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Minimisation of Construction Waste Using the Principles of Waste Management

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Construction waste especially material waste is one major concern for the construction projects and has important implications in terms of socioeconomic and environmental aspects for the country. Construction industry being largest consumer of raw materials derived from natural resources also produces high amount of material waste that negatively impacts the environment. The building industry alone in Malaysia has reportedly generated approximately 25,600 tonnes of construction and demolition wastes daily due to rapid development. Therefore, any means of reducing material waste will not only result in significant cost savings within the projects but also reducing the pressure on the landfills and ease environmental concerns dealing with such waste conversion and recycling; and reduction. This study examines the causes and prevention of material waste in the construction specifically the building industry through the principles of waste management available. Questionnaires survey is the main tool deployed for data collection. The average and relative index were used to analyse the various aspects of the data collected. Stages of works used for the study include the material handling and storage stage; procurement of material stage; usage and operation of the material stage; and the design and documentation stage. The results indicate that respondents are aware of the concept of waste management but lack of awareness on the availability of such guidelines. It is hopeful that this study can improve on waste management implementation in order to uptake the principle of reduce, recycle and reuse material waste so as to reduce construction costs, provide good savings to the end users and improve the level of productivity of the nation.

Keywords: Construction; material waste; minimisation; waste management

I. INTRODUCTION

Malaysia has executed many construction projects from buildings, high rises to highways, expressway and major transportation system; and major infrastructure facilities (Raze *et al.,* 2013). Due to the rapid growth, consumption of resources and material has correlated which in turn led to increase in the amount of waste produced from construction sites (Wong & Roslan, 2019). The Malaysian construction industry's waste constitute a large portion of solid waste every year in Malaysia (Begum *et al.,* 2007). The excessively generated waste is one major concern for the construction projects and has important implications in terms of socioeconomic and environmental aspects for the country (Eze *et. al.,* 2017; Tafesse *et al.,* 2022).

Construction industry being largest consumer of raw materials derived from natural resources also produces high amount of material waste that negatively impacts the environment (Luangcharoenrat *et al.,* 2019). Construction waste has even taken up to 50 % of the landfill in the United Kingdom, and in developing countries like Malayisa,

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approximately 25,600 tonnes of of construction and demotion waste is produced daily (Saadi *et al.,* 2016).

As mentioned by Osmani (2011), construction wastes and the related issues is a common phenomenon for the construction industry worldwide. Construction waste does not only constitute the unused components of the primary products that the original user aims to produce but also the by-products resulting from the many activities during construction. They can be generally classified into three (3) primary types: 1. Physical, i.e., material; 2. time; and 3. cost (Khaleel & Al-Zubaidy, 2018). This study is focused on material related wastes. Material waste for construction refers to materials from construction sites which cannot be used for construction purposes and they must be disposed due to plethora of reasons (Yahya & Boussabaine, 2006). As indicated by Ekanayake and Ofori (2000), material wastes from construction projects are any material other than earth that has been transported to and used in the said site itself but was somehow not used for their intended purpose due to reasons such as damage, excess or non-use because of non-compliances. They are later transported away but cannot be further used again.

Dania *et al.* (2007) stated that the formation and later the elimination of construction waste is a stream of complex efforts. This is due to the fact that there is a wide of range of waste that can be generated in a construction project, which actually also includes civil works with activities like excavation or formation of land, removal, road work, demolition of existing buildings. Common ones are debris, rubble, steel, concrete and wood. The variation in the wastes requires mixed clearance methods and handling. The Hong Kong Environment Waste Data (2016) describes waste as comprising of materials that is undesirable, produced during construction. Such materials are usually short of the project requirements or in some cases exceed the quantity needed. In most cases these materials that have been used and disposed, and they can also be rejected due to compliance reasons. Wastes can also be generated during building maintenance and they include wrong shaping of parts, faultiness in material, wrappings for material and machinery, surpluses, damaged/un-useable/contaminated building material.

