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Construction and Demolition Waste Management Practices in Sarawak: Priority for Regulation, Human Resources and Construction Method

Emma Marinie Ahmad Zawawi*, Nazirah Shahdan Osman, Siti Suhaidah Sahab

Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

*Corresponding author's email: emmamarinie@uitm.edu.my

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Abstract

Waste management is implemented by destroying and eliminating all waste from any sources of activities such as construction and demolition, minimising the waste, and reusing or recycling it. The primary purpose of managing waste is to reduce the amount of waste generated, and the reduction of waste aims to protect the environment. Improper waste management can cause damage to the ecosystem, increase air and water pollution, and destroy our health. Because of Sarawak's population increase, waste generation is becoming a big challenge. Among the major significant issue is lack of awareness, incompetence of the person in charge, administrative issues, lack of enforcement and poor technology. This study investigates the current implementation of managing construction and demolition waste in Sarawak. A questionnaire set was designed to obtain a perceptive opinion on the waste management practices in construction projects and demolition in Sarawak. A questionnaire survey was designed and distributed to 50 respondents from construction players in Sarawak. The respondents are among the construction players, including architects, contractors and consultants. The finding shows that many construction companies know the importance of managing waste as they have a procedure for managing waste in their construction operation. Moreover, concrete and aggregates list the highest-ranking waste from construction and demolition activities. This study provides mitigation measures and strategies to minimise the problems. It is anticipated that the finding of this study could assist contractors and developers in having a proper waste management system.

Keywords: Waste management, demolition, construction, recycling, pollution

1.0 INTRODUCTION

Construction is a significant business in every developing country. The relevance of the construction sector in a country's socioeconomic level and long-term growth has been acknowledged and considered by both developing and developed countries. The building industry is a valuable economic resource with a long history of contributing to economic growth (Olanrewaju & Abdul-Aziz, 2015). It substantially contributes to a country's development by providing the essential infrastructure and physical structures for commercial activity, services, and utilities (Papargyropoulou et al., 2011). The building industry's expansion is a part of the living environment, with implications for human situations, social well-being, and healthcare. In addition, the sector creates jobs and contributes to the national economy (Wibowo, 2009). Given these advantages, the construction industry is known to have many wasteful activities, resulting in an increase in waste generation, which has become a severe concern in Malaysia.

The most common source of solid waste is construction waste. Construction and demolition (C&D) waste varies from municipal waste as it contains hazardous matters. Heavy metals, asbestos, organic compounds, and other harmful organic materials threaten the environment, so they cannot be directly dumped. Additionally, the volume of solid waste produced daily in Peninsular Malaysia expanded from approximately 23,000 tonnes to 25,000 tonnes from 2010 until 2012 (Eusuf et al., 2012). Recently, Malaysian Solid Waste and Public Cleansing Management Corporation reported that building projects produce roughly 8 million tonnes of waste yearly (Saadi et al., 2016). At the "Towards Sustainable Construction Waste Management in Malaysia" seminar, Dr. Mohd Pauze Mohamad Taha stated that the contracted waste management companies pick up only 15% of C&D waste. Meanwhile, 85% of C&D waste is uncollected (Chen, 2015). Hence, it shows that only a quarter of C&D waste made it to the gazette landfills. At the same time, the rest might be disposed to illegal dumping sites. Rahim et al. (2017) found that illegal C&D dumping occurs monthly. In 2014/2015, a total of 851 illegal dumping (construction waste) was detected by SW Corp Malaysia. Likewise, The Padawan Municipal Council (MPP), Sarawak, is grappling with illegal dumpsites within their jurisdictions, with 100-200 tonnes of bulky and mixed waste dumped illegally (Khung, 2019). The Padawan Municipal Council has identified six "chronic" illegal waste dumping ranging from roadsides, cul-de-sacs, rivers and streams (Mail, 2018). One of the known illegal dumpsites for construction waste is a 2.2-acre piece of land at Jalan Stapok near Sungai Maong bridge (Ruekeith, 2013).

Improper waste management procedures in construction projects are to be blamed for the rise in construction waste (Marzouk & Azab, 2014). Teo and Loosemore (2001) found that a lack of organisational commitment increases construction waste as it is perceived as a low priority in the success of construction projects. According to Kabirifar et al. (2020), the environment, natural resources, economy and society can be saved if the construction waste is managed effectively. Waste management reduces and minimises construction waste by applying waste management techniques (Ali et al., 2019). According to Lu and Yuan (2011), the success of C&D waste management requires multidisciplinary effort from every discipline. It should be considered in administrative, financial, legal, planning and engineering functions.

