ANALYTIC HIERARCHY PROCESS OF REVERSE LOGISTICS IN THE CONSTRUCTION INDUSTRY

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Abstract
Construction industry is one of the major industries that contributes large amount of waste, called construction and demolition (C&D) waste. In this study, four key reverse logistics methods, namely the direct reuse, the remanufacturing, the recycling, and the landfill methods, are used to manage the C&D waste. Two factors, including the Economic and Site Constraints, together with their 15 sub-factors, are examined to implement the reverse logistics in the construction industry. The hierarchy model of reverse logistics decisions, developed through the analytic hierarchy process (AHP), reveal the importance of the Economic factor over the Site Constraint factor. It is suggested that the transportation cost, the processing cost, the specific sorting technology, and the limited project time must be first considered before making the decisions on the reverse logistics plans.

Keywords: Analytic hierarchy process, Construction industry, Economic, Reverse logistics, Site constraints

1. INTRODUCTION

The construction industry, in both developed and developing countries, is viewed as a sector of the economy that, through planning, design, construction, maintenance and repair, and operation, transforms various resources into constructed facilities (Moavenzadeh and Rossow 1976). The industry plays a key role in satisfying a wide range of physical, economic, and social needs, and contributes significantly to the fulfillment of various major national goals (Moavenzadeh and Rossow 1976). However, it is considered one of the major industries that contributed large amount of waste called construction and demolition (C&D) waste (Chen and Wong 2002). According to Fatta et al. (2003), C&D waste is generated on active building sites, and includes a wide range of materials, depending on the source of the wastes,

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such as sand, gravel, asphalt, bricks, gypsum, wood, plastic, glass, and metal.

The C&D waste, when segregated, can include high-value materials and resources for new construction. This leads to the idea of reverse logistics. According to Srivastava (2008), five types of reverse logistics are 1) disposal, 2) recycle, 3) repair, 4) reuse, and 5) remanufacture. Peng et al. (1997), in contrast, recommended six types of reversed logistics, including 1) reduce, 2) reuse, 3) recycle, 4) compost, 5) incinerate, and 6) landfill. El-Haggar (2007) separated the reversed logistics into five types, namely 1) reduce, 2) reuse, 3) recycle, 4) recovery, and 5) disposal.

Based on the above diverse information, this study divided the reverse logistics into four major types, including 1) direct reuse, 2) remanufacturing, 3) recycle, and 4) landfill. These four types of reverse logistics represent the most common reverse logistics methods in Thailand (Oyeshola and Shabbir 2009). Details are explained next.

2. FACTORS AFFECTING REVERSE LOGISTICS DECISIONS

Four types of reverse logistics can be used to manage C&D waste to effectively implement the reverse logistics plans. However, there is a need to understand factors affecting the decision to implement the reverse logistics methods. Based on the construction-related literature, two key factors affecting reverse logistics decisions are Economic and Site Constraint factors. The Economic factor is associated with nine sub-factors, including 1) labor cost (LBC), 2) inventory cost (IVC), 3) transportation cost (TPC): Distances from site to site affect the transportation cost and the project budget, 4) processing cost (PCC), 5) specific sorting machine (SSM), 6) specific technology (STG), 7) matured market (MMK), 8) landfill charge (LFC), and 9) availability of landfill (ALF) (Hao et al. 2008; Tam et al. 2007; Terrance et al. 1992; Waters 2003; Yuan and Shen 2011). On the other hand, six sub-factors under the Site Constraint factor are: 1) site space (SSP), 2) social image (SIM), 3) requirement of virgin material (RVM), 4) limited project time (LPT), 5) environmental concern (EVC), and 6) knowledge of sorting (KLS) (Klang et al. 2003; Knemeyer et al. 2002; Richardson et al. 2010; Terrance et al. 1992; Yuan and Shen 2011). These 15 sub-factors, under the two factors, are used to develop the hierarchy model of reverse logistics for the analytic hierarchy process (AHP) analysis.

3. THE HIERARCHY MODEL OF REVERSE LOGISTICS

The analytic hierarchy process (AHP) is one of the most widely used multiple criteria decision-making tools that is applied in many industries. Examples are the selection of infectious medical waste disposal, the vendor selection of a telecommunications system, and the evaluation of advanced construction technology with AHP (Skibniewski and Chao 1992, Vaidya and Kumar 2004).

This study utilizes the AHP method to assess the important weights of each factor and sub-factor of reverse logistics decisions in the construction industry. The hierarchy model consists of two factors, 15 sub-factors, and four decision options (direct reuse, recycle, remanufacturing, and landfill), as shown in Figure 1.

