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Strategies for Enhancing Construction Waste Recycling: A Usability Analysis

Mazen M. Omer [1], Rahimi A. Rahman [1,2,*] and Saud Almutairi [3,*]

[1] Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Gambang 26300, Malaysia; mazentri@gmail.com
[2] General Educational Department, Daffodil International University, Dhaka 1341, Bangladesh
[3] Unaizah College of Engineering, Qassim University, Buraydah 51431, Saudi Arabia
* Correspondence: arahimirahman@ump.edu.my (R.A.R.); sa.almotiry@qu.edu.sa (S.A.)

Abstract: Prior works have suggested various strategies to increase construction waste recycling (CWR) rates. However, choosing the strategies is challenging without a lateral comparison. Therefore, this study aims to compare the usability of various strategies that target the enhancement of CWR implementation. To achieve this purpose, thirteen CWR enhancement strategies were identified from a systematic literature review. Then, questionnaire survey data were collected from 106 construction project managers. The collected data were analyzed via mean score ranking, normalization, overlap analysis, agreement analysis, and factor analysis. Additionally, the data were analyzed using a proposed formula for computing usability indexes using the cost, easiness, and effectiveness values. The results show that three strategies have high usability indexes: organize temporary bins in each construction zone, identify construction activities that produce recyclable materials, and enhance company policies related to CWR. These strategies with high usability indexes are consistent with the overlapping cheap, effective, and easy strategies. This study provides researchers and practitioners with optimal strategies for enhancing CWR implementation. Effective CWR enhancement strategies can improve CWR rates in construction projects. Future researchers can also adopt this study's approach in computing usability indexes through questionnaire surveys.

Keywords: construction industry; sustainable development; sustainable construction; decision making; construction waste recycling; usability analysis

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1. Introduction

Construction waste (CW) is the waste produced during construction activities in the preconstruction, construction, and post-construction phases, and it is becoming an urgent environmental issue worldwide [1–3]. Specifically, in several countries, disposing in landfills without recycling remains the common method for managing CW [4]. As a result, CW constitutes up to 30% of landfills globally [5]. This high proportion of CW negatively impacts international agendas and nations in achieving sustainability [6,7]. Construction waste recycling (CWR) is considered an essential solution to address CW-related issues [7]. Adopting CWR would lead to significant reductions in various issues related to CW [8]. CWR is worthy because it provides valuable opportunities in exploiting CW's economic and environmental benefits [8]. Moreover, CWR can convert CW into new materials for use, which provides alternative resources [9]. Thus, CWR contributes effectively to achieving sustainability in managing CW.

Better implementation of CWR in construction projects can be achieved by adopting enhancement strategies. Adopting enhancement strategies would directly influence CWR implementation at construction sites by increasing CWR rates [10,11]. However, CWR enhancement strategies face various difficulties that curb their implementation, including a lack of technology options in converting construction waste into recycled material [11], poor quality of recycled products [12], and little opportunity to trade recycled materials [7]. Construction practitioners also ran into some obstacles due to the limited number of CWR facilities [13]. Thus, adopting strategies that address challenges associated with CWR implementation can help increase CWR rates.

Usability analysis is a combination of several properties and attributes [14]. Additionally, usability analysis evaluates an innovation's effectiveness, efficiency, and satisfaction in achieving the desired goals in various environments [15]. Therefore, adopting usability analysis based on cost-effectiveness and cost-easiness would help implement CWR enhancement strategies in construction projects. It could guide decision makers in choosing the appropriate enhancement strategies for implementing CWR within construction practices. Moreover, determining the enhancement strategies in three-dimension such as cost, effectiveness, and easiness would be valuable to stakeholders in implementing CWR in construction projects. Thus, usability analysis based on cost-effectiveness and cost-easiness can provide useful evidence for decision makers.

This study aims to compare the usability of existing CWR enhancement strategies. To achieve that, this study evaluates the cost, effectiveness, and easiness of the strategies from project manager perspectives through a questionnaire survey. The study findings provide an overview of CWR enhancement strategies by determining their cost-effectiveness and cost-easiness. The overview can help researchers and industry practitioners enhance the implementation of CWR enhancement strategies, thereby reducing the rejection among project managers, and offering a new reference for future research.

Prior works indicated several difficulties of CWR, such as insufficient relevant policies, regulations, and acts [16]. Those difficulties contribute to increasing illegal disposal at landfills. The lack of economic feasibility for recycling CW has been a hindrance, which is critical in influencing stakeholder decisions [17,18]. Furthermore, the poor communication among parties involved would hinder CWR in practice [19]. Moreover, a lack of demand for recycled products and the limited availability of recycling facilities is a major challenge for CWR implementation in developing countries [20]. There is a shortage in policy support from the government regarding recycling CW [7]. This causes a depletion of natural resources and an increment in landfill usage. Furthermore, prior works identified several difficulties, including hard-to-collect CW being distributed across various locations at construction sites and the lack of locally qualified companies in CW [18]. Practitioners also consider CWR costly because the recycling process requires more workers, which requires additional money, and no competition among companies, which causes poor quality of recycled products. The poor quality of recycled products also results in reluctance in CWR implementation among stakeholders [12]. Thus, the difficulties faced are considerable and becoming a burden in implementing CWR in construction projects.

Several strategies have been stated for enhancing CWR implementation in construction projects. A mobile recycling crusher on-site could deliver to enhance increasing the recycling rate of CW [21]. Other works reported that applying economic instruments and standards for recycled materials could improve CWR rates [22]. Therefore, government support plays a significant role in enhancing CWR rates. Based on prior work, several enhancement strategies are needed to enhance on- and off-site waste recycling practices, including adopting off-site recycling, developing on-site recycling equipment, and creating a demand-supply information-sharing platform [16]. Thus, determining the appropriate enhancement strategies is necessary to increase CWR implementation in construction projects.