Like many developing countries, Malaysia has many development projects running. Notably, several major infrastructure projects are undertaken in Sarawak, namely constructing the Coastal Highway and bridges and constructing the Pan Borneo Highway. To enumerate, Sarawak recorded the third highest value of construction work done (11.11%) in the first quarter of 2022 (Department of Statistics Malaysia, 2022). For this reason, the paper aims to investigate the current C&D waste management adopted by contractors in Sarawak.

2.0 LITERATURE REVIEW

2.1 Construction and Demolition Waste Definition

Various sources come up with the definition of construction and demolition waste. However, there is no unanimity on the definition of construction and demolition waste. Table 1 provides several definitions of C&D waste by several authors.

Table 1 Definition of construction and demolition waste

Authors (Year)	Definition
Shen et al. (2004)	Waste materials are debris generated from the construction, maintenance, and destruction of buildings, roadways, dams, and other civil engineering projects
Tam and Tam (2006)	Any unwanted items resulting from construction, restoration, or demolition activity
Jeffrey (2011)	A large number of waste materials are generated from the construction and demolition of buildings and civil infrastructure
Rahim et al. (2017)	Undesirable products or resources generated throughout a project's pre- and post-construction phases
Khor et al. (2018)	A substance produced from demolition, excavation, renovation, refurbishment, road work, and site clearance
Gálvez-Martos et al. (2018)	Waste is produced by the economic activities involving the construction, maintenance, demolition, and deconstruction of buildings and civil works
Menegaki and Damigos (2018)	A mixture of different materials, including inert waste, non-inert non-hazardous waste, and hazardous waste, generated from the construction, renovation, and demolition activities
Islam et al. (2019)	Solid waste which generates from construction, renovation and demolition activities
Papastamoulis et al. (2021)	Waste is generated through inefficient use of resources during the implementation of a construction project

From the definitions provided in Table 1, C&D waste can be considered undesirable substances, products, or resources generated from construction activities.

2.2 Categories of Construction and Demolition Waste

The waste composition varies depending on the type and size of a project. For example, demolition works accumulate a large amount of concrete waste. Meanwhile, civil and structure works assemble a large amount of excavated materials. The unique nature of a construction project has made it impossible to establish waste generation rates per m^2 floor area (Gálvez-Martos et al., 2018). Hence, several authors have categorised C&D waste into several attributes (Table 2). Thomas and Wilson (2013) assigned two contributors to C&D waste generation, bulk generators and retail or small generators. Bulk generators may come from infrastructure developments, housing development, commercial buildings and demolitions, whereas retail or small generators come from individual house building or renovation works. Wu et al. (2014) grouped C&D waste into three categories, i.e. construction waste (CW), renovation waste (RW) and demolition waste (DW). According to Skoyles and Skoyles (1987), construction waste can be divided into four categories: natural, direct, indirect, and consequential. Meanwhile, Nagapan et al. (2012c) classified C&D waste into two groups, physical (material waste) and non-physical waste (time and cost overrun). Similarly, Purchase et al. (2022) categorised construction waste as man-made (generated from material handling, design, etc.) or natural (due to earthquakes or other natural disasters). All four categories of waste mentioned can be in the form of physical and non-physical waste. However, the paper focuses only on physical waste.

Table 2 Construction and demolition waste categories

Author	Characterisation	Categories
Thomas and Wilson (2013)	By Contributor	1. Bulk generator
		2. Retail/ small generator
Wu et al. (2014)	By Work/ Activity	1. Construction waste
		2. Renovation waste
		3. Demolition waste
Skoyles and Skoyles (1987)	By Cause	1. Natural waste
		2. Direct waste
		3. Indirect waste
		4. Consequential waste
Nagapan et al. (2012c)	By Quantities	1. Physical waste
		2. Non- Physical waste
Purchase et al. (2022)	By Cause	1. Man-made waste
		2. Natural waste
Yuan et al. (2013)	By Composition	1. Inert
		2. Non- inert
Chen and Li (2006)	By Properties	1. Physical
		2. Chemical
		3. Biological

2.3 Construction and Demolition Waste Materials

Wastes generated from construction activities could be materials such as Concrete / Aggregate Cement / Plaster / Mortar, Timber / Wood such as Plywood, Door, Metal (ferrous and non-ferrous) such as Aluminum, Copper, Steel, Plastic / Rubber, Brick / Blocks / Tiles, Sand / Soil / Stone / Rock, Cardboard / Paper, Product Packaging. In a study of two public housing projects and one private housing project in Hong Kong, Chen and Li (2006) listed construction waste generated during superstructure works consisting of cement, concrete rubbles, scraps (drywall, wood, rebar, concrete block), plastic conduit tailing, packaging materials, nails, and unused materials. The detail is as shown in Table 3.

