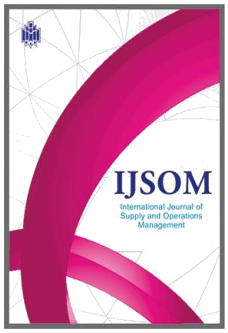
International Journal of Supply and Operations Management

IJSOM

August 2019, Volume 6, Issue 3, pp. 276-281
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



An Integrated MC-HFLTS & MAIRCA Method and Application in Cargo Distribution Companies

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Abstract
Cargo transportation is part of the logistic sectors. Both service quality and customer satisfaction are very important for companies which provide cargo transportation services. This study aims to evaluate cargo companies via DMs (customers) preferences in Erzurum, Turkey. Evaluating cargo companies is the multi-criteria decision making (MCDM) problem and DMs often use uncertain linguistic terms to express their assessments because DMs hesitate among different linguistic terms to provide their preferences. In this study, an integrated MC-HFLTS&MAIRCA (Multi-criteria Hesitant Fuzzy Linguistic Term Set and Multi Attribute Ideal-Real Comparative Analysis) method is used for evaluating and selecting the best cargo company. From this point of view, alternatives, criteria and DMs are defined and the integrated method is applied for the selection of the best cargo company. In order to test the results, MABAC, TOPSIS and VIKOR methods were used.

Keywords: Cargo Distribution Company; MAIRCA; MC-HFLTS; Logistic.

1. Introduction

It is important to ensure product movement in order to create balance of supply and demand in commercial life. The enterprises that delivered their products to the big supply centers quickly in the competitive environment, gained advantage over their competitors (Bulut 2007). As the number of cargo companies increased, the company had to compete to survive. One of the most important things that will ensure continuity for competitors in the service sector is customer satisfaction. For cargo distribution companies, it is quite important to determine the criteria that will provide customer satisfaction. In selecting the appropriate company generally, there are many qualitative and quantitative factors such as quality, price, flexibility that should be taken into consideration. Therefore, the evaluation procedure should include a number of factors and decision-making should be done in a multi-criteria environment. In this context, cargo distribution companies in Erzurum were discussed in this study. Firstly, the criteria to be considered in the selection of the cargo companies are determined. The weights of the determined criteria were determined by using MC-HFLTS method which is one of the multi-criteria decision-making methods based on fuzzy set. Then, the cargo companies in Erzurum were evaluated by using MAIRCA method considering the criterion weights obtained.

Evaluating cargo companies is MCDM problem and DM often use uncertain linguistic terms to express their assessments. The MC-HFLTS method offers a comparative and rich linguistic term set for a decision maker (DM) to express himself/herself more explicitly in cases of hesitation. MAIRCA method is simple mathematic apparatus, solution and the possibility to combine this method with other ones (Gigović et al., 2016; Pamučar & Ćirović, 2015).

MABAC, TOPSIS and VIKOR methods were applied in order to test the obtained results comparatively. These methods are used prevalently in the literature and TOPSIS method takes its basis from the distance to the ideal point like the methods of MABAC and MAIRCA. VIKOR method involves finding an agreed solution and sensitivity analysis.

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Document type: Technical Note

The rest of this paper is organized respectively; the literature related to cargo companies and applications of MC-HFLTS; the process of the best cargo company using the integrated MC-HFLTS&MAIRCA method; the comparison analysis with MABAC, VIKOR and TOPSIS methods; conclusions and possible future works.

2. Literature Review

The literature review is given for the studies on methods and cargo companies.

The Application studies using MC-HFLTS have included the selection of alternative-fuelled vehicles for medical home providers (Yavuz et al., 2015), the evaluation of alternatives to life insurance policies (Adem & Dağdeviren, 2016), site selection for wind turbines (Aktaş & Kabak, 2016) and site selection for court houses (Topraklı et al., 2016), evaluation mental workload (Adar & Delice, 2017), human error analysis in bank sector (Adar & Delice, 2018), selection of the best healthcare waste treatment technology (Adar & Delice, 2019).

For cargo company studies; Duran, 2017; Büyükkeklik et al., 2014; Uzun, 2013; Derici et al., 2015; Çakır et al., 2009; Atmaca and Turğut, 2015; Deniz and Gödekmerdan, 2012; Erdem, 2013. Considering literature, there are not many studies in this regard using MCDM methods.

3. Methods

A major contribution of Fuzzy set theory is its ability of representing to handle the uncertainties in the decision-making process (Nazam et al., 2015; Koupaei 2015; HakimiAsl et al., 2016). But, traditional fuzzy linguistic approaches are limited in that single and simple expressions which are used to model linguistic knowledge. In problems involving uncertainty, it may not be possible for the decision maker to express his / her opinion in a single term, think more than one term, or may be undecided. In this case, the HFLTS term set based on fuzzy set has been developed to eliminate the constraints that occur.