II. PROBLEM STATEMENT

Researches had shown that there are large variations of construction wastes generated from the primary materials used in construction projects such as glass, plastics, wood and steel, surplus mortar, surplus concrete, broken bricks, green wastes (grass, bushes) and excavated soil (Noor *et al.,* 2020). In many instances, excessive production of construction often indicates the performance of unnecessary work and inefficiency in work processes resulting in ineffective use of capital and resources such as material, labour and equipment in quantities during the production of the said facilities (Polat *et al.,* 2017). Womack and Jones (1996) supported that waste is a result of processes that absorbs resources and yet has no added value. These instances of material losses do not increase any value to the product but generate extra costs.

Macomber and Howell (2004) pointed out that wastes can be translated into precisely the expenditures of using the more resources and effort without generating more value. According to Wong and Roslan (2019), by simply reducing construction wasters produces along will reduce subsequently disposal costs. Othman and Mohammed (2019) in their research of achieving value through construction wastes reduction, points out that value of a project decreases with the increases of construction wastes. In order to remain competitive amidst globalisation, the construction industry need to deliver products and services that has value to its customers, which can only be achieved if quality of product is retained but the cost of product is reduced. The Malaysian construction industry needs to gain an appreciation that value of a project is tied inevitably with not only productivity but also creation of waste and ways that waste can be eliminated in projects to achieve minimum construction costs.

Waste management considers waste from construction materials as potential waste that impedes the value flow to the customer and therefore, should be eliminated. Similar study by Huang *et al.* (2018) on waste management principles with the 3R (Reduce, Recycle and Reuse) adopted in this study is deemed capable in improving the issues brought about by construction waste generation.

This study aims to look into the types of construction material wastes created in Malaysia, the main causes of such waste creation in Malaysian construction sites and to suggest

ways to manage such material wastes based on the 3R waste management principles. It is believed that through understanding of construction material wastes and the causes of such wastes, the industry can seek to eliminate issues and problems related to such wastes creation and subsequently manage construction wastes better through waste management principles.

III. RESEARCH METHOD

The study utilised the questionnaire survey format for data collection. The questionnaire forms were distributed randomly to construction and civil engineering personnel to draw out issues related to material wastes and waste management in construction sites in Malaysia. Survey forms were hand delivered to companies and respondents who are willing to answer are surveyed in a face to face manner. There are two methods of distributing the questionnaire, which are, physical delivery to construction sites, and Google forms for respondents outside physical contact areas. Surveys were also followed up via phone calls.

This questionnaire form is divided into six (6) sections. Section 1 focuses on the respondents and their background data. Section 2 works on the factors causing material waste in construction sites, including the types of material wastes. Section 3 discusses about the available strategies in managing and minimising construction material wastes. Section 4 of the questionnaire discusses about the benefits of implementing waste management on construction sites. Section 5 seeks to reveal the barriers to implement waste management principles. Section 6 discusses on measures to overcome these barriers. The first part of the questionnaire is an open ended question while the second until the last part of this questionnaire was rating question.

The sample size for the questionnaires was determined using the formula proposed by Israel (1992):

$$n = \frac{N}{1+N(e)^2}$$

Where n is the sample size, N is the population size and e is the desired level of precision (±5%) at 95% confidence interval. Random sampling approach was used to select the total number of respondents for the study with every unit has an equal chance of being selected. A total of 120 questionnaires were sent to various construction firms mainly in Sarawak state of Malaysia. As there are less than 200 construction companies in the state, 60 forms returned are deemed adequate for analysis.

The data from the rating based questions was analysed by using average index analysis:

$$Mean\ value = \frac{\Sigma\, ai\ xi}{\Sigma\, xi}$$

Where,

ai = constant which represent the weight for I,

xi = variable that represent the frequency of respondents to the I ($i = 1, 2, 3, 4, 5$)

Relative index analysis was used in this research to show the strength of the survey data value. The point 0.20 represent the minimum strength while 1.0 shows the maximum strength of the data collected. Strength of data are presented in a descriptive manner under Relative Index column in the results presented. The formula for relative index is as follows:

$$\frac{\Sigma\,(1n^1 + 1n^2 + 1n^3 + 1n^4 + 1n^5)}{5\,(\Sigma x)}$$

Where,

n_n = the number of respondent agreeing with the choice,

x = number of respondents

IV. RESULTS AND ANALYSIS

The following presents the results and analysis from the survey.

