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Factors Contributing to Physical and Non-Physical Waste Generation in Construction Industry

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ABSTRACT

Construction industry has been developing rapidly around the world. The development has led to serious problem in generation of construction wastes in many developing countries. The construction wastes clustered into physical and non-physical waste and it has greater impact to environment, economy and social of each country. Before it can be managed well, it is important to understand the root cause of the generation. This paper identifies and detects factors contributed to the generation of construction waste. Mapping technique was applied for identification works and interview was conducted to detect the physical and non-physical waste. The triangulation method has found 81 factors in construction activities which are contributing to waste generation. From these factors, 63 contribute to physical waste and 73 contribute to non-physical waste. These factors were grouped into seven categories: Design, Handling, Worker, Management, Site condition, Procurement and External factor. The significant factors of each category of waste were determined. The findings will help construction players to avoid and reduce the physical and non physical wastes. Furthermore, the paper has put forward some recommendations for better improvements.

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1. INTRODUCTION

Construction sector is playing a vital role in every developing country. Nowadays, the industry faces many challenges with issues related to construction waste. During the past two decades, the amount of waste has increased significantly, due to the increase in the standard of living, changes in consumption habits, as well as the natural increase in population [1]. Thus, construction waste has become a serious problem in many countries as in Table 1. Numerous reports and studies have investigated issues on waste which lead to negative impact to the environment, cost, productivity, time, social and economy [2]-[6]. In addition, these issues contribute to a reduction value of construction productivity and reduce the performance of overall projects [7]. Apart from that, current study pointed out that construction waste generated in China is around 30% - 40% and 39.27 million tons in Spain [8], [9]. This is due to the increasing demand of infrastructure; commercial buildings and housing development projects which has generated large amounts of construction waste [10]. Furthermore, design, operational, procurement and material handling activities lead to site waste generation [11]. These waste generation activities consume time and effort without adding values to the client thus resulting losses in material, delay in meeting the stipulated time and execution of unnecessary work. Therefore, to avoid the waste generation, it needs to find the root causes of the waste generation. The factors that contribute to the generation of construction waste are various. The purpose of this paper was to identify

and detect the physical and non-physical waste factors in construction industry. This study will help researchers and construction industry players to understand the main factors contributing to physical and non-physical waste generation.

Table 1. Construction waste become serious problem in many countries

Country	Source
Australia	[12] [13]
Sri Lanka	[14]
Singapore	[11] [15]
Turkey	[16]
South Africa	[17]
Egypt	[18]
Indonesia	[7] [19]
Greece	[20]
Netherlands	[21]
Nigeria	[22]
China	[4] [6] [23]
Chile	[24]
Brazil	[25]
Spain	[9]
Thailand	[26]
Malaysia	[27] [28]

1.1. Construction Waste

Construction waste can be defined as any materials by product of human and industrial activity that has no residual value [24], [29]. Waste is a product or material that is unwanted [30]. Construction waste clustered into two groups namely the physical and non-physical waste [31]. Figure 1 shows the classification of physical and non-physical construction waste.

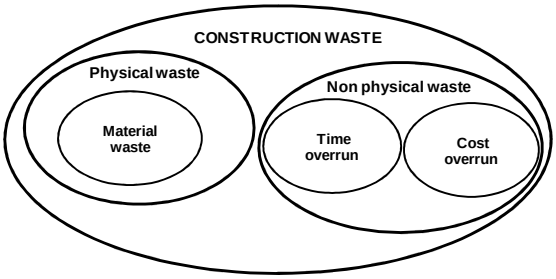

Figure 1.Classification of Construction waste [32]

1.2. Physical waste

Physical construction waste is defined as waste which arises from construction, renovation and demolition activities including land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation [26], [33]-[35]. However, some defined directly to solid waste: the inert waste which comprises mainly sand, bricks, blocks, steel, concrete debris, tiles, bamboo, plastics, glass, wood, paper, vegetation and other organic materials [1], [21],[36]. Another way to understand the physical waste or construction debris can be seen in construction site. This type of waste consists a complete loss of materials, due to the fact that they are irreparably damaged or simply lost. The wastage usually removed from the site to landfills. Figure 2-5 shows example of physical waste taken during a site visit at Simpang Ampat in Penang and at Gambang in Pahang.

