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Current 3R Practices on Construction Waste Minimization in Construction Site

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ABSTRACT

The rise of the construction industry nowadays has a lot to do with the production of industrial waste. The needs of the construction industry whether for developing countries or developed countries is something that cannot be avoided. The main objectives were to find the main causes of construction waste generation, assess the level of awareness of 3R concepts and to evaluate the current approach used at the construction site in reducing construction waste. The study involves companies involved in the construction industry, namely architects, consultants and contractors. The research method used is a questionnaire to the construction industry. Results show that most respondents are aware of the benefits of 3R practices but most of them also do not practice the 3R due to lack of knowledge. The finding of this research is the construction waste can be reducing after practising the 3R.

Keywords: Construction waste; waste minimisation; 3R concepts; reduce; reuse; recycle

INTRODUCTION

Construction waste is waste generated by the construction industry during construction, building rehabilitation, civil construction and construction operations, construction site clean-up, road construction and demolition activities, as well as excavation works. Soil, mortar, concrete, asphalt, glass, wood, plastic, and metal are some of the most frequent types of the debris. Construction waste can be minimised at various stages of the project's life cycle. Consumers, designers, contractors, and suppliers are among the supply chain stakeholders who have possibilities and responsibilities in reducing construction waste (Osmani 2012). Nonetheless, a lack of understanding of resource-efficient construction procedures has contributed to wasteful resource usage and the development of large amounts of frequently recycled construction waste. According to (Sa'adi & Ismail 2015), the government is responsible for providing guidelines in terms of legislation, policy, technology, and guidance to help the building industry execute waste management more effectively. Construction waste management is a system for tracking the cost of disposal of construction waste and promoting alternatives to disposal, such as reuse, reduction, and recycling, in order to limit the quantity of waste disposed of in landfills at the end of the process. The inefficiency of managing construction waste has a severe impact on the environment and the bottom line of construction projects worldwide. The carbon footprint and greenhouse gas emissions from the construction industry are substantial. Therefore, sustainable growth necessitates solutions for building waste management to prevent material waste (Musarat et al. 2023).

LITERATURE REVIEW

CONSTRUCTION WASTE

Waste is defined as "any inefficiency that results in wrong utilisation of equipment, materials, and labour, etc., or loss of capital by ordering larger quantities than those deemed required in the development of a structure," (Akhund et al. 2017). Rather than a single causative element, waste is typically the outcome of a combination of them. Waste is defined as the occurrence of material losses as well as the completion of unnecessary work that incurs additional expenditures but adds no value to the products. Therefore, it is possible to define waste as any financial loss caused by acts that result in direct or indirect costs but do not add value to the product from the perspective of the customer. Furthermore, the phrase "construction waste" refers to a collection of surplus materials originating from site clearing, excavation, construction, reconstruction, and demolition (Mhaske et al. 2017). Construction waste includes construction materials including concrete, plaster, wood, metal, broken tiles, bricks, masonry insulation, nails, and electrical wiring, as well as site preparation garbage such decaying materials and tree stumps. This form of waste is usually the heaviest, densest, and takes up the most storage area.

WAYS OF CONSTRUCTION WASTE GENERATION

According to (Ikau et al. 2016), there are four main causes that influence construction waste generation in construction sites: design cause, procurement cause, construction materials handling cause, and construction cause, which may lead to an increase or decrease in wastages on construction sites. While according to (Luangcharoenrat et al. 2019), the categories that contribute to construction waste are design and documentation, human resources, construction methods and planning, and material and procurement. Design modification, inattentive working attitudes and behaviours, inadequate planning and scheduling, and material storage were the most significant effect variables on construction waste creation in each category. Waste-inducing site and human resource management approaches, insufficient collaboration and support among stakeholders, equipment management, material logistics management, and poor working environments are the five most significant underlying causes of waste generation that obstruct sustainable practises (Fitriani et al. 2023).