Construction projects may not pursue recommended practices to enhance CWR implementation in construction projects. Thus, understanding the importance of usability analysis is critical to minimizing the rejection of CWR in construction projects. As a result, usability analysis can be one of the approaches to reducing project managers' refusal to adopt CWR enhancement strategies in construction projects. However, the current knowledge is missing that information. The strategies for implementing CWR should be identified and assessed to provide that knowledge. Thus, this study will fill the gap by analyzing the usability of the CWR enhancement strategies via cost, effectiveness, and easiness.

The organization of the paper is as follows. The next section details the systematic literature review (SLR) to identify the CWR enhancement strategies. This section also introduces the survey development and participants. Subsequently, section two reports the survey results and analysis. Followed by section three with discussion, implications, and limitations, as well as recommendations for future studies. The last section is devoted to summarizing the findings.

2. Methodology

2.1. Survey Development

A questionnaire survey was developed according to information derived from an SLR. SLR involves a comprehensive approach (e.g., searching techniques, screening criteria, data extraction, and data synthesis) to capture the specific works and synthesize prior findings [23]. Therefore, an SLR is an inclusive and reliable process used to identify, evaluate and interpret work relevant to a determined topic area, research question, or phenomenon of interest in prior published studies [24]. In addition to reviewing the significant literature, SLR is used to answer a particular question, mitigate favoritism in selecting and inclusion of studies, evaluate the quality of the included works, and summarize prior works objectively [25].

The SLR in this study aims to identify and extend the body of knowledge on CWR enhancement strategies in the construction domain. Furthermore, the SLR was established following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method [26]. The PRISMA provides evidence-based findings and enhances the reporting quality of the review through the transparent selection of compatible articles [27]. This method was adopted due to the followed structural methodology and analytic technique [28]. Furthermore, its compliance in the SLR was considered significant in several prior works in construction management [29,30]. In this regard, the development of the review involves the following five steps: (i) research objective definition; (ii) database selection; (iii) keyword identification; (iv) selection of compatible articles; and (v) data extraction [24]. Details related to these five steps for this study are as the following:

i. Research objective: Compare the usability of enhancement strategies for CWR.
ii. Database selection: Scopus as it is the most extensive compared to other databases [31]. Furthermore, its accuracy and significant coverage than other databases [32].
iii. Keywords selection: ‘recycling’, ‘waste’, ‘construction’, and ‘project’. Articles with those keywords in their title, abstract, or keywords are included in the review. The exact search string is: TITLE-ABS-KEY (recycl* AND waste AND construction AND project). The search was on 4 May 2020, yielding 961 papers detected in total.
iv. Selection of compatible articles: The main purpose of this process is to detect those papers aligned with the research subject. The researchers determined the inclusion and exclusion standards to support the selection criteria process. The search selects only articles and reviews papers written in English and published between 2000 and 2020 to ensure that all extracted information was up to date. Moreover, the search considers those only in the area of engineering, business, social science, economics, and decision making to make certain that most papers are related to the research area. Finally, only journals that published at least two articles were selected for the review process [33]. This process resulted in 167 papers from 34 journals. In addition, this process of filtering the SLR is similar to previous works in construction management research [10,29,34]. The article selection process started with reading the titles and abstracts for all the papers and selecting papers with results directly related to the study objective. In this regard, the following inclusion standards were utilized to determine the papers: (1) the paper should be specifically related to construction waste recycling; (2) the paper should cover at least either the concept, process, or application of construction waste recycling in the construction projects; and (3) the paper should mention any discussion related to construction waste recycling. The articles that do not contain the criteria mentioned above were screened out. In addition, some

papers that were not relevant were also excluded via screening. By following the inclusion standards, 123 papers were excluded. In addition, to ensure the reliability of the SLR, all researchers work together in the process of filtering and coding. In order to this process, only when the researchers agree that a paper does not meet the study's inclusion standards can it be excluded. Additionally, if there are any conflicts of opinion, they will resolve via discussion between the researchers. At the end of this step, 44 papers were identified.

v. Data extraction: In this stage, the SLR extracts the CWR enhancement strategies from the 44 papers within one month to finalize the whole process. In addition, all authors validated the latest sample to increase the validity standards.

As a result, thirteen CWR enhancement strategies were identified and inserted into the questionnaire survey. Table 1 shows the list of identified CWR enhancement strategies. The survey design involves measuring the CWR enhancement strategies from three aspects: cost, effectiveness, and easiness. The survey adopts a five-point Likert-type scale to measure those aspects. The Likert scales are used significantly in survey studies to measure respondents' perspectives on given questions [35]. This technique is similar to published works in the construction waste recycling domain [10,36]. Additionally, a five-point Likert scale was utilized to raise the rate and quality of response from participants in the survey [37]. The Likert-scale ranges from 1 (extremely expensive) to 5 (extremely cheap) for cost, 1 (very low) to 5 (very high) for effectiveness, and 1 (very difficult) to 5 (very easy) for easiness. At the end of each question, the respondents can provide their points of view for additional enhancement strategies.

To judge whether the questionnaire is an appropriate measure of the research constructs, and respondents understand the questions, this study acquires expert feedback through a pilot test. The pilot test involves six respondents, three academics, and three industry experts. Furthermore, the pilot test ensured the correct interpretation of the questionnaire by participants [38]. The experts were inquired to review and assess the questionnaire survey for construction validity, time to respond, designing questions, and ease of understanding by respondents. Additionally, the pilot test provided that the variables identified were acceptable and comprehensive. Moreover, it provided an additional opportunity of asking the respondents about other strategies that should be added as part of the CWR enhancement strategies. Figure 1 shows the workflow of the study.

