Investigation of Factors Influencing Construction Waste Recycling Decisions

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Abstract

Construction waste is an unwanted by-product, which is achieved over the whole production flow. It appears in different forms, such as leftovers from new construction materials, packaging waste, and used materials during construction. It is, however, found that less than 10 percent of construction waste is reused and recycled. An ineffective waste management leads to environmental, health, and safety problems. This paper, therefore, examines key factors influencing construction waste recycling decisions, utilizing the exploratory factor analysis approach. The analytic hierarchy process method is also used to weigh the importance of the factors extracted from the exploratory factor analysis. It is expected that the study results help construction organizations make decisions regarding construction waste recycling.

Keywords: Analytical hierarchy process, Construction and demolition waste, Construction industry, Construction waste recycling, Exploratory factor analysis

Introduction

Construction industry is a complex, unique and uncertain industry, when compared with other manufacturing industries (Ibrahim et al., 2010). Examples are high turnover rate, time constraint, and limited site space. Wang et al. (2008) commented that the construction industry is a major contributor of waste and pollution generation. According to Yuan et al. (2011), construction and demolition (C&D) waste is defined as the wastes produced during the construction, renovation, civil, roadwork, and site clearance and demolition. The problem of high amount of C&D waste is a serious problem in many large cities. Hong Kong, for example, has a daily average of about 7,030 tones of C&D waste disposed at landfills (Wang et al., 2008). Rising disposal cost and reduction in number of landfills create a need for Singapore to search for alternatives to reduce, reuse, and recycle construction waste (Hwang and Yeo, 2011). In Thailand, it is estimated that 1.1 million tons of C&D waste was generated per year (Kofoworola and Gheewala, 2009). The attention to recycle C&D waste has, however, not been received from management, as it is believed that the cost of implementing waste management is much higher than the benefits gained (Shen and Tam, 2002).

To better understand and make decisions on construction waste recycling, this paper investigates key factors influencing the construction waste recycling decisions, utilizing the exploratory factor analysis and analytic hierarchy process techniques. The details are explained next.

Items Associated with C&D Waste

Based on a number of construction-related literatures, a total of 20 items, associated with C&D waste, are extracted as follows.

1. Law enforcement (LEM): To ensure all project stakeholders share commitment in waste control, developing law enforcement by the government is needed (Tam et al., 2007).

2. Labors required (LRQ): According to Wang et al. (2008), the processes of C&D waste management require a decent number of labors.
3. Specific machine (SMC): Specific machine is needed to effectively sort construction waste (Tam et al., 2007).
4. Skilled Labor (SLB): Kofoworola and Gheewala (2009) claimed that one of the problems of construction waste recycling in Thailand is the lack of skilled labors in waste collection and disposal.
5. Supported regulation (SRT): Supported regulation from government encourages contractors to recycle the C&D waste (Leigh et al., 2004).
6. Amount of landfills (ALF): The limitation of landfill spaces forces construction companies to search for other techniques to manage C&D waste (Pitt, 2005).
7. Environmental impact (EMI): Air and water pollution is one of the causes that force construction companies to recycle construction waste (Leigh et al., 2004).
8. Transportation cost (TPC): According to Shakantu et al. (2008), high transportation cost of waste disposal forces companies to consider waste recycling.
9. Value of the recycled materials (VRM): Value of recycled materials is important to the benefit of the company (Kofoworola and Gheewala, 2009).
10. Amount of waste generated (AWG): According to Tam et al. (2007), the increase of C&D waste requires more landfills to dispose of; this could be a problem for small country with limited space.
11. Tax reduction (TRD): Leigh et al. (2004) suggested the tax reduction campaign to encourage C&D waste recycling.
12. Reduction of virgin materials (RVM): The use of recycled materials helps reducing the need of virgin materials. (Merino et al., 2009).
13. Lack of market (LOM): Lack of a mature market for trading recycled C&D waste results in only small part of waste recycled and used in the construction processes (Yuan et al., 2011).
14. Government's financial support (GFS): According to Leigh et al. (2004), government support is crucial in a successful waste recycling program.
15. Company's image (CIM): Implementing waste management as a part of company policy allows the company to enhance its public images as an environmental-friendly company (Hwang and Yeo, 2011).
16. Complication of recycling processes (CRP): The complication of recycling processes may increase the cost (Tam et al., 2007).
17. Limited site space (LSP): Limited site space can greatly affect the implementation of on-site construction and demolition waste management activities (Yuan et al., 2011).
18. Standard of the recycled waste (SRW): According to Richardson et al. (2010), if the standard of the recycled waste is not up to the standard, the contractors may not consider use it.
19. Time constraint (TCS): Time constraint may limit the implementation of C&D waste recycling (Lawson et al., 2001).
20. Intense competition (ICP): Intense competition in the construction industry may reduce the attention to recycle the C&D waste (Yuan et al., 2011).

