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A Novel Hybrid Fuzzy Multi-Criteria Decision-Making Model for Supplier Selection Problem (A Case Study in Advertising industry)

Mohammad Ali Beheshti-Nia[1]*, Vahid Nemati-Abozar[1]

[1] *Department of Industrial Engineering, Semnan University, Semnan, Iran*
beheshtinia@semnan.ac.ir, vahidnemati28@googlemail.com

Abstract

Choosing the proper supplier has a critical role in designing of a supply chain. This problem is complex because each supplier may fulfill some of the manufacturer criteria and choosing the best supplier is a multi criteria problem. This paper proposes a novel hybrid approach to rank suppliers in advertising industry and considers two new criteria to evaluate the suppliers. The proposed approach combines Modified Digital Logic (MDL) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) using fuzzy theory. At the end, the results of the proposed approach are compared with a hybrid method using Fuzzy Analytical Hierarchy Process (FAHP) and Fuzzy TOPSIS on a real case study.

Keyword: Fuzzy Theory, Multiple- Criteria Decision-Making, MCDM, MDL, TOPSIS.

1 - Introduction

A supply chain consists of coordination and alignment of those enterprises, which supply products or services to the market (Mentzer et al., 2001). Each supply chain is a network composed of facilities and activities, which includes all production operations such as purchase of materials, parts, and their displacement, manufacturing of products, distribution, and after- sale services. Also, Supply Chain Management (SCM) comprises of coordination in production, inventory (warehouse), positioning and transportation between members of supply chain to reach the best composition of responsiveness and efficiency for achievement in the market (Hugos, 2003).

Performance of suppliers basically effects on success or failure of a supply chain. So, the supplier selection is a strategic task. One of the most crucial issues in an organization is to select appropriate suppliers which may have long impact on its performance. Poor decisions in supplier selection may lead to inevitable consequences which reduce the company's competitiveness and profitability (Makui et al., 2015). The supplier selection is a process consisting of determining criteria, preparing a set of alternative suppliers and using a systematic approach for suppliers' evaluation. On the other hand, Multiple Criteria Decision Making (MCDM) purposes an efficient framework to compare the suppliers based on evaluation of suppliers by various criteria (De Boer et al., 2001).

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*Corresponding author.
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In this paper a hybrid approach is proposed to rank the suppliers in the advertising industry. The approach utilizes a combination of Modified Digital Logic (MDL) and Fuzzy TOPSIS (FTOPSIS), namely MDL-FTOPSIS method. Also, two new criteria are introduced to evaluate the suppliers and a real case study in advertising industry is presented. The results of MDL-FTOPSIS method is compared with another hybrid approach which uses a combination of Fuzzy Analytical Hierarchy Process (FAHP) and FTOPSIS, namely FAHP-FTOPSIS method. The contributions of this paper are as follows:

- Developing two new criteria to evaluate the suppliers in advertising industry
- Proposing a new technique in which MDL and FTOPSIS are combined, namely MDL-FTOPSIS method
- Presenting a case study in advertising industry and compare the result of the proposed approach with another hybrid approach that uses a combination of FAHP and FTOPSIS, namely FAHP-FTOPSIS method.

MDL technique uses the pairwise comparisons of the element to determine the weight of each element. The result of each comparison could be 0, 1 or 2 (Abdoli-Aghaei et al., 2011). Also, TOPSIS is another strong MCDM technique that ranks the alternatives using Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) (Bilbao-Terol et al., 2014). On the other hand, the qualitative criteria could not be definitively compared and it is better to interpret them by linguistics and verbal expressions the theory of fuzzy sets should be used. To model ambiguous an uncertainty in the real world, the theory of fuzzy sets is used (Bellman and Zadeh, 1970).

The remainder of this paper is organized as follows. The previous works on the supplier selection topic is summarized in Section 2. The research method (methodology) is expressed in section 3. In section 4, MDL-FTOPSIS method is described and a case study is proposed to perceive the suggested method. In section 5, FAHP-FTOPSIS method is presented and the results of both methods are compared. Section 6 is dealt with the conclusion and future research scopes.

