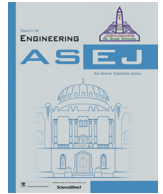




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A case study on the effective implementation of the reuse and recycling of construction & demolition waste management practices in Malaysia



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ABSTRACT

This paper presents a case study on the implementation of the construction and demolition waste management practices in the Malaysian construction sector. The scope was limited to the housing and high-rise buildings. Characterization of reuse and recycling potential was done using descriptive statistics. It is estimated that the waste generated by the housing sector is approximately 16% of the gross materials used, which is about 8.8 million tons/year, and 32% of such waste (approximately 2.8 million tons/year) has the potential for reuse and recycling. However, the high-rise building construction generates construction waste in a large quantity of more than 10 million tons/years (about 70% of the building construction waste), which shows a high potential for reusability and recycling. The reasons behind the low recycling potential for the construction and demolition (C&D) waste generated by the housing sector are found that its quality is low and contains some types of contaminants.

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1. Introduction

The construction sector worldwide is consuming a massive amount of natural resources and energy. There are two types of energy used; embodied energy and operational energy. Embodied energy is the energy used for the extraction of raw materials, their processing, fabrication, and installation. In general, embodied energy is the sum of all the energy required to produce any goods or services. The continuous promotion for environmental management and achieving the goals of sustainable development is urging the policymakers and technical experts for the adoption of an appropriate system for protecting the environment across all industries, including the construction industry [17]. In this respect, the need for reuse and recycling of materials waste has increased over the years due to many infrastructural developments because of rapid population increase and urbanization [25]. For environmental protection, some measures, such as limiting the use of finite resources and managing waste disposal, have led to promote

to recycle these materials at the end of their service life [7]. For instance, many landfills are approaching their full capacity, with many planned to be shut down over the next couple of years [3]. Developing new facilities for either disposal or recycling is extensively controversial, pushing present challenges involving waste exporting and waste importing organization. These are the concerns of Malaysia, which has limited innovative disposable facilities. Therefore, to reduce the construction waste generated on-site, coordination among all stakeholders involved in the planning, design, and construction processes is essential because there is a considerable amount of construction materials are wasted due to inappropriate handling at construction sites [26]. The impact of waste can be reduced by making strategies for waste recycling, which offers three benefits [28]: reduces the demand upon new resources, minimize the transportation and production energy costs, and uses waste materials which would otherwise be lost to landfill sites [29–33]. Apart from environmental protection, reducing the depletion of natural aggregate deposits, shortage of land for waste disposal, and the high cost of waste treatment are the significant factors urging for recycling of construction and demolition (C&D) waste in the global construction industry [5].

Furthermore, air, water, and land contamination are potentially severe consequences of our current resource-intensive infrastructure. There are some opportunities available for managing the industrial infrastructure in a way to maintain a sustainable impact of contaminants over a long period [18]. In the past, researchers

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have suggested or proposed some methods as a reference for industries for efficiently maximizing the process of reuse and recycling of materials in the alignment of the global campaign for a sustainable environment [20,14,24]. All those researchers not only discussed the significance of reuse and recycling of materials but also presented the advantages of waste reduction, reuse, and recycling regarding cost-cutting as well as producing substantial environmental advantages such as the preservation of natural resources and minimization of environmental pollution related to materials production and transportation. Proper reuse and recycling of waste materials can save energy and reduce CO₂ emission. The recycling of several materials demands lower energy as compared to processing from virgin stock and can also decrease transportation needs, and its associated influences. There is limited knowledge available in Malaysia regarding the construction and demolition (C&D) waste dumped at landfills. It appears that there is less emphasis on waste reduction at the source as compared with reuse and recycling. Currently, there are no legal or economic instruments in Malaysia that can guide construction professionals for making efforts to reduce the amount of waste generated and subsequently dispose-off. Therefore, the principal aim of this study was to investigate the real-time reuse and recycling of construction wastes generated in Malaysian residential (housing and multi-story) projects. Promotion of recycling and reusing of construction and demolition waste in Malaysia will not only reduce the burden on the consumption of natural resources, but it will also reduce the embodied energy, which may become significant.

2. Overview of the waste disposal and recycling in the Malaysian construction industry and the rest of the world

In the first part, an overview of the construction and demolition waste practices adopted by the world, particularly the developed countries, are presented. In the European Union territories, construction and demolition (C&D) waste constitute a significant fraction of all kinds of wastes. Therefore, the European Commission urged the member states for the reconciliation of the existing to deal with the C&D waste. It is suggested that the revised practices should consider the complete value chain [9]. For taking into consideration of the entire value chain, creating a linkage between the core principles and best practices is an important aspect. Islam et al. [13] compared the construction waste generation and management in Bangladesh with the developed countries, i.e., the European Union. According to them, the construction waste generation in Bangladesh is very high as compared to the developed world. The identified reasons for the high rate of generation are public awareness is weak, no clear policies for enforcement of the law, lack of community sensitization, and the adoption of old technologies. Islam et al. [13] mentioned that although in European countries, the construction waste generation is much lower (roughly 25–30% of solid waste); however, they managed it very well. It is estimated that by 2020, reuse, recycling, and recovery will reach 70% by weight for non-hazardous and other materials from C&D waste.

