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Design and documentation as attributes to waste generation at construction sites

A A A Moeis¹, A Che Ahmad^{2,*}, A H A Tharim³ and N Othman⁴

^{1,2,3} Department of Built Environment Studies and Technology, Universiti Teknologi MARA, Perak Branch, Perak, Malaysia

⁴ Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

afifazhan99@gmail.com¹, asmalia809@uitm.edu.my², asniz286@uitm.edu.my³, norazli.kl@utm.my⁴

*asmalia809@uitm.edu.my

Abstract. Rapid demand of housing and infrastructure development in Malaysia had result in more construction and consequently increase the construction waste. Construction waste takes major impact to the environmental if there is no proper management of construction waste from earliest point of waste generated until waste disposal. Thus, it is important to identify attributes influencing construction waste generated at construction sites. This study aims to determine design and documentation as attributes of construction waste generation. This study was conducted at Putrajaya, Malaysia. Putrajaya was selected because this city is pioneer in urban development in measuring and promoting green development activities in Malaysia. Quantitative study using questionnaire survey was conducted at construction sites in Putrajaya. A total of 21 respondents from the construction sites have returned the survey. Using relative importance index (RII) as the analysis tools, this study determined that the design and documentation are waste generation attributes at construction sites. Findings of this study could assist more comprehensive study in determining the attributes of waste generation at construction sites.

1. Introduction

Development in construction sector is important to rise in level and quality of life, expansion of income and employment opportunities. Despite these contributions, the construction sector rapid growth has resulted in increase of construction waste, which become one of sustainable issues [1]. The increase of construction waste is one of the problems that had been face by developing and developed countries worldwide. In Malaysia, the government also face problems from enlarged volume of construction waste generated from construction sites. In addition, the project size, attitudes and practices of the contractors toward waste management contribute impact on waste generated [2]. The increase volume of construction waste generated could affect environmental and health of society. Study shows that in year 2018, the construction waste generated is 271,948 tons [3]. Normally, the materials for construction projects are cement, concrete, soil and aggregate, plastic, wood and glass which contributes to construction waste.

The construction materials for construction project produces various types of waste. Wastes are classified into two categories, First, solid waste from construction activities such as site preparation, land excavation, civil building construction, roadwork, site clearance, building renovation, and demolition is known as physical. Secondly, non-physical waste that occurs during the construction



process and is defined as a non-value-adding activity due to schedule and cost overruns in construction projects [4].

Basically, the potential waste generated is classified into four; namely design and documentation, materials and procurement, construction methods and planning, and human resources [5]. The classification of waste generated affects the quantity of the waste generated and the action taken to reduce it. Therefore, it is very important to determine the attributes of waste generated at construction sites. The study aims specifically to determine one of the four waste generation classification i.e the design and documentation attributes of construction waste generated. The study is analysed via the relative importance index (RII) to determine the design and documentation as attributes contributing to waste generation at construction sites. The findings of the study could assist more comprehensive study in waste management including in formulation of policy interventions in controlling waste generated at construction sites.

2. Literature Review

2.1 Waste Generation

Construction sector is the causes of construction waste generation. The construction waste classification can be divided into design and documentation, materials and procurement, construction methods and planning, and human resources. Construction waste is solid waste generated during construction operations such as site preparation, land excavation, civil building construction, roadwork, site clearance, building renovation and construction process [1]. Construction waste generation varies based on the project's size, associated activities, and project location [5]. To lessen the severity of construction waste negative impacts, the root causes of the construction waste generation are necessary to be determined [6].

2.2 Design and Documentation as Attributes Contributing to Construction Waste Generation

Design and documentation are the earlier phase or preconstruction phase as planning before the construction project execution. The development of construction design and documentation is generally consisting of three main steps which are schematic design, detail design development and construction documents. Design and drawings flaws caused by an inexperienced or careless designer at this earlier project phase could contribute waste later during construction [7].

2.3 Design and Documentation

The preconstruction phase is an important in managing construction projects. Study at Thailand has found out that design and documentation is one of the root causes of waste generated [5]. Design, procurement, and external influences are likewise causes of construction waste [8]. Other causes that contribute to construction waste i.e lack of attention paid by designers to detail design as well as the constructability of design intent [5]. Construction waste also caused by design revisions and heterogeneity in the degree of design details [8]. If the design is not validated during the preconstruction phases, there will be many revisions during the construction phase which contribute to more material wastage [9].

Change to design; The change in building design is one of the contributing factors to construction waste [5]. It started when the design is establishes from unfavourable design choice [7]. This issue mainly caused by last-minute changes on the client decisions where alterations have to be conducted during construction at site. Other design changes problem rises due to a lack of communication between contractors, designers, and clients during the design process which finally contribute to generation of construction waste. Having a smooth information flow among stakeholders is the key of success projects [9].

Document problems; Inefficient and carelessness of the design team in preparing construction documents in design phase such as design, drawing, specification and bill of quantity will affect the

construction phase. The incorrect document will result in rework and rebuild of the building due to wrong design or quality of the materials [9].

