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ASSESSMENT TOOL FOR BEST PRACTICES OF CONSTRUCTION WASTE MINIMISATION

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ABSTRACT

A rise in residential construction projects to meet housing demand has inevitably generated substantial amounts of waste. Ineffective waste management and illegal dumping have worsened this problem. This research aims to develop an assessment tool for best practices of construction waste minimisation. The objectives are: 1) To identify criteria and indicators for best practices in waste minimisation, 2) To determine the best practices indicator, and 3) To develop an assessment tool. The study was conducted in Klang Valley which has the highest number of residential. A mixed-method approach was used, combining qualitative and quantitative methods. For the first objective, semi-structured interviews were conducted with 11 construction practitioners such as Site Engineers and Site Managers. By using thematic analysis the results revealed 44 best practice indicators. For the second objective, a questionnaire survey was distributed to 153 construction practitioners in the Klang Valley area focusing on residential projects. The survey was analysed using descriptive analysis and the Relative Important Index (RII) to develop an assessment tool. The analysed results were ranked with the RII. The top rank was "Effective communication on-site" and the lowest was "Appointment of labour just for waste management". Then, the ranking and indicators were used to calculate the weightage for best practices of construction waste minimisation. The weighted scores were grouped into "Excellent," "Good," "Fair," and "Poor". The assessment tool provides a performance percentage chart. In *conclusion, the assessment tool, provides ratings and performance charts, to guide contractors in improving waste management strategies and setting performance benchmarks.*

Keywords: *Waste management, Waste minimisation, Tool, Assessment, Best practice*

INTRODUCTION

The increasing urban population has fueled economic growth, significantly impacting the construction industry (Esa et al., 2017). The importance of sustainable development has gained widespread acceptance among practitioners and researchers, becoming a new value in the field. The expanding construction activities have led to the global rise of construction waste management. In 2015, the construction industry had a substantial impact on both the natural and built environments. By 2019, the construction industry generated 16.6 million tonnes of waste, accounting for 38% of destruction, with 43% of this waste ending up in landfills (Singh et al., 2020; Yaseen et al., 2020).

The rapid growth of Malaysia's construction industry has led to a significant increase in waste generation due to the rise in infrastructure projects, and the construction of commercial and residential buildings (Begum et al., 2010). This includes materials such as concrete, wood, metal, and packaging materials. The high volume of waste poses significant challenges for disposal and recycling (Kupusamy et al., 2019); Maniam et al., 2018). Ineffective waste management practices at construction sites exacerbate the problem (Mahayuddin & Pereira, 2014; Fikri Hasmori et al., 2020) Therefore, effective on-site construction waste management is essential. Appropriate mechanisms and management practices are needed to prevent illegal dumping and mitigate environmental impacts (Hung & Kamaludin, 2017). In addition, ineffective construction waste management leads to environmental pollution. This includes soil contamination, water pollution, and increased greenhouse gas emissions from decomposing waste in landfills. The improper disposal of hazardous materials can further exacerbate environmental degradation (Mustaffa et al., 2018; Yu et al., 2024). Implementing zero-waste strategies is recognised as the best solution for managing construction waste (Liyanage et al., 2019).

One of the identified issues in construction waste management is the absence of a comprehensive performance assessment tool for construction waste minimisation. Despite years of implementation, the performance of construction waste management remains unsatisfactory (Yu et al., 2021). The effectiveness of these practices remained challenged and requires a comprehensive performance assessment framework and an improved approach to achieve the best practices in construction waste management (Kim et al., 2020). Therefore, this paper's objective is to identify criteria and indicators for best practices in waste minimisation, to determine the best practices indicator, and to develop an assessment tool. Data was collected through semi-structured interviews and a questionnaire survey.

CONSTRUCTION WASTE MANAGEMENT

Criteria and Indicators of Construction Waste Minimisation

Globally, the generation of solid waste amounts to roughly 2.01 billion tons annually, with projections indicating an escalation to 3.4 billion tons by 2025 (World Bank Group, 2018). In Malaysia, the construction sector contributes substantially, generating an estimated 8 million tons of waste each year (Saadi et al., 2016). Whereby the volume of waste generated will depend upon the company's practices, level of experience, and the specific characteristics of the project (Harun et al., 2017). Consequently, it becomes imperative to institute best practices to prevent waste sent to landfills (Jia et al., 2017; Liang et al., 2019).