Tam and Lu [23] have done a comparative analysis of the construction waste management profiles, practices, and performance in Australia, Europe, Hong Kong, and the United Kingdom. The analysis showed that Hong Kong generates about 1.3 million tons of construction and demolition waste per year, whereas, China generates more than two billion tons year, which about 40% of the total municipal solid waste, the rate of recovery of such waste is about 55%. Tam and Lu [23] introduced an indicator in the form of a ratio (CDW/CGDP defined as tons/mUS\$) between the annual generation of construction waste (million tons) and the total construction GDP (million US dollars). The analysis showed that the CDW/CGDO for

Australia was found between 28.48 and 44.04, for Europe 47 to 58.89, for UK 34.29 to 51.53, and for Hong Kong 39.85 to 120.86. It can be concluded that most of the developed countries have shown a declining trend in waste generation. The main causes of such achievement are that the developed countries have done a lot for promoting a green environment that has been paid off.

Currently, in Peninsular Malaysia, approximately 95–97% of solid wastes (including construction and demolition (C&D) waste) collected are dumped at the disposal sites, on the balance of 3 to 5% are treated either using incineration technique or recycled and reprocessed [1]. The rate of recycling of C&D waste is quite low as compared to the developed countries, which is most likely due to the lack of data and the culture. [6] opined that applying a fully quantitative approach in decision making in developing countries is quite challenging due to a lack of information and a variety of data, which is often being used in developing countries. The Organization for Economic Co-operation and Development (OECD) countries have established many institutional mechanisms for promoting recycling of the essential items, which contained in Table 1. However, Malaysia does not have institutional mechanisms to provide obligations to stakeholders and further promote waste minimization from the viewpoint of source separation and less waste production, especially from the construction industry.

3. Methodology

3.1. Empirical design and data collection

The questionnaire used in this study was based on focus groups among residential project managers, consultants, and other professionals involved in the construction process. Afterward, a validation process performed on four residential projects in Kuala Lumpur, Johor Bahru, and Perak (Table 2) to determine the real-time reuse and recycle of waste generated on-site, that was obtained about 80% for high-rise building sites and less than 25% for housing project sites. The questionnaire comprised of three sections. The first section included questions related to the

Table 1
Key institutional mechanism for waste recycling.

Country	Key institutional mechanism for recycling
Japan	<ul style="list-style-type: none"> ■ Basic law for establishing the recycling-based society ■ Waste management and public cleansing law ■ Law for the promotion of effective utilization of resources ■ Container and packaging recycling law ■ Electric household appliance recycling law ■ Construction material recycling act ■ Food recycling law ■ Law on promoting green purchasing
UK	<ul style="list-style-type: none"> ■ EC Directive on Waste Electrical and Electronic Equipment (WEEE) (proposal for the implementation of the WEEE Directive) ■ The Producer Responsibility Obligations (Packaging Waste) Regulations ■ End-of-Life Vehicles Regulations ■ Batteries Directive ■ Construction Waste Minimization Act ■ Landfill tax regulations ■ Waste implementation program (WIP) ■ Waste resources and action program (WRAP) ■ Business resources efficiency and Waste (BREW) program
Germany	<ul style="list-style-type: none"> ■ End-of-life vehicle act ■ Act on the disposal of information, office, and communication technology equipment ■ Closed substance cycle and waste management act ■ Battery ordinance ■ Ordinance on bio-waste ■ Packaging ordinance
Malaysia	<ul style="list-style-type: none"> ■ National strategic plan for solid waste management ■ National recycling program ■ The incentive for waste recycling activities

Table 2
Overview of the investigated project.

Project	Project Name	Location	Project types	Build-up (M ²)
Project 1	Bora residential	Johor Bahru	High-rise	76,099
Project 2	Green residential	Kuala Lumpur	High-rise	74,306
Project 3	D'eco lake housing	Perak	Bungalow /Terrace	35,207
Project 4	Ridgewood	Perak	Bungalow /Terrace	22,993

respondent's background, project activities, and organizational level in the construction industry. The second part included a description of the current situation regarding reuse and recycling activities. Current problems and states of the current waste management program, the critical index of waste minimization regarding the method used, the effect of reuse and recycling, main problems encountered during reuse and recycling, and factors considered to encourage the reuse and recycling of construction waste materials at the project site. The third section was aimed to collect additional information from the respondents about their opinion on real-time reuse and recycling of generated waste, and the problems encountered and their impact on construction wastes and way forward.