These 20 items are used in developing the questionnaire survey to gather data for the analyses.

Questionnaire Survey and Preliminary Analyses

The questionnaire survey is developed based on the 20 extracted items. Targeted respondents are in management positions in the construction-related companies. The respondents are asked to rate their agreement on each statement of the 20 items using the five points Likert scale. A total of 400 questionnaires are launched, with 107 returns, representing 26.75% in the response rate. From the returned responses, three are unusable due to data incompleteness, resulting in a total of 104 questionnaires for further analyses. Most of the respondents have working experience of more than five years, both in their current organization and in the construction industry. Also, half of the respondents are in their current position of at least five years. These indicate the reasonably high working experience of the respondents.

After the data is gathered, the normality test and the outliers test are performed to increase confidence in the data. The results reveal that no skewness and kurtosis values exceed limits, thus concluding the normal distribution of the data collected. The results also show no sign of outliers. This, thus, increases confidence in the data for further analyses.

Exploratory Factor Analysis

An exploratory factor analysis is performed to explore relationships among items, in effort to generate theory or facilitate construct formulation. The results help inform construct development (Stevens, 2002). In this paper, the generalized least square analysis, together with the eigenvalue over 1, factor loading of 0.45, and the varimax rotation method, are used to perform the exploratory factor analysis. The first run leads to the removal of the 'SRT' item, as it has factor loading less than 0.45. The second run removes another three items, including 'LEM', 'TRD', and 'ALF', resulting in the remaining 16 items for further analyses.

The next run extracts the 16 items into three factors, which account for 54.1% of the total variance (see Table 1). Factor 1 is predominantly accounted for by six items initially related to economics, so it is called *Economics* factor. Factor 2 is also accounted for by six items, and is called *Market and Site Activities* factor. Factor 3, on the other hand, is associated with four items, and is named *Environment* factor.

A closer examination of the identified factors revealed the potential for further analysis to extract the independent factors for better understanding of the factors extracted. For this reason, the six items of *Economics* factor is further analyzed, and the results give rise to two new factors, which are called *Labor and Machine* and *Related Costs* factors, as shown in Table 2. Similarly, two factors are extracted from the six items of *Market and Site Activities* factor, and are called *Market* and *Site Activities* factors (see Table 3). No new factors are, however, extracted from *Environment* factor, thus this factor is considered as a single construct.

In summary, five factors, within the 16 items, are extracted from the exploratory factor analysis, including *Labor and Machine* (three items), *Related Costs* (three items), *Market* (three items), *Site Activities* (three items), and *Environment* (four items) factors. These five factors are confirmed with the reliability test; the results, as shown in Table 4, are considered acceptable.

Table 1. Three Factors Extracted from the 16 Items

Item	Factor Loading		
	Economics	Market and Site Activities	Environment
LRQ	0.75		
SMC	0.72		
VRM	0.63		
SLB	0.59		
TPC	0.52		
GFS	0.47		
AWG		0.70	
ICP		0.67	
LOM		0.63	
TCS		0.61	
SRW		0.58	
ALF		0.51	
CRP			0.74
EMI			0.57
CIM			0.55
RVM			0.51

Table 2. Two factors extracted from Six Items of Economics Factor

Item	Factor Loading	
	Labor and Machine	Related Costs
SMC	0.75	
LRQ	0.57	
SLB	0.48	
TPC		0.63
VRM		0.60
GFS		0.50

Table 3. Two factors extracted from Six Items of Market and Site Activities Factor

Item	Factor Loading	
	Market	Site Activities
AWG	0.99	
ICP	0.60	
LOM	0.58	
SRW		0.71
TCS		0.63
ALF		0.51

Table 4. The Reliability Test Results

Factor Extracted	Cronbach's Alpha
Labor and Machine	0.77
Related Costs	0.70
Market	0.80
Site Activities	0.82
Environment	0.79

To assess the importance of the five factors extracted, the analytic hierarchy process (AHP) is next performed.

Analytic Hierarchy Process

The analytic hierarchy process (AHP) was developed in 1970s by Professor Thomas Saaty. It is becoming popular in research due to the fact that its utility outweighs other research methods (Cheng and Li, 2001). It decomposes a problem into a systematic decision hierarchy, assigns weights to each set of elements at various levels, employs a pairwise comparison to validate the consistency of responses, and determines the priorities of the alternatives (Shapira and Simcha, 2009).