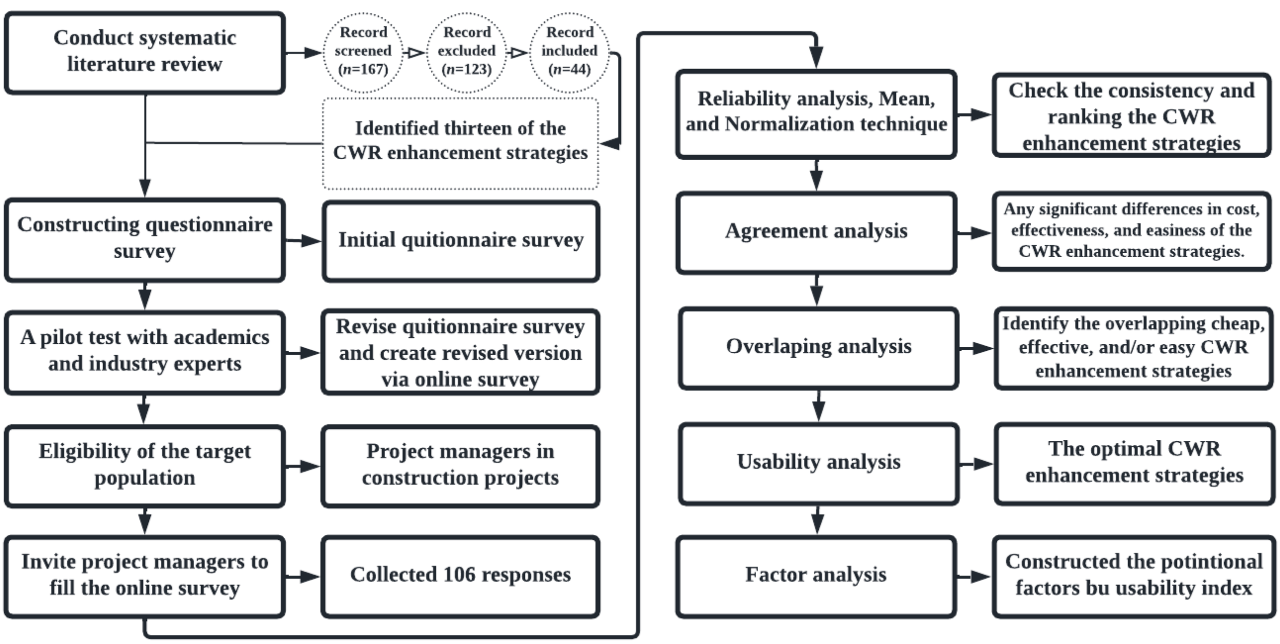

Figure 1. The workflow of the study.

Table 1. Strategies for enhancing construction waste recycling (CWR).

Code	Strategy	References
S01	Raise project team awareness on CW	[39–54]
S02	Adopt off-site construction practices (e.g., prefabrication)	[49,53,55–59]
S03	Adopt on-site construction practices (e.g., mobile recycling)	[45,60–63]
S04	Acquire certifications related to CW recycling from the government (e.g., green building, LEED)	[40,41,64,65]
S05	Prepare dedicated spaces to sort CW	[56,66–69]
S06	Organize temporary bins in each construction zone	[67,69,70]
S07	Identify construction activities that produce recyclable materials	[39,40,71]
S08	Adopt a database for collecting CW	[43,46,48,49,59,62,69,70]
S09	Use information technology to facilitate CWR processes (e.g., website)	[39,48,49,72,73]
S10	Use CW recycled materials as alternative construction materials	[54,55,57,74–81]
S11	Satisfy the requirements of CWR processes	[42,48,67,68,77,82]
S12	Enhance company policies related to CWR	[51,56,74]
S13	Adhere to national legislations related to CWR	[51]

2.2. Survey Participants

The main significant part of the data collection is selecting the appropriate target population. This study's target population is project managers in the Malaysian construction industry because implementing the strategies in construction projects is under a project manager's responsibility [83]. To proceed with this, this study uses electronic communication platforms to reach a wide range of the target population. Therefore, the survey was converted using an online platform to distribute the questionnaire to project managers. This technique could save survey time, reduce social desirability bias, and make it easier to reach the target population [84]. The online survey was available to participants from 14 September 2020 to 22 October 2020. During this period, authors sent numerous invitations to project managers. Furthermore, follow-up reminders were periodically sent out for non-respondents to encourage participation. Additionally, after responding, the participants were asked to send the survey to other project managers. In other words, the respondents were selected based on their willingness to participate in the survey.

Eventually, a total of 106 valid responses were collected. The total responses of the study may seem small. However, scholars agree that a minimum sample size of 30 is sufficient for statistical data analysis and finding significant conclusions [85]. Furthermore, the obtained sample size is within the range outlined by [86] and higher than the threshold of 100 needed for factor analysis. Moreover, this sample size is similar to that of other prior works related to construction waste recycling, with 109 responses [36] and 108 practitioners [10]. Therefore, the total responses were considered adequate for this study. Table 2 summarizes the respondent information involved in the survey. Furthermore, the other information, such as organization type, years of experience, region, and contractor grade, are described in the table.

Table 2. Respondent information.

