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A Hybrid Fuzzy MCDM Approach for Sustainable Third-Party Reverse Logistics Provider Selection

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Abstract. Third-party reverse logistics providers(3PRLPs)selection has become an important logistics function which can help companies to maintain their competitive edge. Traditionally, companies solely considered economic aspects for selecting their 3PRLPs. However, due to increased pressure from different types of stakeholders regarding environmental and social issues in recent years, companies have been obliged to incorporate these issues in their logistics and supply chains functions. Although many studies have been conducted in the field of3PRLPs selection, much less attention has been devoted to incorporating all three aspects of sustainability (social, environmental, and economic) in this field.In this research, a hybrid fuzzy multi-criteria decision-making (FMCDM) approach is proposed for selecting 3PRLPs while all three dimensions of sustainability were taken into account.Fuzzy analytic hierarchy process (FAHP)was used in order to weight the selected sustainability criteria and subcriteria. Then, fuzzy technique fororder preference by similarity to ideal solution (FTOPSIS)was applied for determining the ranking of suppliers. The applicability of the proposed approach wastested in an electronic manufacturing company.

Introduction

Reverse logistics (RL) is a business management tool that can contribute to reducing the cost of procuring raw materials and moderate environmental deterioration caused by waste[1]. RL concentrates on the backwards flow from customers to point of origin or recovery centers within logistics systems. This trend drives goods beyond the straight supply chain horizon [2]. The aim of this trend is to establish additional business transactions and value sustaining activities to recapture the waste values at the end of life of a product.In RL,value-sustaining activities consist of reclaiming, recycling, remanufacturing, reusing, refurbishing and disposal[3,4,5]. Recently, numerous manufacturers have deduced that their core competences are not in the logistics field, hence, gradually required to purchase logistics services and functions from third-party reverse logistics providers(3PRLPs)[6]. Therefore, selection of3PRLPs has achieved an enormous extent of importance as a strategic issue in the area of RL. Organizations have recently held responsible for the environmental and social performance of their suppliers and partners. This is caused by growth in the globalization of industry and outsourcing in different industries, concurrently intensifying demands on strong economic performance of supply chains [7].The adoption of supply chain with environmental issues is impossible without cooperation with all partners in a chain. Thus, finding appropriate 3PRLPs based on sustainability criteriacan help companies to improve the sustainability degree of their supply chains.Althoughmany authors are addressing reverse logistics providers selection issues in economic and environmental aspects of sustainability[5,8,9,10,11], assessment of the social performance of 3PRLPsare rather limited. Recently, some researchers have tried to incorporate social aspects of sustainability for evaluating the performance of 3PRLPs and suppliers [12,13,14]. Some studies have been carried out to evaluate the performance of third party reverse logistics where, little attention has been devotedto develop a hybrid method for 3PRLPs evaluation and selection by considering all three sustainable dimensions simultaneously. Hence, in this research, a hybrid approach of fuzzy analytic hierarchy process (FAHP) and fuzzy technique for order performance by similarity (FTOPSIS)is proposedfor selecting appropriate 3PRLPs based on all three dimensions of sustainability. FAHP was used for weighting the sustainability criteria and subcriteria. Then, FTOPSIS was utilized in order to evaluate and rank the 3PRLPs.

Research Methodology

Identifying Sustainability Criteria for Selecting 3PRLPs. Based on characteristics of the product under consideration and structure of the company, all sustainability criteriawere identifiedfrom an extensive literature and point of views of experts**.**

Determining the Weight of Criteria and Subcriteria. In this step, the selected criteria and subcriteria were weighted using FAHP. Therefore, based on the steps of Chang's FAHP[15] company's experts were asked to fill up some pairwise comparisons matrices using the scale shown in Table 1 in order to determine the importance weight of criteria and subcriteria. For aggregating the individual judgments of experts, the geometric means was introduced and applied as follows[16].

$$\overline{\widetilde{W_i}} = \left(\prod_{k=1}^{k} \widetilde{W_i^k}\right)^{\frac{1}{k}} \ , K = 1,2,\ldots,k \tag{1}$$

Where:

$\overline{\widetilde{W_i}}$: Combined fuzzy weight of decision element *i* of K decision makers

$\widetilde{W_i^k}$: Fuzzy weight of decision element *i* of decision maker *k*.

