Selection of Transportation Service Provider Employing Fuzzy TOPSIS Method

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Abstract: - Sustainable transportation has also an important role in supply chain and logistics management. It constructs the basis of sustainable supply chain management. Determining the most suitable sustainable transportation service provider requires considering multiple conflicting criteria. In this study, fuzzy TOPSIS methodology is utilized in order to evaluate sustainable transportation service provider alternatives.

Key-Words: - Decision Support Systems, Fuzzy TOPSIS, Fuzzy Sets, Multi-criteria Decision Making, Performance Evaluation, Sustainable Transportation Service Provider.

1 Introduction

Recently, due to technological advancements, changes in public needs, and growing in urban population, sustainable development received great interest. Sustainable development is described as the concept of meeting the present requirements without compromising the capacity of future generations to meet their requirements [1]. Different financial, natural, and social factors ought to be taken as a great importance to meet basic objectives of sustainability while seeking after financial, environmental, and social objectives. Sustainability has also gained attention in the transportation field. The development of approaches for sustainable transportation frequently includes cross disciplines participation, as well as regional and central governmental coordinated effort [2].

Sustainable transportation has an important role in supply chain and logistics management. Supply chain management (SCM) can be seen as a strategic partnership between retailers and suppliers. To transfer goods and materials, firms usually outsource transportation services. Sustainability is one of the key aspects in selecting the most suitable transportation service provider, which requires to consider multiple criteria. Sustainable transportation is also the basis of sustainable SCM.

Although sustainable transportation service provider evaluation is an important problem in SCM, in the literature, there are only a few studies on the subject. Paul et al. [3] integrated expert opinion, best-worst approach, and VIKOR method to valuate transport service providers using sustainable criteria. Mavi et al. [4] combined fuzzy SWARA and fuzzy MOORA for evaluating the third-party reverse logistic providers in the plastic industry by considering sustainability and risk factors. Yayla et al. [5] employed Buckley's fuzzy AHP and fuzzy TOPSIS methods for third-party logistic providers evaluation.

The remaining parts of the paper are planned as follows. In Section 2 fuzzy TOPSIS method is explained. Section 3 illustrates the case study. Finally, concluding remarks and future researches are delineated in Section 4.

2 Fuzzy TOPSIS

It is a well-known fact that, to express the necessities, preferences and thoughts is not sufficient by using crisp numbers only. Fuzzy set theory was evolved to eliminate this limitation by allowing to model uncertainty of human judgments (Zadeh, 1965).

TOPSIS is a common method introduced by Huvang and Yoon [6]. This technique is typically used for solving MCDM problems. In TOPSIS method, two solutions are identified, positive ideal solution (PIS) and negative ideal solution (NIS). While PIS maximizes the benefit criteria and minimizes the cost criteria, NIS maximizes the cost criteria and minimizes the benefit criteria. Because of this reason, the principal idea behind TOPSIS is, locating shortest distance to PIS and longest distance to NIS. While in classical TOPSIS, the ratings for criteria are known literally, in fuzzy TOPSIS, the ratings for criteria are described in linguistic terms.

The steps of fuzzy TOPSIS method is given below [7]:

Step 1: Determine the alternatives and the required evaluation criteria

The criteria are determined by carrying out a literature survey and utilizing expert knowledge. There are m alternatives denoted as $A_i = \{A_1, A_2, \ldots, A_m\}$, which are evaluated under n criteria, $C_j = \{C_1, C_2, \ldots, C_n\}$.

Step 2: Construct the fuzzy decision matrix $(\tilde{D})$ that denote the evaluation of alternatives with respect to criteria and the weight matrix of criteria $(\tilde{W})$ as

$$\tilde{D} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad i = 1,2, \ldots, m; j = 1,2, \ldots, n. \quad (1)$$

$$\tilde{W}_j = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n) \quad j = 1,2, \ldots, n. \quad (2)$$

where $\tilde{x}_{ij}$ and $\tilde{w}_j$ can be represented as $\tilde{x}_{ij} = \left(x_{ij}^1, x_{ij}^2, x_{ij}^3\right)$ and $\tilde{w}_j = \left(w_j^1, w_j^2, w_j^3\right)$, respectively, in triangular fuzzy number format.