3.2. Questionnaire distribution

In this study, 179 questionnaires were sent out to the stakeholders of residential construction projects, which were approved by the Construction Industry Development Board (CIDB), Malaysia. The questionnaire survey was conducted from January to March 2014. Out of 179, a total of 89 questionnaires were received, representing a 49% response rate, as presented in Table 3. The sample size was determined using a statistical method based on z-score with the help of SPSS. For this study, the z-score was calculated for a 95% confidence level. It is considered a satisfactory response rate of the questionnaire survey based on recommended practices based on the Central Limit Theorem, as discussed by Smith [21]. The response rates were comparable to those achieved by others in similar studies in the areas of engineering and technology management. These include, for instance, 21% by [19], 30–40% by [2], and 27% by [12]. The whole 179 number of residential projects were taken as sample size that consisted of 3 several types of residential buildings, as illustrated in Table 2. According to the sampling method employed, the survey was representative of the sampled population. All respondents were, however, qualified and experienced enough to give a credible opinion on the subject matter of the study.

3.3. Importance index factors for reuse and recycling of generated waste

A list of 4 importance index factors for effective reuse and recycling of construction materials, which were both identified in construction waste management (CWM) literature and thematically isolated based on the various methods, issues, and practical implementation, were presented to the respondents. They were asked to rate the factors on a 5-point Likert scale on how important they felt each factor was to the efficient reuse and recycling in their projects based on their practice and experiences over the years. After that, the relative importance index (RII) analysis was conducted to rank

Table 3
Questionnaire distribution.

Residential Project Type	Send	Receive	Response rate (%)
High-rise building	73	31	42%
Terrace/link houses	91	51	56%
Bungalows	15	7	40%
Total	179	89	49%

the most critical factors amongst the variables. The relative importance factor (RII) was calculated using the following expression:

$$RII = \frac{\sum W}{AN}$$

where W is the weightage given by each respondent on a 1 to 5 scale, A is the maximum weightage, which is five, and N is the total number of respondents.

3.4. Cluster analysis

Cluster analysis was used in this research to investigate further the core issues related to construction waste. The Cluster analysis tried to identify different segments in a project and figure out the number of materials reused and or recycled. It is used to identify further the homogeneous groups of the segments, such as contractor's grade level, types of construction projects (High-rise building, terrace/link houses, and bungalows) and estimated construction waste that could be reused or recycled that have similar needs and challenges but are distinctively different from other project segments. It then identified attributes of the homogeneous groups within a construction project (for example, high achiever's project in reuse and recycle waste generated on-site, or project that excels in particular aspect but fails in others). Therefore, significant factors were clustered into three indexes. The cluster analysis was using SPSS software.

3.5. Case study approach

Conducting a case study as a part of the research methods in engineering and technology management research is being widely appreciating [27]. Currently, many types of research studies in the field of construction and waste management are adopting case studies as part of the methodology [11]. Many authors [27,10] highlighted that case study research could be used for exploratory, descriptive as well as critical studies. This study adopted a combination of a descriptive and explanatory approach to explore, describe, and establish a causal relationship of the waste management processes, the major challenges, and possible mechanisms that would lead to improving the performance of construction waste processes. As there are over 179 construction residential projects constructed during the study period, it was complicated to select all these buildings for a case study in this research. As pointed out by Eisenhardt, the use of four to ten cases was recommended for better external validity [8]. Therefore, this research focuses on four construction projects located in three regions of Peninsula Malaysia as follows: Central region (Kuala Lumpur), Northern region (Perak), and Southern region (Johor), as shown in Fig. 1.

4. Result and discussion

4.1. Current situation of reuse and recycling

The Bar chart shown in Fig. 2 indicates the percentages of construction waste generated that could be recycled from the total waste generated. The result illustrates that 25% of the respondents believe that only below 10% of the construction wastes generated could be reused or recycled. Besides that, there is also a sizeable



Fig. 1. Case study location.

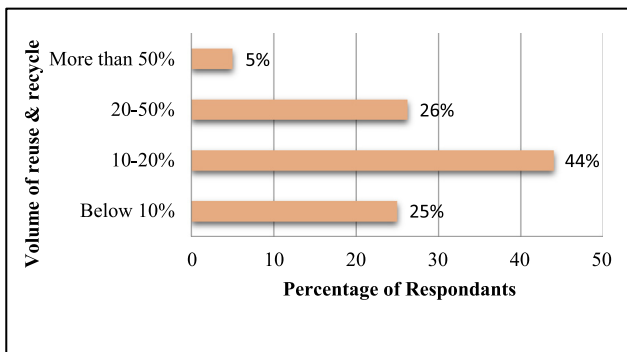


Fig. 2. Waste generated to be reused or recycled.

