

Decision Making on Reverse Logistics in the Construction Industry

[Thanwadee Chinda]

Abstract—With the growing competition, many construction organizations attempt to improve their productivity, quality, and efficiency. Construction waste management, by means of reverse logistics, becomes a key issue to improve the productivity, and raise the company's green image. In this study, four key reverse logistics methods, including the direct reuse, the remanufacturing, the recycling, and the landfill methods, are considered to manage the construction and demolition (C&D) waste. Two factors (Economic and Site Constraints factors), with their 15 sub-factors, affecting the decisions to implement the reverse logistics are examined. The hierarchy model of reverse logistics decisions, developed through the analytic hierarchy process (AHP), reveal the importance of each factor and sub-factor. A case study of a construction company utilizing the developed hierarchy model to make the decision on the best reverse logistics method to implement is also provided.

Keywords—analytic hierarchy process, construction industry, reverses logistics

I. Introduction

One of the best definitions of the construction industry is the extent of which the facilities are designed and constructed with the available materials from the suppliers and labor as stipulated by the government's regulatory agencies in the area of safety, health and employment [1]. The construction industry plays a major and vital role in transforming the aspirations and needs of people into reality by physically implementing various construction development projects. It is undeniably essential to the growth of a nation and a key sector in the nation's economy.

Construction activities are generally administered or managed at a relatively fixed place of business, but the actual construction work is performed at one or more different project sites [2]. Traditional ways of performing and managing construction processes face unprecedented challenges. The growing competition forces construction organizations to rethink their construction for improving productivity, quality and efficiency [3]. When any industries make construction, for example, buildings, airports, dams or streets, the construction and demolition waste (C&D) is occurred.

C&D wastes are a general term for a diverse range of materials that, when segregated, can include high-value materials and resources for new construction [4]. They are generated on active building sites, and include a wide range of materials depending on the source of the waste, such as sand, gravel, and rocks from the excavation processes; gravel, sand, blocks of concrete, bricks, and gypsum from the demolition processes [4]. According to Peng et al. [5], the C&D wastes represent a major component of municipal solid waste. If the waste is not properly treated, it will have negative impacts on

the hygienic conditions, and pollute the air and surface and groundwater, as well as the soil.

Reverse logistics is one of the methods to manage C&D wastes. Srivastava [6] classified five types of reverse logistics, including 1) disposal, 2) recycle, 3) repair, 4) reuse, and 5) remanufacture. Peng et al. [5], in contrast, recommended six types of reversed logistics, including 1) reduce, 2) reuse, 3) recycle, 4) compost, 5) incinerate, and 6) landfill. El-Haggar [7] 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 aims to develop a hierarchy model of four major types of reverse logistics, including 1) direct reuse, 2) remanufacturing, 3) recycle, and 4) landfill, that represent the most common reverse logistics methods in Thailand [8]. A number of key factors, as well as their associated items, are listed to make decisions on the implementation of reverse logistics in the construction industry. It is expected that the construction organization use the developed hierarchy model to help make the decision on the best reverse logistics method to implement.

II. The Hierarchy Model of Reverse Logistics

This study utilizes the analytic hierarchy process (AHP) method to investigate the key factors and sub-factors of reverse logistics decisions in the construction industry. Based on Chinda et al. [9], the hierarchy model of reverse logistics consists of two factors (i.e. Economic and Site Constraints factors), 15 sub-factors, and four decision options (i.e. direct reuse, recycle, remanufacturing, and landfill), as shown in Figure 1. Importance weight of each factor and sub-factor derives from the analysis results using the Expert Choice program [9].

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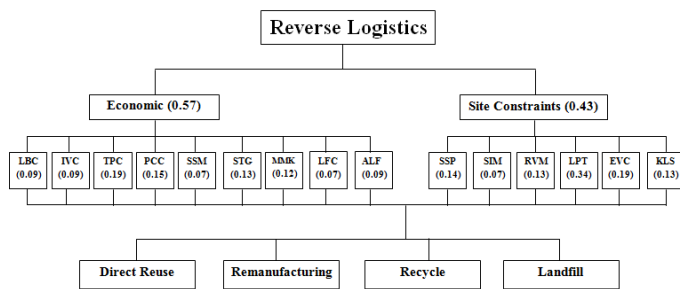


Figure 1. Factors and sub-factors of reverse logistics decisions.

The Economic factor consists of nine sub-factors, namely:

- Labor cost (LBC)
- Inventory cost (IVC)
- Transportation cost (TPC)
- Processing cost (PCC)
- Specific sorting machine (SSM)
- Specific technology (STG)
- Matured market (MMK)
- Landfill charge (LFC)
- Availability of landfill (ALF)

The Site Constraint factor, on the other hand, consists of six sub-factors, namely:

- Site space (SSP)
- Social image (SIM)
- Requirement of virgin material (RVM)
- Limited project time (LPT)
- Environmental concern (EVC)
- Knowledge of sorting (KLS)

It is clear that the transportation cost (TPC), the processing cost (PCC), and the specific sorting technology (STG) must first be considered, as they have high weights among the Economic sub-factors. The pressure on the limited project time (LPT, with the weight of 0.34) also affects the decision to perform the reverse logistics in terms of Site Constraints factor.