CURRENT APPROACH IN CONSTRUCTION WASTE (CW) MINIMISATION

In helping to minimise the CW has come up with a model of assessment that comprised of three subsystems : the waste generation and disposal, waste reduction, and economic performance assessment (Hao et al. 2019). It is based on the interdependencies of important components that determine the economic performance of CW reduction. According to his report, improving trash sorting, reducing unlawful dumping, increasing government financial subsidies for waste recycling, and hiking the waste landfilling levy are all viable approaches to increase CW reduction's economic performance. Furthermore, model simulations show that integrating several waste reduction approaches produces better CW reduction results than using a single option. The study also reveals significant interrelationships of components affecting CW reduction's economic performance. In addition, (Jaillon et al. 2009) had also pointed out that one of the key advantages of prefabrication over traditional building, was a 52 percent reduction in construction waste. His study reveals that increasing the use of prefabrication in Hong Kong had significantly reduced construction waste production and alleviate management issues. On the other hand, (Salgın et al. 2017) further added that, a variety of factors such as incorrect planning decisions, insufficient work schedules, sudden weather conditions, and product supply shortages could all affect the construction process, resulting in debris generation at construction sites. These wastes have the potential to harm both living and non-living things. While eliminating all construction waste generated during the construction process is theoretically unattainable, it is possible to manage and recycle it.

Construction work modifications on a regular basis have caused uncertainty, making project management dynamic and unstable. Rework accounts for 30% of construction expenditures. Change orders were also the leading cause of construction debris. Construction experts were compelled to make changes based on their prior knowledge and assumptions, which were frequently based on incomplete data. One of the techniques to minimize changes is by using Building Information Modeling (BIM). Throughout the project life cycle, BIM provides a method for simulating field data and analysing the effects of building changes. The dynamic behaviour of variables due to changes in the scope of work could be examined by using virtual BIM data. A study done by (Porwal et al. 2020) shows that a client's efforts to reduce waste during the pre-project planning phase through coordinated BIM design work can save up to 25% on construction waste. Most respondents estimated that no more than 20% of the construction waste created on their site could be reused, whereas a smaller percentage estimated that more than 50% of the garbage created on their site could be reused (Mohammed et al. 2021).

CURRENT PRACTICES ON 3R CONCEPT IN CW MANAGEMENT

The need for reuse and recycling of materials waste has developed throughout time as a result of numerous infrastructure advancements, owing to rapid population expansion and urbanisation. For environmental reasons, some initiatives, such as limiting the use of finite resources and controlling waste disposal, have led to a push to recycle these materials when they reach the end of their useful lives (Mhaske et al. 2017). With present challenges with garbage exporting and waste importing corporations, developing new facilities for disposal or recycling is tough. Malaysia is concerned about these issues due to a lack of adequate waste disposal facilities in the country. A significant amount of construction materials is wasted on construction sites due to improper handling. Collaboration among all stakeholders involved in the planning, design, and construction stages is critical in reducing construction waste generated on-site. Implementing waste recycling systems would, in fact, aid in reducing the waste effect. The system has three main advantages: it requires fewer additional resources, it helps to reduce transportation and manufacturing costs, and it repurposes waste materials that would otherwise be disposed of in landfills (Umar et al. 2021). Furthermore, due to the depletion of natural aggregate reserves, a lack of land for waste disposal, and the high cost of waste treatment, the global construction industry is pushing for recycling of building and demolition waste.

Construction and demolition (C&D) waste management systems, particularly the 3Rs, would most likely need to expand to Asian cities. This necessitates coordination and cooperation among local, state, and federal governments in order to direct pressing environmental issues, as well as their innovative solutions and strategies, to the C&D sector. To achieve sustainable development in Asian countries, the construction sector can work to reduce waste in management by utilising and efficiently implementing waste minimization measures. Stakeholder participation, waste minimization strategies, adoption of appropriate environmental measures related to the 3Rs, policymaking, and efficient implementation of C&D waste management and capacity building are all important factors to consider in Asian countries (Nitivattananon & Borongan 2007).