proportion of respondents (about 44%) who stated that waste generated between 10 and 20% would be reused or recycled in their project. Only 5% of the respondents stated that their projects reuse and recycle more than 50% of the entire waste generated. Fig. 3 demonstrates the estimated average weight of waste generated per day in a residential project. It shows that most of the waste produced in the project is from less than a ton per day to 5 tons

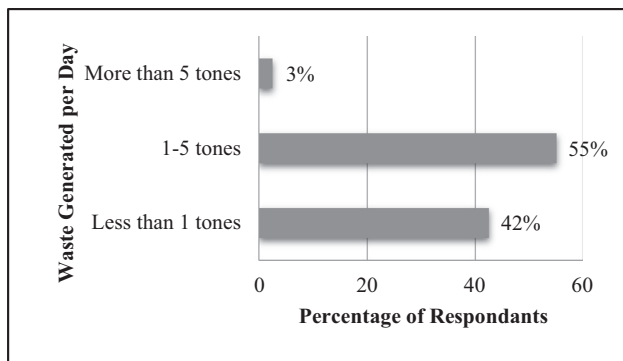


Fig. 3. Estimated waste generated per day.

per day, which is about 97%. There is merely a small amount of waste generated in the residential project that is greater than 5 tons (only 3% of the projects). The case study performed in this research showed that the waste generated in high-rise building projects was about 4.4 ton/day, whereas, in the housing projects, it was obtained as 2.47 tons/day.

4.2. Importance index factors for reuse and recycling of generated waste

4.2.1. Waste minimization during construction (WMC)

The data of waste minimization during construction (WMC) shown in Fig. 4 demonstrates the significance of the approaches to waste minimization during construction works. The results imply that the most important methods of waste minimization during the construction works are reuse or recycling of packaging materials and the use of recycled material, as these two factors are the limited techniques employed to minimize waste during the construction works at that project. While the third most crucial factor is a careful evaluation of materials to ensure over-ordering at the site is reduced. Minimize or preventing over-ordering of materials is essential as damages may cause poor storage areas or because the materials ordered are improper [4].

4.2.2. Effect of waste minimization by reuse or recycling (EWM)

The effect of waste minimization by reuse or recycling (EWM) illustrate in Fig. 5 presents the importance index of the effects of waste minimization by reuse or recycling. It was discovered that most of the participants consider that the most important effects are to minimize environmental impacts at an importance index of 0.87. On the other hand, make new products

4.2.3. Problems in reuse and recycling (PRR)

The problems in reuse and recycling (PRR) results shown in Fig. 6 shows that participants had rated the key issues in the recycling of the construction wastes, which varies according to the significance of the problems. Participants had rated that the main problem is difficulty in sorting, transforming, and disposing of

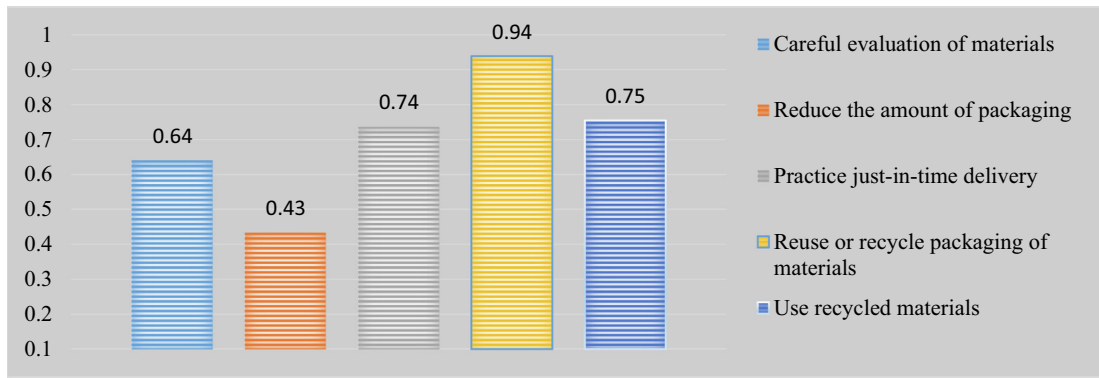


Fig. 4. Importance index of waste minimization during construction.