A. Respondents' Data

Out of the 60 respondents, majority are project managers (32%) and contractors (35%). A majority of 85% has been working actively in the construction industry for more than five (5) years of experience. 23 respondents came from private companies and organisations whilst the other 37 are from government and other public organisations. More than

half of the respondents (61%) worked with local clients, while other projects are international clients.

B. Sources of Construction Material Wastes

Figure 1 and Table 1 shows the average index and relative index on types of material waste generated from construction sites with the highest number of average index of 4.22, whichistimber. The second highest is the pipes with average index of 3.77 followed by average index of 3.75, which is steel. The lowest number of average index is paint with the average index of only 2.53.

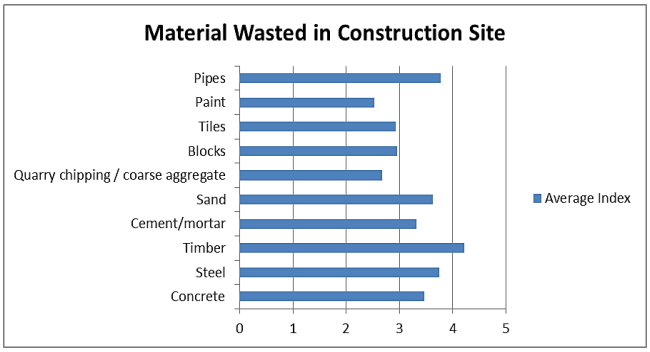

Figure 1. Average Index on Materials Wasted in Construction Site (X-axis represents the average index from the average index analysis)

Table 1. Material of Highest Wastage in Construction Sites

Materials Which is Severely Wasted in Construction Site	Average Index	Relative Index
Timber	4.22	Very Severe

Figure 2 and Table 2 shows the average index on which stage of work the construction waste is from with the highest value of 4.68, which is during operational/construction stage. The second highest is the generated from materials storage and handling with average index of 4.35 followed by procurement, design and documentation with the average index of 3.65 and 3.79, respectively.

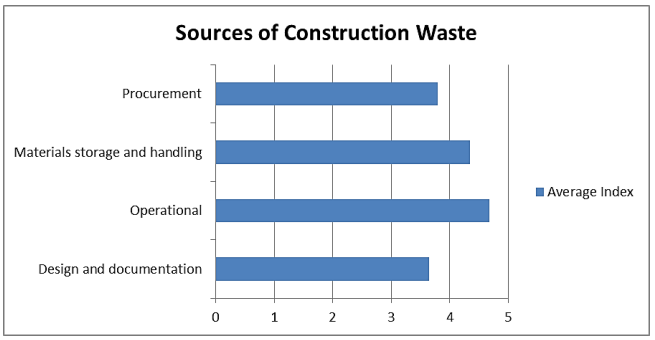

Figure 2. Average Index on Stages of Works (Sources) that Contributes to the Generation of Waste (X-axis represents the average index from the average index analysis)

Table 2. Major Stage of Work (Source) that Contributes to Construction Material Waste

Stage of Work (Source) Construction Material Waste	Average Index	Relative Index
Operational/Construction	4.68	Major Waste Cause

Figure 3 and Table 3 show that the activities from the stages of works which contributed to waste generation during operational stage is the “Replacement due to incorrect usage”, which has the highest number of average index of 4.17. The second highest is the “Delay in communicating on types and/or sizes of products to the builders” with average index of 4.15 followed by average index of 3.98 which is the “wrong choice of construction method”.