A case study conducted by Nagapan et al. (2013) at three construction project sites in Batu Pahat District identifies six common construction waste materials; timber, packaging, brick, metal, and mortar. The research also found that timber waste was the dominant waste produced at three sites. Similarly, a study done by Mydin et al. (2014) found that timber has the highest mean score as the material most frequently thrown out. Mah and Fujiwara (2016), in their research conducted on mixed-development projects in Malaysia, also found timber materials were the highest generated waste. A research by Lau et al. (2008) at three construction sites in Sarawak also found wood as the most considerable C&D waste generated. The finding is not surprising as timber is often used to fabricate building frameworks. In Sarawak, wood is widely used due to the abundant timber resources (Lau et al., 2008). Mah et al. (2016) conducted a case study on 11 projects across Malaysia and found that concrete, aggregate, and cement represent the most significant total waste generated. Ansari and Ehrampoush (2018), in a study on a waste disposal site in Yazd, also found that cement and concrete have the highest volume of waste generated. Similarly, most of the C&D waste in Tehran consists of cement, concrete, bricks and soil (Asgari et al., 2017). Wong and Roslan (2019) also noted concrete and aggregate as the highest contributor to waste generation. Research conducted by Islam et al. (2019) also found that the most significant waste generated is concrete, followed by brick waste, as such materials are the primary materials in typical building construction. Bricks and blocks are also one of the main components of construction waste. Metal refers to ferrous and non-ferrous materials. Due to their inherent properties, metals are the first choice material for structures, reinforcement, frames, roofing, plumbing, and many others. Examples of metals in construction are reinforced bar, piper, copper, aluminium brass, and zinc. However, metal products are among the lowest waste generated compared to timber and concrete. According to Lau and Whyte (2007), the low metal waste generation might be due to its high recycling value.

Waste is generated at every construction stage (Lau & Whyte, 2007). However, common causes of construction waste generation are inappropriate material storage (Ikau et al., 2016; Nagapan et al., 2011, 2013; Polat et al., 2017), frequent design changes (Ikau et al., 2016; Nagapan et al., 2011; Polat et al., 2017), poor material handling (Ikau et al., 2016; Kaliannan et al., 2018; Nagapan et al., 2011, 2013; Polat et al., 2017), ordering errors and mistakes (Kaliannan et al., 2018; Nagapan et al., 2011, 2013; Polat et al., 2017), end of life cycles (Lau & Whyte, 2007), installation mistake (Ikau et al., 2016; Polat et al., 2017), the effect of weather (Kaliannan et al., 2018; Polat et al., 2017) and lack of waste management plans (Nagapan et al., 2013; Polat et al., 2017).

Table 3 Construction and demolition waste composition

Author	Concrete/ Aggregate	Timber/ Wood	Metal	Plastic/ Rubber	Brick/ Block	Sand/ Soil/ Stone	Cardboard / Paper	Packaging
Chen and Li (2006)	/	/	/		/	/		/
Nagapan et al. (2013)	/	/	/		/			/
Noor et al. (2013)	/	/	/	/	/	/	/	/
Mydin et al. (2014)	/	/	/		/			/
Wu et al. (2016)	/	/	/	/	/			
Mah et al. (2016)	/	/	/		/	/		
Mah and Fujiwara (2016)	/	/	/		/	/		
Asgari et al. (2017)	/	/	/		/	/	/	/
Ansari and Ehrampoush (2018)	/	/	/	/	/			
Islam et al. (2019)	/	/	/	/	/			
Córdoba et al. (2019)	/	/	/	/	/	/	/	
Wong and Roslan (2019)	/	/	/	/	/	/	/	/

2.4 Construction and Demolition Waste Management Strategies

In many large urban areas, construction waste has become a severe environmental concern (Chen et al., 2002). Hence, it is imperative to for managing construction waste. Construction waste management may be addressed in various ways; selecting suitable strategies in order of preference consists of waste avoidance, minimisation, recycling, treatment and disposal (Wolsink, 2010). The method of preserving building waste extends much beyond simple garbage disposal. It entails efficiently utilising building sources to decrease waste output and improve trash utilisation. According to Nasir et al. (2016), industrial and construction wastes account for 28% of municipal solid wastes in Malaysia's southern and central regions. Building debris, in most situations, comprises harmful elements that can harm people and the environment. Paints, solvents, adhesives, caulks, insecticides, wood preservatives, oil, or expired stored items are hazardous wastes commonly created during construction operations.