2 - Literature review

A lot of researches investigate the supplier selection process and each research considers a certain aspect of the issue. Gaballa (1974) uses mathematical programming for supplier selection in a real case. Lee (2009) proposes a model for supplier selection due to four factors: Benefit, Opportunities, Cost and Risks (BOCR). Using FAHP method, BOCR is considered as the main criteria. The approach is implemented in TFT-LCD industry in Taiwan, considering 5 suppliers as alternatives. Bhattacharya et al. (2010) combined AHP with Quality Function Deployment (QFD) with Cost Factor Measures (CFM) to rank suppliers. This method uses the QFD to identify customer's needs and cost factors. Other method to supplier selection using MCDM is proposed by Sanayei et al. (2010). They propose a MCDM model based on VIKOR method and define 4 sets consist of decision makers, possible suppliers, criteria and performance. The method is implemented in 9 steps on an auto parts manufacturing company. Yucel and Guneri (2011) propose a method in which the weights of criteria are calculated using a method similar to TOPSIS. Then a fuzzy linear programming method is used to achieve the optimal result. Kilincci and Onal (2011) utilize FAHP to solve the supplier selection problem. Buyukozkan & Cifci (2012) use 3 methods of FANP, FTOPSIS and fuzzy DEMATEL for green supplier selection. In this method, both FANP and fuzzy DEMATEL are combined to establish casual relations and FTOPSIS used to select the best supplier. Shaw et al. (2012) combine FAHP with fuzzy multi objective linear programming for developing a low carbon supply chain. They consider cost, quality, lead time, greenhouse gas emission and use FAHP for supplier selection, considering 4 suppliers as alternatives. Arikan (2013) suggests multiple- objective linear programming problem to choose suppliers, considering three objectives: (1) minimization of cost, (2) maximization of quality, and (3) maximization of on-time receiving and delivery. Kannan et al. (2013) propose an approach composed of fuzzy theory and multiple- objective mathematical model to rank and select the suppliers in a green supply chain, considering economic and ecological criteria. Qian (2014) use a linear function based on various criteria to evaluate and select suppliers. Nazari-Shirkouhi et al. (2013) propose Fuzzy Multi-Objective Linear Programming for supplier selection problem considering total purchasing costs, number of defective units and tardy orders reduction. Dursun and Karsak (2013) employ Quality Function Deployment (QFD) as a MCDM method for supplier selection problem. Rezaei et al. (2014), investigate supplier selection in the airline industry. They discuss a number of issues that make airline retail complex and distinguish it from conventional retail. They use a two-phased methodology in which in the first phase, a conjunctive screening method is used, which aims to reduce the initial set of potential suppliers prior to the comprehensive final choice phase. In the second phase, an AHP method is used, in which suppliers are evaluated against some main criteria and sub-criteria. Lima Junior et al. (2014) discuss the supplier selection problem in a real case in the automotive industry using FAHP and FTOPSIS. Rahmani and Ebrahimi (2015) used MCDM in order to evaluate and rank the membrane applications. Then the problem was divided into more simple problems and modeled as a four-level hierarchy MCDM problem. The analysis of the structure of the membrane selection problem as well as the determination of the criteria, sub criteria and experts were done using AHP. Eventually, the final ranks of membrane applications were achieved by the TOPSIS method. The other application of MCDM in the supplier selection can be found in the green supplier selection. Hashemi et al. (2015) propose a method that combines Analytic Network Process (ANP) and traditional Grey Relational Analysis (GRA). The first approach is used for the interdependencies among the criteria and the second approach is used to eliminate the ambiguity of supplier selection. Galankashi et al. (2016) proposed a new BSC for supplier selection in automotive industry. The model was an integrated Balanced Scorecard Fuzzy Analytic Hierarchical Process (BSC–FAHP). Bruno et al. (2016) evaluated the applicability of AHP and fuzzy set theory (FST) in supplier selection for real-world multi-stakeholder problems. Kannan et al. (2014) discuss green supplier selection based on a framework using FTOPSIS. After identifying the criteria and alternatives, they compare the proposed method with the geometric mean method and graded mean method.

Some criteria such as price, quality, financial condition, on time delivery and after-sale service are frequently used in the literature. So, these five criteria are used in this paper. Based on the experts' opinions and the circumstances in advertising industry, three criteria are added to the previous ones. One of the added criteria is the supplier background that is used in the literature, but the other two criteria are new. They are remote communication and comprehensiveness of services.

Many researches employ various techniques to select and rank suppliers, but MDL techniques have not been so far used in the supplier selection problem. Also, no method is used to evaluate suppliers in advertisement industry. In this research we present a case study in advertisement industry and introduce a new hybrid approach using MDL and FTOPSIS methods to solve the supplier selection problem.

3 - Research method

3-1- Research questions

This research tries to address some research questions. The major question and the minor questions are as follows:

Major question:

1- How to rank the suppliers in advertising industry?

Minor questions:

2- Which criteria have critical roles in choosing suppliers in advertising industry?

3- What is the importance of each criterion?

4- What is the grade of each supplier in each criterion?