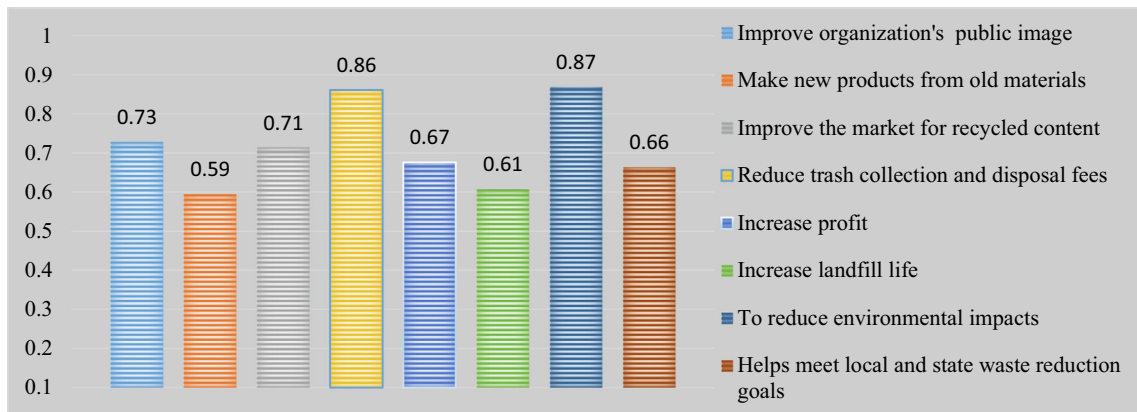


Fig. 5. Importance index of the impact of waste minimization by reuse or recycling.

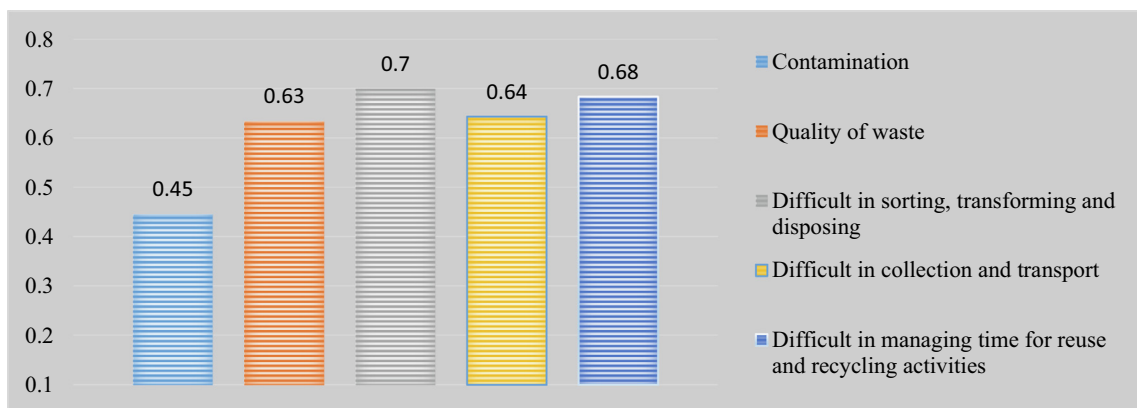


Fig. 6. Importance index of problems in reuse and recycle.

which importance index of 0.7. Difficulty in managing time for reuse follows it and recycle activities and difficulty in collection and transport at importance index of 0.68 and 0.64, respectively. The contamination is rated as the smallest importance index, which is 0.45.

4.2.4. Factors to encourage waste reused and recycling (ERR)

The factors to encourage waste reused and recycling (ERR) shown in Fig. 7 were collected from a construction project that shows the signature elements that promote construction waste recycling. Considering recycle base material have the broadest importance index at 0.85. Then by imposing charges when the wastes exceed a quantity at an importance index of 0.81. Subse-

quently, the lowest crucial factor to encourage the construction waste recycling is maximized landfill tax to prevent indiscriminate disposal with an importance index of 0.62.

4.2.5. Clustering Importance index factors

The importance index factors were clustered into three clustered. The clustering quality indicates that the overall model is 'Good' based on the Silhouette measure of cohesion and separation, which Average Silhouette of 0.7 (Fig. 8).

Furthermore, the predictor importance factors were determined, which show how good the variable can separate different clusters. For both range (numeric) and discrete variables, the more considerable the significance measure, the less likely the variation

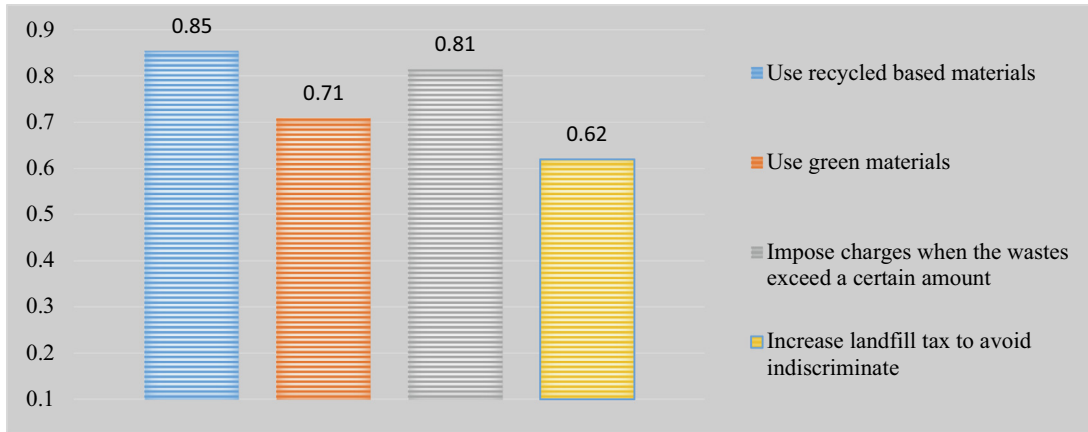


Fig. 7. Importance index of factors to encourages waste reused and recycled.

