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Determining Root Cause of Construction Waste Generation: A Global Context

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Abstract

Construction sector is one of the main sectors in contributing Gross Domestic Product (GDP) growth rate in every developing country. The rapid growth of this sector directly produces a huge amount of construction waste. Hence, to find out the main root causes of the generation, this paper aimed to determine root causes of the construction waste generation in the construction sector. The research is carried out through triangulation technique (questionnaire survey and practitioner's validation). This technique is adopted to facilitate cross validation by analysing 38 articles and then the final results have been validated by construction practitioners. A total of 80 root causes were identified from 38 articles and the 5 main root causes determined have scored more than 50% out of the total number of articles. Finally, the result was validated and found out that 87.5% of construction practitioners agree with the findings. The agreed root causes are 'Constant design changes', 'Incorrect storage of materials', 'Poor handling of materials', 'Effect of weather' and 'Mistakes while ordering from suppliers'. Therefore, these initial findings will be able to aid the construction practitioner (contractors, consultants and developers) to be aware of the root causes that is mostly causing construction waste generation.

Keywords: Construction Waste; Root Causes; Construction Practitioners; Triangulation Technique; Malaysia.

1. Introduction

Construction is a colossal, dynamic, and composite industry that plays a vital part on the global [1]. Construction work incorporates remodeling of structures, renovations, or maintenance and repair of buildings or other projects such as highways or infrastructures [2]. Asia-Pacific will keep on accounting for the biggest offer of the worldwide construction industry, given that it incorporates the expansive markets of China, Japan and India and Global Construction 2030 is the authoritative review of a standout amongst the most imperative areas of the worldwide economy [3]. The construction industry represents a core economic activity of a developing country. It is linked to basic development of infrastructure exchange of technology and improved access to information channels [4]. The construction industry has become in the course of the most recent decades and brought about upgrades in organization benefits, financial accessibility and expanded commodities in every nations [5]. The huge growth of construction industry incidentally produces huge sum of construction waste. Construction waste was produced all through the development procedure, for example, amid site clearance, material damages, material utilize, material non-utilize, overabundance acquirement and human blunder. Construction waste generated contributes to serious environmental effect. Thus, it is crucial to determine the root causes of construction waste generation in the construction industry in order to reduce the construction waste and the environmental effects.

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2. Literature Review

2.1. Construction Waste

The measure of construction waste is significant in numerous countries which has tested the execution of the production and its sustainable target [6]. Construction waste can begin at any period of the development procedure, and its underlying foundations may lie in design choices, technique for construction or even with dispositions of individuals [7].

Waste in the construction field does not only pivot on amount of waste generated at site but also closely connected to action such as waiting time, overproduction, handling of material, processing, and movement of labourers [8]. As indicated by Begum et al. [9] and Rahim et al. [10], construction waste generation has been expanding each year.

Most of the construction waste are recyclable and reusable, nevertheless, a large portion of the waste are normally dumped in landfill [11]. In summary, it is well entrenched that the construction industry produces a consequential amount of wastes and also imposes great effect towards the environment and social issues.

2.2. Issues in Construction Industry

2.2.1. China

Construction industry of China is required to proceed with its impressive development for years to come. As of late, huge scale urban development programs, especially the broad urban restoration program in metropolitan cities, have created billions of huge amounts of construction waste, and caused huge ecological effects [12]. A report from National Development and Reform Commission of China says that China produced approximately 1 billion tons of construction waste in 2013, which was five times more than the measure of municipal waste created in China in a similar period, nonetheless, just around 5% of the construction waste was recycled or reused [13]. An unmistakable case of this prediction happened in Shenzhen, China, end of the year 2015, where pile of construction waste calamitously collapsed [14]. The landslide covered almost three dozen structures and left no less than 85 individuals missing, emerging from the heaping of construction waste. This emotional circumstance shows that China is confronting enormous difficulties for overseeing construction waste with significant urban advancement all through the nation.

2.2.2. Indonesia

Amid the most recent 10 years, research focusing mainly on construction waste, has been crucial in Indonesia. Through past researches, there has been worry with the abnormally high state of waste inside Indonesian construction venture and proposed that waste can influence the execution of the development progress [15]. Indonesia's legislature has numerous program with a specific end goal to expand the growth of economy. One of them is MP3EI (*Masterplan Percepatan dan Perluasan Pembangunan Ekonomi Indonesia*). This program ought to be supported by right waste administration framework [16]. There is no practical or adequate technique been settled upon by all gatherings associated with construction undertakings to diminish construction waste. Indonesia, as a developing nation has not been adopting recycling innovation as in created with the exception of reuse asphalt hot mix called Reclaimed Asphalt Pavement (RAP) [15, 17].