2.4.1 Landfill

Malaysia's government has taken a variety of steps to limit garbage creation. Nonetheless, many contractors cannot implement effective waste management, resulting in construction waste mismanagement (Tey et al., 2013). The most common handling of construction waste in Malaysia is to dispose of waste in landfills. A common reason is a perception that little value was placed on construction waste (Hasmori et al., 2020), and it became a culture (Nagapan et al., 2012b). According to Fishbein (1998), construction and demolition (C&D) wastes contribute 10 to 30 percent of the wastes produced at different landfill sites worldwide. In a study on concrete waste management, Wong and Roslan (2019) found that respondents are keen to opt for disposal in landfills as a waste management strategy. Begum et al. (2009) studied 130 contractors from the Klang Valley area and found that most contractors dispose of construction waste at landfills.

Despite the continuous effort to encourage alternative means for C&D waste disposal, the landfill is deemed the most efficient way to settle the collected solid waste (Ahmad et al., 2019). Nevertheless, the measures must no longer be practical in the long term because the building industry creates massive volumes of waste. Construction waste is increasing every year, further congesting already overburdened landfills. Based on a research conducted by Tang (2020), municipal solid waste of the local authority in Sarawak reveals significant problems. There is low waste collection coverage in remote local authorities due to constrained by terrains and accessibility. This increasing waste generation weighs on the capacity of the existing dumpsites and the presence of a large amount of organic waste, particularly food residues in the municipal solid waste received at the landfills and dumpsites. In addition, they are also facing a problem due to low waste segregation and recycling activities, probably due to limited recycling facilities and agents in Sarawak. Therefore, the 'ecosystem' for recycling has yet to exist (News Desk, 2020). Figure 1 presents the daily tonnage generated in Sarawak.

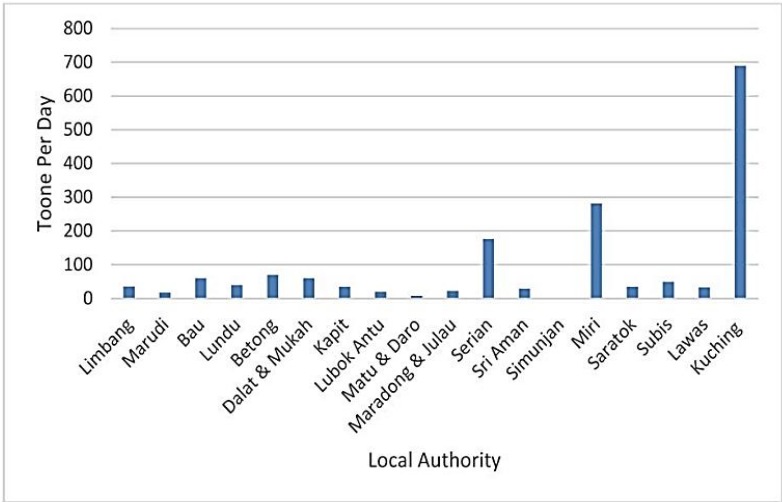

Figure 1 Daily tonnage of municipal solid waste generated based on the data of local authorities in Sarawak (Tang, 2020)

However, with the constant increase in waste generation, more landfills were closed due to running out of space. According to the National Solid Waste Management Department (NSWMD), 137 landfills are in operation throughout Malaysia, while 174 landfills were already closed (MIDA, 2021). Comparatively, 46 landfills are operating in Sarawak, including 41 open landfills. Out of 41 open landfills, only Kuala Baram and Seng Ling landfills were used to dump bulky wastes, including construction waste (Natural Resources and Environment Board Sarawak). For this reason, relying solely on landfills is not a sustainable solution (Jeffrey, 2011). Hence, construction waste disposal is not sustainable (Nagapan et al., 2012a) and a viable solution to managing construction waste as it raises ecological concerns (Subramaniam et al., 2018).