Construction and demolition (C & D) trash is responsible for 27% of all MSW shipped to landfills in Canada. However, it is apparent that over 75% of the waste generated by the construction sector has a residual value, meaning it may be recycled, recovered, and/or repurposed. There is widespread recognition of the necessity for comprehensive and integrated waste management procedures, technologies, assessment systems, and regulations. Due to rising levels of construction waste, a lack of landfills, and the long-term environmental, economic, and social effects of disposed construction waste, sustainable construction waste management is a public health and natural ecology issue. Protection of the system is becoming increasingly vital. By implementing a sustainable and comprehensive strategy throughout the life cycle of a construction project, the study aims to maximise the 3Rs (reduction, reuse, recycling) and minimise the disposal of construction waste. A conceptual framework for managing C&D waste is proposed. In addition, C & D waste sustainability indicators based on the lifetime have been created. This method can be used to make judgments on construction and demolition waste material selection, sorting, recycling / reuse, and disposal or disposal options (Yeheyis et al. 2012).

Managing various wastes in many sections of the industry appears to be quite crucial nowadays. Different legislation exists in most modern Western countries around the world to reduce and manage waste in various industries. However, waste generation is unavoidable in the building industry, and waste is not decreased on construction sites. Malaysia has a number of construction projects underway and is considered a developing country. Needless to say, in these high-construction-demand countries, the amount of garbage produced skyrockets. Various sorts of garbage on building sites can result in a slew of social and environmental issues. In such a condition, it is evident that the country's waste disposal needs are extremely large. New ways to the disposal of construction waste have been developed in recent years. The "3R" strategy refers to the three fundamental waste management concepts of reuse, recycling, and reduction. 3R's achievement of construction waste reduction productivity indicates adaptability in construction waste management. Construction waste management may become unexpected as a result of 3R waste reduction among contractors. Increased building trash on landfills would be hazardous, while land might be constrained for solid waste disposal (Islam et al. 2021).

METHODOLOGY

The questionnaire was based on important topics discovered in the literature as well as professional interviews. A pilot poll of experienced architects, consultants, and contractors was used to finalise the questions. Respondents were asked to rate each factor on a scale of 1–5, with 1 being the most important and 5 being the least important, to reflect the importance of the factors in each question. An online questionnaire using Google Form was used due to its broader benefits, including the ease of reaching the target audience. The questionnaire was divided into four sections: background and consent information, demographic information about the participants, as shown in Figure 1, and a list of the questions utilised on a five-point Likert scale. The use of the Likert scale made it simple to determine the relative importance of the variables. A list-based random sampling strategy was used for the research population of Malaysian construction professionals.

The goal of this study is to determine how effective the 3R strategies of reuse, reduction, and recycling are in decreasing construction waste. In addition, this research also looked into a number of construction waste management techniques. The questionnaire was designed to determine the amount of construction waste generated, assess respondent awareness of construction waste minimization, identify approaches to construction waste minimization, and determine current construction waste minimization techniques. As indicated in Figure 1, there were 162 respondents, with Architect companies accounting for 22%, Consultant firms for 26%, and Contractor firms accounting for 52%. Figure 2 illustrates that the vast majority of respondents (74%) came from the private sectors, while another 26% came from the public sectors. As shown in Figure 3, the majority of respondents for this study had more than 10 years of experience in their field (57%), 17 percent had been working for about 5 to 10 years while the respondents with 3 to 5 years of experience and less than 3 years of experience recorded the same percentage at 13 percent for each category.