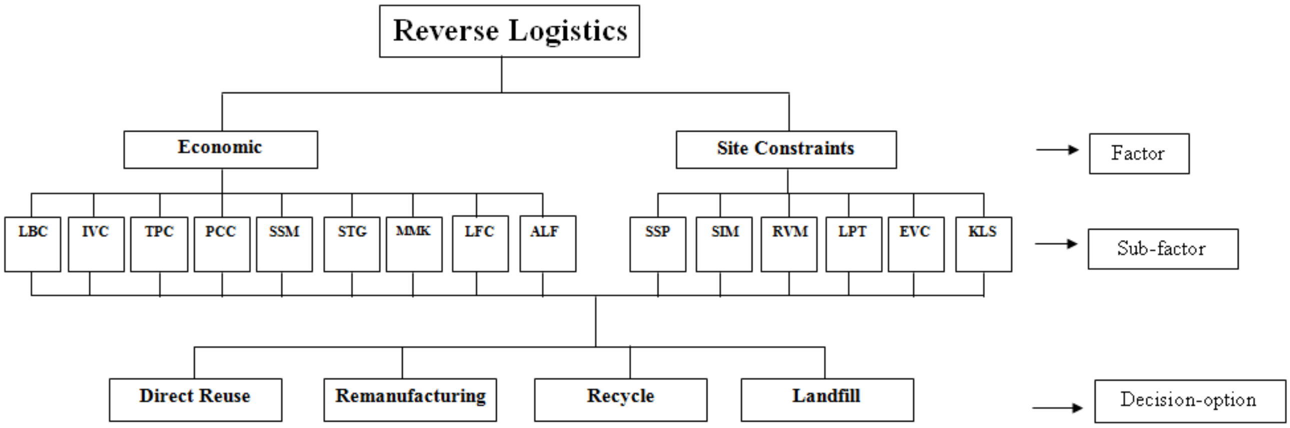

Figure 1: The hierarchy model of the reverse logistics in the construction industry.

This hierarchy model is used to develop the interview questions to gather information for the AHP analysis using the Expert Choice software. 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. In this study, six interviewees involved in the interviews are experts in the construction industry, and engage in the C&D waste recycling decisions in their organizations. They have been working in the industry for more than 10 years. They can make decision regarding reverse logistics implementation.

Each of the experts was asked to rate his opinions on a number of pairs of factors or sub-factors, pair-by-pair, using the Saaty score, as explained in Table 1. For example, the interviewee was asked to consider the importance of the Economic factor over the Site Constraints factor in making the reverse logistics decision. If he considered the Economic factor as having extremely most importance in order to make decision regarding the reverse logistics implementation, he then gave the score of Economic factor of 9. This, vice versa, gave the score of the Site Constraints factor over the Economic factor of 1/9 (see Table 2).

Table 1: The Saaty score (Saaty, 2008).

Comparison scale intensity	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment favor one factor over another
5	Essential or strong importance	Experience and judgment strongly Favor one factor over another
7	Very strong importance	An factor is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence of favoring one factor over another is of the highest possible order of affirmation
2, 4, 6, 8		Intermediate values when compromise is needed

Table 2: The example of rating scores of the two factors.

Factor	Economic	Site Constraints
Economic		9
Site Constraints	1/9	

Similarly, the nine sub-factors under the Economic factor are compared, pair-by-pair; the scores are filled in the matrix (see Table 3). The scores of the six sub-factors under the Site Constraints factor are displayed in Table 4.

Table 3: The example of rating scores of the sub-factors under the Economic factor.

Sub-factor	LBC	IVC	TPC	PCC	SSM	STG	MMK	LFC	ALF
LBC		1	1/7	1/3	3	1/3	1/3	3	1
IVC	1		1/7	1/3	5	1/3	1/3	5	5
TPC	7	7		3	9	5	5	9	7
PCC	3	3	1/3		7	1	3	9	5
SSM	1/3	1/5	1/9	1/7		1/7	1/5	1	1/3
STG	3	3	1/5	1	7		1	9	3
MMK	3	3	1/5	1/3	5	1		7	3
LFC	1/3	1/5	1/9	1/9	1	1/9	1/7		1/3
ALF	1	1/5	1/7	1/5	3	1/3	1/3	3	

Table 4: The example of rating scores of the sub-factors under the Site Constraints factor.