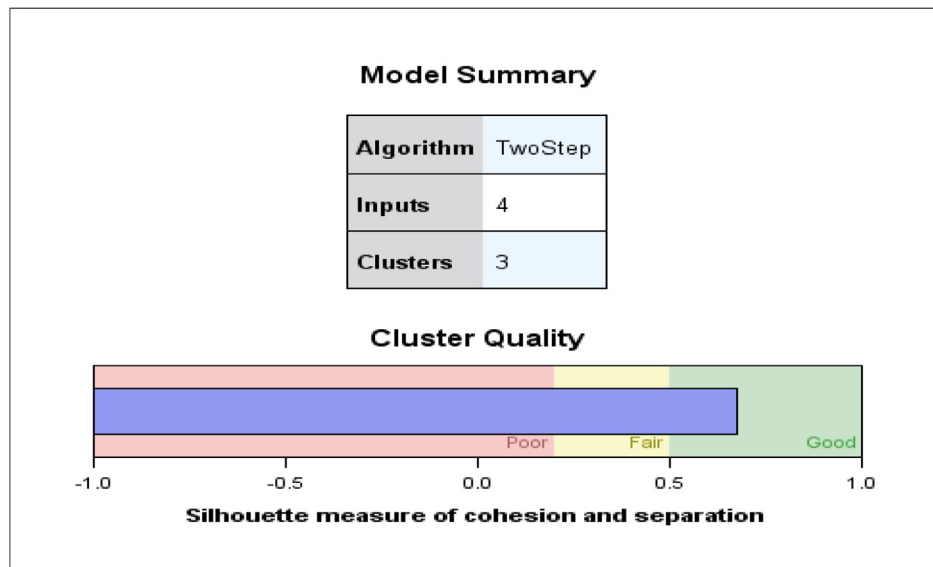


Fig. 8. Model summary and cluster quality.

Table 4
Importance factor for different clusters obtained from SPSS analysis.

Cluster	Code	1	2	3
Size Input	PRR _{total}	15.9% Importance = 1 Mean: 11.0	35.4% Importance = 1 Mean: 19.83	48.8% Importance = 1 Mean: 14.82
	EWM _{total}	Importance = 0.85 Mean: 16.62	Importance = 0.85 Mean: 37.97	Importance = 0.85 Mean: 31.02
	WMC _{total}	Importance = 0.76 Mean: 9.08	Importance = 0.76 Mean: 21.76	Importance = 0.76 Mean: 16.70
	ERR _{total}	Importance = 0.63 Mean: 10.31	Importance = 0.63 Mean: 18.55	Importance = 0.63 Mean: 13.95
	Evaluation Field	Contractor Grade Level	Importance = 0.23 Most Frequent Category: 6.0 (53.8%)	Importance = 0.23 Most Frequent Category: 7.0 (93.1%)
Types of Construction Projects		Importance = 0.23 Most Frequent Category: 1.0 (92.3%)	Importance = 0.23 Most Frequent Category: 4.0 (51.7%)	Importance = 0.23 Most Frequent Category: 1.0 (47.5%)
Estimated Waste to be Reused or Recycled		Importance = 0.46 Most Frequent Category: 1.0 (92.3%)	Importance = 0.23 Most Frequent Category: 3.0 (72.4%)	Importance = 0.23 Most Frequent Category: 2.0 (80.0%)