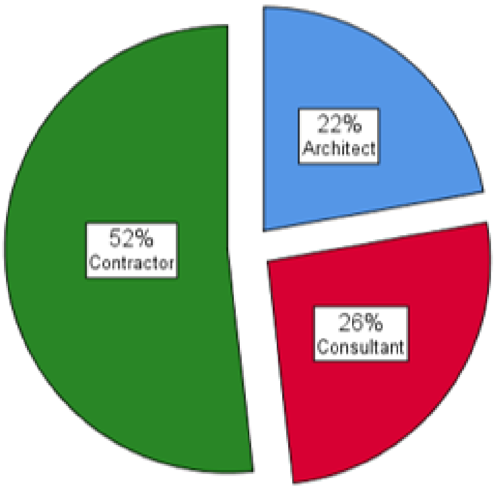

FIGURE 1. Response of questionnaires received from respondents

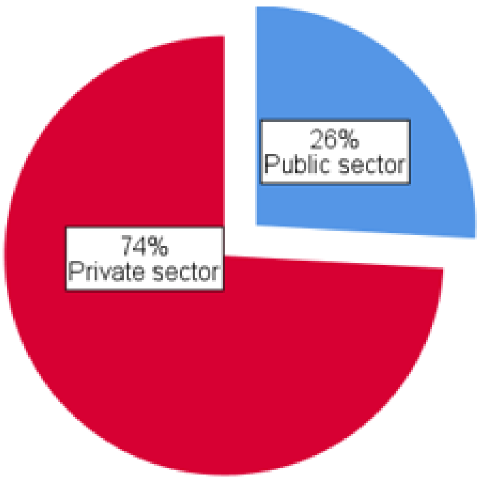

FIGURE 2. Type of Company

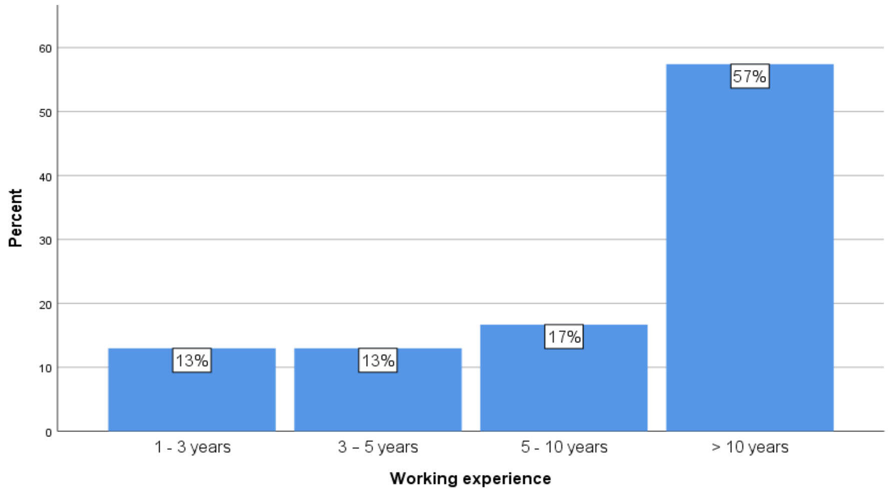

FIGURE 3. Experience level of respondents

RESULT AND DISCUSSION

RESULT ON WAYS OF CONSTRUCTION WASTE IS GENERATED

Table 1 displays the various types of construction waste that were generated on the job site. There are 20 items on the list to determine the most significant source of construction waste. These items were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Strongly agree). Higher scores suggest that the majority of respondents believed human errors (M=3.2778, SD=0.75798) were the leading cause of construction waste. Design changes (M=3.0741, SD=1.01880) and design mistakes (M=2.9815, SD=0.93564) came next.

The results from Table 1 are consistent with the findings of Mokhtar et al. (2011), who identified human and technical errors as the primary sources of waste generation. According to him, other construction activities that could be classified as human errors are untidy construction waste, over ordering, and poor handling. Furthermore, "frequent design changes and change orders," "design and construction detail errors," and "waste from cutting uneconomical shapes" have all contributed significantly to the generation of construction waste (Polat et al.2017). According to Fitriani's findings, there are eight underlying waste reasons accountable for construction waste generation in the Indonesian construction industry. Waste-inducing site and human resource management approaches, inadequate collaboration and support among stakeholders, equipment management approaches, material logistics management, and poor working environments are the five most significant underlying causes of waste generation that impede sustainability practises (Fitriani et al. 2023).