Best practice indicators play an essential role in constraining construction waste within a project. One of the important criteria of best practices is knowledge. All construction practitioners need to have adequate knowledge of construction waste to improve the performance of the project (Wibowo et al., 2017). Nevertheless, understanding the principles of reduction, reuse, and recycling is another important aspect to consider for minimising construction waste. Next, on-site practice criteria play an important role in minimising construction waste. The implementation of on-site practices has a significant impact on the project (Sáez et al., 2019). Separating or segregating construction waste at a specified location in a construction project will help ease the reuse and recycle phase later (Marinelli et al., 2014; CIDB Malaysia, 2015). Encouragement is important to ensure segregation and separation is successful (Mustafa et al., 2022)

Moreover, materials and equipment stand as pivotal criteria in every construction project. Effective management of these resources is essential to avoid discrepancies in project costs (Khandve et al., 2015). Double handling of material should be avoided on-site since the action can contribute to the generation of waste (Ajayi et al., 2017). Another crucial consideration involves regulations for waste management. These regulations need to be strengthened and updated to address the current situation (Lu & Yuan, 2011). Besides, human resource management criteria are also important. It ensures that all staff are aware of waste management practices (Udawatta et al., 2015; CIDB Malaysia, 2015). Finally, technology criteria play a vital role in minimising construction waste. To achieve sustainable waste management, construction practitioners must adopt relevant approaches and technologies (Sin et al., 2013). However, implementing new technologies can be costly.

Performance Assessment Tool

Assessment of the effectiveness of construction waste management is crucial (Wu et al., 2019). Today, the problems of construction waste and its environmental impact are no longer local issues. Therefore it is important to assess and identify best practices for minimising construction waste. Accordingly, one of the primary strategies the construction industry must adopt to achieve new efficiency and productivity goals is benchmarking key performance indicators and identifying best practices (Moradi et al., 2022). There are several assessment rating tools used to evaluate building and project performance. For example Building Research Establishment's Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Building Environment Assessment Method (HK-BEAM) Green Building Index (GBI) and Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). All of the tools have different classifications of rating. LEED and GBI share a similar system, categorising performance as Certified, Silver, Gold, or Platinum. Similarly, HK-BEAM uses Bronze, Silver, Gold, or Platinum ratings. BREEAM employs a different classification, ranging from Unclassified to Outstanding. CASBEE distinguishes itself with categories like Superior, Very Good, Good, Slightly Poor, and Poor. While MySTAR rates results with 1 to 5 Stars. As for the end product, most tools display the result in per cent (%) of credit achieved and also points earned (/100). Table 1 shows the summary of all assessment tool.

Table 1. Summary of the Assessment Tool

Assessment Tool	Rating	End Product Feature	Indicator
BREEAM (U.K, 1990)	Unclassified/ Pass/ Good/ Very Good/ Excellent/ Outstanding	Percent (%) of creadit achieved	Management Health & Wellbeing Energy Transport Water Material Waste Land Use & Ecology Pollution
LEED (U.S, 2000)	Certified/ Silver/ Gold/ Platinum	Points earned (/100)	Location and Transportation Sustainable Sites Water Efficiency Energy and Atmosphere Material and Resources Indoor Environmental Quality Innovation Regional Priority
CASBEE (Japan,2004)	C/ B-/ B+/ A/ S	Spider Diagram, Histogram & BEE Graph	Indoor Environment Quality Service Outdoor Environment On-site Energy Resources and Material Off-site Environment
HK-BEAM (Hong Kong, 1999)	Bronze/ Silver/ Gold/ Platinum	Per cent (%) of credit achieved	Integrated Design and Construction Management Sustainable Site Material and Waste Energy Use Water Use Health and Wellbeing
GBI (Malaysia, 2011)	Certified/ Silver/ Gold/ Platinum	Points earned (/100)	Energy Efficiency Indoor Environmental Quality Sustainable Site Planning & Management Material & Resources Water Efficiency Innovation