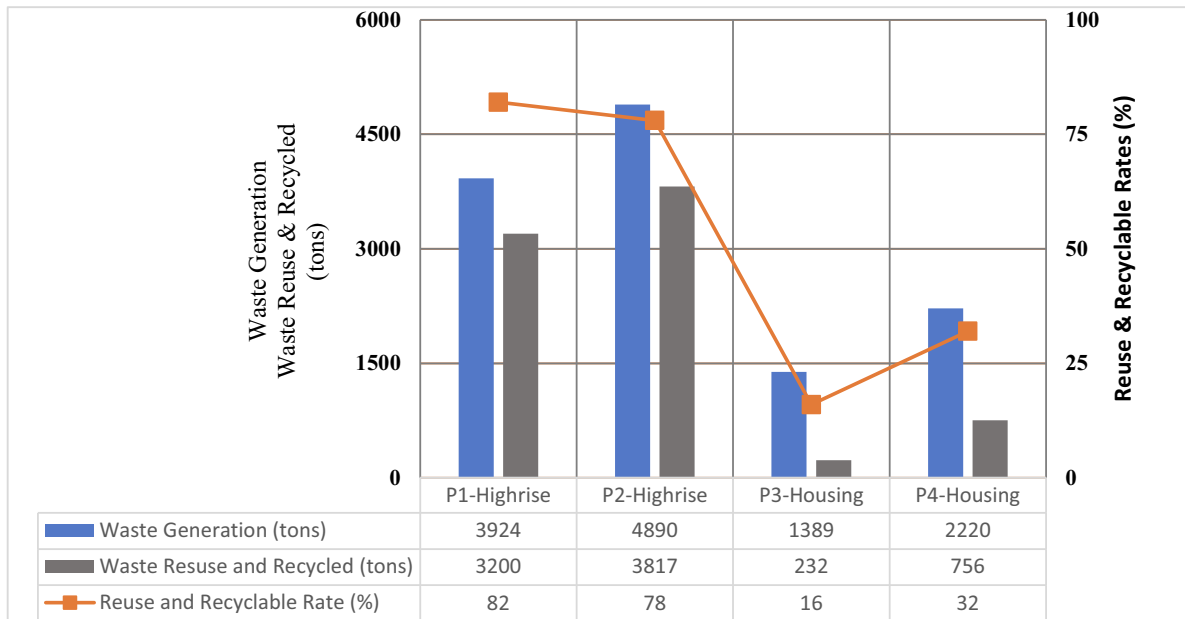


Fig. 9. Comparison of project waste generated and recyclable.

in a variable between groups because of chance and more probably because of some central variation. The Predictor Importance indicates the relative importance of every area in calculating the model from less importance variable to the most important one, as represented in Table 4.

4.2.6. Validation: Comparison analysis of case study

The comparison analysis of the case study enables visualization across multiple analyses with varying conditions to identify trends or similarities and differences between states [22]. The comparative

analysis was primarily helpful, as every case served as an excellent guideline or structure for comprehending the other. Fig. 9 illustrates waste generated and recyclable rates from the four projects under investigation, while Fig. 10 presents project waste composition from different construction materials across the projects.

Furthermore, the data analysis shows that there is a high degree of agreement among the participants resulting in an overall mean of 6.6714. What this means is that a more significant percentage of the respondents agree that the factors presented to them were a critical index to effective reuse and recycling of materials waste.