The above hierarchy model is then used to make the decision on the best reverse logistics method the construction company should utilize to manage its C&D wastes.

III. Decision Making on the Reverse Logistics Method using the Developed Hierarchy Model

The hierarchy model of reverse logistics decisions is used to make the decisions on the reverse logistics implementation in the construction company. To explain, two construction companies, specializing in the building construction and operating in Bangkok, were involved in the assessment. Each company set up a team, consisting of senior engineers, project

managers, and managers, to provide data for the assessment. The steps of assessment are as shown in Figure 2.

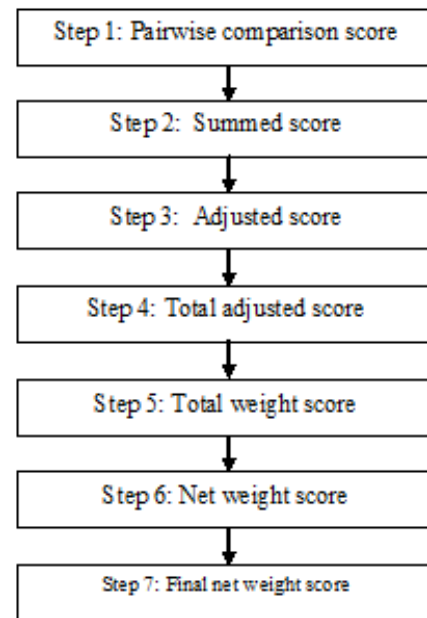


Figure 2. Seven steps of decision making on reverse logistics implementation.

Details of each step are as the followings:

1. Score of each sub-factor, when considering a pair of decision options, was filled by the team using the Saaty score system (see Table 1). To illustrate, by considering the “labor cost” (LBC) sub-factor, if the team considered the direct reuse method as having moderate possibility to implement than the remanufacturing method, the team then gave the score of 3 to the direct reuse method (see Table 2). The score of the remanufacturing method, compared with the direct reuse method, was then vice versa.
2. For each sub-factor, the scores in each column (represented each decision option) were summed. For example, the sum of the direct reuse column = $1+0.33+0.33+0.20 = 1.86$ (see Table 2).
3. For each sub-factor, each score in each column was then adjusted by dividing its score with its summed score to make the adjusted sum of 1. For example, adjusted score of comparing the remanufacturing method with the direct reuse method = $0.33/1.86 = 0.177$ (see Table 3). The adjusted sum of the direct reuse column was then $0.538+0.177+0.177+0.108 = 1.00$.
4. After that, the adjusted scores in each row (each decision option) were summed, and divided by the number of decision options (four in this case) to achieve the total adjusted score (see Table 3). Please

note that the sum of total adjusted score column must equal 1.

5. Once the total adjusted scores of the 15 sub-factors (nine sub-factors in Economic factor and six sub-factors in Site Constraint factor) were calculated, the total weight score of each decision option of each sub-factor was calculated by multiplying each total adjusted score with its sub-factor weight (calculated from the AHP). For example, the total weight of the direct reuse method when considering the “labor cost” sub-factor equaled to the total adjusted score of 0.508 multiplied by the weight of the “labor cost” sub-factor (0.09, see Figure 1). It was then $0.508 \times 0.09 = 0.046$. The total weight of the remanufacturing method when considering the “labor cost” sub-factor was, on the other hand, equal to the total adjusted score of 0.193 multiplied by the weight of the “labor cost” sub-factor, which was $0.193 \times 0.09 = 0.017$.
6. Once the total weight scores of each decision option of the 15 sub-factors were calculated, the net weight score of each decision option of each sub-factor was achieved, by multiplying each total weight score with its associated factor’s weight achieved from the AHP. For example, the net weight score of the direct reuse method when considering the “labor cost” sub-factor equaled the total weight score of 0.046 multiplied by the weight of Economic factor (0.57, see Figure 1). It was then $0.046 \times 0.57 = 0.026$. The net weight score of the remanufacturing method when considering the “labor cost” sub-factor, alternatively, equaled the total weight score of 0.017 multiplied by the weight of Economic factor, which $0.017 \times 0.57 = 0.010$.

TABLE I. 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 II. EXAMPLE OF THE “LABOR COST” SUB-FACTOR SCORES WHEN CONSIDERING THE FOUR DIFFERENT REVERSE LOGISTICS METHOD

Reverse Logistics Method	The “Labor Cost” Sub-Factor			
	Direct reuse	Remanufacturing	Recycle	Landfill
Direct Reuse	1	3	3	5
Remanufacturing	1/3 = 0.33	1	1	3
Recycle	1/3 = 0.33	1	1	5
Landfill	1/5 = 0.20	1/3 = 0.33	1/5 = 0.20	1
Summed Score	1.86	5.33	5.20	14