Figure 2. Cement waste

Figure 3. Waste component

Figure 4. Surplus of reinforcement bar component waste

Figure 5. Concrete construction waste

1.3. Non Physical waste

The Non-physical waste normally occurs during the construction process. By contrast with material waste, non-physical waste are time and cost overrun for a construction projects. Similarly, researchers from Indonesia defined waste as not only associated with waste of materials but also other activities such as repair, waiting time and delays [13].

Besides that, the waste can be considered as any inefficiency that results in the use of equipment, materials, labor and money in the construction process [19]. In other words, waste in construction is not only focused on the quantity of materials on-site, but also overproduction, waiting time, material handling, inventories and unnecessary movement of workers [37], [38]. From the interview it was found that least attention was given for this type of waste in construction industry. Figures 6 and 7 are pictures taken regarding non-physical waste generated due to construction activities. These pictures were taken during site visit to Simpang Ampat in Penang and also at Parit Raja in Johor.

Figure 6. Design error leads to rework

Figure 7. Equipment failure leads to stoppage

2. RESEARCH METHOD

This study was conducted by developing the matrix of causative factors of construction waste generation. The matrix was developed based on past research articles published worldwide. This matrix analysis can identify the severity of each factor based on the calculated statistical frequency. These factors matrix was then validated by construction experts. The validation was to detect the relevant factors in local construction industry. The process was done through interview session of selected experts involve in construction. The interview was conducted with 7 personnel to cross check the contributory factors. The interview was carried out from 13th October 2011 until 15 January 2012. The respondents' demography is shown in Table 2.

Table 2. Respondents' demography

No	Position	Organization /Company	Experiences
1	Civil Engineer	Public Works Department (JKR)	11 years
2	Executive Director	Construction Industry Development Board (CIDB)	27 years
3	General Director	Binaan Desjaya Sdn. Bhd. (Contractor Class A)	26 years
4	Professional Engineer	Office of Asset and Development, UTHM	29 years
5	Senior Quantity Surveyors	Office of Asset and Development, UTHM	23 years
6	Director	Office of Asset and Development, UTHM	25 years
7	Assistant Vice-Chancellor (Professional Engineer)	Universiti Tun Hussein Onn Malaysia	29 years

Table 2 indicates that 6 respondents have more than 20 years of working experience in construction related field. All 7 respondents concur with the contributory factors of the waste generation. This triangulation method was applied in the study to validate the data and converge into document mapping and interview [39]. Outcome of applying these methods indicates, 81 factors of the generation of construction waste were found in the study. These factors are separated into 7 categories as in Table 3.

3. RESULTS AND DISCUSSION

Based on the factors in Table 3, the highest frequency for physical and non-physical waste factors were presented in Figure 8. This factor contributes to both physical and non-physical waste

