A BIM-aided construction waste minimisation framework. *Automation in Construction*, 59, pp.1–23.

Lu, W., Webster, C., Chen, K., Zhang, X. and Chen, X., 2017. Computational Building Information Modelling for construction waste management: Moving from rhetoric to reality. *Renewable and Sustainable Energy Reviews*, [online] 68(November 2015), pp.587–595. Available at: <http://dx.doi.org/10.1016/j.rser.2016.10.029>.

Lu, W. and Yuan, H., 2011. A framework for understanding waste management studies in construction. *Waste Management*, 31(6), pp.1252–1260.

Lu, W. and Yuan, H., 2012. Off-site sorting of construction waste: What can we learn from Hong Kong? *Resources, Conservation and Recycling*, [online] 69, pp.100–108. Available at: <http://dx.doi.org/10.1016/j.resconrec.2012.09.007>.

Magalhães, R.F., Danilevicz, Â. de M.F. and Saurin, T.A., 2017. Reducing construction waste: A study of urban infrastructure projects. *Waste Management*, 67, pp.265–277.

Mallak, S.K. and Ishak, M.B., 2012. Waste minimization as sustainable waste management strategy for Malaysian industries. *UMT 11th International Annual symposium on sustainability, science and management*, (July), pp.1245–1252.

Maniam, H., Nagapan, S., Abdullah, A.H., Subramaniam, S. and Sohu, S., 2018. A Comparative Study of Construction Waste Generation Rate Based on Different Construction Methods on Construction Project in Malaysia. *Engineering Technology & Applied Science Research*, 8(5), pp.3488–3491.

Mydin, M.A.O., Khor, J.C. and Sani, N.M., 2014. Approaches to construction waste management in Malaysia. *MATEC Web of Conferences*, 17, pp.3–9.

Nagapan, S., Kaliannan, S., Abdullah, A.H., Sohu, S., Deraman, R., Hasmori, M.F. and Abas, N.H., 2018. Preliminary Survey on the Crucial Root Causes of Material Waste Generation in Malaysian Construction Industry. *Engineering Technology & Applied Science Research*, 8(6), pp.3580–3584.

Nagapan, S. and Rahman, I.A., 2014. Construction Waste Management : Malaysian Perspective. In: *International Conference on Civil and Environmental Engineering for Sustainability*. Thistle Hotel, Johor Bahru, Malaysia.pp.1–12.

Nagapan, S., Rahman, I.A., Asmi, A., Memon, A.H. and Latif, I., 2012. Issues on construction waste: The need for sustainable waste management. In: *2012 IEEE Colloquium on Humanities, Science and Engineering Research*. Kota Kinabalu, Sabah, Malaysia: IEEE.pp.325–330.

Noh, F.M. and Mydin, M.A.O., 2017. Review of Solid Waste Management Practice, Handling and Planning in the Construction Industry. *Analele Universitatii Eftimie Murgu*, 24(1), pp.287–301.

Ong, W.H., 2020. *Personalities Factors Toward Engineering Entrepreneurial Attitudes*. Universiti Tunku Abdul Rahman.

Osmani, M., 2012. Construction Waste Minimization in the UK : Current Pressures for Change and Approaches. *Procedia - Social and Behavioral Sciences*, [online] 40, pp.37–40. Available at: <http://dx.doi.org/10.1016/j.sbspro.2012.03.158>.

Osmani, M., 2015. *Integration of waste minimisation strategies into the design process of buildings*. [online] Loughborough University. Available at: <https://dspace.lboro.ac.uk/2134/21775>.

Osmani, M., Glass, J. and Price, A.D.F., 2008. Architects ' perspectives on construction waste reduction by design. *Waste Management*, 28, pp.1147–1158.

Oyedele, L.O., Ajayi, S.O. and Kadiri, K.O., 2014. Use of recycled products in UK construction industry: An empirical investigation into critical impediments and strategies for improvement. *Resources, Conservation and Recycling*, [online] 93, pp.23–31. Available at: <http://dx.doi.org/10.1016/j.resconrec.2014.09.011>.

