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Improving Waste Management Performance of Construction Projects by Assessing Influence Factors

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Abstract— **Environmental sustainability has become one of the key drivers for continuous growth in the construction industry. However, most of these efforts are focused on planning and/or design strategies; therefore, they fail to thoroughly cover the environmental issues based on the construction execution level. Further, there is a lack of quantitative measurement system and management-level guidance. To overcome these limitations, this paper proposes a new methodology that assists project managers to assess the performance level of a project in terms of waste management practice. This study is based on a two-pronged approach. One is the identification of the waste management influence factors that play an important role in decreasing waste and increasing recycled materials on construction sites. The other is the development of an assessment tool to measure the level of waste management performance for a particular project. As a result of this work, 59 factors were identified and an assessment tool was developed based on quantification of these factors. The tool has been proved to effectively measure waste management performance throughout four real-case validity tests. From the industry perspective, this paper contributes to establishing the environmentally sustainable production systems by providing the project stakeholders with an established set of influence factors and with a diagnosis tool for measuring their current performance. Additionally, project owners can use the output of the tool, especially the total index score, as a measure to benchmark the level of waste management for continuous improvement.**

Keywords; Total index score, waste management influence factor

I. INTRODUCTION

Resource depletion, global warming, high pollution level, and an increased legislation in the business environment are forcing the construction industry to give more consideration to environmental issues than any other times Many countries are putting much effort into establishing environmentally sustainable building production systems. As a result, there is a strong need for methods and techniques that facilitate sustainability assessment for the building environment .Many researchers put great emphasis on evaluating environmental issues on building projects in the design phase. However, it should be regarded as a crucial element to evaluate and provide a rigorous evaluation criteria or system for the construction phase. It is also critical to assess environment related management efforts in the construction phase, because there is a reinforcing relationship between design and construction execution

However, most building environmental assessment is focused on the performance levels resulting from building design strategies. Although there are many environmental assessment methods in many countries, including the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, the Leadership in Energy and Environment Design (LEED) in the United States, they still fail to thoroughly cover the environmental issues based on construction execution level. Further, there is a lack of quantitative measurement systems and no management level guidance.

There are four major environmental harmful impacts of construction phase, namely: construction waste, noise, dust, and air pollution. Among these items, construction waste has been re-ported to be one of the most harmful sources during construction execution.

This paper consists of six sections: 1 an introduction section including research background and objectives; 2 an overview of the current status of existing building environmental assessment methods used in waste management practice; 3 identification of the key factors having an influence on waste management in the construction phase; 4 development of a computerized evaluation tool based on the identified factors to assess the level of waste management performance on a project basis; 5 real-case studies and a validity test; and 6 conclusions from the research findings and suggestion of future research topics.

II. OVERVIEW OF CONSTRUCTION PROJECT ENVIRONMENTAL ASSESSMENT

"Environmental assessment" is defined as "a management tool used to set specific, measurable goals and objectives to various stages of environmental management processes, including planning, implementation, monitoring, measurement, and management review" and it should take a role in comprehensive assessment of the building environmental performance.

Therefore, environmental assessment of a building should address any management factor in relation to waste management performance to achieve overall environmental improvement. As described earlier, much effort has been devoted to assessing this performance in building construction such as BREEAM, LEED, CASBEE, GBC, GB Tool, BEPAC, and BEAM. However, these environmental assessment tools have focused on the early design phase of a project.

"BREEAM-Code for Sustainable Home" deals with construction waste management issue in the "Waste" category, where an on-site waste management plan is necessary. LEED has been developed to improve occupants' safety and health, as described in the previous section; many existing studies indicate that there is a significant lack in evaluating the performance level of waste management in the construction phase. As it is obvious that reduction, reuse, and recycle of construction waste can decrease the environmental impact and increase the economic benefits, an effective waste minimization practice plays an essential role in the area of project management.