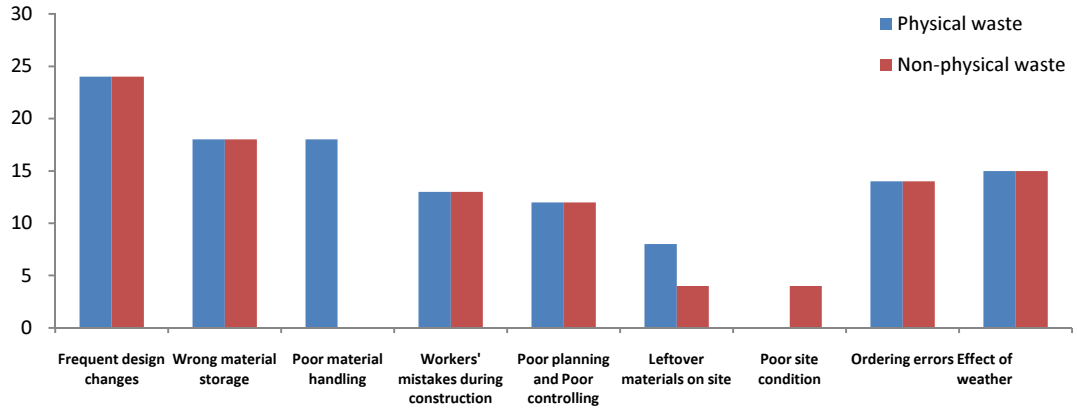

Figure 8. Bar Chart of physical and non-physical waste generation

generation. The highest factor contributes to the waste generation is frequent design changes with 24 researchers admit as contributory factor. The bar chart shows there are 9 factors contributing to physical waste while 8 factors contributing to non-physical waste. Most factors are same for both waste generation except for the handling category and site condition category. For the handling, two different factors lead to the generation of physical waste. The factors are wrong material storage and poor material handling. On the other hand, the only factor which contributes to non-physical waste is the wrong material storage. For the site condition, very obviously determine different factors contribute to two different stream of waste. The physical waste generates from Leftover materials on site factor while non-physical waste arises because of the factors related to poor site condition factor. Furthermore, significant for both physical and non-physical factors of waste generation are based on categories summarized in Table 4.