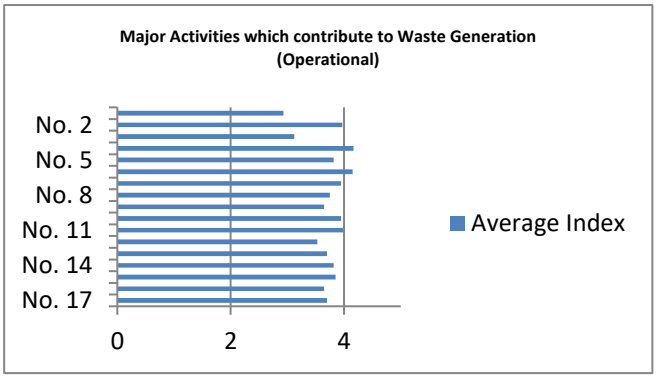

Figure 3. Major Activities Contributing to Waste Generation (Operational/Construction) (X-axis represents the average index from the average index analysis)

Table 3. Activities that Causes Material Waste Generation during Operation Stage

Operational/Construction Stage	Average Index	Relative Index
Replacement due to incorrect usage	4.17	Significant Waste Cause
Delay in communicating on types and/or sizes of products to the builders	4.15	Significant Waste Cause

From the data obtained, other activities that cause material waste generation under Design & Documentation stage, Materials Handling and Storage stage and Procurement stage are presented in Tables 4 to 6. The main contributor of waste during Materials Storage and Handling, ranked by the respondents is "Over-production or ordering more than required" and "Damage to materials during work process". Meanwhile, the "Substitution of a costlier option on the pretext of better performance" and "Purchasing products that do not comply with specifications" ranked as the major contributor to waste generation in Procurement stage. "Design without attention to standard sizes available" and "Lack in detailing in Drawings" are the major activities that create material waste under Design & Documentation.

Table 4. Activities that Causes Material Waste in Design & Documentation Stage

Design & Documentation Stage	Average Index	Relative Index
Design without attention to standard sizes available	4.10	Significant Waste Cause
Lack in detailing in Drawings	4.07	Significant Waste Cause

Table 5. Activities that Causes Material Waste in Materials Handling and Storage Stage

Materials Handling and Storage	Average Index	Relative Index
Over-production or ordering more than required	4.15	Significant Waste Cause
Damage to materials during work process	4.02	Significant Waste Cause

Table 6. Activities that Causes Material Waste in Procurement Stage

Procurement Stage	Average Index	Relative Index
Substitution of a costlier option on the pretext of better performance	4.02	Significant Waste Cause
Purchasing products that do not comply with specifications	3.77	Significant Waste Cause

C. Waste Management and its Benefits

This section explores waste management in two (2) aspects 1) the site practices/techniques and 2) management strategies that can reduce or eliminate wastes generated from projects. Parameters are drawn from various literatures related to waste management. Results are expressed by the respondents. Benefits of waste management implementation as perceived by the respondents are also covered in this section.

Figure 4 and Table 7 show the average index on practices techniques on to reduce the quantity of waste. Based on the data obtained, the top three (3) effective practices ranked by respondents to reduce waste are "Effort for Continuous Improvement to achieve better value and higher productivity" which has the highest average index of 4.02, followed by "Waste minimisation by maximising the use of all resources and eliminating non-value-added activities" and "make constant effort to improve work processes" with average index of 3.95 and 3.82, respectively.

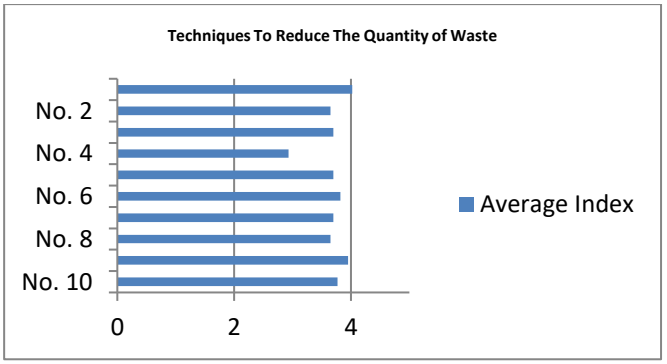

Figure 4. Average Index on Techniques to Reduce the Quantity of Waste (X-axis represents the average index from the average index analysis)

Table 7. Top (5) Most Effective Practices to Reduce the Quantity of Material Waste