Attributes	Categories	(*n* = 106)		Attributes	Categories	(*n* = 106)	
		n	%			*n*	%
Position	Project Manager	106	100.0	Location	Central Region	51	48.1
Organization	Contractor	63	59.4		Southern Region	20	18.9
	Consultants	22	20.8		Northern region	16	15.1
	Clients	16	15.1		East Malaysia	15	14.2
	Other.	5	10.7		East Coast Region	4	3.8
Experience	11–20 Years	45	42.5	Contractor Grade	Grade 7-No limit	56	52.8
					Not applicable	37	34.9
	More than 20 years	25	23.6		Grade 1	4	3.8
					Grade 2	4	3.8
	6–10 years	23	21.7		Grade 6	2	1.9
					Grade 3	1	0.9
	1–5 years	13	12.3		Grade 4	1	0.9
					Grade 5	1	0.9

2.3. Survey Results and Analysis

2.3.1. Reliability Analysis

Before conducting the analysis, a reliability test was performed using Cronbach's alpha coefficient to check the reliability and internal consistency of the thirteen enhancement strategies. A Cronbach's alpha value of 0.75 or more usually is addressed as a rule to denote an agreeable level of reliability [87]. In this regard, the study adopts Equation (1) to compute Cronbach's alpha value for the cost, effectiveness, and easiness of the CWR enhancement strategies. The formula of Equation (1) is as follows:

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \tag{1}$$

where, N equals the number of items, $\bar{c}$ is the average item-pairs covariance among the items. $\bar{v}$ is the average variance. The results of the Cronbach's alpha values for the data on cost, effectiveness, and easiness are 0.862, 0.928, and 0.878, which is higher than the recommended threshold. As a result, the data were reliable and valid.

2.3.2. Mean Score Ranking and Normalization Technique

The mean score ranking technique and standard deviation were adopted to determine the relative significance of the thirteen CWR enhancement strategies. Suppose two or more CWR enhancement strategies have the same mean score. In that case, the enhancement strategy with the lowest standard deviation is assigned as the highest rank [88]. Additionally, the normalization technique was employed to facilitate the extraction of important CWR enhancement strategies by calculating the normalized values of each enhancement strategy based on the mean scores. These techniques are commonly used in similar studies in construction management to assess the relative significance of specific items [10,36,89]. Additionally, normalized value refers to adjusting all collected data to standardized values assigned to specific ranges between 0 and 1. Equation (2) shows the formula used for computing the normalized values for each strategy, as adopted from [90,91]. Moreover, the normalized value of $\geq$0.60 was adopted as the threshold because the adopted value is equal to a three on the five-point Likert scale, which is the minimum for a significant or very significant value [92].

$$\text{Normalized value} = \frac{(\text{Mean value of strategy} - \text{Minimum mean value})}{(\text{Maximum mean value} - \text{Minimum mean value})} \tag{2}$$

Table 3 shows the mean, standard deviation, and normalized values of collected data from respondents on the cost, effectiveness, and easiness of thirteen CWR enhancement strategies. Based on normalized values, seven strategies (S06, S07, S08, S01, S12, S10, S09) have normalized values $\geq$ 0.60 for cost. Five strategies (S06, S07, S12, S11, S04) have normalized values $\geq$ 0.60 for effectiveness. For easiness, five strategies (S06, S07, S01, S12, S05) have normalized values $\geq$ 0.60. In other words, these are the cheap, effective, and/or easy CWR enhancement strategies.

Table 3. Results for mean score ranking, normalization technique, and Kruskal–Wallis.