TABLE 1. Ranking on Way of Construction waste is generated

	Ways of Construction waste is generated	Mean	Std. Deviation	Rank
A1	Human errors	3.2778	.75798	1
A2	Design changes	3.0741	1.01880	2
A3	Design errors	2.9815	.93564	3
A4	Plan errors	2.9444	.85065	4
A5	Defective material	2.9259	.90242	5
A6	Rework	2.8889	.95878	6
A7	Essential cut offs	2.8704	.94664	7
A8	No waste management	2.8333	.83592	8
A9	Change orders	2.7778	.89858	9
A10	Equipment malfunction	2.7593	1.02032	10
A11	Poor workmanship	2.7037	.85530	11
A12	Error in planning	2.7037	.97731	12

continue ...

... *cont.*

A13	Poor supervision	2.6852	.88094	13
A14	Material deterioration	2.6296	.82574	14
A15	Improper machinery	2.5926	.83074	15
A16	Shipping error	2.5741	.78658	16
A17	Ordering error	2.4815	.81311	17
A18	Improper handling	2.4074	.87445	18
A19	Improper storage	2.2963	.97731	19
A20	Poor storage facilities	2.2222	.91909	20

RESULTS ON AWARENESS OF 3R CONCEPT IN CONSTRUCTION WASTE MINIMIZATION

This section illustrates the findings on respondents' awareness of 3R concept in minimizing construction waste. Table 2 indicates the respondents' awareness on the increasing of construction waste while Table 3 shows their awareness on the implementation of the 3R (Reuse, Reduce, Recycle) concept in assisting waste minimization at the construction sites.

TABLE 2. Respondents' Awareness on The Increasing of Construction Waste

Awareness on the increasing amount of construction waste in construction site.	Frequency	Percent
Not Aware	3	1.9
Neither Aware or Not Aware	9	5.6
Aware	24	14.8
Fully aware	126	77.8
Total	162	100.0

TABLE 3. Concept of 3R (Reuse, Reduce, Recycle) in practicing

Awareness on the concept of 3R (Reuse, Reduce, Recycle) in practicing the minimization of construction waste	Frequency	Percent
Not Aware	6	3.7
Neither Aware or Not Aware	15	9.3
Aware	54	33.3
Fully aware	87	53.7
Total	162	100.0

Table 2 reveals that more than half of those polled were fully aware of the growing volume of construction debris on the job site. As indicated in Table 3, the respondents were also aware of or had knowledge of the 3R idea, which could be employed on the construction site to reduce construction waste.

TABLE 4. Waste management with 3R concept to minimize construction waste.

Waste management with 3R concept to construction waste.	Frequency	Percent
Undecided	6	3.7
Agree	33	20.4
Strongly agree	123	75.9
Total	162	100.0

Table 4 shows the data on waste management with 3R concept to minimize construction waste, the results show that, the majority of respondents (96.1%) believed that the 3R concept should be used to manage construction waste on the job site. This demonstrates their confidence in applying the 3R principle to construction sites in order to reduce waste.

TABLE 5. Respondents' knowledge about 3R

Knowledge on 3Rs.	Frequency	Percent
Poor	6	3.7
Moderate	39	24.1
Good	45	27.8
Very Good	72	44.4
Total	162	100.0

Table 5 is on respondent's knowledge about 3R. According to the findings data, the majority of respondents (more than 50%) had a good understanding of the 3R idea.