MyCREST (Malaysia, 2015)	1 Star/ 2 Star/ 3 Star/ 4 Star/ 5 Star	Percent (%) of creadit achieved	Pre-Design Infrastructure and Sequestration Lowering Operational Carbon-Energy Performance Impacts Occupant & Health Lowering the Embodied Carbon Water Efficiency Factors Social and Cultural Sustainability Demolition & Disposal Factor Sustainable and Carbon Initiatives Pre-Design Infrastructure and Sequestration Lowering Operational Carbon-Energy Performance Impacts Occupant & Health Lowering the Embodied Carbon Water Efficiency Factors Social and Cultural Sustainability Demolition & Disposal Factor Sustainable and Carbon Initiatives

Previously, many rating systems and tools prioritised aspects related to energy and water efficiency, often overlooking construction waste management. While some waste management considerations are incorporated within material and resource criteria, however, there remains a notable gap in detail and coverage. Therefore an assessment tool specifically focused on on-site construction waste management is necessary.

METHODOLOGY

This research utilised both qualitative and quantitative approaches with the philosophical assumptions of a pragmatic research paradigm. Pragmatism perceived the complete acceptance of one philosophy as useless and instead viewed this as either end of a spectrum, allowing choosing whichever stance or combination of positions to help in the research (Saunders et al., 2016). The relevant issues related to best practices and performance in construction waste minimisation were identified through a comprehensive review of current research and rigorous articles. Initially, semi-structured interviews were conducted to gather participants' perspectives and understandings of best practices for construction waste minimisation, based on their work experience. The insights from these interviews were then contributed to the development of a questionnaire survey, which was then distributed to construction practitioners in the Klang Valley area to evaluate the effectiveness and importance of these practices. The methodology was divided into 2 stages namely data collection through qualitative methods (semi-structured interviews), and data collection using quantitative methods (questionnaire survey). For the qualitative methods, the data were analysed using thematic analysis with qualitative software. Meanwhile, for the quantitative methods, the data were analysed using the Relative Importance Index (RII) with statistical analysis.

The first stage begins with a semi-structured interview, conducted to identify the best practices for construction waste minimisation in a construction project. The participants were construction personnel who were short-listed based on specific participant criteria. The criteria namely Project Manager, Project Coordinator, Site Manager or Environment Officer, CIDB personnel, and SwCorp personnel who have more than 5 (five) years of working experience in the construction industry and the personnel need to be involved directly or indirectly in construction waste management at construction projects. Therefore, eleven participants were involved in this semi-structured interview, which was conducted via an online platform due to the participants being located in various geographical areas. The data obtained was analysed using thematic analysis. The results of this analysis were then used to develop a questionnaire survey which led to the second stage of data collection.

The questionnaire survey was distributed to construction practitioners in the Klang Valley area to identify the level of importance of the listed indicators of construction waste minimisation. The respondents include Project Manager, Project Director, Site Manager, Site Coordinator, General Manager, Safety, Health and Environment Manager, Environmental Officer, or other roles in their company. For this study, the online survey method was applied. The population size of the study was 378, and the sample size was 191. After some time, the survey resulted in 153 valid responses with an 80% response rate. A response rate of 30% is considered acceptable in many cases (Sekaran & Bougie, 2016).

Finally, the development of an assessment tool of best practices for construction waste minimisation was based on a synthesis from semi-structured interviews and the questionnaire survey. The data was analysed with Spreadsheet Software. BPI (Best Practice Indicator) Score Analysis was used to determine the score of each best practice. Equation 1 below is used to calculate the score of each indicator based on the value score and the weightage.

$$BPI\ Score = \Sigma\ BPIn\ W \times V\ score \qquad (1)$$

Finally, rating classification was determined from the assessment using the tool. Four ratings are used in the determination of the final performance assessment of the project, namely “excellent”, “good”, “fair” and “poor”.