Code	All Respondents				Contractor		Consultants		Clients		Other		Kruskal–Wallis *p*-Value
	Mean	SD	NV	Rank	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Cost													
S06	3.07	0.796	1.000 [a]	1	2.97	0.822	3.09	0.684	3.38	0.885	3.20	0.447	0.476
S07	2.99	0.724	0.906 [a]	2	2.87	0.684	3.05	0.722	3.25	0.856	3.40	0.548	0.172
S08	2.89	0.666	0.776 [a]	3	2.78	0.683	2.95	0.635	3.19	0.655	3.00	0.000	0.124
S01	2.85	0.728	0.729 [a]	4	2.76	0.756	2.86	0.640	2.94	0.574	3.60	0.894	0.132
S12	2.82	0.778	0.694 [a]	5	2.70	0.687	3.00	0.976	2.88	0.806	3.40	0.548	0.148
S10	2.81	0.794	0.682 [a]	6	2.83	0.834	2.68	0.716	2.75	0.775	3.40	0.548	0.299
S09	2.76	0.724	0.624 [a]	7	2.76	0.777	2.73	0.631	2.75	0.683	3.00	0.707	0.866
S05	2.63	0.760	0.459	8	2.67	0.762	2.45	0.739	2.56	0.814	3.20	0.447	0.142
S03	2.55	0.745	0.353	9	2.46	0.800	2.77	0.685	2.56	0.629	2.60	0.548	0.242
S13	2.54	0.706	0.341	10	2.48	0.715	2.36	0.658	2.94	0.680	2.80	0.447	0.058
S02	2.53	0.693	0.329	11	2.54	0.714	2.50	0.598	2.38	0.806	3.00	0.000	0.095
S11	2.52	0.693	0.318	12	2.49	0.693	2.45	0.671	2.69	0.793	2.60	0.548	0.939
S04	2.26	0.694	0.000	13	2.33	0.741	2.14	0.640	2.13	0.619	2.40	0.548	0.536
Effectiveness													
S06	3.58	0.850	1.000 [a]	1	3.41	0.816	3.86	0.834	3.63	0.885	4.20	0.837	0.041 [b]
S04	3.57	0.805	0.960 [a]	2	3.48	0.759	3.86	0.941	3.63	0.719	3.20	0.837	0.054
S12	3.54	0.819	0.846 [a]	3	3.46	0.858	3.73	0.767	3.50	0.816	3.80	0.447	0.475
S07	3.53	0.907	0.808 [a]	4	3.38	0.974	3.73	0.827	3.75	0.775	3.80	0.447	0.373
S11	3.50	0.759	0.692 [a]	5	3.41	0.816	3.77	0.752	3.50	0.516	3.40	0.548	0.203
S03	3.46	0.917	0.538	6	3.25	0.933	3.82	0.958	3.69	0.704	3.80	0.447	0.062
S01	3.45	0.947	0.500	7	3.27	0.954	3.77	0.922	3.63	0.957	3.80	0.447	0.107
S13	3.45	0.917	0.500	8	3.35	0.953	3.91	0.921	3.31	0.602	3.20	0.837	0.093
S05	3.44	0.895	0.462	9	3.27	0.954	3.55	0.671	3.75	0.856	4.20	0.447	0.036 [b]
S08	3.38	0.961	0.192	10	3.30	0.891	3.59	0.854	3.38	0.806	3.40	0.894	0.607
S02	3.38	0.867	0.192	11	3.25	0.999	3.36	0.902	3.94	0.854	3.20	0.447	0.032 [b]
S09	3.34	0.925	0.038	12	3.21	1.003	3.73	0.767	3.31	0.704	3.40	0.894	0.193
S10	3.33	1.021	0.000	13	3.13	1.070	3.45	1.101	3.88	0.500	3.60	0.548	0.037 [b]
Easiness													
S06	3.25	0.944	1.000 [a]	1	3.17	0.871	3.14	1.207	3.44	0.814	4.00	0.707	0.148
S07	3.02	0.828	0.733 [a]	2	2.33	0.622	2.41	0.666	2.50	0.966	2.80	0.837	0.480
S12	2.95	0.832	0.656 [a]	3	2.81	0.859	3.14	0.834	3.06	0.680	3.60	0.548	0.055
S05	2.94	0.934	0.644 [a]	4	3.08	0.867	2.82	0.853	3.00	0.632	3.20	0.837	0.275
S01	2.92	0.973	0.622 [a]	5	2.54	0.668	2.59	0.796	2.81	0.655	3.20	0.447	0.590
S09	2.86	0.856	0.544	6	2.78	0.906	2.91	0.921	2.75	0.931	3.40	0.894	0.225
S08	2.84	0.745	0.522	7	2.84	0.884	2.86	0.941	3.31	1.138	3.00	1.581	0.380
S03	2.83	0.910	0.511	8	2.40	0.730	2.59	0.908	2.63	0.806	3.20	0.447	0.504
S02	2.81	0.896	0.489	9	2.86	0.931	2.95	0.999	3.06	0.929	3.60	0.548	0.667
S10	2.62	0.798	0.267	10	2.75	0.695	3.05	0.785	2.81	0.834	3.20	0.837	0.651
S11	2.62	0.696	0.267	11	2.81	0.877	2.82	1.053	2.69	0.793	3.20	0.837	0.128
S13	2.51	0.784	0.133	12	2.89	0.845	3.00	0.690	2.50	1.033	3.00	1.000	0.122
S04	2.40	0.699	0.000	13	2.62	0.812	2.55	0.739	2.81	0.750	2.40	1.140	0.675

[a] The normalized value indicates that the success factor is critical (normalized $\geq$ 0.60). [b] The Kruskal–Wallis *H*-test result is significant at the significance level at *p*-value < 0.05.

2.3.3. Agreement Analysis

To validate whether different organization types, including consultants, contractors, clients, and others, Kruskal–Wallis *H*-test was conducted to determine any significant differences in their perception of cost, effectiveness, and easiness of the CWR enhancement strategies. The Kruskal–Wallis *H*-test is the most common alternative nonparametric statistical analysis method to compare the means between two groups or more [93]. Moreover, the comparison can be equal or different sample sizes among the groups. Table 3 shows that the Kruskal–Wallis *H*-test results present no statistically significant differences among the organization types in cost and easiness. In contrast, effectiveness indicates statistically significant differences among the organization types of consultants, contractors, and clients.

A post hoc Dunn's multiple comparison test was performed to find the mean differences among groups of organization types [94]. Therefore, in conformity with the Dunn test results, it was found that statistical differences between contractors and clients in (S05, S02, and S10). Additionally, it identified statistical differences between contractors and consultants (S06). In addition, it indicated statistical differences between consultants and clients (S02). The results are shown in Table 4.

Table 4. Results for post hoc Dunn's multiple comparison test.

Code	Strategy	Contractors-Clients	Contractors-Consultants	Consultants-Clients
S06	Organize temporary bins in each construction zone	0.328	0.020 [a]	0.359
S05	Prepare dedicated spaces to sort CW	0.047 [a]	0.339	0.331
S02	Adopt off-site construction practices	0.005 [a]	0.680	0.036 [a]
S10	Use information technology to facilitate CWR processes	0.006 [a]	0.157	0.200

[a] The significant difference level at $p < 0.05$.

2.3.4. Overlap Analysis

The overlap analysis technique was employed to identify the overlapping cheap, effective, and/or easy CWR enhancement strategies. The overlap analysis is a decision-making technique that can compare two or more groups to determine resemblances and differences [95]. Additionally, the overlap analysis simply combines the best variables and eliminates the non-explanatory variables [96]. This technique is commonly adopted in similar works in construction management to recognize the overlapping among the variables [10,97,98]. This technique used circles to show a group with edges that overlap clearly. The findings would help the stakeholders in selecting the optimal strategy. Figure 2 shows the results of the overlap analysis.