Papargyropoulou, E., 2011. Sustainable construction waste management in Malaysia: A constructor's perspective. In: *Management and Innovation for a Sustainable Built Environment*. [online] Amsterdam, The Netherlands. Available at: <http://misbe2011.fyper.com/proceedings/documents/224.pdf>.

Pheng, L.S., Shang, G. and Peter, L.K.W., 2016. Using Lean Principles To Reduce Wastes in the Concreting Supply Chain. *International Journal of Construction Project Management*, [online] 8(1), pp.3–23. Available at: <https://search.proquest.com/docview/1842449729?accountid=174776>.

Poon, C.S., Yu, A.T.W., Wong, A. and Yip, R., 2013. Quantifying the impact of construction waste charging scheme on construction waste management in Hong Kong. *Journal of Construction Engineering and Management*, 139(5), pp.466–479.

Rahmat, N.R. and Ibrahim, A.H., 2007. Illegal Dumping Site: Case Study in The District of Johor Bahru Tengah, Johor. In: *International Conference on Sustainable Materials (ICoSM)*. pp.89–91.

Razkenari, M., Fenner, A., Shojaei, A., Hakim, H. and Kibert, C., 2020. Perceptions of offsite construction in the United States : An investigation of current practices. *Journal of Building Engineering*, [online] 29, pp.1–13. Available at: <https://doi.org/10.1016/j.jobe.2019.101138>.

Sa'adi, N., Ismail, Z. and Alias, Z., 2015. Construction waste minimization for Contractors in Malaysia. *Recent Advances in Environment, Ecosystems and Development*, pp.64–70.

Saadi, N., Ismail, Z. and Alias, Z., 2016. A review of construction waste management and initiatives in malaysia. *Journal of Sustainability Science and Management*, 11(2), pp.101–114.

Salgın, B., Akgün, A., Coşgun, N. and Agyekum, K., 2017. Construction Waste Reduction Through BIM-Based Site Management Approach. *International Journal of Engineering Technologies IJET*, 3(3), pp.135–142.

Soo, Z.H., 2019. *Developing a Motivation Framework for Retrofitting Buildings in Construction Industry*. Universiti Tunku Abdul Rahman.

Taherdoost, H., 2016. Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *International Journal of Academic Research in Management*, 5(2), pp.18–27.

Tam, C.M., Tam, V.W.Y., Chan, J.K.W. and Ng, W.C.Y., 2005. Use of Prefabrication to Minimize Construction Waste - A Case Study Approach. *International Journal of Construction Management*, 5(1), pp.91–101.

Tam, V.W.Y., Le, K.N. and Zeng, S.X., 2012. Review on waste management systems in the Hong Kong construction industry: Use of spectral and bispectral methods. *Journal of Civil Engineering and Management*, 18(1), pp.14–23.

Tam, V.W.Y. and Tam, C.M., 2006. A review on the viable technology for construction waste recycling. *Resources, Conservation and Recycling*, 47(3), pp.209–221.

Teo, M.M.M. and Loosemore, M., 2001. A theory of waste behaviour in the construction industry. *Construction Management and Economics*, 19(7), pp.741–751.

Tikkanen, S., 2019. *Circular Economy in Construction - Experiences from Finland*. [online] Ministry of the Environment, Finland. Available at: <https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupMeetingDoc&docid=35644>.

Turkyilmaz, A., Guney, M., Karaca, F., Bagdatkyzy, Z., Sandybayeva, A. and Sirenova, G., 2019. A Comprehensive Construction and Demolition Waste Management Model Using PESTEL and 3R for Construction Companies Operating in Central Asia. *Sustainability (Switzerland)*, 11(6), pp.1–16.

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G., 2015. Resources , Conservation and Recycling Improving waste management in construction projects : An Australian study. *'Resources, Conservation & Recycling'*, [online] 101, pp.73–83. Available at: <http://dx.doi.org/10.1016/j.resconrec.2015.05.003>.

Umar, U.A., Shafiq, N., Malakahmad, A., Nuruddin, M.F., Khamidi, M.F. and Salihi, I.U., 2016. Impact of construction waste minimization at construction site: Case study. *Jurnal Teknologi*, 78(5–3), pp.33–40.