Although these tools have a strong impact in the earlier phases of a project, they have deficiencies in assessing and managing the environmental performance in the construction phase, where large amounts of time and resources are required and the outcome has a very strong impact on project performance. Therefore, a new approach for assessing the performance of waste management in the construction phase is strongly required.

III. ASSESSMENT OF CONSTRUCTION WASTE MANAGEMENT PERFORMANCE

A. Identifying Waste Management Influence Factors

For the purpose of this study, Waste management influence factor WMIF is defined as "a management factor that has an impact on either reducing construction wastes or facilitating the use of re-cycled materials for evaluating individual projects." The environment factors should match one of the following characteristics: 1 reflecting the trends or the cause–effect relationships; 2 providing information to make people understand the environment issues and measure the progress toward an established goal; 3 determining the performance level of individual companies; and 4 highlighting the problematic areas for further improvement.

With the help of these sources, a preliminary listing of factors that might improve the waste management practice has been developed. They are divided into five areas including manpower. Construction methods, materials and equipment, industry policy, management practice.

The complete set of 59 factors identified in this study is listed in fig1.These factors can be regarded as the potential factors that relate with improving construction waste management practice .In the manpower category, there are seven factors relating to support and commitment of the staff. Material and equipment category has 9 categories which includes maximization of recycling. Construction method 13 factors include storing up of materials. Management practice includes 16 factors relating to contractors approach towards waste management .Industrial policy includes rules and regulations towards waste management. Based on the factors the mean score of relative importance of factors were all above average (5) with the highest score of 10.