Sub-factor	SSP	SIM	RVM	LPT	EVC	KLS
SSP		7	1	1/5	1	1
SIM	1/7		1/5	1/9	1/9	1/3
RVM	1	5		1/7	1/5	3
LPT	5	9	7		3	7
EVC	1	9	5	1/3		5
KLS	1	3	1/3	1/7	1/5	

A total of 52 comparison statements were asked (based on a pair of two factors and 51 pairs of 15 sub-factors), and the data were gathered. The AHP analysis was then performed, and the results were checked with the consistency ratio to accept or reject the results. According to Saaty (2008), the ratio of less than or equal to 0.1 is considered acceptable.

4. WEIGHTS OF FACTORS AND SUB-FACTORS OF REVERSE LOGISTICS DECISIONS

Data gathered from the six interviewees were used to calculate the important weights of each factor and sub-factor of reverse logistics decisions in the construction industry. Four out of six experts considered the Economic factor as having more importance in making reverse logistics decisions than the Site Constraint factor. The transportation cost (TPC), the limited project time (LPT), and the environmental concern (EVC) were critical issues when developing the reverse logistics plan, as they contained high weights from the analysis results.

To gain the overall opinions of the reverse logistics decisions, the geometric mean was employed to finalize the weight of each factor and sub-factor. The results, as shown in Figure

2, confirmed the Economic factor with higher weight (weight = 0.57) than the Site Constraint factor (weight = 0.43).

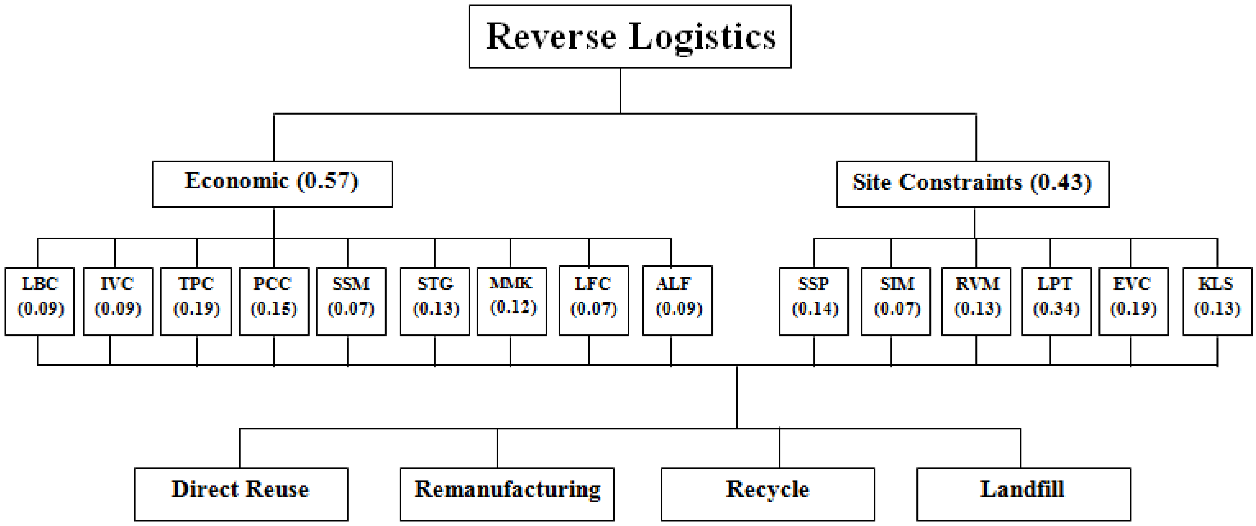

Figure 2: The final weights of factors and sub-factors of reverse logistics decisions.

When consider implementing the reverse logistics in the construction industry, the transportation cost, the processing cost, and the specific sorting technology must first be considered, as represented by the highest weights among the Economic sub-factors (the weights of 0.19, 0.15, and 0.13, respectively, see Figure 2). The pressure on the limited project time (with the important weight of 0.34) also affected the decision to perform the reverse logistics.

5. CONCLUSION

This study considered four types of reverse logistics methods, namely the direct reuse, the remanufacturing, the recycling, and the landfill methods, in the construction industry. The Economics and Site Constraints factors were used, together with their 15 sub-factors, to develop the hierarchy model of reverse logistics decisions using the AHP program. The results revealed the importance of the Economic factor over the Site Constraints factor, especially in the transportation cost, the processing cost, and the specific sorting technology sub-factors. Apart from that, the intense project time might also affect the decision to reuse or recycle the C&D waste.

The construction company can utilize the developed hierarchy model as a guideline to assess the most appropriate reverse logistics method to implement, and plan for their reverse logistics program based on the assessment results.

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