In this paper, the AHP method is used to assign the important weights of the three factors, together with their associated items. The results of the AHP method can be used for decision making in waste recycled program establishment. The interview method is used to gather data from six experts with high experiences in the construction industry. According to Melon et al. (2008), six to 12 interviewees are considered appropriated for the interviews to gain greater depth of responses with less cost. Each interviewee is asked to rate the intensity of importance between a pair of main components or sub-components, pair-by-pair, using the scale 1 to 9, as illustrated in Table 5. After all components are compared, a paired comparison matrix is formed, and the weights of the five factors are calculated, as shown in Figure 1. It is to note that these weights are the geometric mean values of the six experts' calculated scores.

Table 5. Scale Measurement for the AHP Analysis

Scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one over another
5	Strong importance	Experience and judgement strongly favour one over another
7	Very strong importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above

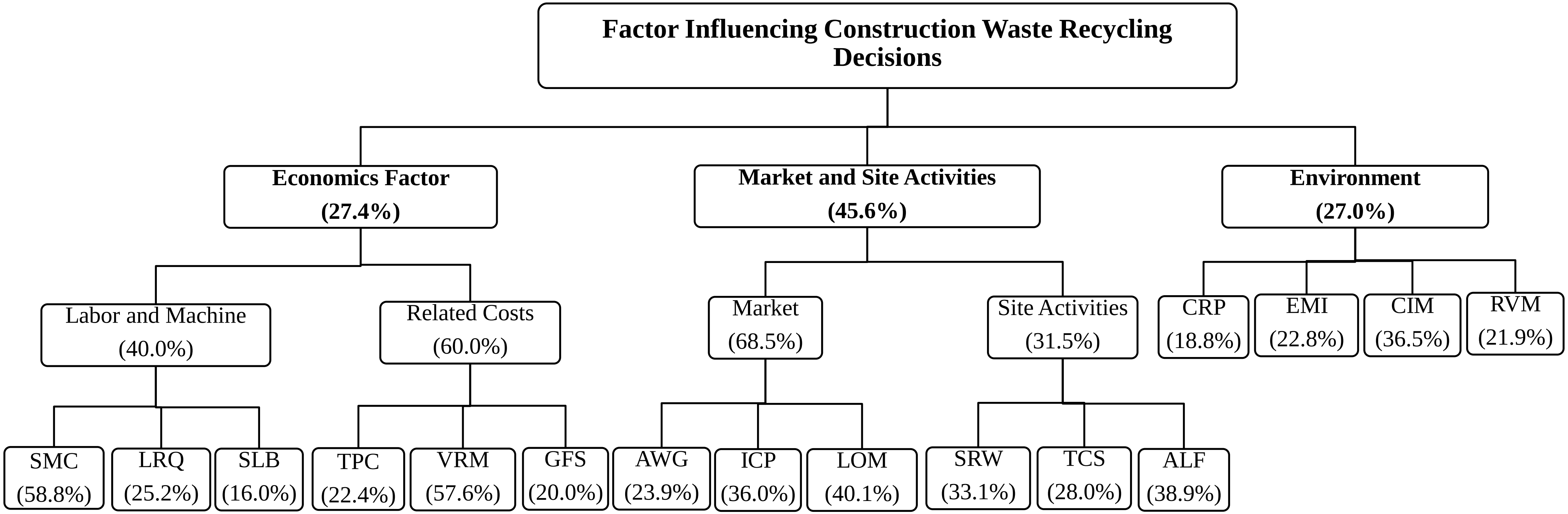

Figure 1. Weights of the Five Factors Calculated from the AHP Method

It is clear that the *Market and Site Activities* factor has the most influence on the decision making to recycle C&D waste, compared with the *Economics* and the *Environment* factors. Among the *Market* sub-factor, lack of market for trading the recycled waste (LOM) is a major concern of construction organizations, with the weight of 40.1%. Intense competition in the construction industry (ICP) and the amount of landfill (ALF) are also important criteria influencing the decision to recycle C&D waste.

In the *Economics* factor, the value of the recycled materials (VRM) and the need of specific machine for sorting C&D waste (SMC) affect the decision to recycle, with 57.6% and 58.8% importance, respectively.

Company's image as an environmental-friendly company (CIM) might be an important factor for companies, especially joint-venture companies, to recycle C&D waste.

Conclusion

The construction industry is one of the industries that generate high amount of C&D waste. To better understand and manage C&D waste, this project aims to investigate factors influencing construction waste recycling decisions using the exploratory factor analysis. The results reveal five key factors, namely *Labor and Machine*, *Related Costs*, *Market*, *Site Activities*, and *Environment* factors. The analytic hierarchy process (AHP) is then used to evaluate the important weights of the five factors extracted. It is found that *Market* is the most important factor affecting the decision to recycle C&D waste, especially the amount of market for trading the recycled waste and the value of the recycled materials. The government should, therefore, promote the recycling program to stimulate the market, and encourage the use of the recycled waste.

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