2.4.2 Illegal Dumping

In a report prepared by Chen (2015), only a quarter of C&D waste made it to the gazette landfills. Consequently, many resorts to illegal dumping as fast, hassle-free waste management. Begum et al. (2009), in their finding, found that lower-grade contractors (G1 to G3) are more likely inclined to commit illegal waste disposal. Mayor of Kuching South City Council (MBKS) Datuk James Chan pointed out illegal dumping in Kuching, Sarawak contractors resorted to illegal dumping after completing renovation works (Ten, 2018). Similarly, in a case study, Nagapan et al. (2013) noted that illegal dumping is also a way for the contractor to dispose of C&D waste. In a study by Wong and Roslan (2019), contractors know that illegal dumping is not the best way to dispose of waste. According to Rahim et al. (2017), illegal dumping activities are prevalent in every state and occur monthly.

2.4.3 Waste Composition

Most of the literature reviewed in this study highlighted that good handling of waste is vital to sustainable construction. In this perspective, minimising waste where feasible; signifies avoiding waste where possible and reusing materials which can usually end up as waste. C&D waste management strategies have regarded waste reduction, recycling, and reuse as essential for sustainable management of resources since much C&D waste produced is legitimately destined for disposal in landfills. Hence, the waste composition can be achieved by onsite sorting. Hong Kong construction industry, for example, categorised C&D waste into inert and non-inert waste. The inert waste can be accepted by public fill reception facilities, whereas non- inert is dumped at landfills (Yuan et al., 2013). Quantities of C&D waste disposed of at landfills can be reduced via onsite sorting (Hao et al., 2008).

Despite the benefits of waste composition, construction players are still reluctant to carry out the activity (Poon et al., 2001). Several known reasons are; not enough site space, the need to invest in equipment for onsite sorting, and the activity disturbing the regular construction activity.

2.4.4 Reduce, Reuse and Recycle

According to Córdoba et al. (2019), 73% of generated C&D waste has the potential to be recycled in C&D. Where timber is the most common recycled and reused construction waste (Hamid et al., 2020; Nagapan et al., 2013). Waste reduction, reuse, and recycling techniques are limited in construction, and natural resources used as building materials are often inexpensive (Begum et al., 2009). Furthermore, there is no legislation for construction enterprises to use sustainable resources and waste management, and illegal dumping remains an issue for authorities (Begum et al., 2009). Contractors often resort to burning waste material on site (Nagapan et al., 2013). As a result, the government formed the Construction Industry Development Board (CIDB), which aims to modernise the construction industry by increasing its environmental productivity. In support of national policy, the CIDB has enhanced the industry's dedication as well as an environmentally sustainable industry in the "Construction Industry Master Plan" (CIDB, 2007) and is trying to enlighten sector-major

players through training classes, seminars, understanding, and knowledge boosting events. Furthermore, the Green Building Index (GBI) provides a framework for planning and constructing green, sustainable construction and increasing industry awareness.

2.4.5 Implementation of Site Management Practice

Due to increased concern about the environmental implications of construction waste, waste management has been recognised as an effective strategy for building project management. It is vital to control building wastes in strategies to cope with impending environmental sustainability. Managing waste processes for building projects was designed to conserve the environment and understand that waste from construction and demolition projects contributed significantly to environmental harm (Shen et al., 2004). According to Fauziah and Agamuthu (2012), waste management is the field that encompasses waste creation, storage, collection, transportation, processing, and disposal while considering the environmental, economic, aesthetic, and social. Waste management includes tracking, gathering, transportation, processing, and disposal.

Construction project development can contribute to economic and social growth and increase the quality of life, but it is related to environmental deterioration. According to Azqueta (1992), construction operation impacts the environment throughout the development life cycle. The impact of construction and operation occurs from the site's activity's beginning until the structure's ultimate removal. The atmosphere also accumulates pollution due to raw material extraction and construction operations. According to Levin (1997), construction is liable for 40% of air, 20% of wastewater, and 13% of other emissions in the United States. In dust and other emissions, hazardous chemicals such as nitrogen oxides and sulphur oxides can be found. These chemicals are released during the manufacturing and transportation of materials and field operations, posing a significant environmental risk. Srinivas (n.d.) summarised several negative impacts of waste, including waste from construction and demolition. These include affecting human health, serious health risks to residents, increased diseases, and fire risks. Failure to protect our environment could affect living creatures, including humans. It is necessary to investigate the practices of construction and demolition waste in Sarawak. Early investigation can detect any serious problem that could be solved at an earlier stage.