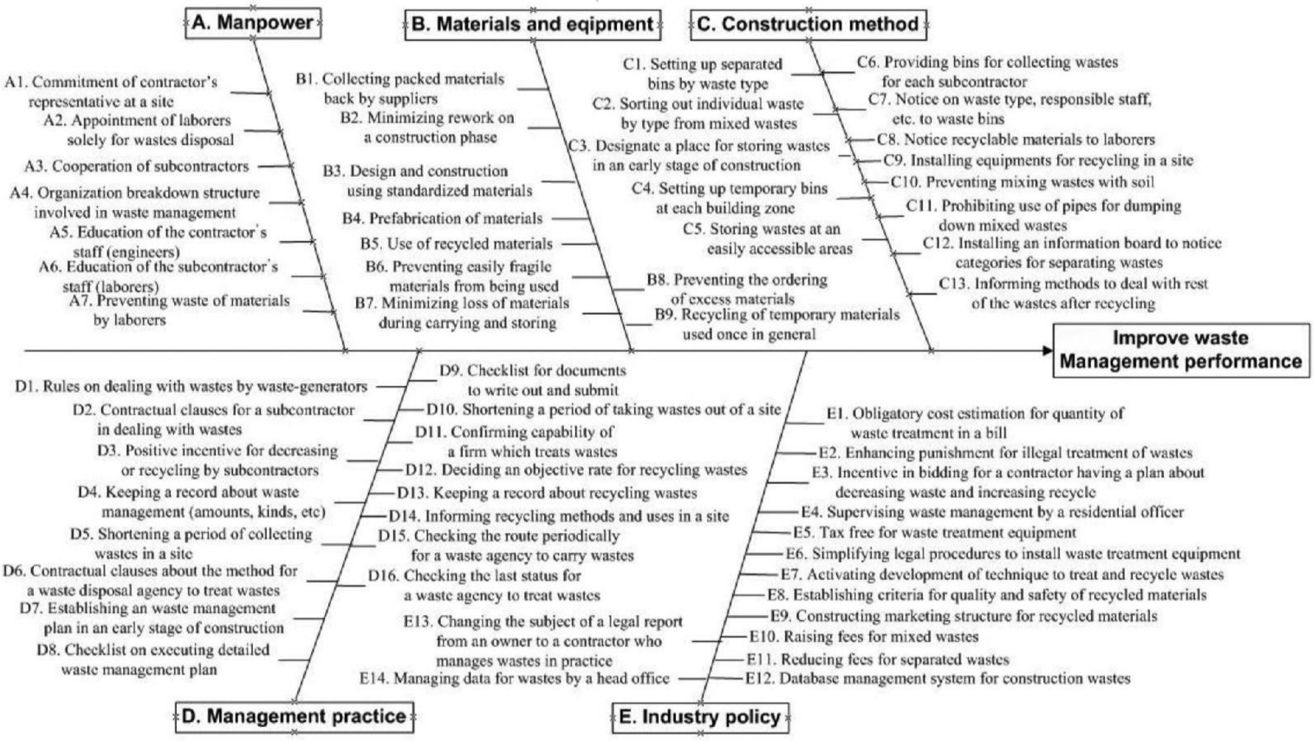

Fig 1 Cause and effect diagram for waste management performance improvement

Table 1;Survey results: Waste Management Influence Factors

Rank	Factor identification	Mean	Standard deviation
1	A1	4.05	0.959
2	A2	3.95	0.815
3	A6	3.80	0.883
4	A5	3.75	0.840
5	B1	3.67	1.023
6	B2	3.63	1.192
7	B5	3.57	1.279
8	E5	3.55	1.319
9	C4	3.43	1.035
10	D3	3.33	0.813
11	D1	3.43	1.035
12	D13	3.33	1.047
13	C2	3.30	1.305
14	C1	3.27	1.109
15	E1	3.23	1.250
16	B3	3.20	1.285
17	B4	3.18	1.338
18	D14	3.03	1.165
19	E4	3.00	0.961
20	B9	2.88	0.939
21	D7	2.83	0.874
22	E7	2.80	0.791
23	E12	2.73	0.987
24	E5	2.70	1.137
25	D10	2.68	1.347

B. Questionnaire Survey:Relative Importance Of WMIFS

To investigate the magnitude of relative importance of all 25 factors, a questionnaire survey has been conducted. In the questionnaire, the identified factors are provided and the respondents are requested to select the best option between 1 and 10 in terms of their relative importance. A score of "10" represents "the most significant influence on decreasing wastes and increasing recycling, "whereas a score of "1" represents "no influence on decreasing wastes and increasing recycling." More than 60 questionnaires were distributed to the construction sites around South India. After completing the data collection process, the average values and variances for each factor were computed using SPSS. In Table 1, the partial listing of rank-ordered WMIFs is provided. It is noteworthy that four factors A1, A2, A6, and A5 in the "Manpower category are included in the top 10 ranked list.

- Commitment of contractor's representative on site A1
- Appointment of laborers solely for waste disposal A2
- Lack of education of contractors staff A6
- Collecting packed materials back by suppliers B1
- Minimizing rework on a construction phase B2

Although a more rigorous statistical analysis should be conducted, the results can simply imply that there exists a difference among the indentified factors in terms of relative importance in achieving better waste management. It is also note-worthy that higher scored factors have relatively lower standard deviations. When ranking the five categories, the "manpower" category comes first, with the highest mean of 3.845. "Management practice," "materials and equipment,""construction method," and "industry policy" are sorted in descending order as provided in Fig. 2.

Based on the survey results, top-ranked 10 factors were selected as the relatively more influential factors. Among them, six factors were related to the "policy" category E and were excluded from the set because policy-related factors were considered to be uncontrollable at the individual construction site see Table 1. As a result 10 factors were finalized as improving on site waste management performance .To measure the degree of agreement on the finalized factors quantitatively. Each factor is converted into a question response format.

The tool user of the subject project is requested to select the most appropriate response for each factor. For example, one is asked whether the contractor's representative is committed to waste management to quantify the agreement level of factor A1. In this case, there are four options based on the degree of commitment, i.e., strongly agree, somewhat agree, moderate, somewhat disagree, and strongly disagree.