Techniques	Average Index	Relative Index
Effort for Continuous Improvement to achieve better value and higher productivity	4.02	High Contribution
Waste minimisation by maximising the use of all resources and eliminating non-value added activities	3.95	High Contribution
Make constant effort to improve work processes	3.82	High Contribution
Establish stable and long term relationships with supplier	3.77	High Contribution
Improving on constructability by involving all parties in all necessary work processes	3.70	High Contribution

Figure 5 shows the average index ranking for management strategies to minimise material waste. The highest number of average index is 4.17 which is "Regularly educating and training personnel on material handling". The second highest is the "Good construction management practices" with average index of 4.15 followed by average index of 4.02 which is the "Care for accurate material measurement" and "Special task force/officer for waste management".

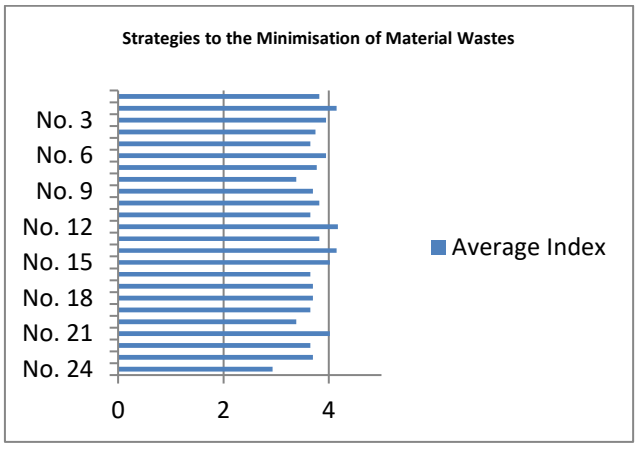

Figure 5. Average Index on Management Strategies to the Minimisation of Material Wastes (X-axis represents the average index from the average index analysis)

The respondents were further asked to evaluate ten advantages that can be gained by the implementing the concept of waste management for the construction industry. As per the data obtained, most respondents opined that top three (3) benefits from the application of waste management principles are "On time and on budget delivery of products or services", which has the highest average index of 4.27. The other two important benefits are "Minimisation of direct costs via effective project management" and "Provision of honesty and accountability; and reliability and certainty in the project" with the average index of 4.08 and 4.05 respectively. This is further iterated in Figure 6 below.

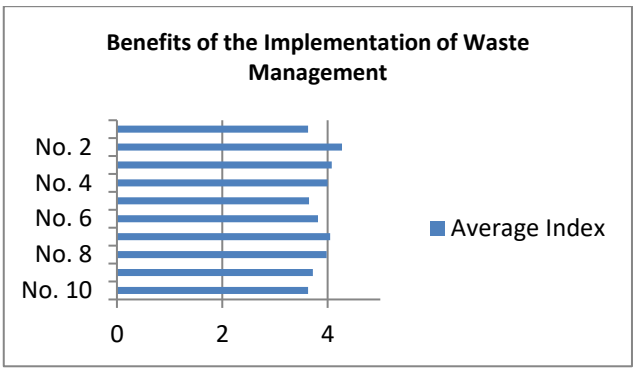

Figure 6. Average Index on Benefits of the Implementation of Waste Management

D. Barriers to the Implementation of Waste Management Principles

The challenges faced by the project managers when implementing waste management principles identified from literature and confirmed by industry practitioners is explored in this study. From the data obtained, the strongest barrier to implement waste management principle which has the average index of 4.27 is "Lack of technical skills" followed by "Lack will and commitment for change and innovation", "Prolonged implementation period", "High level of illiteracy" and "Incomplete designs".

Most of these barriers deal with the human resources on sites. Unskilled workers with high illiteracy rate will undoubtedly causes difficulties for waste management plans to be followed through. Without proper training in work processes, the tendency of misuse, damage of material and non-compliances will be high. From the management perspective, waste management need to be driven and

prioritised by top management of any organisation; mapped out, monitored, and controlled by the middle management; and executed by the ground team who is hands on and practical. Without commitment from all levels, waste management will remain a miss.