Malaysia's construction industry saw a 5% increase in productivity in 2009 (MPC, 2012). On the other hand, this statistic indicates how vital the Malaysian construction industry may be in helping the government achieve its sustainable development goal. Moreover, research confirms expectations that construction waste generation rates will keep growing, burdening the country's existing overburdened waste management infrastructure. In conclusion, many policies and volunteer work in the Malaysian construction sector encourage sustainable resource and waste management, but the facts remain tough. The sector's continued growth allows for more extensive adoption of sustainable waste management practices, adding to the country's goals for sustainable development.

3.0 METHODOLOGY

Referring to past similar studies in Costa Rica, Vietnam, Saudi Arabia and Malaysia (Table 4), quantitative methods via questionnaire survey were applied to measure C&D waste management practice in the construction industry. Hence, this study applies the quantitative data collection method.

Table 4 Past Research

Authors (Year)	Country	Methodology	Measure
Abarca et al. (2007)	Costa Rica	Questionnaire survey	• Impact of C&D waste • Causes of C&D waste generation • Motivators and barriers
Ling and Nguyen (2013)	Vietnam	Questionnaire survey	• Performance standard of waste management • Barriers to implementing waste management • C&D waste management practice
Ouda et al. (2018)	Saudi Arabia	Questionnaire survey	• Construction Waste Plans • Pollution Control and Construction Waste
Esa et al. (2017a, 2017b)	Malaysia	Questionnaire survey	• C&D waste management strategies • Awareness of circular economy

This study was carried out in Kuching, Sarawak, Malaysia. Fifty questionnaires were collected and analysed. The questionnaires were distributed to the related population from various construction backgrounds- architects, contractors, engineers, and consultants to gather their input on C&D waste management practice in Sarawak. The selection was made considering the government has unveiled to spend RM22 billion to roll out mega infrastructure projects that could catalyse the Sarawak construction sector.

The questionnaires were divided into demographic, current practice, knowledge, awareness of waste management, and mitigation measures. Due to the time constraint and restriction order of movement and standard operating procedure during the pandemic of Covid-19, this research applies purposive sampling for data collection as this sampling method was approved to be one of the most cost-effective and time practical. Purposive sampling is the best choice where researchers rely on their own judgement when choosing the numbers of the population to participate in the survey. The questionnaire was distributed personally to the respondents and was gathered entirely in April 2022. The respondents' details are shown in Table 5.

Table 5 Details of the respondents

	Category	Frequency	Percentage
Age	20-29	12	24
	30-39	14	28
	40-49	18	36
	>50	6	12
	Total	50	100
Profession	Contractor	6	12
	Site Supervisor	10	20
	Engineer	9	18
	Architect	2	4
	Consultant	8	16
	Others	15	30
	Total	50	100
Sector	Public Sector	24	48
	Private Sector	26	52
	Total	50	100
Years of Working Experience	<5 years	14	28
	6-10 years	15	30
	11-20 years	12	24
	>20 years	9	18
	Total	50	100

4.0 ANALYSIS, FINDINGS, AND DISCUSSION

4.1 Contribution Factors of Construction Waste

This section discusses the analysis of data and findings of the study. Figure 2 illustrates that 94% of the company has Waste Management Procedure while 6% do not have the procedure. It shows that companies in Kuching, Sarawak emphasise the importance of having a procedure to manage waste. However, they still need more improvements to keep their employees constantly aware of waste management. According to Chan et al. (2014), a lack of new information among contractors has created another obstacle to achieving long-term C&D waste management. As a result, the younger generation and experienced personnel cannot agree. In addition, 62% of the respondents think there is not enough encouragement from their company to practice C&D waste management.

In comparison, only 38% were encouraged to conduct C&D waste management. This situation occurs because, until a year back, environmental concerns were not considered significant and hence were not addressed in education. Even if they do not have new information regarding sustainable methods, the experiences of expert contractors are vital and valued in the sector. However, Abidin et al. (2008) claimed that the younger generation, who are trained and aware of information about sustainability in C&D waste management, had challenges in putting the theoretical understanding of the concept into reality. As a result, developers are more prone to reject ideas given by the younger generation.

Figure 2 Information on waste management in the company

The composition of waste materials is not only for emissions during waste treatment and final disposal but also for the potential recovery and recycling of valuable resources (Bisinella et al., 2017). Table 6 shows that 62.7% of companies in Kuching, Sarawak uses Waste Composition, and 33.3% opt for Landfill Disposal. However, only 4% use the 3R Concept – Reduce, Reuse & Recycle. The 3R concept is supposed to be one of the most popular but was not reflected in Sarawak. This scenario might be due to a lack of expertise and

technology in 3R concepts in Sarawak. Lu and Yuan (2011) identified the 3R principles as the common practice used to minimise waste and a traditional priority in environmental thinking of waste management (Esty & Winston, 2006). Huang et al. (2018) describe waste reduction as the optimal waste management measure with the lowest adverse environmental impact. Correspondingly, Umar et al. (2021) stated that 3R could reduce the embodied energy and the utilisation of natural resources. Hence, it is essential to emphasise the implementation of 3R methods for construction and demolition waste reduction in Sarawak.