Table 3. Frequency of Construction Waste

Category	Factors Contributing to Construction Waste	Type of waste generation		References																																Freq.
		Physical	Non Physical	[12]	[14]	[40]	[11]	[16]	[7]	[18]	[13]	[19]	[21]	[22]	[15]	[23]	[4]	[24]	[25]	[41]	[42]	[43]	[6]	[3]	[44]	[17]	[9]	[26]	[45]	[46]	[5]	[47]	[48]	
Design	Frequent design changes	√	√	*		*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*		*	*				24
	Design errors	√	√	*		*		*	*		*		*		*				*		*	*	*				*	*						13
	Lack of design information	√	√				*	*	*	*	*	*						*						*		*				*				10
	Poor design quality	√	√								*	*			*		*		*					*										6
	Slow drawing distribution		√					*	*		*	*																						4
	Incomplete contract document	√	√				*																	*		*				*				4
	Complicated design	√	√				*	*																						*				3
	Inexperience designer	√	√				*						*											*										3
	Error in contract documentation	√	√				*																	*		*								3
	Interaction between various specialists		√					*		*																								2
	Poor coordination of parties during design stage	√	√																							*				*				2
	Last minute client requirements	√	√																					*						*				2
Handling	Wrong material storage	√	√	*		*	*			*	*	*	*	*		*	*		*	*	*	*				*			*	*		*		18
	Poor material handling	√		*		*	*	*		*	*	*		*		*			*	*	*	*				*		*	*	*		*		18
	Damage during transportation	√	√				*			*			*	*		*	*		*				*			*		*		*				11
	Poor quality of materials	√	√				*				*	*	*			*	*	*	*		*				*									10
	Equipment failure		√			*	*						*		*		*				*					*									7
	Delay during delivery		√					*			*	*			*			*																	5
	Tools not suitable used	√	√												*		*				*														3
	Inefficient methods of unloading	√	√																					*						*		*			3
	Materials supplied in loose form	√	√					*																*											2
Workers	Workers' mistakes during construction	√	√			*	*	*		*			*			*	*		*	*	*					*	*		*					13
	Incompetent worker	√	√					*			*	*				*			*				*												6
	Poor attitudes of workers		√				*			*						*	*	*																	5
	Damage caused by workers	√					*	*					*							*						*									5
	Insufficient training for workers	√	√							*							*		*						*				*					5
	Lack of experience	√	√								*	*				*								*											4
	Shortage of skilled workers	√	√					*			*								*																3
	Inappropriate use of materials	√									*	*	*													*									4
	Poor workmanship	√	√	*																	*								*						3
	Worker's no enthusiasm		√												*								*												2
	Inventory of materials not well documented	√	√																							*			*						2
	Abnormal wear of equipment	√	√							*																									1
	Lack of awareness among the workers	√	√																										*						1
	Too much overtime for workers	√	√								*																								1
Management	Poor planning	√	√	*	*		*	*			*	*	*		*			*	*			*		*											12
	Poor controlling	√	√		*			*		*			*		*			*	*	*		*				*		*		*					12
	Poor site management	√	√			*	*			*				*	*	*	*		*			*				*									10
	Poor supervision	√	√								*	*			*		*	*	*				*			*									8
	Inappropriate construction methods	√	√					*			*	*		*				*	*		*														7
	Lack of coordination among parties	√	√					*		*	*	*							*			*	*			*	*								9
	Poor information quality		√		*					*	*	*					*	*	*																7
	Late information flow among parties		√		*		*		*		*		*					*						*											7
	Scarcity of equipment		√					*			*	*			*			*	*																6
	Lack of waste management plans	√	√					*		*			*													*								*	5
	Resources problem		√		*					*				*				*																	4
	Rework	√	√					*		*				*								*													4
	Waiting periods		√						*	*					*			*																	4
	Communication problems	√	√			*											*						*	*											4
	Outdated equipment	√	√							*	*	*																							3
	Non availability of equipment		√												*			*																	2
	Lack of knowledge about construction	√	√																							*		*							2
	Long project duration		√																					*						*					2
	Lack of influence of contractors	√	√																							*									1
	Lack of environmental awareness	√	√														*																		1
Site Condition	Leftover materials on site	√		*		*							*				*			*						*		*				*			8
	Waste resulting from packaging	√		*									*				*										*	*				*			6
	Poor site condition		√								*	*			*				*																4
	Congestion of the site	√	√												*			*																	2
	Lighting problem	√	√												*																				1
	Difficulties accessing construction sites		√																					*											1
	Unforeseen ground conditions	√	√																											*					1
	Interference of others crews at site		√												*																				1
Procurement	Ordering errors	√	√	*		*	*	*		*			*			*	*		*	*	*					*			*	*				14
	Items not in compliance with specification	√	√				*			*									*					*											4
	Error in shipping	√	√			*											*				*														3
	Mistakes in quantity surveys	√	√				*	*													*														3
	Supplier errors	√	√																							*									1
	Wrong material delivery procedures	√	√																							*									1
	Over allowances	√																						*											1
	Frequent variation orders	√	√																												*				1
	Different methods used for estimation	√	√																													*			1
	Waiting for replacement		√					*																											1
External Factor	Effect of weather	√	√	*	*	*	*	*	*		*	*	*	*	*			*			*			*		*									15
	Accidents	√	√	*		*	*	*					*								*					*									7
	Pilferage	√	√	*			*			*			*													*									5
	Lack of legislative enforcement	√	√														*								*								*	3
	Vandalism	√								*				*																					2
	damages caused by third parties	√									*	*																							2
	Festival celebration		√															*																	1
	Unpredictable local conditions	√	√					*																											1
	Total, ∑ = 81 factors	63	73																																

Table 4. Significant factors that contribute to the construction waste based on category

Category	Significant factor	
	Physical	Non Physical
Design	Frequent design changes	Frequent design changes
Handling	Wrong material storage and Poor materials handling	Wrong material storage
Worker	Workers' mistakes during construction	Workers' mistakes during construction
Management	Poor planning and Poor controlling	Poor planning and Poor controlling
Site condition	Leftover materials on site	Poor site condition
Procurement	Ordering errors	Ordering errors
External Factor	Effect of weather	Effect of weather

3.1. Design

In this category there are 12 factors that contribute to physical and non-physical generation of waste. It was found that frequent design changes as the main contributor for waste generation. The physical waste arises at the construction site due to the changes made by the clients at the verge of completion of projects. When the first design drawing is approved by both parties (contractors and client), the contractor begins the construction works at site, while the construction work is in progress, the sudden requirement of the client will complicate the near completion work and end up with rework. The built structure has to be demolished and need to be constructed again as to the requirement of the new design drawing. This issue is the main contributor to the large amount of physical waste, such as concrete, bricks, blocks and steel bar [6], [49].