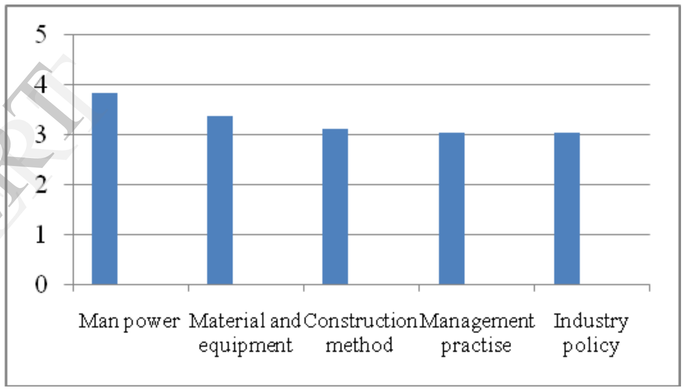

Fig. 2. Weightings of the WMIF by category

In this way, all of the finalized 23 WMIPs factors have been converted into a "question response "format. It is noteworthy that some of these factors have more than two questions to be answered. Table 2 shows the converted factors in the "Manpower" category with the corresponding questions and their responses.

As seen in Table 2, the responses have their own scores ranging from 0 to 1. With 0 as the minimum value and 1 as the maximum, the intermediate scores i.e., 0.5, 0.75, etc. have been computed by averaging the weights provided by the practitioners. As the result of the interviews, 31 question items for 23 WMIFs have been completed.

IV. DEVOLOPMENT OF WASTE MANAGEMENT PERFORMANCE ASSESSMENT TOOL

To assess the performance of a company towards waste management a tool called total index score was proposed

$$\text{Total index} = \sum_{i=4}^{4}\left(\sum_{j=1}^{1}\left(\sum_{k=1}^{m}(RS_{ijk}\ X\ RW_{ijk})xFW_{ij}\right)xCW_i\right.$$

Table 2. Question–Response Format for WMIF (Partial)

Factor Identification	Question	Response option	Score
A1	Is the contractor's representative committed to waste management?	A. Strongly agree B. Somewhat agree C. Moderate D. Somewhat disagree E. Strongly disagree	1.00 0.65 0.40 0.15 0.00
A2	Are there any laborers solely in charge of wastes disposal?	A. Yes B. No, worker on contractor side partly in charge C. No, worker on subcontractor side partly in share D. None is designated	1.00 0.54 0.29 0.00
A3	Are subcontractors cooperative for waste management?	A. Strongly agree B. Somewhat agree C. Moderate D. Somewhat disagree E. Strongly disagree	1.00 0.65 0.50 0.35 0.00
A4	Are wastes decreased by cooperation of subcontractors?	A. Strongly agree B. Somewhat agree C. Moderate D. Somewhat disagree E. Strongly disagree	1.00 0.65 0.50 0.25 0.00
A5	Is there an organization breakdown structure for waste management?	A. Yes, well-structured B. Yes, informal C. No	1.00 0.50 0.25
A6	Is an education program for waste management provided for engineers?	A. Yes, periodical basis B. Yes, once in a while C. No	1.00 0.45 0.15
A7	Is there a manual for engineer education program?	A. Yes, company-level manual B. Yes, on-site manual C. No	1.00 0.31 0.20
A8	Is an education program for waste management provided for laborers?	A. Yes, periodical basis B. Yes, once in a while C. No	1.00 0.25 0.20

where RS*ijk*=score of *k*th response for *j*th factor in *i*th category;RW*ijk*=weight of *k*th response for *j*th factor in *i*th category(0≤RW*ijk*≤10): CW*i* =weight of *i*th category (0≤CW*i*≤10);FW*ij*=weight of *j*th factor in *i*th category (0≤FW*ij*≤10);*l*=number of factors in *i*th category; and *m*=number of responses for *j*th factor in *i*th category In quantitatively developing a measurable indicator, the system uses three different types of weights, including response ,factor and category.The computation for these weights is currently based on the industry survey and expert experience and knowledge. It is noteworthy; therefore, the tool results should be rigorously validated in terms of applicability and reliability of the outcome. Although the factors identified in this study come from a rigorous data collection, weight quantification falls short of extensiveness. One of the main reasons for this deficiency comes from the short history of familiarity to the environment in the construction industry compared to other issues of interest, such as time and cost savings.