TABLE III. THE ADJUSTED SCORES OF THE “LABOR COST” SUB-FACTOR

The “Labor Cost” Sub-Factor	Adjusted Score				Total Adjusted Score
	Direct reuse	Remanufacturing	Recycle	Landfill	
Direct reuse	1/1.86 = 0.538	3/5.33 = 0.563	3/5.20 = 0.577	5/14 = 0.357	(0.538 + 0.563 + 0.577 + 0.357)/4 = 0.509
Remanufacturing	0.33/1.86 = 0.177	1/5.33 = 0.188	1/5.20 = 0.192	3/14 = 0.214	(0.177 + 0.188 + 0.192 + 0.214)/4 = 0.193
Recycle	0.33/1.86 = 0.177	1/5.33 = 0.188	1/5.20 = 0.192	5/14 = 0.357	(0.177 + 0.188 + 0.192 + 0.357)/4 = 0.229
Landfill	0.20/1.86 = 0.108	0.33/5.33 = 0.062	0.20/5.20 = 0.038	1/14 = 0.071	(0.108 + 0.062 + 0.038 + 0.071)/4 = 0.070
Sum	1	1	1	1	1

Once the net weight scores of each decision option of the 15 sub-factors were calculated, the final weight score of each decision option was achieved by summing the net weight scores of the 15 sub-factors in that decision option. To illustrate, the final net weight score of the direct reuse option was achieved by summing the net weight score of the “labor cost” sub-factor with the net weight score of the “inventory cost” sub-factor with the “transportation cost” sub-factor, and so on. The decision option with the highest final net weight score was considered the best reverse logistics decision to implement in the organization.

Table 4 shows the final net weight scores of the studied companies. The first company should utilize the direct reuse method for reverse logistics implementation, as it has the highest final net weight score among the four methods (i.e. 0.59). This is due to the fact that the direct reuse of construction materials does not cause high expenses. This is consistent with Tam [10] that reusing the construction wastes is the best option when the reduction is not possible. The company also considered recycle and the remanufacture the construction materials in order to save landfill space and enhance the environmental concern image.

TABLE IV. FINAL NET WEIGHT SCORES OF THE TWO STUDIED COMPANIES

Final Net Weight Score	Direct Reuse	Remanufacturing	Recycle	Landfill
Company # 1	0.59	0.17	0.20	0.04
Company # 2	0.45	0.05	0.16	0.34

The second company had similar opinion as the first company that the direct reuse is the most appropriate method to implement (with the highest final net weight score of 0.45). However, if the materials cannot be direct reused, the company designed to dump them into landfill without considering recycling or remanufacturing them. This might

have to do with the high transportation and processing costs (as shown in Figure 1 with high weights of the “transportation cost” and the “processing cost” sub-factors). Moreover, with the intense project time, the recycling or remanufacturing methods might be considered inappropriate.

iv. 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 construction company can utilize the developed hierarchy model to assess the most appropriate reverse logistics method to implement. In this study, two case studies selected the direct reuse method, as it has the highest final net weight score among the four methods. This might be because of the cost and time savings of this method to implement.

The company can plan for their reverse logistics program based on the assessment results. Data used for the analysis in this study, however, derived from experts who their companies are located in Bangkok. More interviews, nevertheless, might be conducted from experts in different geographical areas to increase the accuracy of the data.

References

- [1] D.S. Barrie and B.C. Paulson, Professional Construction Management. USA: McGraw Hill, 1978.
- [2] US Census Bureau and Economics Census, Construction, Economics and Statistics Administration. Washington D.C.: US Department of Commerce, 1997.
- [3] S. Karna and H. Jonnonen, “Project feedback as a tool for learning,” Proceedings of the IGLC-13, Sydney, Australia, 2005.
- [4] D. Fatta, A. Papadopoulos, E. Avramikos, E. Sgourou, K. Moustakas, and F. Kourmoussis, “Generation and management of construction and demolition waste in Greece – an existing challenge,” Resource Conserve Recycle, vol. 40, no. 1, pp. 81-91, 2003.
- [5] C.L. Peng, D.E. Scorpio, and C.J. Kibert, “Strategies for successful construction and demolition waste recycling operations,” Construct Management and Economics, vol. 15, no. 1, pp. 49-58, 1997.
- [6] S.K. Srivastava, “Network design for reverse logistics,” Omega, vol. 36, pp. 535-548, 2008.
- [7] S.M. El-Haggar, Sustainable Industrial Design and Waste Management: Cradle-to-Cradle for Sustainable Development. Maryland Heights, USA: Elsevier Academic Press, 2007.
- [8] K. Oyeshola and H. Shabbir, “Estimation of construction waste generation and management in Thailand,” Waste Manage., vol. 29, no. 2, pp. 731-73, 2009.
- [9] T. Chinda, P. Supsinpaiboon, P. Kaewpitak, S. Tangbunjarvanich, and T. Virivaroj, “Analytic hierarchy process of reverse logistics in the construction industry,” Proceedings of the 4th International Conference on Engineering, Project, and Production Management, Bangkok, Thailand, 23-25 October 2013.
- [10] V.W.Y. Tam, “Rate of reusable and recyclable waste in construction,” The Open Waste Management Journal, vol. 4, pp. 28-32, 2011.

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