RESULTS AND DISCUSSION

Semi-structured Interview

Participant Background

There are eleven participants involved in the semi-structured interview consisting of different backgrounds and organisations. There are Managing Directors, Project Managers, Safety Health and Environment Managers, and Engineers. Most of the participants are from the CIDB (Construction Industry Development Board), SWCorp (Solid Waste and Public Cleansing Management Corporation) and Construction Company. Concerning participants' work experience, the majority had over ten years of professional experience. The range of experiences emphasised the reliability of experts' perspectives on best practices for minimising construction waste within a project.

Best Practice Indicator for Waste Minimisation

The participant gave their opinion based on their working experience on the criteria and indicators of best practices that are suitable to minimise construction waste in the project. As a result, a total of 6 criteria and 44 indicators were finally identified including 15 new indicators that were suggested by the participants to be added to the list. Table 2 shows all the criteria and indicators of the best practice. These results will be used to enrich and lead to the establishment of the questionnaire survey.

Table 2. List of Criteria and Indicators of Best Practice

ID	Criteria	Indicators
KN1	Knowledge	Adequate knowledge of construction methods and sequence
KN2		Knowledge of reduce, reuse, and recycle
KN3		Adequate knowledge of construction waste
KN4		Adequate knowledge of advanced technology
KN5		Adequate knowledge of design background.
OSP1	Onsite Practices	Waste segregation at the site.
OSP2		On-site reuse and recycling of construction material
OSP3		Safe storage is provided to reduce broken material
OSP4		Effective communication on-site
OSP5		Appropriate space located for construction waste
OSP6		Temporary Bins are provided at each zone of a building
OSP7		Storing waste in an easily accessible area
OSP8		Update staff on reuse and recycling material
OSP9		Avoid waste mixture with oil
OSP10		Reduce the number of design changes that take place during construction.
OSP11		Keeping the site clean to prevent waste generation (housekeeping)
OSP12		Every project must have a recycling goal.
OSP13		A proper construction waste management logistic plan is carried out
OSP14		Label construction waste bins according to categories of waste
ME1	Material and Equipment	Use of mechanical fixture (proper handling)
ME2		Avoid over-ordering of material
ME3		Use material with a high content of recycled material
ME4		Avoid double-handling material
ME5		Just in Time (JIT) deliveries to reduce material waste
ME6		Proper storage for material
ME7		Experienced operator in handling machine or crane
ME8		Adoption of material that can be used repeatedly (e.g., supporting for prop or falsework)
ME9		Adoption of new machines or technology

RG1	Regulation	The market structure for recycling material
RG2		Improved waste management regulation
RG3		Improve database management for construction waste
RG4		Integrate construction waste management into the assessment of contractor
RG5		All regulations must be promoted by the authority
RG6		Enforcement needs to be complied with by all level contractors.
RG7		Create another authoritative body responsible just for waste management
RG8		Incentives provided by the government as encouragement to contractors
HR1	Human Resource Management	Appoint Environment Officer onsite
HR2		Appointment of labour just for waste management
HR3		Awareness of waste management to all staff (for example talk, briefing, campaign etc.)
HR4		Incentives provided to site personnel for reduction of construction waste
HR5		Budget allocation by the top management for managing waste
TC1	Technology	Reuse technology or innovation for construction waste
TC3		Use of Industrialized Building System (IBS)
TC4		Use of mobile crusher machine to recycle on-site

Source: Author

Questionnaire Survey

Demographic Background

The respondents comprised Site Supervisors (n=36), Site Engineers (n=31), Safety, Health, and Environment Managers (n=15), Site Managers (n=15), Project Coordinators (n=14), Project Managers (n=12), Environmental Officers (n=11), Project Directors (n=7), and others (n=12). Regarding years of experience, 21% had 1-5 years of experience, 27% had 6-10 years, 33.3% had 11-15 years, 12.2% had 16-20 years, and 6.5% had over 20 years of experience.