TABLE 6. Respondents' Opinion on making the 3R Practice as mandatory at Construction Sites

Mandatory 3R practice in construction waste minimization	Frequency	Percent
Undecided	9	5.6
Agree	36	22.2
Strongly agree	117	72.2
Total	162	100.0

Table 6 displays the responses to the question of whether the 3R practise should be made mandatory on building sites. According to the findings, 94.4 percent of those polled felt that the 3R technique should be made mandatory at building sites to help reduce waste. This outcome is consistent with Table 5's findings that 72.2 percent of respondents had an excellent comprehension of the 3R concept.

RESULT ON CONSTRUCTION WASTE MINIMIZATION APPROACH IN CONSTRUCTION SITE

TABLE 7. The frequently used approach in construction waste minimization.

	Which are the frequently used approach in construction waste minimization?	Mean	Std. Deviation	Rank
C1	Careful evaluation of materials so that over ordering and site wastage is reduced.	4.2407	.96398	1
C2	Concreting – It is common to order extra concrete as a backup, minimize the quantity of backup concrete to reduce the quantity of scrub out.	4.2222	.99689	2
C3	Is there a regular cleaning of the waste collection centres?	4.1111	1.10335	3
C4	Rebar cutting - Placing order according to the correct dimension from the supplier so can reduce the steel reinforcement cutting.	4.0370	1.03892	4
C5	How frequent do you use the recycling bins?	4.0185	1.04835	5
C6	How often do you reduce the ordering construction materials for construction site?	4.0185	1.13374	6
C7	Practice just-in-time delivery to minimize damage to materials during on-site storage.	4.0185	.91551	7
C8	Material - Reduce bulk orders of material and order material according to the master schedule planning.	3.9815	1.03042	8
C9	There are enough recycling bins in your construction site.	3.9630	1.09141	9
C10	Is there a regular waste collection from the recycle bins in your construction site?	3.9074	1.07948	10
C11	Fragile material - Demand for lesser wrapping for fragile material.	3.7778	1.01541	11
C12	Do you clean and reuse construction materials for the next usage?	3.6667	.90547	12
C13	How often do you differentiate between what items to recycle?	3.5926	.95589	13

The data was analysed to determine the most effective method for reducing construction waste. Table 7 shows the mean value of each significance component of the approach technique in building waste minimization, along with its rank. The majority of respondents agree that their most common practise on construction sites was "carefully evaluating materials" (M = 4.2407, SD = 0.96) to avoid over-ordering and site waste. Second place went to "concreting work" (M = 4.222, SD = 1.0), where a specific amount of extra concrete was allowed in order to limit the amount of scrub out. The approval of site employees on the "regular cleaning service" (M = 4.1111, SD = 1.10) at a building site came in third.

Items C1-C4 in Table 7 are the four most commonly used methods for reducing construction waste on the job site. Thus, material taking off works are critical in ensuring the exact total of materials required at the sites. These include building materials such as concrete, formwork, and reinforcing/steel bar. The amount of work activities carried out at the construction site must be verified by the calculation on the volume of concrete to be used in concrete works. Furthermore, the size of the formwork and the cutting of the materials must be precisely measured to avoid mistakes that can contribute to construction waste.

Items C5-C8 are moderately used in reducing construction waste. These include using recycle bins, reducing construction material orders, planning delivery times, and reducing bulk orders at construction sites. Reducing construction material orders necessitates stock monitoring to ensure that the materials can be stored in an appropriate location. It is also critical to ensure that all deliveries at the site take place on the scheduled dates and times.

Table 7 items C9-C13 are not fully utilised by respondents in reducing waste on construction sites. To avoid congestion and untidiness on construction sites, all construction parties must adopt these approaches. Ignoring the importance of these approaches may result in larger problems in the future.

CURRENT TECHNIQUE USED IN CONSTRUCTION WASTE MINIMIZATION

This part is designed to assess the most recent 3R approach currently in use on a construction site. The respondents were asked about a variety of 3Rs (Reduce, Reuse, and Recycle) approaches that were likely to be used or applied. Table 8 illustrates the outcome.