It is critical for the industry to understand these barriers element and places efforts to overcome these barriers in order to effectively reduce waste generation on construction sites. The following section discusses on the methods in overcoming the barriers in the implementation of waste management.

E. Methods in Overcoming the Barriers

This section discusses the results related to measures to overcome the barriers in implementing waste management as presented in previous section. Most respondents agreed that the five (5) most significant measures to overcome potential barriers to implementation of waste management principles for the construction industry are "Improved Communication among project parties", "Management to train employees on waste management principles", "Construction managers should be committed to changes", "Promoting team building and trust among project parties" and "True understanding of client's needs and expectations to proceed accordingly".

To effectively overcome these barriers in waste management, it is important to include in project management plans at all levels of staff training on waste management; engaging skilled site operators; and promoting the waste management concept to the major stakeholders including construction companies, professional bodies. Even though all plans aim to better achieve the project goals, it is important that all level of staffs are aware and support the plans through their own respective work processes. Communication of the plans to workers, motivating them to follow and rewarding those who has done make a difference, and should be able to improve the issues related to waste generation. In addition, with more rigorous training in jobs especially in the work processes, workers will be able to handle material on hands better. Overcoming issues in waste management requires effort of entire organisations from top management to ground workers. Waste management efforts need to be driven, practical and executed rigorously in a discipline manner.

V. CONCLUSION

Construction material waste has long poses a substantial and long standing issue in the construction industry in Malaysia. Through this study, the type of material waste and their causes of such wastes creation can be better understood. Based on all the data from the survey that related to knowledge of material wastage in construction sites, most respondents had ranked "Timber" as the most wasted materials in construction site followed by "Steel". In terms of which segment of stage of works these wastes is from, majority of the respondents agreed on operational/construction phase. The results shine a light on which elements project managers can prioritise the waste reduction efforts.

Majority of the respondents believed that the most significant activities contributing to waste generation during operational stage of the construction are "replacement due to incorrect usage" and "delays in communicating on types and/or sizes of products to the builder as the major". From the data obtained, it is seen that the main contributor of waste during materials handling and storage stage, ranked by the respondents are "over-production or ordering more than required" and "damage to materials during work processes". Whilst the "substitution of a costlier option on the pretext of better performance" and "purchasing products that do not comply with specifications" are both ranked as the some of the major contributors to waste generation during the procurement stage of the projects. These top contributors in different stage of works show the trend of needing skills and training on jobs and work process make waste management effort effective. Many contributors deal with on job specific skills and experience, requiring more training, education and commitment from ground team.

The study further investigated on site practices and waste management strategies that can reduce waste generation and the barriers that create problems to not fully utilised these strategies and practices. From the data obtained from the respondents, it can be concluded that top barriers for waste implementation are issues such as lack of technical skill followed by lack of will and commitment for change and innovation at the top management. Top site practices for waste reduction are efforts for continuous improvement to achieve better value and higher productivity, maximising the

use of all resources and eliminating non-value-added activities and making constant effort to improve work processes while top management strategies are efforts for regularly educating and training personnel on material handling and achieving good construction management practices.

Again, the above results iterate three (3) critical success factors in waste management implementation, and they are all people based. Commitment and long-term strategising from top management is critical when implementing waste management processes. Middle management who creates waste management plans needs to include all project stakeholders (including project partners like suppliers) and project team in their plans and their rigorous monitoring and controlling effort will contribute immensely to the successful implementation of any waste plans. Ground team needs to be fully supportive and well committed to carry out the practical on-site aspects of the waste reduction. In Malaysia, ground team skills training, awareness education and motivation are important success factors that are needed to overcome the barriers in waste management implementation.

It is hopeful that through a better understanding of the current construction waste practice and waste minimisation practices and strategies, the industry poses a step forward in reducing material waste on construction sites. It is only through a discipline and rigorous implementation of waste management strategies and practices that could help project managers better manage the industry waste production. And only through waste reduction, the industry could produce higher value product at a lower cost that is beneficial to the end users and the nation.

VI. ACKNOWLEDGEMENT

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