Assessment Indicator Value of Best Practices of Waste Minimisation

To analyse the most important best practices indicator in minimising construction waste, Equation 2, the Relative Important Index (RII) was used. RII has been widely used to determine the relative importance of the variables (Umar et al., 2020). Hence, the five important levels are then transformed from RII values: high (H) ($0.8 \leq RII \leq 1$), high-medium (H–M) ($0.6 \leq RII \leq 0.8$), medium (M) ($0.4 \leq RII \leq 0.6$), medium-low (M-L) ($0.2 \leq RII \leq 0.4$) and low (L) ($0 \leq RII \leq 0.2$)

$$RII = (\Sigma W / AN), \qquad 0 \leq RII \leq 1 \qquad (2)$$

The data were subsequently analysed using statistical methods. The best practices were ranked based on their overall ranking, as presented in Table 3.

Table 3. List of Criteria and Indicators of Best Practice

Item	ID	Criteria	Indicators	RII	Rank	Level Of Importance	Mean
1	OP4	On-site Practice	Effective communication on-site	0.940	1	H	4.699
2	KN1	Knowledge	Adequate knowledge of construction methods and sequence	0.936	2	H	4.680
3	ME6	Material & Equipment	Proper storage for material	0.925	3	H	4.628
4	HR3	Human Resource Management	Increase awareness of construction waste management to all staff including top management	0.914	4	H	4.569
5	ME4	Material & Equipment	Avoid double-handling material	0.908	5	H	4.543
6	ME8	Material & Equipment	Adoption of material that can be used repeatedly (e.g., supporting for prop or falsework)	0.908	5	H	4.543
7	OP7	On-site Practice	Store waste in an easily accessible area	0.906	7	H	4.529
8	KN3	Knowledge	Adequate knowledge of construction waste	0.905	8	H	4.523
9	OP5	On-site Practice	Adequate space allocated for construction waste	0.902	9	H	4.510
10	OP11	On-site Practice	Keep the site clean to prevent waste generation (housekeeping)	0.902	9	H	4.510
11	KN2	Knowledge	Adequate knowledge of reducing, reusing, and recycle	0.897	11	H	4.484
12	OP13	On-site Practice	A proper construction waste management logistic plan is carried out	0.895	12	H	4.477
13	RG6	Regulation	Enforcement needs to be complied with by all level contractors.	0.895	12	H	4.477
14	ME2	Material & Equipment	Avoid over-ordering of material	0.894	14	H	4.471

15	ME7	Material & Equipment	Experienced operator in handling machines or crane	0.893	15	H	4.464
16	OP9	On-site Practice	Avoid waste mixture with oil	0.892	16	H	4.458
17	OP6	On-site Practice	Temporary bins are provided at each zone of a building	0.89	17	H	4.451
18	OP1	On-site Practice	Waste segregation at the site	0.889	18	H	4.444
19	RG2	Regulation	Improve waste management regulation	0.889	18	H	4.444
20	OP3	On-site Practice	Safe storage is provided to reduce broken material	0.886	20	H	4.431
21	RG5	Regulation	All regulations must be promoted by the authority	0.884	21	H	4.418
22	OP2	On-site Practice	On-site reuse of construction material	0.881	22	H	4.405
23	HR5	Human Resource Management	Budget allocation by the top management for managing waste	0.877	23	H	4.386
24	TC3	Technology	Use of Industrialized Building System (IBS)	0.869	24	H	4.346
25	RG3	Regulation	Improve database management for construction waste	0.868	25	H	4.340
26	RG8	Regulation	Incentives provided by the government as an encouragement to contractors	0.867	26	H	4.333
27	HR4	Human Resource Management	Incentives provided to site personnel for reduction of construction waste	0.864	27	H	4.320
28	RG4	Regulation	Integrate Construction Waste Management performance level into the assessment of contractors for tender award	0.863	28	H	4.314
29	HR1	Human Resource Management	Appoint an Environmental Officer on-site	0.863	28	H	4.314
30	OP8	On-site Practice	Update staff on reuse and recycling material	0.861	30	H	4.307
31	ME1	Material & Equipment	Use of mechanical fixture (proper handling)	0.861	30	H	4.307
32	RG1	Regulation	Improve market structure for recycled material	0.861	30	H	4.307
33	OP14	On-site Practice	Label construction waste bins according to categories of waste	0.856	33	H	4.281
34	ME5	Material & Equipment	Just in Time (JIT) deliveries to reduce material waste	0.856	33	H	4.281
35	KN4	Knowledge	Adequate knowledge of advanced technology	0.85	35	H	4.248