2.2.3. India

In India, it is extremely normal to see gigantic heaps of construction waste, stacked close by the roadside, causing massive traffic, clog and interruption and chocking of drains. Around 30% of the total waste produced in the nation is from construction waste [18]. Attributable to advancement in construction, construction waste production in India is expected to increase. If measures to limit and handle the construction waste are not created and coherently applied, it might risk the environmental condition and also sustainable development of the nation. Construction waste minimization and handling are essential in perspective of constrained landfill space and expanding quantum of construction waste or there might be issues identified while dealing with the waste and discovering space for landfilling [19].

2.2.4. United States of America (USA)

Most construction waste at present produced in the USA is legitimately bound for disposal in landfills directed under Code of Federal Regulations (CFR). In a few zones all or part of construction waste stream is unlawfully disposed on land, or in drainage including water, as opposed to controls to ensure human wellbeing, commerce and nature [20]. Costa Rica is a developing nation in Central America, with roughly 4.9 million occupants, in which 60% lives in urbanized regions. The contribution of the construction industry to the Gross Domestic Product over the most recent 5 years is quite high. This demonstrate the significance of this area in the economy of the nation. Construction waste generated from residential projects extends about 700 kg/m^2 [21].

2.2.5. Malaysia

Construction industry in Malaysia is very important for socioeconomic development of the country. It shears 3.9% to the overall Gross Domestic Product of the country [22]. Malaysian economy is predicted to display a sustained growth between 4.3% to 4.8% in the year 2017, and 5.0 % to 6.0% for 2018 [23], the development of construction activities has

prompted a prominent increment in the production of construction waste [24]. Moreover, Rahman and Nagapan [25] pointed out that construction industry is facing severe problems due to the massive quantity of construction waste generation in the country. Unfortunately, Malaysia does not have exact information of construction waste data and factors causing the waste production at a particular site [9, 26]. Similar issues were likewise highlighted by other researchers [27-29]. In order to defeat this issue, the Construction Industry Development Board of Malaysia (CIDB) started the Construction Industry Transformation Programme (CITP) 2016 -2020 to carry out construction waste records for the country [23]. Furthermore, policy maker such as National Solid Waste and Public Cleansing Corporation (SWCorp) have initiated research works on construction waste quantification [30]. Unfortunately, only a few researchers have studied the issue of construction waste in Malaysia.

2.2.6. Turkey

Construction industry in Turkey is considered as one of the main driving force of the whole economic growth. Besides, Turkey is a country where it has high risks of natural disaster such mainly earthquake [31], whereas 66% of land is in the first and second level earthquake zone where this reflects nearly 71% of the country's population. When the existing development of Turkey is considered, it is clear that majority part of the development must be transformed through demolition, retrofitting and reinforcement activities which should be done in the short period of time due to high earthquake risk [32]. The construction wastes are recycled and the remaining materials will be transferred to the landfills by the contracting firm [33, 34]. Recycling has been established and practiced in Turkey since the year 2006.

2.3. Root Causes Generating Construction Waste

Construction wastes are being created all through the entire construction time frame from the earliest starting point of the outline arranged until the last stage. There are numerous factors that have prompted the construction wastes generation. It is certainly essential to distinguish those causes in order to control waste generation at source. Most of the construction waste is produced during the design and construction stage as the tendency to produce waste is higher. According to Nagapan et al. [8], there are several root cause factors of construction waste generation such as design, workers, management, procurement, site condition, handling and external factors. Literally, a certain type of the construction materials uses huge quantity of non-sustainable resources of energy such as, timber, sand, and crushed stone [35].

3. Methodology

There method applied in this study is triangulation techniques. Triangulation implies utilizing 1 or more methods to gather information on the same subject. This is a method for guaranteeing the validity of research through various techniques to gather information on a similar point [36]. Document analysis is a type of quantitative research where documents are deduced by the researcher to provide relevant explanation revolving an assessment topic [37]. The methodology flowchart can be seen in Figure 1.