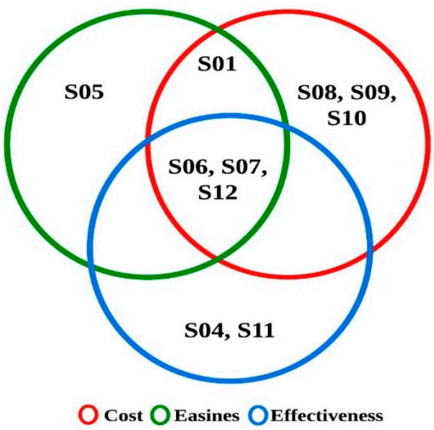

Figure 2. Results for the overlap analysis (Legend: S01: raise project team awareness on CW; S04: acquire certifications related to CW recycling from the government (e.g., green building, LEED); S05: prepare dedicated spaces to sort CW; S06: organize temporary bins in each construction zone; S07: identify construction activities that produce recyclable materials; S08: adopt a database for collecting CW; S09: use information technology to facilitate CWR processes (e.g., website); S10: use CW recycled materials as alternative construction materials; S11: satisfy the requirements of CWR processes; S12: enhance company policies related to CW).

2.3.5. Usability Analysis

Using the output of the mean score ranking technique for cost, effectiveness, and easiness of the thirteen CWR enhancement strategies, the study adopts Equation (3) to compute the usability index. Moreover, Equation (3) considered the cost as the significant side to decide the usability index values by dividing the result by multiplying the value of effectiveness and easiness values on the reverse cost value. In this study's survey, respondents responded to the identified CWR enhancement strategies using a five-point Likert scale ranging from 1 (extremely expensive) to 5 (extremely cheap) for cost. To reverse the cost of CWR enhancement strategies, we reverse the Likert scale so that 1 turns into 5, and 5 turns into 1. The following Equation (3) is the formula that could reverse the cost scoring.

$$\text{Usability index} = \frac{(\text{ Effectiveness } \times \text{ Easiness })}{(\text{ Reverse Cost })} \tag{3}$$

where the respective actual values represent effectiveness and easiness. On the other hand, reverse cost = maximum scale + 1 − (the actual cost value). For example, in this study, the maximum Likert scale is 5. Therefore, the reverse cost for an actual cost value of 1 would be 5 + 1 − 1 = 5.

Additionally, Equation (2) was adopted to calculate the normalized values to assist in ranking the list of usability indexes. As a result, the usability index findings are three CWR enhancement strategies as following 'organize temporary bins in each construction zone (S06)', 'identify construction activities that produce recyclable materials (S07)', and 'enhance company policies related to CW (S12)', respectively. Table 5 represents the results for the usability index.

Table 5. Results for the usability index.

Code	Strategy	Usability Index	Standard Deviation	NV	Rank
S06	Organize temporary bins in each construction zone	4.64	3.232	1.000 [a]	1
S07	Identify construction activities that produce recyclable materials	4.07	2.701	0.746 [a]	2
S12	Enhance company policies related to CW	3.84	2.750	0.644 [a]	3
S01	Raise project team awareness on CW	3.67	3.166	0.567	4
S05	Prepare dedicated spaces to sort CW	3.42	2.474	0.456	5
S08	Adopt a database for collecting CW	3.42	1.891	0.457	6
S09	Use information technology to facilitate CW recycling processes (e.g., website)	3.24	1.850	0.376	7
S10	Use CW recycled materials as alternative construction materials	3.18	2.751	0.347	8
S03	Adopt on-site construction practices (e.g., Mobile Recycling)	3.09	1.724	0.310	9
S02	Adopt off-site construction practices (e.g., prefabrication)	2.96	2.161	0.252	10
S11	Satisfy the requirements of CW recycling processes	2.83	1.443	0.191	11
S13	Adhere to national legislations related to CW	2.73	1.754	0.149	12
S04	Acquire certifications related to CWR from the government (e.g., Green Building, LEED)	2.40	1.018	0.000	13

Notes: (NV) = Normalized value (Equation (1)); [a] the normalized value indicates that the strategy is critical (normalized $\geq$ 0.60).

2.3.6. Factor Analysis Using the Usability Index

For further analysis and a deeper understanding, factor analysis (FA) was used to statistically identify potential groups of the CWR enhancement strategies based on each strategy's usability index. FA is an effective statistical tool for identifying small groups from many interrelated variables [99]. The Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity were conducted to determine the study data's suitability for FA. In addition, the KMO value should be higher than the suggested threshold of 0.50 [100]. On the other hand, Bartlett's test of sphericity score must be lower than 0.05 [101]. In this study, the KMO for the thirteen CWR enhancement strategies is 0.847, which is appropriate for exceeding the 0.50 threshold. Additionally, Bartlett's test of sphericity suggests an approximate Chi-square of 776.018 (p = 0.000), in which the p-value was lower than 0.05. Therefore, the correlation matrix is not an identity matrix [99]. Thus, affirming the variables are intercorrelated. These conditions indicate that the study variables can be considered to have sufficient factors in common and, therefore, suitable for FA.

Moreover, principal component analysis (PCA) was employed to extract the underlying components from the thirteen CWR enhancement strategies derived from the usability indexes. Furthermore, PCA is suitable for data reduction. This study used PCA as an extraction method and varimax with Kaiser Normalization as the factor rotation method to better interpret the enhancement strategies [102]. The enhancement strategies with a factor loading of $\geq$0.45 are recommended to be included because of their contribution to the interpretation of the component [103]. Furthermore, the examination of the scree plot of thirteen enhancement strategies was performed. A scree plot is a graph of the eigenvalues associated with the number of the factors [104]. A scree plot view indicated that the eigenvalue curve began to bend out at the third component. Wherefore, three components were retained. Figure 3 shows the scree plot of thirteen enhancement strategies. In addition, the rotation converged in 6 iterations. Additionally, it produced a three-factor solution with eigenvalues greater than 1.00, explaining 67.445% of the total variance, which is higher than the 60% needed for satisfactory construct validity [104]. Table 6 shows the results of the rotated component matrix with loading values higher than 0.45 [105].