On the other hand, the frequent design change also contributes to the generation of non-physical waste generation. Whenever changes during the post construction phase occur, there need a lot of time to rebuild the structure. Contractor and the client have to discuss again in order to finalize the design drawing. Meanwhile, workers energy, material cost, and time will end up as waste. Therefore, to overcome this problem, more attention should be given in waste reduction during the design phase. Whoever involves in any construction projects should always keep good communication with clients to avoid the last minutes changes [15], [18]. In addition, the waste generated during design process mainly due to 'poor communication' leading to overlapping of design [50]. Another way to avoid the recurrence of problems is giving advice to clients by briefing them on the impact of waste generation and highlighting the benefits of cost savings. Practicing good communication between contractor and client will help both parties to reduce the material waste, cost overrun and delay problem in a construction projects.

3.2. Handling

In this category, wrong material storage and poor materials handling become key factors for physical waste generation. The examples of wrong material storage for physical waste generation are aggressive handling of bricks and blocks during construction leads to cracks and spoil. Apart from this, physical waste does occur due to inappropriate protection strategy used during materials storage. For examples, cements wrongly stored under bridge or stored at any open space. These cause the materials to be exposed to moisture and rain. Without proper storage, the materials too will end up as physical waste [42]. Another key factor generating physical waste is poor materials handling and score equals to wrong material storage factor. For example, mistakenly handle construction material cause material loss or damage to bricks or blocks. Notwithstanding, contractor should need an effective materials handling strategies, which include educating the workers on waste minimization and always communicate with supplier. This will help to make them aware of the environmental problems caused by the waste.

Beside that, the wrong material storage also contributes to the non-physical waste. If the bricks and cement spoils at site due to improper storage by worker, then this leads to shortage of material during construction. Insufficient stock of construction materials, will lead to stoppage of construction works at site. The materials need to reorder and cause longer waiting time to receive materials from supplier. The manpower of waiting workers during supply and payment of hourly salary, always will end ups as non-physical waste. Thus, proper storage of material is necessary in order to avoid the generation of construction waste. Besides that, a very comprehensive and good storage technique should be adopted for better protection of materials at site.

3.3. Workers

The worker's category comprises 14 factors for physical and non-physical waste generation. The highest frequency score by workers mistakes during construction while too much overtime for workers, lack of awareness and abnormal wear of equipment factors score the lowest place in the workers category. Unskilled workers tend to make more mistakes due to lack of skills and poor working attitude. For example

most of workers fail to read the blueprint or drawing. The mistakes include wall frame improperly cut or assembled.

At the same time, workers mistakes also contribute to non-physical waste. Mistakes during concreting works can cause rework. These improper works need to be repaired and time consuming. Besides that, mistakenly handle of equipment can cause damage. This will contribute to a sudden stop of work and overrun of project cost. Waiting period to get back for the equipment or machine leads to delay. Thus, workers mistakes can generate lots of physical and non-physical waste. This can be avoided by selecting experienced or trained workers for site works.

3.4. Management

Management involves the biggest number of contributory factors that are 20 factors which contributes to physical and non-physical waste generation. The highest score in this category is poor planning and controlling factor and the lowest score is lack of environmental awareness and lack of influence of contractors' factors. Poor planning is due to lack of planning skills of the management staff. Without detailed planning of construction process, requirement and material storage facilities can lead to the generation of physical waste. For example during planning stage throughout review requirement of material supply and projects specification can help to reduce waste [12]. Besides that, poor controlling factors also significantly contribute to physical waste. This is because majority of construction waste is generated at uncontrolled sites. For example, these problems related to material delivery, lack of control in the amount of bricks delivered and the damage of bricks during the unloading operation. The controlling value must come at the starting place for every management staff at construction site.