Valtierra-Pacheco, E., 2017. *What is the minimum sample size require for the social science research?* [online] Available at: <https://www.researchgate.net/post/What_is_the_minimum_sample_size_require_for_the_social_science_research_users_perception/595c0e0796b7e49f4b0960c3/citation/download.> [Accessed 2 Aug. 2020].

Vasudevan, G., 2019. Study on Adoption of Building Information Modelling in Reducing Construction Waste in Malaysia. In: *IOP Conference Series: Earth and Environmental Science*. pp.1–6.

Wang, J., Li, Z. and Tam, V.W.Y., 2014. Critical factors in effective construction waste minimization at the design stage: A Shenzhen case study, China. *Resources, Conservation and Recycling*, [online] 82, pp.1–7. Available at: <http://dx.doi.org/10.1016/j.resconrec.2013.11.003>.

Wang, J., Yu, B., Tam, V.W.Y., Li, J. and Xu, X., 2019. Critical factors affecting willingness of design units towards construction waste minimization: An empirical study in Shenzhen, China. *Journal of Cleaner Production*, 221, pp.526–535.

Waste & Resources Action Programme (WRAP), 2014. *Achieving good practice Waste Minimisation and Management*. [online] *Waste & Resources Action Programme*. Available at: <file:///D:/EC705/EC705 Part 3/ECM 737/INFO/New folder/WMM guide Mid level.pdf%0Ahttp://www2.wrap.org.uk/downloads/achieving_good_practice_waste_minimisation_and_management.3494db01.5139.pdf>.

Won, J. and Cheng, J.C.P., 2017. Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization. *Automation in Construction*, [online] 79, pp.3–18. Available at: <http://dx.doi.org/10.1016/j.autcon.2017.02.002>.

Won, J., Cheng, J.C.P. and Lee, G., 2016. Quantification of construction waste prevented by BIM-based design validation : Case studies in South Korea. *Waste Management*, [online] 49, pp.170–180. Available at: <http://dx.doi.org/10.1016/j.wasman.2015.12.026>.

Xu, J., Shi, Y., Xie, Y. and Zhao, S., 2019. A BIM-Based construction and demolition waste information management system for greenhouse gas quantification and reduction. *Journal of Cleaner Production*, [online] 229, pp.308–324. Available at: <https://doi.org/10.1016/j.jclepro.2019.04.158>.

Yates, J.K., 2013. Sustainable methods for waste minimisation in construction. *Construction Innovation*, 13(3), pp.281–301.

Yuan, H., 2013. Critical Management Measures Contributing to Construction Waste Management: Evidence From Construction Projects in China. *Project Management Journal*, [online] 44(4), pp.101–112. Available at: <http://onlinelibrary.wiley.com/doi/10.1002/pmj.20053/full>.

Yusof, M.F., 2006. *Study on construction & demolition waste management in construction site*. University College of Engineering &.Technology Malaysia.

Yusof, N., Awang, H. and Iranmanesh, M., 2017. Determinants and outcomes of environmental practices in Malaysian construction projects. *Journal of Cleaner Production*, [online] 156, pp.345–354. Available at: <http://dx.doi.org/10.1016/j.jclepro.2017.04.064>.

Zezhou, W., Yu, A.T.W., Wang, H., Wei, Y. and Huo, X., 2019. Driving factors for construction waste minimization: Empirical studies in Hong Kong and Shenzhen. *Journal of Green Building*, 14(4), pp.155–167.

APPENDICES

APPENDIX A: Questionnaire Survey Sample

A FRAMEWORK DESIGN FOR CONSTRUCTION WASTE MINIMIZATION IN MALAYSIA

TO WHOM IT MAY CONCERN

Dear Sir / Madam,

I am a student from University Tunku Abdul Rahman (UTAR) Sungai Long Campus. Currently, I am conducting a survey for my Final Year Project entitled "A Framework Design for Construction Waste Minimization in Malaysia" as a partial fulfilment of my Bachelor of Engineering (Honours) Civil Engineering.

This research aims to identify the most effective construction waste management plan for the construction industry in Malaysia by proposing a framework design for construction waste minimization. The objectives of this study are as following:

i. To offer contextual information regarding the construction waste issue in Malaysia.
ii. To identify current barriers to implement construction waste minimization.
iii. To highlight strategies and guidelines for effective construction waste minimization.