The method used to determine the main root causes is using two stages. For the first stage, a total of 38 articles have been reviewed for identifying the root cause of construction waste generation in a global context. All the root causes and the references have been gathered in Table 1. The frequency was obtained through the number of references which have mentioned the similar root causes. The percentage was calculated according to the frequency of each root cause, then divided with a total references and finally multiply by 100% or Root Cause Frequency / Total References x 100%. For the second stage, a cross validation is done with construction practitioners to verify the identified root causes which found from the percentage calculation in the first stage. A total of 8 construction practitioners have been chosen to validate the root cause factors leads to waste generation.

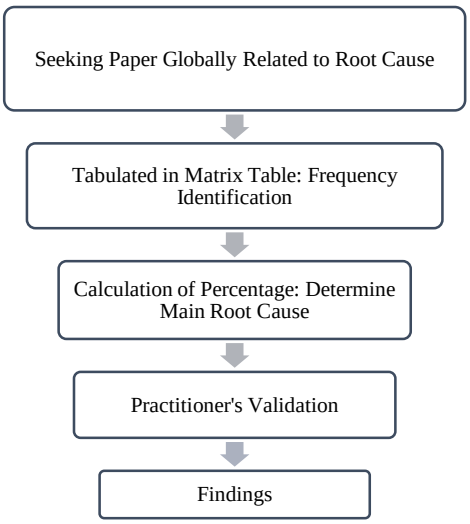

Figure 1. Methodology Flowchart

4. Results and Discussion

The root causes contributing to construction waste are presented in Table 1. The outcome of past researches, shown in Table 1, affirm that there are various root causes that leads to construction waste generation. In fact, past studies show that these causes have prompted negative effects on the environment, economy and social Noor et al. [38]. Most of the researchers have categorized the factors according to construction stages and also according to the different group of industrial players as shown in the Table 2. Referring to Table 3, the highest root cause which contributes to construction waste is Constant Design Changes with 78.9% from the past research. This issue happens due to the most sudden drawing changes amid the construction activities. This becomes an issue due to miscommunication among contractors, designers and the clients during the design work stage. This could be avoided if all the industrial players involved could have a frequent productive meeting during design stage to confirm the design prior to the construction.

The second highest root cause is Wrong Material Storage with 68.4%. This contributes to the waste generation because error in storing materials properly will cause delay in project and physical waste generation. For example, cement have to be stored in a closed or shaded area in order to maintain its quality but most of the site stores cement at open space under direct weather. Next third highest root cause, Poor Material Handling shows quite a high percentage in the generation of waste which is 60.5%. All materials received at site should be unpacked and arranged properly to avoid any damage. This can be due to carelessness of workers while handling the materials. Besides, the fourth highest root cause is Effect of Weather with 55.3%. The root cause has also been one of the primary reason which contribute to construction waste generation. Site activities such as concreting and excavation works must be halted due to heavy rain and storm. This severe weather condition causes major delay in site progress. For construction projects, time is the crucial element. Weather or change in climate is one of the factors which acts beyond our control. The fifth highest root cause is Ordering Mistakes which is 52.6%. Construction waste generated due to over ordering construction materials such as blocks, timber, tiles and concrete mixture. Furthermore, poor order of material without particular specification details and low quality materials will also end up as construction waste.

Table 3. Main Root Causes

No	Root Causes	Percentages (%)
1	Constant Design Changes	78.9
2	Incorrect Material Storage	68.4
3	Poor Material Handling	60.5
4	Effect Of Weather	55.3
5	Ordering Mistakes	52.6