Other than that, poor planning and controlling factor also contribute to non-physical waste. For example, lack of coordinated planning with subcontractors leads to argument, waiting time and interference with other trades. Incorrect planning and selection of equipment also cause the work to stop [19], [24]. Furthermore, lack of control on sub-contractor progress or site workers' attitude will eventually delay the work. Thus, proper planning and controlling is the key supervisory function that should be used to be effective in eliminating these physical and non-physical factors. All management leaders should be paying more attention towards these factors on waste generations.

3.5. Site Condition

The site condition category contains 8 contributory factors to physical and non-physical waste. It was found that leftover materials on site are the main contributing factor to the physical waste. The generated waste known as cut of steel bar, used formworks and broken bricks are parts of leftover materials on site. This residual always occurs at the end of construction project. The poor attitude of project supervisors and workers lead to this occurrence [8], [40].

For non-physical waste, the poor site condition factor scores the highest frequency. The example of poor site condition in roadwork is the difficulty to construct road on hilly and swampy surface. The rough surface can cause equipment failure, which contributes to delay. Another example is the construction of tall building in the middle of metropolitan city that needs transportation of heavy equipment which consumes lots of time. Time overrun during construction process is non-physical wastes. Therefore, site investigation needed to be done systematically and properly before starting construction at site.

3.6. Procurement

Category on procurement consists of 10 factors contributing to physical and non-physical waste. Ordering errors factor scores the highest frequency. The examples of waste generated over ordering materials in construction projects are excessive orders of bricks and concrete mixture that end up as waste. Sometimes, poor ordering of material without specification details and low quality materials also cause physical waste [21].

The wrong ordering factor also generates non-physical waste. There are the shortages of materials during construction activity which can lead to stoppage of works. Another example is the lack of concrete premix in concreting works, can also cause delay during ordering time. Hence, ordering of enough construction material plays an important part and helps to reduce physical and non-physical waste during construction works.

3.7. External Factor

The external factor category consisted of 8 uncontrollable factors that lead to physical and non-physical waste. Effect of weather becomes the most dominant and influential factor contributing to construction waste. Heavy rain with strong storm spoil many construction materials at site, such as formwork broke, wet concrete diluted and steel bar become rusty. Besides that, if hot sun with high temperature also

creates problems for example it quickly hardens the wet concrete before use and this will end up as physical waste at site.

Apart from that, the effect of weather is also the main contributor for non-physical waste where the weather or climate change cause delay in construction works. Site works, such as concreting and excavation work will be disturbed due to heavy rain and storm. Many constructions projects have to be rescheduled due to this unpredictable factor.

4. CONCLUSION

Construction waste management is vital for a country to develop in a sustainable manner. It helps to address issues related to environment, social and economy. Once the root causes of waste generation are notified, it can either be avoided or minimized to benefit the world for better future. This study has identified significant factors contributing to physical and non-physical waste in construction projects. By identifying the significant factors in construction process, construction players are able to notice the best ways to apply new practice for reducing material waste, time delay and cost overrun in any project. Based on the results and findings of this study, the following recommendations are made to reduce the construction waste generation in any construction projects:

i. Contractors should have a regular meeting and good communication between clients
ii. Construction players should have a systematic method for handling construction materials, equipments, and human resources.
iii. Construction workers need a construction waste generation training course before starting their work.
iv. Construction personnel should adopt or adapt any new technique for planning and controlling the construction waste generation.
v. Site investigations need to be properly designed and carried out for collect the right, quality and quantity of information before starting any projects.
vi. Procurement document at site should be planned properly and monitored regularly.
vii. Construction players should be watched or listened daily news about climate changes before working on site.

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