This questionnaire consists of THREE sections, in which each round of survey is not expected to exceed 15 minutes in duration. Your responses will be kept confidential and strictly used for academic purpose only.

Your participation in this survey is truly appreciated. If you have questions or concerns about your role and rights as a research respondent or would like to obtain information or offer additional input, you may contact Lew Kar Hui. (Email: lewkarhui@1utar.my)

<u>Section A: Sociodemographic of Respondent</u>

1. Please select your gender.
   - o Male
   - o Female

2. Please select your age.
   - o 25 and below
   - o 26 - 30
   - o 31 - 35
   - o 36 - 40
   - o 41 - 45
   - o 46 - 50
   - o Above 50

3. Please select your highest level of academic qualification.
   - o Primary Education
   - o Secondary Education
   - o Tertiary Education
   - o Postgraduate Qualification
   - o Others: __________________

4. Please select your years of experience in the construction industry.
   - o 5 years and below
   - o 6 - 10 years
   - o 11 - 15 years
   - o 15 years and above

5. Please select the organizations you are currently involved with.
    - ○ Other:
    - ○ Developers
    - ○ Contractors
    - ○ Government Agencies (JKR, CIDB etc.)
    - ○ Consultants
    - ○ Others: ___________________

6. Please select your current career position.
    - ○ Architect
    - ○ Quantity Surveyor
    - ○ Manager
    - ○ Site Leader
    - ○ Engineer
    - ○ Site Supervisor
    - ○ Others: ___________________

Section B: Construction Waste Related Status and Policies

7. Please rate the importance of elements in construction projects from the 1st ranking to the 5th ranking; where:

   1 = Most Important, 2 = 2nd Important, 3 = 3rd Important, 4 = 4th Important, 5 = Least Important

Elements	1	2	3	4	5
Cost	○	○	○	○	○
Time	○	○	○	○	○
Quality	○	○	○	○	○
Safety	○	○	○	○	○
Environmental	○	○	○	○	○

8. What do you think about the current practice of construction waste management in Malaysia?
   - Strongly Dissatisfied
   - Dissatisfied
   - Neutral
   - Satisfied
   - Strongly Satisfied

9. Is there any kind of construction waste management system available in your company?

   If your answer is YES, please state the construction waste management system available in your company; ELSE, please answer NO.

   ____

10. Do you think the Waste Management Strategies are necessary to reduce construction waste production in Malaysia?
    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

11. Please rate the factors that might motivate your company to establish construction waste management; where:

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

Statements	**1**	**2**	**3**	**4**	**5**
Law and legislation	○	○	○	○	○
Cost reduction	○	○	○	○	○
Increase commitment to environmental sustainability	○	○	○	○	○
Improve health and safety work conditions	○	○	○	○	○
Improve the company’s public image	○	○	○	○	○

<u>Section C: Construction Waste Generation Factors and Suggested Ways of Minimization in Malaysia</u>

12. Please rate the significance of factors that generate construction waste in Malaysia; where:

    1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

Statements	**1**	**2**	**3**	**4**	**5**
Conventional way of construction	○	○	○	○	○
Unsustainable nature of construction industry	○	○	○	○	○
Improper design documentation	○	○	○	○	○
Design change	○	○	○	○	○
Improper site management	○	○	○	○	○
Lack of design-based tools	○	○	○	○	○
Uncertainty of legislation	○	○	○	○	○
Immaturity of waste recycling industry	○	○	○	○	○

13. Please rate the proposed strategies to minimize construction waste in Malaysia; where:

    1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree

Statements	**1**	**2**	**3**	**4**	**5**
Site Waste Management Plan (SWMP)	○	○	○	○	○
Circular Economy Concept	○	○	○	○	○
Building Information Modelling (BIM)	○	○	○	○	○
Reduce, Reuse, Recycle (3R)	○	○	○	○	○
Industrialized Building System (IBS)	○	○	○	○	○
Design standardization and dimensional coordination	○	○	○	○	○
Design documentations assurance and appropriateness	○	○	○	○	○
Incentive reward or penalty program	○	○	○	○	○
Logistic management	○	○	○	○	○