K: Number of decision makers

Table 1. Linguistics variables for FAHP

Linguistic variables	Triangular fuzzy numbers
Just equal	(1, 1, 1)
Equally important	(1/2, 1, 3/2)
Weakly more important	(1, 3/2, 2)
Strongly more important	(3/2, 2, 5/2)
Very strongly more Important	(2, 5/2, 3)
Absolutely more important	(5/2, 3, 7/2)

Table 2. Linguistics variables for TOPSIS

Linguistic variable	Triangular fuzzy numbers
Very poor	(1, 1, 3)
Poor	(1, 3, 5)
Fair	(3, 5, 7)
Good	(5, 7, 9)
Very good	(7, 9, 9)

Compute the total score of each provider usingFTOPSIS. In this step, FTOPSIS is used to rank the 3PRLPs. A group decision-making of the company wasasked to express their opinion for evaluating the 3PRLPs based on the selected criteria and subcriteria.Decision makers used linguistic terms to express their opinions regarding the potential performance of each alternative in a matrix format,linguistic terms are shown in Table 2. The steps of FTOPSIS are given as follows[17]:

Based on the first step of FTOPSIS , all content in decision matrix have to be normalized. The $\tilde{R}$ represents the normalized fuzzy decision matrix and the second step is to obtainthe weighted normalized decision matrix whichis shown by $\tilde{V}$. Assume that(a, b, c) is a triangular fuzzy number:

$$\tilde{R} = [r_{ij}]_{m\times n} \quad i=1, 2,.., m;\ j=1, 2,.., n \tag{2}$$

where

$$\tilde{r}_{ij} = \begin{cases} \dfrac{\tilde{x}_{ij}}{x_j^+} = \left(\dfrac{a_{ij}}{c_j^+}, \dfrac{b_{ij}}{c_j^+}, \dfrac{c_{ij}}{c_j^+}\right), x_j^+ = \max c_{ij} = c_j^+, \text{ if had a positive effect (Value)} \\ \dfrac{x_j^-}{\tilde{x}_{ij}} = \left(\dfrac{a_j^-}{c_{ij}}, \dfrac{a_j^-}{b_{ij}}, \dfrac{a_j^-}{a_{ij}}\right), x_j^- = \min a_{ij} = a_j^-, \text{ if had a negative effect (Cost)} \end{cases}$$

$\tilde{V}$ is obtained by multiplying the importance weights of the criteria obtained from FAHP by the contents of the normalized fuzzy decision matrix.

$\tilde{V}=[\tilde{V}_{ij}]_{m\times n}$, i=1, 2,.., m; j=1, 2,.., n
$\tilde{V}_{ij}=\tilde{r}_{ij}\otimes w_j$ (3)

Next,the distances of each alternative from the fuzzy positive ideal reference point (A^+) and fuzzy negative ideal reference point (A^-) are determined by:

$$A^+ = (\tilde{V}_1^+, \tilde{V}_2^+, \dots, \tilde{V}_n^+)\ ; A^- = (\tilde{V}_1^-, \tilde{V}_2^-, \dots, \tilde{V}_n^-) \quad (4)$$

Where $\tilde{V}_j^+ = \begin{cases} \text{Max}\tilde{V}_{ij}, \text{ for the positive aspects;} \\ \text{Min}\tilde{V}_{ij}, \text{ for the negative aspects} \end{cases}$ $\quad \begin{cases} \text{Min}\tilde{V}_{ij}, \text{ for the positive aspects;} \\ \text{Max}\tilde{V}_{ij}, \text{ for the negative aspects} \end{cases}$

In the fourth step, the Euclidean distances from A^+ and $A^-$for each alternativeare calculatedrespectively as follows:

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{V}\text{ij}, \tilde{V}_j^+), \quad i = 1,2,..,m\ ; j = 1,2,..n \quad (5)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{V}\text{ij}, \tilde{V}_j^-), \quad i = 1,2,..,m\ ; j = 1,2,..n$$

Finally,in the fifth step, the closeness coefficient (CC) or similarities to the ideal solution are determinedand the feasible ranking is provided.A large value of index CC_i indicates a good performance of the alternative.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}\ , i=1, 2... m \quad (6)$$