Table 1. Matrix Table of Root Causes

Root Causes	References																																										F	%
	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[47]	[48]	[49]	[50]	[28]	[51]	[52]	[53]	[54]	[55]	[56]	[57]	[58]	[59]	[60]	[61]	[62]	[63]	[54]	[64]	[65]	[66]	[67]	[68]	[69]	[70]	[71]	[72]	[73]	[35]		
Constant design changes	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**			**1**	**1**	**1**	**1**				**1**	**1**	**30**	**78.9**
Incorrect material storage	1		1	1			1	1	1	1	1		1	1		1	1	1	1				1			1	1	1		1	1	1	1		1	1	1	1	26	68.4
Poor material handling	1		1	1	1		1	1	1		1		1			1	1	1	1				1		1	1	1	1		1	1	1	1	1					23	60.5
Effect of weather	1	1	1	1	1	1		1	1	1	1	1			1			1			1		1							1	1	1	1				1	1	21	55.3
Ordering mistakes	1		1	1	1		1			1			1	1		1	1	1					1			1	1			1	1	1	1		1		1		20	52.6
Damage during transportation				1			1			1	1		1	1		1				1			1		1		1			1	1	1			1		1	1	17	44.7
Workers' mistakes during construction			1	1	1		1			1			1	1		1	1	1					1	1		1				1	1						1		16	42.1
Design errors	1		1		1	1		1		1		1				1		1	1	1				1	1					1	1								15	39.5
Improper planning	1	1		1	1			1	1	1		1			1	1			1		1															1		1	14	36.8
Poor standard of materials				1				1	1	1			1	1	1	1		1				1								1		1		1						13	34.2
Poor controlling		1			1		1			1		1			1	1	1		1				1		1		1									1				13	34.2
Residue materials at site	1		1							1				1			1						1		1			1		1	1		1			1			12	31.6
Poor supervision at site								1	1			1		1	1	1				1			1							1	1							1	11	28.9
Bad design quality				1	1	1	1	1	1						1						1		1				1									1				11	28.9
Pilferage	1			1			1			1													1							1	1	1				1	1	1	11	28.9
Poor site management			1	1			1				1	1	1	1		1			1				1																	10	26.3
Items incompliance to specification				1			1									1					1									1	1	1			1		1	1	10	26.3
Lack of coordination among parties					1		1	1	1							1			1	1			1	1																9	23.7
Error in construction methods					1			1	1		1				1	1		1												1	1									9	23.7
Damage caused by workers				1	1					1							1						1							1	1	1	1							9	23.7
Accidents at site	1		1	1	1					1								1					1							1								1		9	23.7
Waste from packaging	1									1				1										1	1			1			1					1				8	21.1
Waiting periods at site		1	1			1	1					1			1																									8	21.1
Vandalism							1				1																			1	1	1	1				1	1		8	21.1
Scarcity of equipment					1			1	1			1			1	1															1	1								8	21.1
Rework at site					1		1				1								1												1	1	1				1			8	21.1
Shortage of waste management plans					1		1			1													1							1	1	1	1							8	21.1
Incomplete contract document				1																	1		1				1			1		1					1	1	8	21.1
Error in contract documentation				1																	1		1							1	1		1				1	1	8	21.1
Equipment failure during construction			1	1						1		1		1				1					1							1										8	21.1
Complicated design				1	1																						1			1	1	1					1	1	8	18.4
Information quality is poor		1					1	1	1					1	1	1																									7	18.4
Materials supplied unbound				1																	1										1	1				1	1	1	7	18.4
Delay in information flow between parties		1		1		1		1					1								1																			7	18.4
Lack of experience							1	1				1									1										1	1		1						7	18.4
Incompetent worker					1			1	1				1			1				1										1											7	15.8
Poor labour workmanship	1																	1								1				1	1							1		6	15.8
Poor site condition								1	1			1				1														1		1								6	15.8
Unpleasant attitudes of workers				1			1						1	1	1																						1				6	15.8
Careless in quantity surveys				1	1													1												1	1	1								6	15.8
Mistakes in shipping			1											1				1													1			1				1		6	15.8
Communication problems			1											1					1	1										1							1			6	13.2
Suppliers incorrect shipment																							1							1			1	1			1			5	13.2
Slow drawing distribution					1	1		1	1																					1										5	13.2
Shortage of skilled workers					1			1								1															1			1						5	13.2
Resources problem		1					1				1				1																					1					5	13.2
Dealings between numerous experts					1		1																							1		1						1		5	13.2
Insufficient training for workers							1							1		1						1				1															5	13.2
Inappropriate use of materials								1	1	1													1							1										5	13.2
Delay during delivery					1			1	1			1			1																										5	10.5
Extended project duration																					1						1					1					1				4	10.5
Lack of legislative enforcement														1						1								1	1											4	10.5
Inexperience designer				1						1											1																	1		4	10.5
Damages caused by third parties								1	1																						1						1			4	13.2
Tools not suitable used									1		1							1																							3	7.9
Excessive overtime for workers							1																							1					1					3	7.9
Poor coordination of parties during design																							1				1											1			3	7.9
Over allowances																					1										1	1									3	7.9
Outdated equipment							1	1	1																																3	7.9
Non-availability of equipment												1			1																							1			3	7.9
Inefficient methods of unloading																					1						1	1													3	7.9
Congestion at the site												1			1																1										3	7.9
Worker’s no interest												1								1																					2	5.3
Unpredictable local conditions						1																									1										2	5.3
Unforeseen ground conditions																											1		1												2	5.3
Lighting problem												1																			1										2	5.3
Last minute client requirements																					1						1														2	5.3
Lack of knowledge about construction																							1		1																2	5.3
Lack of environmental awareness														1																	1										2	5.3
Materials Inventory not well documented																							1			1															2	5.3
Frequent discrepancy in orders																																		1							2	5.3
Diverse approaches used for estimation																												1								1					2	5.3
Wrong material delivery procedures																							1																		1	2.6
Waiting for replacement						1																																			1	2.6
Absence of influence in contractors																							1																		1	2.6
Lack of attentiveness among the workers																										1															1	2.6
Interference of other crews at site												1																													1	2.6
Festival celebration															1																										1	2.6
Difficulties accessing construction sites																					1																				1	2.6
Abnormal wear of equipment							1																																		1	2.6