The MC-HFLTS method used in this study was developed by Yavuz et al. (2015). The complicated problems of MCDM, which are hierarchical, could also be solved with this method. The method steps can be reviewed in detail in this study (Yavuz et al., 2015). The steps of MAIRCA method were taken from the Gigović et al., (2016) study.

3.1. Application of the Best Cargo Company Selection

The process of selecting the best cargo company with MC-HFLTS and MAIRCA method has four stages (Figure 1): data collection (determining DMs, criteria, and alternatives), weight determination for criteria using Multi-criteria HFLTS method, the choice of the most appropriate alternative using MAIRCA method and comparative analysis using MABAC, TOPSIS and VIKOR methods.

3.1.1. Stage 1. Data Collecting

In this study, 3 decision makers, 7 criteria (Time, Personnel, Information level of personnel, Communication, Assurance, and Speed of answer and Price) and 5 alternatives for cargo distribution companies were defined. Hierarchy structure of criteria for evaluation cargo distribution companies is shown in Figure 2. The decision makers were selected from the people who received service from all the cargo companies discussed.

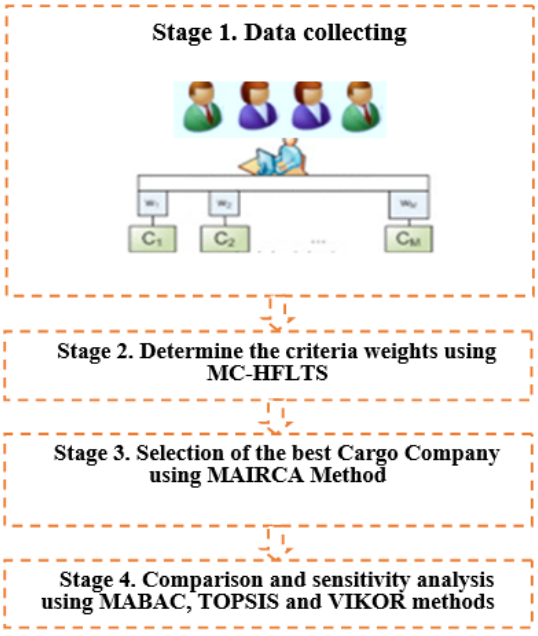

Figure 1. The flow chart of the application

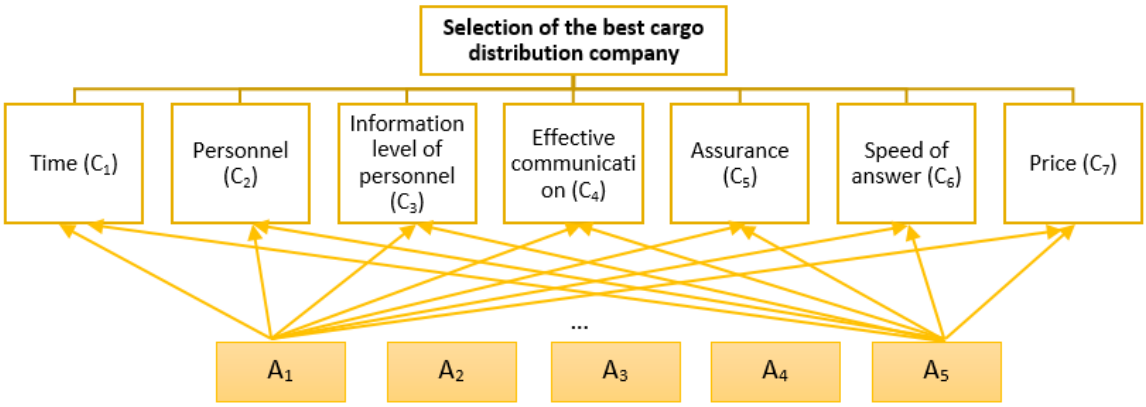

Figure 2. Hierarchy structure for evaluation of cargo distribution companies

3.1.2. Stage 2. Determine the criteria weights using HFLTS

After the data collection phase, the MC-HFLTS method steps are applied in sequence.

First, the linguistic term set S and CFG G_H were formed. Preference relationships matrices were created by decision makers for paired comparison matrices and criteria. Then, following the production rules, the preference relation matrices E_{GH} determined by the DMs were formed (Table 1). Due to space limitation, the preference relations are shown for DM_1, only.