Design errors; Design errors will lead to design revisions that prolong to errors in construction [8]. These construction errors have to be demolished, repaired, rebuild, rework or replace [9]. These activities obviously will generate construction waste.

Construction drawing errors; Construction drawing errors happened when the architect and engineers fail to prepare the drawings accordingly. The contractor would follow the construction drawings during construction. Eventually when the inspection being held and the errors is spotted, the building need to demolished or rework resulting in material waste [9].

Complicated design; Designers tend to design complicated structure in order to express creativity and uniqueness. This complicated design gives high contribution on waste generation because of waste from cutting and shaping uneconomically [10]. Failure to construct base on the complicated design will also generate waste as repair and rebuild works is required [5].

Long project duration; Construction projects usually takes more than one year to complete. Large scale development takes between 3 - 5 years. This long project timeline contributes to more and longer duration of waste generated as construction waste are being produce during the construction [11].

Specification of products and sizing of products; Failure to specify details of the product and size of materials in the documentation will affect the ordering or purchasing of materials. Preparing accurate documentation during preconstruction is critical because it will impact on the project's performance and results in the creation of construction waste [7].

Poor schedule of materials procurement; Failure to manage material schedule properly might result in failure to provide sufficient and accurate order. This poor management could increase the construction cost and can generated waste [7]. This may be avoided if the project planner alert and make confirmation on the material schedule in fitting to the construction process schedule [12].

Over-ordering; Over ordering of material will ultimately results in material wastes [12]. The purchasing staff should carefully check the quantity and documentation for the related construction process before ordering the material to avoid wastage.

Under-ordering; If materials are ordered less than required, the construction process will be disturbed throughout the site resulting in a work stoppage [12]. The contractors need to reorder and the excessive quantity of the materials could become waste at site.

Errors in ordering; Errors in ordering material from mistake of workers are surely would generate waste [5]. Less attentive working attitudes and behaviours have significant impact on construction waste generation [13]. If the materials are not suitable to be used for the project, it will become waste.

Requirements to bulk purchase; Some of the suppliers of construction materials required purchase in bulk even though the contractor need the material in minor volume. This under used material can generated waste on site if there is no proper material storage and failure to sell the material to other projects [11].

Impossibility to order small quantities; Lack of possibility of ordering small quantities of construction materials could also contribute to wastage [13]. Most of the construction materials are packed and supplied in large volume such as tiles and bricks which give the contractors no choice in ordering.

Substitution of a material by a more expensive one; There would also be material wastage if the client request substitution of other material during construction after the material has been installed. This due to lack of communication and oversee the clients desire and taste on the material choices [7].

Purchase of materials contrary to specification; Mistake occurs due to lack of experience purchasing staff can lead to addition waste generation. For example, the purchase of material that contrary from the specification in the contract document that cannot be returned such as sand and cement will generate waste. Other issues are the order with less desired aesthetic and wrong dimension are not returnable to the supplier [15].

Unforeseen conditions; The construction waste also influenced by external factors such as unforeseen ground issues, theft, and disaster due to weather [8]. These unforeseen conditions such as flood and heavy rains damage the site and caused waste of the materials and machineries.

3. Methodology

The questionnaire form comprises of Section A and Section B. Section A is related to demographic while Section B is the survey on design and documentation as attributes to waste generation at construction sites. These data were collected at Putrajaya and the survey was conducted for six months period, starting from 1 November 2021 - 1 April 2022. There are 20 construction projects at Putrajaya that been list out by Construction Industry Development Board (CIDB), Malaysia. The data was obtained at CIDB official website [14]. Sample size of 19 respondents is needed at the 20 construction projects [15]. Survey questionnaires were distributed to all 20 construction sites at Putrajaya by hand. The study was able to gain 21 valid responses within the time frame. Using Microsoft Excel applications, the result is analysed via frequency and relative importance index (RII) analysis. The analysis result was ranked to obtained the findings of this study. RII was computed with the following formula [16]:

$$RII = \frac{\sum W}{(A \times N)} \quad (1)$$

where,

- W = The weighting assigned by the respondent on the scale of 1 to 5 (1 Lowest Contribution the least and 5 Highest Contribution is the highest)
- A = The highest weight
- N = The total number of samples

4. Results and Discussion

The following tables describe the survey results on characteristics of the respondents (Table 1) as well as relative importance index (RII) and ranking of construction waste generation from design and documentation attributes (Table 2).