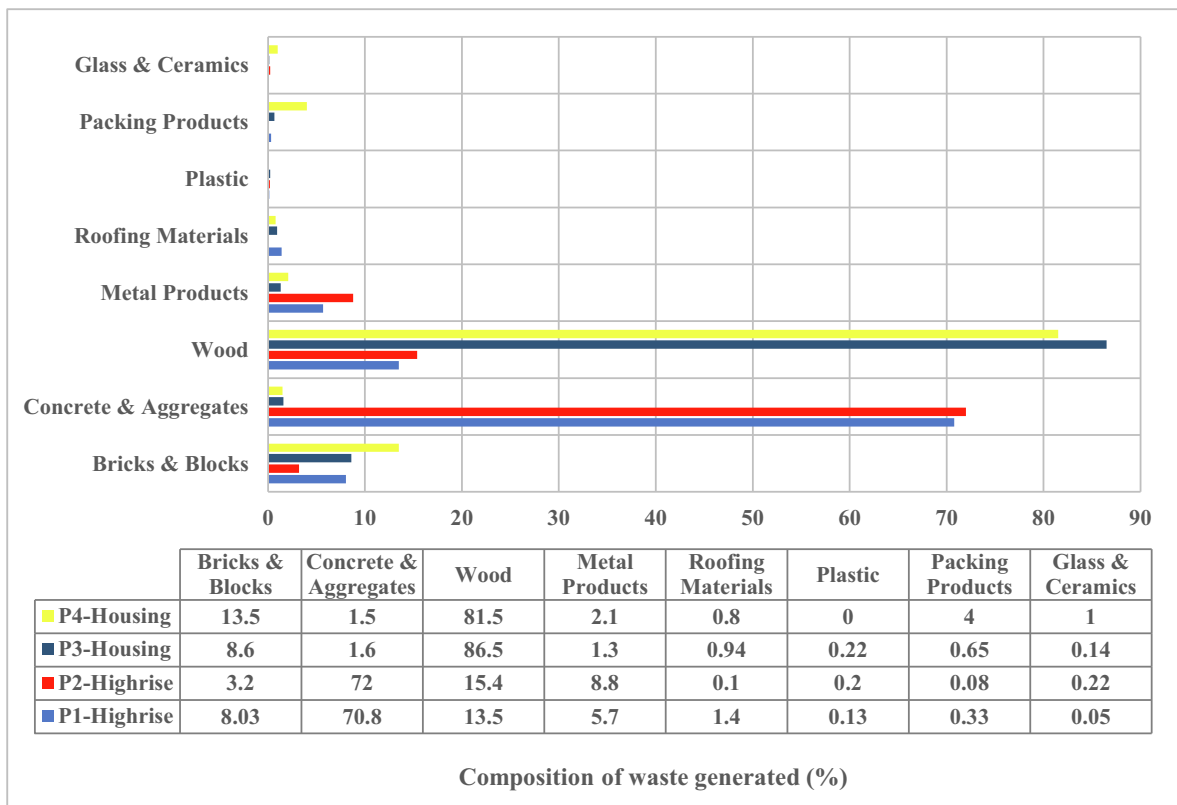


Fig. 10. Comparison of project waste composition.

A further check of the five %t trimmed-mean reveals whether the extreme values in a particular data set has influenced the mean [15,16]. If the value of the mean and 5% trimmed-mean are significantly different, it means the impact of the extreme value on the mean. In this study, the mean (6.6714) and the 5% trimmed mean (7.9603) are very similar, indicating that extreme values did not have any effect on the way. Looking at some of the critical index factors demonstrates that minimizing or preventing over-ordering of materials is essential as damages may causing weak storage areas or because the materials ordered are improper. Also, there exists that the construction industry is generating a massive portion of construction waste because of the need for executing construction work in Malaysia. Hence, minimizing the environmental impact is an essential subject of priority in the implementation of the construction. It is additionally a fundamental part of the dedication to improving the world sustainability challenges. Construction wastes like demolition wastes, which are most combined, can cause obstacles in sorting, transforming, and disposal. Besides that, sorting and crushing can demand a high price in the recycling approach since the operations need many workers.

According to the data collection and analysis in Fig. 3 above, the percentage of the estimated weight of waste generated per day for a construction project at the site was different. For instance, less than 1 ton is 43%, 1–5 tons is 55%, and more than 5 tons produced is only 3%. It means that much waste generated without considering the impact it causes on the project and the entire environment. It is because the level of reuse and recycle from the mass housing (semi-detached and bungalow) was, i.e., about 16% to 32% from projects three and four respectively, unlike the high-rise building which generated a lot of construction waste but had a very high rate of reusable and recyclability as shown in Fig. 8. Regarding the composition of material waste, the amount of waste generated at each site was also evaluated accordingly. It was found that high-rise buildings (projects 1 and 2) and semi-detached and bungalows housing (projects 3 and 4) yielded different material wastes. In projects, one and two, the highest amounts of waste generated originated from concrete and aggregate, which were about 71% and 72%, respectively. Because of the reason that the two projects produced less waste from wood, as shown in Fig. 10. However, looking at projects 3 and 4, the highest percentage of waste originated from wood, constituting about 87% and 82%, respectively.

Furthermore, the clustering predictor importance factor was determined by selecting the highest importance and mean value from the full analysis. According to this result, PRR with a mean value of 14.82 that consists of contamination, quality of waste, difficulty in collection and transport, and problem in sorting, transformation and disposing of indicates the main reason for the low rate of reuse and recycling of the waste in this study. It further corresponds to the importance factor from the evaluation field of Table 4, which indicates that the estimated construction waste to be reused or recycled in which predictor importance of 0.46 was entirely dependent on when PRR variable issues were critically addressed.

5. Conclusion

1. The perception and understanding of the Malaysian construction industry professionals regarding the construction waste management were assessed using questionnaires survey. The majority of respondents (>70%) believed that about 10% to 20% of the construction waste generated at their site could be reused in their project whereas about 5% of respondents thought that more than 50% of the waste generated at their site could be reused in their project.
2. The knowledge of respondents about the quantum of waste generated at a construction site revealed that an estimated

average of 5 tons/day of construction generated at the residential construction sites in Malaysia. The real-time analysis of the construction waste generated at the high-rise building construction was estimated as 4.4 ton/day, and for the housing projects, it was obtained as 2.47 ton/day, which was agreed with the predicted amount.

3. The construction waste generated in residential construction projects in Malaysia is usually composed of bricks and blocks, concrete, wood, metals, roofing materials, plastic, and glass. In the high-rise building construction, more than 70% of the generated waste was composed of concrete and aggregate. In contrary to high-rise building construction, the housing construction generated more than 80% wood as the waste. The composition of plastic, glass, ceramic, and the packing products was found quite low in all types of projects (<1%) 0.80% of the waste generated at the high-rise building sites was exported for recycling, whereas only 20% of the waste was exported from housing sites for recycling.
4. In Malaysia, there is a lack of information regarding the quantity of C&D waste reused and or recycled. The responses showed that the low rate of reuse and recycling of waste is due to many issues and challenges. The dominant issues are contamination, quality of waste, challenges in collection and transportation, and difficulties in sorting, transforming, and disposing of wastes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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