Table 1. Preference relations of DM_1 for criteria

DM_1	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**
C_1	-	At least hi	Betw. mi and hi	mi	At most vli	hi	Betw. mi and hi
C_2	At most li	-	li	Betw. li and mi	vli	hi	vli
C_3	Betw. li and mi	hi	-	mi	li	mi	At most vli
C_4	mi	Betw. mi and hi	mi	-	Betw. li and mi	mi	li
C_5	At least vhi	vhi	hi	Betw. mi and hi	-	vhi	mi
C_6	li	hi	mi	mi	vli	-	vli
C_7	Betw. li and mi	vhi	At least vhi	hi	mi	vhi	-

Using the linguistic term scale, for each HFLTS, the envelope is obtained. Obeying the rounding rules and using the arithmetic mean operator, decision makers' views on the criteria are combined, and pessimistic and optimistic preferences are obtained. Then, the preference interval value obtained in terms of linguistics was given in numerical values (Table 2). Then the weight values were obtained by normalizing the values (Table 2).

Table 2. Linguistic intervals and weights for the criteria

Criteria	**Linguistic Intervals**	**Midpoints**	**Weights**
C_1	[(mi, 0), (hi, -0.44)]	3,28	0,155
C_2	[(li, -0.44), (li, +0.22)]	1,89	0,089
C_3	[(li, +0.22), (mi, -0.28)]	2,50	0,118
C_4	[(mi, -0.44), (mi, 0))]	2,78	0,132
C_5	[(hi, +0.22), (hi, +0.5)]	4,36	0,206
C_6	[(li, +0.056), (li, +0.22)]	2,14	0,101
C_7	[(hi, +0.11), (hi, +0.28)]	4,19	0,198

According to the results obtained, the most important criterion was determined as assurance given to the cargo (C_5), followed by pricing (C_7) and respectively delivery time of cargo (C_1).

Stage 3. Selection of the best Cargo Company using MAIRCA Method

In applying the MAIRCA method, the criteria weights which are calculated by MC-HFLTS are used. For the evaluation of the alternatives, linguistic and numerical scale (Very Low (VL), Low (L), Med. Low (ML), Medium (M), Med. High (MH), High (H), Very High (VH); 0-6 scale) are used and the matrix of paired comparison was formed (Table 3). The criteria values are determined as the initial decision matrix for each of the observed alternatives. The initial decision matrix is shown for DM_1, only.

Table 3. Linguistic evaluation values of DM_1

DM_1	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	G	F	G	MG	F	F	MG
A_2	VG	G	VG	G	MG	G	VG
A_3	MG	VG	VG	VG	VG	VG	G
A_4	MG	MG	G	G	G	G	MG
A_5	F	MG	MG	F	G	MG	G

Linguistic terms in the matrix given in Table 3 are written in numerical values and the calculations are carried on. DMs' opinions are combined using Arithmetic aggregation operator. After the formation of the initial matrix, preferences according to the alternative is calculated. After the calculation of T_p and T_r, the elements' normalization is completed by using benefit equation (for others) and cost equation (C_1 and C_7). Then, the total gap matrix element was obtained. The best ranking alternative, the one with the lowest gap value is the A_3, as it is shown in Table 4.

Table 4. Alternative ranking according to MAIRCA method

Alternatives	Q_i	Rank
A_1	0,144	5
A_2	0,129	4
A_3	0,000	1
A_4	0,078	2
A_5	0,121	3

3.1.3. Stage 4: Comparison and Sensitivity Analysis

The problem presented in the paper was solved by using the following approaches: MC-HFLTS&VIKOR, and MC-HFLTS &TOPSIS and MC-HFLTS&MABAC. The list of cargo distribution companies obtained by using these methods is given in Table 5.

Table 5. The results of comparison analysis

	MAIRCA	Rank	VIKOR	Rank	TOPSIS	Rank	MABAC	Rank
A_1	0,144	5	1,000	5	0,415	4	-0,203	5
A_2	0,129	4	0,842	4	0,333	5	-0,130	4
A_3	0,000	1	0,000	1	1,000	1	0,516	1
A_4	0,078	2	0,474	2	0,634	2	0,125	2
A_5	0,121	3	0,772	3	0,473	3	-0,087	3

The comparison of the results of the MC-HFLTS&MAIRCA approach with results of the MC-HFLTS&VIKOR, MC-HFLTS&TOPSIS and MC-HFLTS&MABAC approaches indicated that all methods suggested the A_3 alternative was the best one and produced the same ranking of cargo company alternatives.

4. Conclusions

In this study, MC-HFLTS&MAIRCA approach was used in order to choose the best cargo distribution company under the effect of multiple conflicting hierarchical criteria, in Erzurum city of Turkey. Consequently, the rank of alternatives that were obtained as a result of trying comparative analyses was as $A_3 \succ A_4 \succ A_5 \succ A_2 \succ A_1$. This result showed that the integrated MC-HFLTS&MAIRCA approach resulted in effective and valid outcomes in the selection of cargo Distribution Company, and it could be applied to decision-making problems that consider other complicated and conflicting criteria.

The future studies would include making comparative analyses using the methods based on Intuitionistic Fuzzy Sets, Interval-valued Intuitionistic Fuzzy Sets and classical Fuzzy Sets.

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