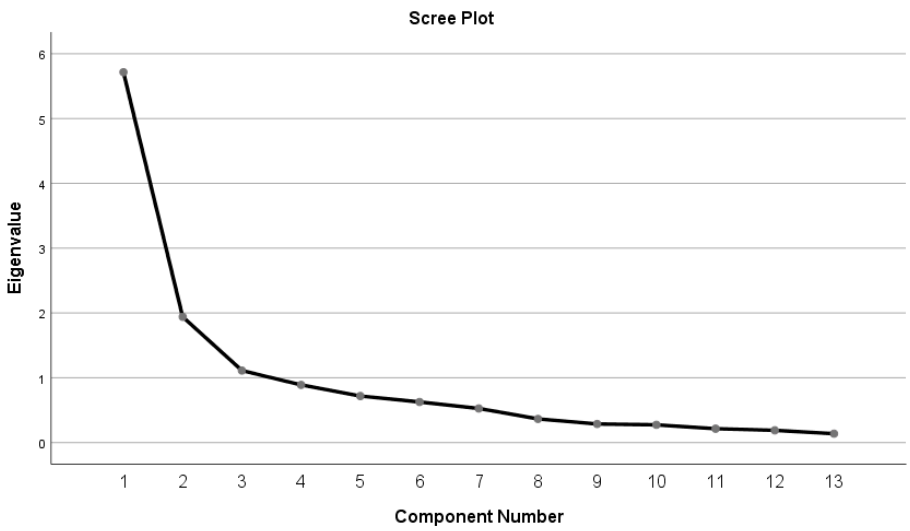

Figure 3. Scree plot of factor analysis.

The first produced construct accounted for 43.961% of the total variance explained and named workplace laws and policy management, which is the construct with the most variables (S13, S02, S10, S11, S05, S12, S04), whereas (S08, S09) create the second construct of information technology and capability management, which accounted for 14.929% of the total variance explained, and (S01, S06, S03) create the third construct of workplace laws and policy management, explaining 8.554% of the variance. Table 6 summarizes the result of FA.

Table 6. The summary of factor analysis.

Code	Strategy	Factor Loadings	Eigenvalue	PVE	CPVE	Cronbach's Alpha
Factor 1: Workplace laws and policy management		—	5.715	43.961	43.961	0.876
S13	Adhere to national legislations related to CW	0.886	—	—	—	—
S02	Adopt off-site construction practices (e.g., prefabrication)	0.871	—	—	—	—
S10	Use CW recycled materials as alternative construction materials	0.856	—	—	—	—
S11	Satisfy the requirements of CW recycling processes	0.833	—	—	—	—
S05	Prepare dedicated spaces to sort CW	0.787	—	—	—	—
S12	* Enhance company policies related to CW	0.751	—	—	—	—
S04	Acquire certifications related to CWR from the government (e.g., Green Building, LEED)	0.504	—	—	—	—
S07	* Identify construction activities that produce recyclable materials	0.473	—	—	—	—
Factor 2: Information technology and capability management		—	1.941	14.929	58.890	0.716
S08	Adopt a database for collecting CW	0.835	—	—	—	—
S09	Use information technology to facilitate CW recycling processes (e.g., website)	0.831	—	—	—	—
Factor 3: Workforce and workplace management		—	1.112	8.554	67.445	0.725
S01	Raise project team awareness on CW	0.711	—	—	—	—
S06	* Organize temporary bins in each construction zone	0.674	—	—	—	—
S03	Adopt on-site construction practices (e.g., Mobile Recycling)	0.585	—	—	—	—

Notes: * Illustrates the findings of usability index; (PVE) = percentage of variance explained; (CPVE) = cumulative percentage of variance explained; extraction method—Principal Component Analysis; rotation method—Varimax with Kaiser normalization.

3. Discussion

3.1. Easy, Cheap, and Effective Strategies

3.1.1. Organize Temporary Bins in Each Construction Zone (S06)

The strategy identifies the potential CW by placing the numbers and types of CW bins for each construction zone. It could also be adopted for a construction zone with high-generation waste rates to avoid overfilling central bins [70]. Several reasons might result in the strategy being cheap, easy, and effective. The short distance between temporary bins and CW sources results in a shorter distance to move CW inside construction projects. This strategy is easy to implement because project stakeholders could easily install temporary bins on-site, and quickly reinstall them after filling and emptying the major bins. This strategy is effective because it can promptly sort various CW types than different sorting approaches, such as customizing specific containers for each type of waste.

3.1.2. Identify Construction Activities That Produce Recyclable Materials (S07)

Identifying which construction activities could produce recyclable materials can decrease construction projects' environmental impacts by adopting those materials into new construction projects. Furthermore, with the difficulty of obtaining natural materials and their ever-increasing cost, recyclable materials utilization has become an attractive alternative to construction projects. Therefore, identifying construction activities that produce recyclable materials during project planning is essential to exceeding the potential difficulties of obtaining natural materials during project implementation. The process of this strategy can ensure that the quality and quantity of materials would be easier to handle during construction activities and effective handling on-site [106]. This strategy is cheap to implement because it requires investing enough planning time before working on-site, which means extra effort without additional machines or equipment. This strategy is easy because it can be adopted through the early stages of implementation by a few workers with minimal additional effort. Furthermore, using software, such as building information modeling (BIM), can assist in implementing this strategy [67,101]. This strategy is effective because it increases the number of materials needing to be recycled in the project through effective planning. In other words, effective planning can enhance the decrease in the disposal of CW in landfills, which means reducing environmental and economic impacts.