36	OP10	On-site Practice	Reduce the number of design changes that take place during construction	0.848	36	H	4.242
37	TC1	Technology	Reuse technology or innovation from construction waste	0.848	36	H	4.242
38	OP12	On-site Practice	Every project must have a recycling goal	0.847	38	H	4.235
39	KN5	Knowledge	Adequate knowledge of design background	0.829	39	H	4.144
40	ME9	Material & Equipment	Adoption of new machines or technology	0.827	40	H	4.137
41	ME3	Material & Equipment	Use material with a high content of recyclable material	0.822	41	H	4.111
42	TC4	Technology	Use of mobile crusher machine to recycle on-site	0.809	42	H	4.046
43	RG7	Regulation	Create another authoritative body responsible just for waste management	0.799	43	H-M	3.994
44	HR2	Human Resource Management	Appointment of labour just for waste management	0.775	44	H-M	3.876

Source: Author

The highest-ranked best practice is OP4: Effective on-site communication with an RII value of 0.940. This practice is crucial for minimising construction waste. Miscommunication often occurs due to diverse worker backgrounds sometimes leading to disputes (Gamil & Abd Rahman, 2022). The second-ranked practice is KN1: Adequate knowledge of construction methods and sequences with an RII value of 0.936. this practice is essential for reducing waste, as highlighted by Participant 6. The third-ranked practice is proper material storage, which involves good planning, and training to prevent material damage which contributes to waste (Luangcharoenrat et al., 2019). Finally, the least important practice is appointing labour specifically for waste management, as existing workers can handle this while reducing costs.

Overall, on-site practices ranked highest for minimising waste, followed by knowledge, material and equipment management, regulations, human resource management, and technology.

Development of Assessment Tool

The tool was developed as the performance assessment scheme for a residential project to minimise on-site construction waste. This indicator tool was developed with a thorough and systematic process comprising three (3) assessment steps, as shown in Figure 1.

Figure 1. Assessment steps of PITBCWM

Source: Author

The first step was to assess and rate each best practices indicator (BPI) to minimise construction waste on-site. The score of each indicator was derived from the weighted score of mean calculation from the questionnaire survey. The second step was to include the overall score for BPI constituted of the score of performance in every five criteria, specifically knowledge, on-site practices, material and equipment, human resource management, and technology. This score will be automatically calculated with a maximum point of 100. The third step was the final assessment, where the assessed residential project is summarised by signifying a rating classification. This tool will also generate a chart of each criterion's performance level percentage. The key activities and procedures in these steps are described in the following sub-section (Khalil, 2016)

Weightage of indicators in the assessment tool

The weighting process for the Best Practices Indicator (BPI) score relied on prior statistical analysis from a questionnaire survey. Each practice indicator's weight was determined by averaging the mean values within each criterion. This process resulted in the selection of 36 indicators to be included in the tool.

Components of assessment tool

This assessment tool is a self-assessment instrument for contractors, developed using spreadsheet software to automatically generate assessment results based on predefined codes and formulas. Focusing on five main criteria: knowledge, on-site practices, materials and equipment, human resource management, and technology. The tool comprises six sections namely, Section A: Introduction to the Tool, Section B: Project Information, Section C: Assessment Criteria for Overall Points, Section D: Rating Classifications, Section E: Assessment of Best Practices, and Section F: Interpretation of assessment results with a performance graph feature. Figure 2 shows the features of Sections A and B. Meanwhile, Figure 3 shows the features of Sections C and D.