By multiplying the option scores for each WMIF with the three types of weightings, the TI is easily obtained, and ranges from 0 to 1000. The score can show the current level of waste management practice in construction projects, mainly for buildings as the data collection has been based on high-rise residential projects.

In order to give some guidance for the waste management practice, the TI score has been classified into four levels, i.e., excellent, good, fair, and poor. For example, to be classified as an excellent project, the TI score should be over 800, whereas in poor projects, the score is below 400

V. IMPLEMENTATION OF TOOL IN CONSTRUCTION PROJECTS

A case study of four residential buildings has been taken and their total index score has been calculated. Table 3 shows the performance of residential building towards waste management. Case 1 with a total index score of 667 is performing well in waste management, according to the total index score project is ranked as good. Were as in case 4 is showing poor waste management performance with a total index score of 395, according to the total index score project is showing poor performance. The total index score studies help us to know the overall performance of a project towards waste management.

Table 3. Case Examples of the Significant Factors: Options Chosen by the Participant

Factor identification	Question	Case 1 Good (TI=667)	Case2 Fair (TI=499)	Case 3 Fair (TI=424)	Case 4 Poor (TI=395)
A1	Is the contractor's representative committed to waste Management?	Very high	Very high	Moderate	Moderate
B1	Are packed materials collected Back by suppliers?	Moderate	Somewhat high	Somewhat low	Somewhat low
B2	Does a general contractor manage design quality to Minimize rework?	Moderate	Somewhat high	Moderate	Somewhat low
B3	Do the drawing plans meet The standard requirements Of materials?	Very high	Very high	Somewhat high	Somewhat high
A2	Are there any laborers solely In charge of wastes disposal?	No, general contractor partly in charge	No, general contractor partly in charge	No, subcontractors partly in charge	No, subcontractors partly in charge

VI. CONCLUSIONS AND RECOMENDATIONS

Environmental sustainability has become a major driving force for continuous improvement in the construction industry. The industry is also facing challenging circumstances to find an effective way to prevent environmental destruction and to make the best use of the increasingly scarce natural resources. To keep pace with this trend, many countries are trying to have sustainable building production systems and developing effective tools for assessing their performance. The existing assessment methods, however, are mainly focused on the planning or design phase with little emphasis on construction phase, although the management performance in the construction stage can highly affect both environmental damage and economic loss.

To overcome these limitations, this paper proposes a new methodology that assists project managers to assess the performance level of a project in terms of waste management practice. This study is based on a twofold approach. One is the identification of the waste management influence factors that play an important role in decreasing waste and increasing reused materials. The other is the development of an assessment tool for a particular project in order to measure the level of waste management performance. Although a more rigorous data collection and validation process should be followed, the salient findings from this study are noticeable as follows.

- The commitment of project participants, including laborers, subcontractors, and general contractors, are more important in effective waste management systems than new technologies or regulatory guidelines. This result quantitatively supports the preceding research emphasizing that the factors related to human commitment have a relatively greater impact on the waste management performance.

- As there has been little research quantitatively comparing the level of the waste management performance construction site, the TI score in the proposed tool can provide good guidance for Continuous improvement in the field of construction waste management. from the industry perspective, this paper contributes to establishing an environmentally sustainable construction by providing the project stakeholders with the influence factors and diagnosis tool for measuring their current performance level. Additionally, project owners can use the output of the tool, i.e., the TI score, as a measure to benchmark the level of waste management for their continuous improvement in environment-friendly construction.

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