Items D1-D6 are the statements related to the use of recycling methods; items D7-D13 are about reducing methods; while items D14–D20 are about reusing methods used in minimising waste generation at construction sites. Item D1 (M = 4.18; SD=0.84) was the most popular choice among respondents in the recycling group. Item D7 (M = 4.69; SD=0.54) was the top choice for the reducing method, while item D14 (M = 4.69) was ranked as the most popular option for the reusing method.

The top three spots in the ranking come from the restricted category. Modern construction methods (M = 4.7, SD = 0.54), improved logistics (M = 4.5, SD = 0.63), and regulating and standardising management plans (M = 4.4, SD = 0.69) all contribute to cost savings.

TABLE 8. Current 3Rs technique used in construction waste minimization

	Current 3Rs technique used in construction waste minimization	Mean	Std. Deviation	Rank
D1	“Recycle” -Harvesting materials or auxiliaries at construction or demolition site	4.1852	0.84311	7
D2	“Recycle” -Limiting number of materials and components and easy-to-separate materials	4.1296	0.86433	10
D3	“Recycle” -Using recycled material for business-to-business refund system	4.0556	0.87228	12
D4	“Recycle” -Driving innovation in recycling opportunities	3.8333	0.87937	17
D5	“Recycle” -Recycling waste plasterboard and other sources of waste gypsum	3.7222	0.914	18
D6	“Recycle” -Concrete can be pulverize and recycled back into concrete for reuse purpose	3.6667	1.0031	19
D7	“Reduce” -Using modern methods of construction	4.6852	0.53998	1
D8	“Reduce” -Improving logistics of materials	4.5	0.63295	2
D9	“Reduce” -Regulating or standardizing management plans of hazardous materials.	4.463	0.63186	3
D10	“Reduce” -Identifying and quantifying amounts of construction waste and treatment needs.	4.2963	0.7632	5
D11	“Reduce” -Using prefabricated materials and elements	4.2778	0.70711	6
D12	“Reduce” -Employing construction waste management plans	4.1481	0.82825	9
D13	“Reduce” -Monitoring waste generation	4.037	0.74674	13
D14	“Reuse” -Using same materials for same applications	4.463	0.68831	4
D15	“Reuse” -Establishing waste separation and collection strategies	4.1667	0.74141	8
D16	“Reuse” -Applying innovative storage and handling practices	4.0926	0.82511	11
D17	“Reuse” -Renting and reusing of auxiliaries	4.037	0.79508	14
D18	“Reuse” Metals like aluminum, copper, reinforcement steel and steel can be sent to scrap yard for reuse purpose	4.037	0.79508	15
D19	“Reuse” -Maximizing production of high quality recycled aggregate	3.9074	0.95101	16
D20	“Reuse” -Timber such as wood can be re-milled and reuse for other purposes	3.6296	0.80286	20

CONCLUSION

The major goal of this study is to determine the elements that influence construction waste minimization on a construction site. A questionnaire survey was used to establish the level of relevance of these causal elements. The responders were drawn from the architectural, consulting, and construction industries, with on-the-job experience. The mean value was used to determine the relative relevance of the causative elements before ranking them. The study's findings revealed the most important aspects in building waste minimization practises based on the 3R concept, as well as the level of awareness of the 3R concept. Construction waste is generated mostly by human errors, design revisions, and design flaws.

Most construction workers are aware of or have heard of the 3R concept, which could be used on the job site, and they agreed that it should be made mandatory to use on construction sites in order to reduce waste. On construction sites, the most commonly used approach and practise was "carefully evaluating materials" to avoid over-ordering and site wastage, "concreting work" as an add-on to reduce scrub out and maintain "regular cleaning service." The most recent 3R techniques being used on a construction site are reducing construction waste using modern construction methods, improving site logistics, and standardising management plans. As a result, the study indicates that employing reduce, reuse, and recycle ways to reduce construction waste on building sites is critical.

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DECLARATION OF COMPETING INTEREST

None.

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