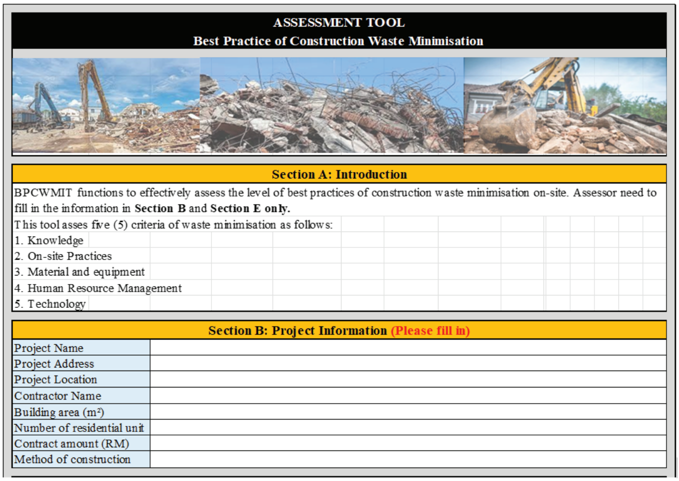

Figure 2. Features of Sections A and B of the tool

Source: Author

Section E explains how to analyse the BPI Scores. A range scale from 1 to 5 was suggested. Whereby the scale value represents 1 equal to a 0.0 score, 2 equal to a 0.25 score, 3 equal to a 0.5 score, 4 equal to a 0.75 score, and 5 equal to 1 score. Table 4 shows the scale, score, and description of the scale used. The score of each indicator was evaluated using the value score that ranges from 0.0 to 1.0. The score obtained is then multiplied by the weight assigned to each indicator using Equation 1.

Section C: Assessment Criteria (Overall Point Score)		
ID	**Criteria**	**Maximum Point**
KN	Knowledge	14.0
OP	On-site Practice	39.3
ME	Material and Equipment	25.0
HR	Human Resource Management	13.6
TC	Technology	8.0
	TOTAL	**100.0**

Section D: Rating of Best Practices of Construction Waste Minimisation		
Points	**Rating**	**Description**
81 to 100	Excellent	Excellent practices performance in mimimising construction waste on-site
61 to 80	Good	Good practices performance in mimimising construction waste on-site
41 to 60	Fair	Fair practices performance in mimimising construction waste on-site
0 to 40	Poor	Poor practices performance in mimimising construction waste on-site

Figure 3. Features of Sections C and D of the Tool

Table 4. Value, Scale, and Description for Best Practice Indicator Score (BPI score) for each Indicator.

Value		Scale	Scale Description
Scale	Score		
1	0.0	No implementation	construction practitioner/ the project implements 0% of the practices
2	0.25	Less implementation	construction practitioner/ the project implements 1% - 30% of the practices
3	0.5	Moderate implementation	construction practitioner/ the project implements 31% - 50% of the practices
4	0.75	High implementation	construction practitioner/ the project implements 51% - 70% of the practices
5	1.0	Very high implementation	construction practitioner/ the project implements 71% - 100% of the practices

Section E is the most important section, whereby the assessor needs to rate the value of each indicator that is implemented in their project. Figure 4 shows an example of the filled value in Section E. Next, the overall score of BPI can be calculated by summing up the individual BPI scores after the criteria for all indicators are completed. This will generate the overall score for each criterion, which are knowledge, on-site practices, material and equipment, human resource management, and technology.

Section E: Best Practices Assessment of Construction Waste Minimisation (Please rate accordingly)								
Citeria	ID	Indicator	Weight (W)	Scale				
				1	2	3	4	5
On-site Practice	OP1	Waste segregation at site	2.819					5
	OP2	On-site reuse of construction material	2.794					
	OP3	Safe storage is provided to reduce broken material	2.811					5
	OP4	Effective communication on-site	2.981					5
	OP5	Adequate space allocated for construction waste	2.861					5
	OP6	Temporary bins are provided at each zone of a building	2.824				4	
	OP7	Store waste at easily accessible area	2.873					5
	OP8	Update staff on reuse and recycle material	2.732					5
	OP9	Avoid waste mixture with oil	2.828				4	
	OP10	Reduce the number of design changes that take place during	2.691					5
	OP11	Keep site clean to prevent waste generation (housekeeping)	2.861					5
	OP12	Every project must have a recycling goal	2.687					5
	OP13	Proper construction waste management logistic plan is carried out	2.840				4	
	OP14	Label construction waste bin according to categories of waste	2.716				4	

Example of Scores

Figure 4. Example of scores in Section E

Source: Author

A summary of scores for each criterion will then be calculated and tabulated automatically using the tool as shown in Figure 5. Each of the criteria was assigned with the maximum weightage derived from the result of the mean calculation. Thus, the score that shall be obtained from the assessment cannot be more than the maximum weightage.