Step 3: Normalize the fuzzy decision matrix

The normalized fuzzy decision matrix $\tilde{R}$ is constructed as $\tilde{R} = \left[\tilde{r}_{ij}\right]_{mxn}$, i=1,2,…,m; j=1,2,…,n,

$$\tilde{r}_{ij} = \begin{cases} \left(\frac{x_{ij}^1}{x_j^*}, \frac{x_{ij}^2}{x_j^*}, \frac{x_{ij}^3}{x_j^*}\right), & x_j^* = \max_i x_{ij}^3, \quad j \in B_j \\ \left(\frac{x_j^-}{x_{ij}^3}, \frac{x_j^-}{x_{ij}^2}, \frac{x_j^-}{x_{ij}^1}\right), & x_j^- = \min_i x_{ij}^1, \quad j \in C_j \end{cases} \quad (3)$$

where B_j represents the set of benefit-related criteria for which the greater the performance value the more its preference, C_j represents the set of cost-related criteria for which the greater the performance value the less its preference.

Step 4: Compute the weighted normalized decision matrix, $\tilde{V} = \left[\tilde{v}_{ij}\right]_{mxn}$, as

$$\tilde{v}_{ij} = \tilde{r}_{ij}\tilde{w}_j \quad (4)$$

Step 5: Define the ideal solution $(A^*) = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots, \tilde{v}_n^*)$, and the anti-ideal solution $(A^-) = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-)$, where $\tilde{v}_j^* = (1,1,1)$ and $\tilde{v}_j^- = (0,0,0)$ for j = 1,2, …, n.

Step 6: Compute the distances from ideal and anti-ideal solutions (d_i^* and d_i^-, respectively) for each alternative A_i as

$$d_i^* = d(A_i, A^*) = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) \quad (5)$$

where

$$d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) = \sqrt{\frac{1}{3}\left[\left(v_{ij}^1 - v_j^{*1}\right)^2 + \left(v_{ij}^2 - v_j^{*2}\right)^2 + \left(v_{ij}^3 - v_j^{*3}\right)^2\right]} \quad (6)$$

and

$$d_i^- = d(A_i, A^-) = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \quad (7)$$

Where

$$d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) = \sqrt{\frac{1}{3}\left[\left(v_{ij}^1 - v_j^{-1}\right)^2 + \left(v_{ij}^2 - v_j^{-2}\right)^2 + \left(v_{ij}^3 - v_j^{-3}\right)^2\right]} \quad (8)$$

Step 7: Calculate the closeness coefficient (CC_i) of each alternative as follows:

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, \quad i=1,2,\ldots,m \quad (9)$$

Step 8: Rank the alternatives according to CC_i values in descending order. Identify the alternative with the highest CC_i as the best alternative.

3 Case Study

The case study is performed in a dye manufacturer in Turkey. Fuzzy TOPSIS method is adopted for transportation service provider selection problem for the related case. The firm has 6 potential transportation service provider. First, evaluation criteria are determined by reviewing the literature as in Table 1.

Table 1. Evaluation criteria.

Criteria
Economic Performance (C_1)
Environmental Performance (C_2)
Relationships with clients (C_3)
Employee welfare (C_4)
Operational Issues (C_5)
Flexibility (C_6)

The evaluation is performed by four experts and they give their opinions by constructing a consensus utilizing the fuzzy linguistic scale given in Table 2.

Table 2. Linguistic scale.

Linguistic term	Fuzzy number
VH	(0, 0, 0.25)
H	(0, 0.25, 0.50)
M	(0.25, 0.50, 0.75)
L	(0.50, 0.75, 1)
VL	(0.75, 1, 1)

The evaluations are given in Table 3.

Table 3. Evaluation of the alternatives and criteria.

Criteria	Weights of criteria	A_1	A_2	A_3	A_4	A_5	A_6
C_1	H	M	H	L	VH	L	M
C_2	M	M	VH	VL	H	M	L
C_3	VH	H	M	M	H	H	M
C_4	M	M	H	M	M	H	H
C_5	H	L	M	VH	M	H	M
C_6	H	L	L	M	L	M	H

Employing the fuzzy TOPSIS method, the results are obtained as in Table 4.

Table 4. Ranking of the Alternatives

Alternatives	d_i^*	d_i^-	CC_i	Rank
1	4.317	2.316	0.349	4
2	4.081	2.638	0.393	1
3	4.624	1.194	0.293	6
4	4.073	2.580	0.388	2
5	4.186	2.505	0.374	3
6	4.575	2.074	0.312	5

4 Conclusion

Sustainable transportation systems object to make contribution to economy and reduce environmental damages by providing a number of benefits namely road safety, efficient city management, energy efficiency, and reduced travel time and fuel consumption. They are also critical to maintain sustainable supply chain and logistics management. Sustainable transportation service provider evaluation is an important MCDM problem, which requires considering multiple conflicting. Hence, this paper employs fuzzy TOSIS methodology to select the most appropriate sustainable transportation service provider in a dye manufacturer in Turkey.

Future researches may focus on calculating the weights of the evaluation criteria employing an analytical technique. Moreover, a group decision making framework can be utilized for the evaluation.

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