Table 6 Current practices of waste management in Sarawak

Practices	Frequency	Percentage
Landfill Disposal	17	33.3
Illegal Dumping	0	0
Waste Composition	32	62.7
3R Concept (Reduce/Reuse/Recycle)	2	4
TOTAL	50	100

Table 7 Stages to contribute to construction waste and recommended practices for waste management

Stages in construction operation	Frequency	Percentage
Design	0	0
Procurement (requirement to bulk purchase, over-ordering)	3	6
Material Handling	4	8
Construction	43	86
TOTAL	50	100

Construction and demolition (C&D) waste contribute 10 to 30 percent of the waste produced at different landfill sites worldwide (Fishbein, 1998). The nature of waste composition might differ at various construction stages (Gulghane & Khandve, 2015). Hence, it is crucial to identify the construction stage that contributes the most waste generation. According to Table 7, most respondents (86%) agree that Construction Stage contributes more to waste in the company, 8% agree on Material Handling, and 6% agree on Procurement. This result is supported by a statement from a previous literature review by Chen et al. (2002), who stated that construction waste had become a serious environmental concern in many large urban areas.

Table 8 Waste management strategies

Stages	Frequency	Percentage
3R Practices	16	31.4
Industrialised Building System (IBS)	28	54.9
Landfill Disposal	3	5.9
Proper site management practice	4	7.8
TOTAL	50	100

Based on Table 8, the most recommended type of C&D waste management practice chosen by the respondents is the implementation of an Industrialised Building System (IBS) (54.9%). Followed by 3R practices – Recycle, Reuse & Reduce (31.4%) and enforcement of proper site management practices (7.8%), such as enforcing rules and regulations on onsite management and control. However, 5.9% chose Landfill Disposal as a Waste Management Practice. IBS is a building method produced of prefabricated elements. According to Zeng et al. (2005), implementing the IBS is critical for the construction industry because it can reduce waste from construction operations, save landfill space, and ensure the sustainability of waste management.

Table 9 shows the result of materials that contribute most to construction and demolition waste in Kuching Sarawak. The respondent was asked to rank the survey containing types of waste from 'Lowest Contributors' (1) to the 'Highest Contributors' (5). The data collected based on the results shows that the first ranking is concrete and aggregates with a mean of 4.32. More than 50% of the respondents ranked above average 'highest contributor' to concrete aggregate with 29 participants. Furthermore, Metal products/ Reinforced steel, Wood, Sand & Soil have moderate waste contributors in the construction sites. Besides, the author observed that most respondents said the "Sand and Soil" component moderately contributes to construction and demolition wastes (25 participants selected 'moderately contributor) with a mean value of 3.48. It is also found that "plastic materials/ rubber", "brick& blocks", "cardboards/ paper", and "packaging products" have below the moderate mean value. Such materials are minor contributors to construction and demolition waste materials.

Table 9 Types of materials that contribute to the construction waste

No	Types of waste	1	2	3	4	5	Total	Mean	Ranking
1	Concrete and aggregates	1	2	6	12	29	50	4.32	1
2	Wood	0	0	9	36	5	50	3.92	2
3	Metal product/reinforces bar	1	1	22	20	6	50	3.58	3
4	Plastic Material/Rubber	6	28	9	5	2	50	2.38	6
5	Brick and block	3	0	20	25	2	50	3.46	5
6	Sand and soil	1	3	19	25	2	50	3.48	4
7	Cardboards/papers	13	20	5	2	0	50	1.92	7
8	Packaging product	22	22	1	3	2	50	1.82	8

The data gathered show that most respondents know the importance of managing construction waste. There are specific barriers that might be the reason for managing it efficiently. Knowing the highest types of materials that contribute to construction waste, the researcher continued to determine strategies for the better management of construction waste. Adapted from the questionnaire survey by Hasmori et al. (2020), the author found that the strategies to minimise construction and demolition waste in Sarawak are shown in Table 10. The result was ranked from 1 to 5 from strongly not agree to agree strongly.