Section F: Assessment Result			
ID	Criteria	Maximum Point	Score
KN	Knowledge	14.0	0.0
OP	On-site Practice	39.3	0.0
ME	Material and Equipment	25.0	0.0
HR	Human Resource Management	13.6	0.0
TC	Technology	8.0	0.0
	TOTAL	**100.0**	**0.0**

Figure 5. Summary Scores of Maximum Point for each Criterion

Source: Author

The next final step of the assessment is to determine the rating classification for the assessed project. The final performance measurement of the assessed project is determined by four ratings: "excellent," "good," "fair," and "poor." These ratings are based on the final score obtained from the performance assessment of all indicators. Finally, this tool is designed to offer informative statistics through visual presentations, delivering a strong visual impact on the project performance results for waste minimisation. The visual histogram graph illustrates the performance of each criterion for best practices in construction waste minimisation. Figure 6 shows an example of the final assessment results.

The tool proposed in this study will allow construction practitioners to evaluate the best practices implemented for minimising on-site construction waste. This, in turn, will aid them in developing effective waste management strategies and benchmarking their performance. Additionally, this tool will help practitioners to reduce the amount of waste generated during the project.

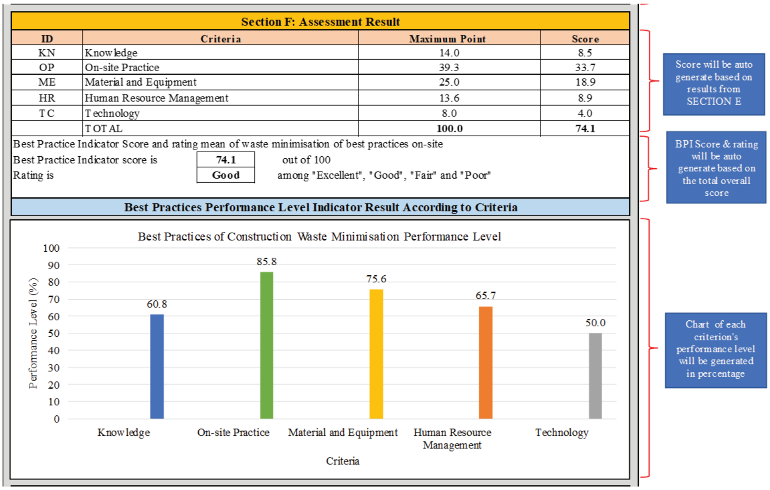

Figure 6. Example of the Score Rating and Performance Chart

Source: Author

CONCLUSION

The criteria and indicators for best practices in construction waste minimisation were successfully identified, addressing the issue of poor implementation of these best practices. Determining the best practice indicators for construction waste minimisation in a project effectively addresses the issue of large volumes of construction waste being disposed of in landfills. Thus, the proposed assessment tools for best practices of construction waste minimisation developed in this study provide a standardised method to measure the effectiveness of best practices in reducing construction waste in a construction project. This tool enables a rapid assessment of how well best practices are performing in minimising construction waste. Additionally, by using numerical weightage and rating descriptions in this tool, empirical studies on best practices for construction waste minimisation can be conducted with more reliable data. The study is limited by its focus on specific project types and locations. It establishes a list of best practices for construction waste minimisation, specifically for new residential projects in the Klang Valley area. Additionally, it only addresses the construction phase and excludes pre- and post-construction phases. Future research should include all types of construction projects and phases. Therefore the tool can be expanded to include not only the construction phase but also the pre- and post-construction phases.

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Both authors contributed equally to the conceptualisation, literature review, data analysis and writing of the manuscript. Finally, both authors have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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