Results and discussion

In order to show the applicability of the proposed model,a case study of an electronic manufacturing company has been carried out. Usually, after selling a product, some defects may be found which caused by production process failure or during usage by customers. Therefore, return flowsare exist in order to satisfy customers. In this case, the manufacturer does not consider the RL as one part of its core competencies and tend to make a partnership with appropriate third party providers.The topmanagement of companyhasrecently decided to evaluate the 3PRLPs based on sustainability issues in order to improve the company sustainability profile. In this study, among all products of this company the return flow of a car audio system was chosen. Currently, the company has four alternatives, namely RLPA, RLPB, RLPC and RLPD. The appropriate criteria were gathered from literature. Then,eighteensubcriteriawerechosen in accordance with the experts' opinions. Subsequently, according to the steps of FAHP, the experts of the company including financial manager, managing director, logistic manager, and production manager were asked to make the pairwise comparison using the linguisticsvariables shown in Table 1 in order to find the importance weight of each criterion and subcriterion. Then, the experts' opinionswere finally aggregated into one fuzzy numberusing the geometric mean by Eq.1. Afterward, the weights of the criteria and subcriteria were calculated and tabulated in Table 3. After obtaining the weight vectors of the all criteria through FAHP, the decision matrix was prepared for the FTOPSIS method.Each element of the decision matrix was normalized using Eq.2. Then,the weighted normalized decision matrix was obtained using Eq.3. Followed by that, the rest of the calculations were done respectively based on Eq. 4 to 6. Table 4 illustrates the results of theFTOPSIS.

Table3. Selected criteria and subcriteria with their related importance weights

Main criteria	Weight	subcriteria	Weight	Final Weight
Economic	0.3438	-Overall cost	0.23391	0.080418
		-Quality	0.19407	0.066721
		-Technology Capabilities	0.14839	0.051016
		-Financial Capabilities	0.15619	0.053698
		-Delivery	0.11116	0.038217
		-Service	0.08100	0.027848
		-Relationship	0.03107	0.010682
		-Flexibility	0.04421	0.015199
Environmental	0.4344	-Environmental management system	0.30190	0.131145
		- Environmental cost management	0.15090	0.065551
		-Electrical and electronic equipment	0.23190	0.100737
		-Product recovery management	0.2495	0.108383
Social		-The interest & right of employee	0.20034	0.044455
	0.2219	-The rights of stakeholders	0.22326	0.049541
		-Work safety and labor health, Safety training	0.31624	0.070174
		-Respect for policy	0.13062	0.028985
		-Contractual stakeholders influence	0.07562	0.016780
		-Employment practices	0.05392	0.011965

Table4. Obtained results with fuzzy TOPSIS

Alternatives	Closeness Coefficient(CCj)	Rank
RLPA	0.02639	4
RLPB	0.76491	2
RLPC	0.77620	1
RLPD	0.22801	3

Table 4 shows, the highestvalue of closeness coefficient belongs to the RLPC , CC = 0.77620. Therefore, it is selected as the best 3PRLP for this casecompany. The sequence of the other alternatives according to the ascending order of their CC is RLPB, RLPD, and RLPA. Moreover , based on Table 3, among of all three main criteria, environmental criterion aspect is the most significant factor in 3PRLPs selection for this case. Under the“Environmental“ criterion, “Environmental Management System” was determinedas the most significant subcriteria with the total weight of 0.13115. Thus , the 3PRLPs must implement or improve environmental management systems such as ISO 14001 besides the other factors. “Lower overall cost “ was determined as the most significant criteriawith the total weight of 0.08042 in the subgroup of economic criterion. Consequently, the RL provider companies would be better to possibly keep their overall cost at the lowest level to surpass their competitor companies. Moreover, in terms ofsocial criterion “The right of stakeholders” is the most important factor which has to be considered by 3PRLPs.

Conclusions

The reverse logistic provider selection decision has become more important for companies in the current competitive market. Although most of studies in the field of 3PRLPs selection considered economic and environmental issues, ignoring social aspect of sustainability would lead to some illusive decisions for the companies towards sustainable development. Therefore, in this research, an integrated approach of FAHP and FTOPSIS was developed for evaluating and selecting appropriate 3PRLP while all three aspects of sustainability were taken into account simultaneously.

The results obtained through the proposed methods can help the companies to choose the most appropriate 3PRLPs and refine the relationships with the existing 3PRLPs. Moreover, by implementing the proposed approach companies can provide feedback to their 3PRLPs. Therefore, 3PRLPsmay be able to compare themselvesand improve their weaknesses.

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