Table 10 Strategies to minimise construction and demolition waste

No	The strategies	1	2	3	4	5	Total	Mean	Ranking
1	Human Resources: Improve education and awareness regarding waste management	0	0	0	15	35	50	4.70	2
2	Administrative: Standardisation of design and materials to improve built ability.	1	5	23	17	4	50	3.34	5
3	Regulation: Usage of offsite products and components (low waste construction technology)	0	0	0	13	37	50	4.74	1
4	Material and Equipment: Using mechanical handling to reduce damage to materials during delivery	0	9	18	13	10	50	3.48	4
5	Construction Method: Provision of waste skips for specific materials (waste segregation)	0	0	0	18	29	50	4.52	3

Table 10 presents the strategies to minimise construction and demolition waste. Thirty-seven respondents strongly agreed that regulation is essential and should be enforced toward waste minimisation. Regulation is the highest ranking agreed by the majority of the respondent, with a mean value of 4.74. It clearly shows that regulation plays a significant role in ensuring the implementation of waste management is in control. Enforcement includes penalties and rewards, where best practice is rewarded while wrongdoing is penalised (Liu et al., 2019). Authority should patrol the implementation of construction and waste management locally. Reports and complaints from the neighbourhood related to illegal dumps waste should be put at the highest priority.

Thirty-five of the respondents strongly agreed that the strategies must involve human resources. Human resource refers to improving education and awareness regarding waste management with a mean value of 4.70. Implementing construction and demolition waste will not be successful without its players' awareness. The government and companies should offer training and workshops for workers to acquire and develop knowledge and skills on C&D waste management and apply the concept of sustainable development (Liu et al., 2019).

Leveraging technology can help in reducing C&D waste. The construction technology method is at the third rank in this result with a 4.52 mean value. Such technology uses BIM to simulate and analyse the ripple effect of construction changes and the possible amount of waste generated (Akinade et al., 2018; Porwal et al., 2020). As the industry is labour-intensive, material handling and construction methods play a role in waste generation (Luangcharoenrat et al., 2019). Likewise, Zain et al. (2018) found that proper waste segregation and placement can influence the reuse of onsite materials. The Construction Industry Development Board (CIDB) Malaysia agreed that the Industrialised Building system is a very efficient construction method for reducing waste. Hence, applying Industrialised Building System (IBS) can reduce construction waste. Mechanical handling can also minimise potential waste due to mishandling and mishaps. In addition, IBS also supports sustainable construction agenda. However, the IBS implementation in Sarawak is still behind due to some barriers. Hence the contractors and developers must invest in other technology to improve waste management practices.

Materials, equipment, and administrative strategies were ranked at 4 and 5 with 3.48, and 3.34 mean values, respectively. Most respondents were not sure this strategy could contribute to waste minimisation in construction and demolition. The majority of them choose the moderate answer.

5.0 CONCLUSION

The findings of this study reveal construction and demolition waste contributes a lot to the generation of waste in Sarawak. Many strategies have been implemented by construction players to support the government agenda of reducing waste and protecting the environment. The strategies include 3R practices, proper site management practice, implementation of IBS technology as well as landfill disposal. However, construction players are aware of the importance of managing waste and the impact of waste on the environment and quality of life, the

local authority must take more comprehensive action to enforce the regulation and act related to waste minimisation in Malaysia. Nevertheless, it is crucial to identify the current waste management practice to raise awareness and improve C&D waste management in the construction industry. The are several suggestions for future studies in the area to be considered by the future researcher.

1. Future studies could focus on enforcing current acts and regulations in waste management in Malaysia.
2. The local authority must review their guideline for construction operations, which implies the health and safety of the labourers and the public exposed to the danger at the construction site. The danger might come from the improper waste management method implemented.
3. Future researchers could also study the challenges many contractors and developers face due to the agenda on minimising construction waste.
4. Further investigation should be conducted to obtain more information, especially on the technology that could speed up the process of managing construction and demolition waste. It is anticipated that this study has contributed to the body of knowledge in the area that opens up ideas to the construction players to manage waste professionally.
5. A comparison study among developing and developed countries in waste management and minimisation could reveal the best practice to follow.

Suggestions for solving the problems have been identified in light of the causes. It is believed that waste reduction also involves human behaviour and attitudes. The waste management strategy requires the management team to strengthen their policy and enforce the C&D waste management regulation. C&D waste management must be adopted as early as the planning stage and continuously incorporated to reduce waste generation at every stage. This research does benefit not only the government or private organisations but also the community. This research can be a reference for future scholars and academia.

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