3.1.3. Enhance Company Policies Related to CWR (S12)

This strategy's significance is to enhance the company's policy on removing the restriction and supporting CWR's future developments. To illustrate, improving the policy of recyclable construction materials could prioritize pushing CWR in construction projects [74]. Furthermore, continuous monitoring and enhancing CWR policies are essential to construction practitioners because they could increase the CWR rate via constant enhancement. This strategy is cheap because company policy enhancement is among company team responsibilities without the need for another party. This strategy is easy is due to the independent decision-making for addressing CWR, such as enhancing workers' policies about adopting training approaches. Moreover, this strategy is effective because of continually improves the company's CWR policies, such as dealing with CW periodically without accumulating during on-site practices. Additionally, incentive policies for employees such as monetary rewards. As a result, the efficiency and strictness of company policies can effectively increase the CWR rate.

3.2. Effective but Not Cheap nor Easy Strategies

The following effective enhancement strategies can enhance the CWR rate by acquiring the needed requirements for the CWR process. In addition, this paper discusses the effective but not easy and/or cheap strategies due to the effective capability toward enhancing practical activities of CWR from various aspects. Furthermore, understanding the effectiveness of the strategies can guide stakeholders in making optimal decisions toward CWR in construction projects [36]. Additionally, the CWR would be profitable to the projects' stakeholders in the construction domain [107,108]. Thus, the strategies in the following enhancement strategies would be significant to the CWR rate.

3.2.1. Acquire Certifications Related to CWR from the Government (S04)

Acquiring certifications related to CWR from the government involves having recycling facilities providing accurate CW data. Those data are necessary to acquire most sustainability-related certifications [109]. For example, the Leadership in Energy and Environmental Design (LEED) and Malaysia Carbon Reduction and Environmental Sustainable Tool (MyCREST) consider CWR as part of the certification criterion [102–104,110]. Additionally, the strategy contributes effectively from the preconstruction until the demolition stages. As a result, this strategy provides an opportunity to achieve the highest level of effectiveness in implementing CWR. However, the strategy is not cheap because training is required to understand the certification processes and requirements. The certification fees are also high. This strategy is also difficult to implement because the certification requirements should be strictly satisfied. The certification process also takes time as project owners need to gather all required details and documents for submission.

3.2.2. Satisfy the Necessary Requirements of CWR Processes (S11)

The strategy contributes to the importance that construction practitioners understand the requirements to deal with CWR, such as estimating the quantities and types of CW for the recycling process and the legal requirements of CWR. To illustrate, sorting CW on-site and increasing environmental awareness of the CWR process [111,112]. This strategy is effective because it can enhance CW sorting, promote the project's financial subsidy, reduce illegal dumping of CW, and raise the effective performance of CWR by being adopted early in the project's stage. However, this strategy is not cheap. Additionally, it is not easy to implement because it relates to requirements of financial subsidies, such as difficulty providing the bank's loan needs to support the CWR process. Therefore, reducing the cost and increasing the easiness of implementing this strategy can be through adopting on-site practices rather than off-site practices of the CWR process for better implementation. In other words, preparing an organization chart containing the practitioners' responsibilities for CWR on-site is valuable.

3.3. Theoretical, Practical, and Managerial Implications

The study findings add to the construction management body of knowledge by providing a better understanding of the usability of different CWR enhancement strategies. The findings could open theoretical and practical opportunities for increasing CWR rates in the construction industry. Policymakers could use the study findings to suggest optimal CWR enhancement strategies to practitioners and researchers. Additionally, the findings would assist policymakers in enacting new laws relating to CWR. Practitioners can use the study findings to select appropriate CWR enhancement strategies for implementation in construction projects. Researchers can reduce the gap between theoretical and practical applications of CWR enhancement strategies. Future research can also adopt the study's approach in computing usability indexes through questionnaire surveys.

3.4. Study Limitations and Future Recommendations

The study has several limitations; the first limitation is that the study did not differentiate between types of construction projects and types of construction wastes. Therefore, recommended for future works to fill this gap by focusing on specifying the types of projects or wastes in the construction domain. Second, the enhancement strategies are general for construction waste recycling, which means the study does not concentrate on technique details or tools of the strategies. Nevertheless, the process of the pilot study with academics and industry experts assists in minimizing this limitation. In addition, the pilot study process ensures agreement by experts from academic and industry aspects that the survey is suitable for distribution to respondents from the industry. Similarly, several studies use the pilot study to help in evaluating their survey from experts [89,97,113]. The third limitation is the comparatively small sample size for organization types such as consultants (22), clients (16), and others (5) in the number of participants in the survey. However, the position and level of experience of the participants help to reduce this limitation. Although the study has attempted to overcome the current limitations, the study recommends future studies on increasing the number of respondents of organization types. Additionally, differentiate between the types of projects and types of wastes in the construction field to extend the existing knowledge of this study on enhancing the CWR rate.

4. Conclusions

This paper investigated the interrelated aspects of strategies that target the enhancement of CWR rates in construction projects. The study adopts the usability analysis approach because it provides an unbiased examination of the enhancement strategies. Based on a dataset from 106 project managers, this study's outcomes can help illustrate problematic areas within the enhancement strategies that might not have been obvious otherwise. The results showed that:

- Thirteen strategies can target the enhancement of CWR rates in construction projects.
- Three out of those thirteen strategies can be considered relatively cheap, effective, and easy compared to the others. The strategies are: 'organize temporary bins in each construction zone' (S06), 'identify construction activities that produce recyclable materials' (S07), and 'enhance company policies related to CWR' (S12).
- Additionally, two others are rated as effective but not cheap or easy. The strategies are: 'acquire certifications related to CWR from the government' (S04) and 'satisfy the necessary requirements of CWR processes' (S11).
- The study proposed a formula for computing usability indexes using the cost, easiness, and effectiveness values.

- Factor analysis produced three-factor for the usability index's list, which were named workplace laws and policy management (S13, S02, S10, S11, S05, S12, and S04), information technology and capability management (S08 and S09), workforce and workplace management (S01, S06, and S03).

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