Table 1. Characteristics of survey respondents (n = 21)

Characteristic		Frequency
Age	20-29	15 (71%)
	30-39	5(24%)
	40-49	1(5%)
Level of education	Diploma	10 (48%)
	Degree	9 (43%)
	Master	2 (10%)
Experience in the construction industry	< 5	9 (43%)
	6 – 10	10 (48%)

Characteristic		Frequency
(Unit: Years)	11 – 15	1 (5%)
	16 -20	1 (5%)
The current position in the construction industry	Top management level	2 (7%)
	Managerial Level	7 (25%)
	Executive Level	7 (25%)
	Supervisor	7 (25%)
	General Labour	3 (11%)
	Others	2 (7%)
Type of construction project	Residential (High rise)	8 (38%)
	Public building	9 (43%)
	Mix development	4 (19%)
Project construction period (Unit: month)	6	2 (10%)
	24	5 (24%)
	36	3 (14%)
	42	1 (5%)
	46	3 (14%)
	60	4 (19%)

Majority of respondent reveals that have certification and experience that validates this study. Most of respondents have diploma (48%) as their qualification of education followed by degree (43%) and master (10%). Normally, workers with diploma qualification are site supervisors while with degree and master qualification hold executive, managerial and top management positions. The common working experience of the respondents is at the range of 6 to 10 years (47%), followed by below 5 years (43%), and both with the 11 to 15 years and 16 to 20 years working experience are 5%. This data shows that survey was participated with majority of 57% having more than 5 years' experience in various construction projects that contribute to the validity of the survey respondents.

Table 2. Relative important index (RII) and ranking on design and documentation attributes waste generation at construction sites (n = 21)

Item	Design and documentation attributes to waste generation at construction sites.	RII	Ranking
DD6	Long project duration	0.686	1
DD5	Complicated design	0.638	2
DD1	Change to design	0.619	3
DD2	Document problems	0.619	4
DD11	Errors in ordering	0.600	5
DD16	Unforeseen conditions	0.600	6
DD7	Specification of products and sizing of products	0.571	7
DD15	Purchase of materials contrary to specification	0.571	8
DD8	Poor schedule of materials procurement	0.562	9
DD14	Substitution of a material by a more expensive one	0.552	10
DD3	Design errors	0.543	11
DD9	Over-ordering	0.533	12
DD4	Construction drawing errors	0.524	13
DD12	Requirements to bulk purchase	0.524	14
DD10	Under-ordering	0.514	15
DD13	Impossibility to order small quantities	0.438	16

4.1 Raking for design and documentation as attributes to waste generation at construction sites

The ranking on design and documentation as attributes to waste generation at construction sites is listed out based on the relative important index (RII) value. From the analysis, 1st ranked is the long project

duration. Construction wastes are produced during the construction period [11]. Most construction takes more than one year to complete and most site apply for extension of time. Poor planning, error in timing as well as weather condition are among the major contributors to longer construction project duration [8]. These lead to longer project duration which generated more waste. Project managers, site supervisors, and general foremen must uphold their project management expertise in order to coordinate the flow of construction in order to complete on time [7].

Complicated design is the 2nd ranked that contribute to waste generation. Complicated design would cause the workers failed to follow the designers plan and need to redo the work at construction site [5]. The degree of complexity and difficulty of to build the building will contribute to longer construction duration and mistakes in constructing it. The workers have no expertise to construct the complicated design. Eventually, construction mistakes will be rejected by designer as not following the approved detail design and has to be demolished. Due to the redo and rework of the complicated design at construction site, more waste will be generated. Change to design is rank at 3rd place in this study. The change in design element also was evaluated as the significant contributing factors for construction waste generation at Thailand [5]. The wastes are generated from frequent design revisions, change orders [10] and design choice [7]. These issues develop due to last-minute design changes and alterations request from the client. Lack of communication between client and the designers during the design process could also result in design changes during construction. The repair works to ensemble the new design changes will definitely generated construction waste.

The 4th rank is document problems. Problems in documentation such as the bill of quantities, specification, drawings, terms and conditions and other documentation errors will lead to mistakes during construction. These document problems will contribute to design error, incorrect quantity and specification of building material ordered that leads to inappropriate constructed building. Carelessness on the part of the architect, engineer and quantity surveyor at the design phase may result in destruction, rework, or the use of the wrong materials [7]. The heterogeneity will generate more construction waste as it need patch-up works [8].

Errors in ordering in term of quantity, quality, brand, dimension, or proportions is ranked 5th as contribution to waste generation. Poor material ordering is critical issues because in relates to material losses, damages to the building and effect the cost of project [12]. These mistakes will ultimately result in material wastes since the material unsuitable to be use for the project. Unforeseen conditions are ranked 6th in this study. Unforeseen ground conditions are the unanticipated or unexpected environments or situations that affect the project. Situation influenced by external factor such as landslide, flood and extreme rain could be disaster and damage the construction site including the machineries and materials. This unforeseen situation will end up producing more waste and loss [8].

5. Conclusion

From this study, design and documentation shows considerable facts as attributes to waste generation at construction sites. Out of 16 survey items on design and documentation, 6 items point out the RII more than 0.6 and 15 items with more than 0.5 as waste generated at construction sites. The items with RII more than 0.6 are long project duration (1st ranked), complicated design (2nd ranked), change to design (3rd ranked), document problems (4th ranked), errors in ordering (5th ranked) and unforeseen ground conditions (6th ranked). Overall, design and documentation are the attributes to waste generation at construction sites. To conclude, design and documentation should be considered as priority action taken by the stakeholders especially in design and construction phase of projects towards reduce waste generated from construction sites. Findings of this study could assist in more comprehensive study in construction waste and in the formulation of policy interventions in managing waste at construction sites.

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