All these 5 root causes have been validated by 8 construction practitioners and about 87.5% of them agreed with the findings. Therefore, it can be concluded that the root causes are similar to the practical environment. In addition, there is a further work addressed in this research paper, namely grouping all the root causes in 6 different groups as shown in Table 2.

Table 2. Group of Root Causes of Construction Waste

Group	Root Causes	Group	Root Causes
Design & Documentation	Incomplete contract document		Scarcity of equipment
	Error in contract documentation		Equipment failure during construction
	Constant design changes		Outdated equipment
	Design errors		Non-availability of equipment
	Bad design quality	**Human Resources**	Mistakes during construction
	Complicated design		Error in construction methods
	Information quality is poor		Damage caused by workers
	Slow drawing distribution		Waiting periods at site
	Poor coordination of parties during design		Rework at site
	Inexperience designer		Lack of experience
	Careless in quantity surveys		Incompetent worker
Project Management	Poor controlling		Poor labour workmanship
	Dealings between numerous experts		Unpleasant attitudes of workers
	Improper planning		Shortage of skilled workers
	Last minute client requirements		Insufficient training for workers
	Poor supervision at site		Worker's no interest
	Poor site management		Lack of knowledge about construction
	Lack of coordination among parties		Lack of environmental awareness
	Delay in information flow between parties		Over allowances
	Waste from packaging		Abnormal wear of equipment
	Shortage of waste management plans		Lack of attentiveness among the workers
	Last minute client requirements		Excessive overtime for workers
	Delay during delivery		Absence of influence in contractors
Material & Equipment	Incorrect material storage		Communication problems
	Poor material handling	**Project Site Situation**	Difficulties accessing construction
	Ordering mistakes		Extended project duration
	Damage during transportation		Lack of legislative enforcement
	Poor standard of materials		Congestion at the site
	Residue materials at site		Unpredictable local conditions
	Items incompliance to specification		Unforeseen ground conditions
	Materials supplied unbound		Poor site condition
	Resources problem	**External Root Cause**	Effect of weather
	Materials Inventory not well documented		Pilferage
	Frequent discrepancy in orders		Accidents at site
	Diverse approaches used for estimation		Vandalism
	Wrong material delivery procedures		Damages caused by third parties
	Inappropriate use of materials		Lighting problem
	Inefficient methods of unloading		Festival celebration
	Tools not suitable used		Interference of other crews at site
	Waiting for replacement		

5. Conclusion

This study discovered 5 main contributory root causes of construction waste generated, namely 'Constant design changes', 'Incorrect storage of materials', 'Poor handling of materials', 'Effect of weather' and 'Mistakes while ordering

from suppliers'. From all of these 5 root causes, 4 of the root causes can be controllable by construction practitioners if managed correctly (Constant Design Changes, Incorrect Material Storage, Poor Material Handling and Ordering Mistakes) and 1 is uncontrollable (Effect of weather). The weather related root cause is unpredictable and only can be reduced the impact with a proper planning of any construction project. As a conclusion, every country should be more serious in tackling these 5 main root causes and also in implementing sustainable construction management in each project.

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7. Conflicts of Interest

The authors declare no conflict of interest.

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