3-2- Methodology

To determine the most important criteria in the advertising supply chain, we use previous researches in the literature and experts' opinions. We propose a hybrid approach to solve the supplier selection problem in advertising industry. The approach uses MDL technique to determine the weight of each criterion and fuzzy TOPSIS to determine the score of each supplier in each criterion. This hybrid approach tries to utilize the advantages of both techniques and named MDL-FTOPSIS. Some concepts and techniques used in this research are described as follows:

3-2-1- Fuzzy theory

Fuzzy theory transforms non random uncertainty to numerical measures. The origin of uncertainty discussed here, is the human's judgment. The linguistic variables are employed under uncertain conditions. In order to consider the vagueness in the decision making process, the linguistic variables are transformed into fuzzy numbers. In this research, triangular fuzzy numbers are used for fuzzy numbers. The following function indicates the membership function of a triangular fuzzy number (l, m, u).

$$\mu(x) = \begin{cases} \dfrac{x-l}{m-l} & x \in [l,m] \\ \dfrac{u-x}{m-u} & x \in [m,u] \\ . \quad Otherwise & \end{cases} \tag{1}$$

Furthermore, the Eq. (2) calculates the distance among two fuzzy numbers $\tilde{m} = (l_m, m_m, u_m)$ and $\tilde{n} = (l_n, m_n, u_n)$.

$$d = \sqrt{\frac{1}{3}\{(l_m - l_n)^2 + (m_m - m_n)^2 + (u_m - u_n)^2\}} \tag{2}$$

3-2-2- MDL technique

We use MDL method as an MCDM technique. MDL uses the pairwise comparisons of the elements. The result of each comparison could be 1, 2 or 3. In this technique, the element with higher preference gets score 3 and the element with lower preference gets score 1. On the other hand, if both elements have the same preference, weight 2 is considered for both of them.

There are some similarities and some differences between MDL method and AHP. The AHP technique is a suggested method by Saaty (2008). AHP has a main weakness in the pairwise comparisons in which the decision maker should remember previous scoring records when assigning a score to the current pairwise comparison. For example, suppose we assigned number 3 in the pairwise comparison between elements A and B, and number 3 between elements B and C. So, in the pairwise comparison between the elements A and C, we should remember our previous scores and consider a number of 5 or 7. On the other words, the difference between elements should be considered in the pairwise comparisons. Paying attention to the size of differences among qualitative variables is a confusing task and increase human errors. But in MDL technique, the size of differences between elements has no importance and numbers 1, 2, and 3 are used in pairwise comparisons. So, human errors in scoring the pairwise comparisons are reduced significantly.

For more explanation of MDL technique, suppose that we intend to compare 4 criteria, namely C_1, C_2, C_3 and C_4. First, we should prepare a table to be completed by the decision maker, like Table 1. In this example, according to the decision maker viewpoint C_1 is more important than C_2 and C_4, while C_1 and C_3 have the same preference.

The weight of any criterion is derived by summation of its scores. If several decision makers are employed, the average of scores should be used.

Table 1. An example of MDL technique

Criteria \ Comparison	1	2	3	4	5	6	Sum
C_1	3	2	1				6
C_2	1			2	1		4
C_3		2		2		3	7
C_4			3		3	1	7

3-2-3- Fuzzy TOPSIS technique

TOPSIS is a MCDM technique proposed by Hwang and Yoon (1981). This method ranks the alternatives based on the shortest Euclidean distance from a dummy alternative named Positive Ideal Solution (PIS) and the longest Euclidean distance from another dummy alternative named Negative Ideal Solution (NIS) and calculates an indicator called relative closeness coefficient. Fuzzy TOPSIS method has been adapted in this paper to determine the score of alternatives, regarding various criteria.

4 - MDL-FTOPSIS method (Case Study: Advertising industry)

In this section we identify the key criteria in advertising industry and use MDL-FTOPSIS to rank the suppliers.

Commercial advertising is one of the marketing branches that tries to increase the consumption of products or services. Also, advertising industry has several branches and many agents provide these services. Selecting the best advertising supplier has a critical role in success of any enterprise. Although selecting an advertising supplier is a very important task, the shortage of researches in order to contribute identifying and choosing the appropriate advertising suppliers is obvious.

4-1- Recognition of criteria

In this research, we consider a real world case with 5 advertising suppliers and use 8 experts to gather required data and criteria. Eight criteria were recognized for evaluation and ranking suppliers in this study in which six criteria were extracted from the literature, and two new criteria were emerged from the experts' opinions. These two criteria are ability of remote communication of the suppliers and comprehensiveness of services provide by the advertising suppliers. All criteria used in this study are as follows:

- Price (Safa et al., 2014): The price is considered as a value that is paid for receiving products or services, and it is a critical and effective factors in choosing the suppliers.
- Quality (P.-S. Chen and Wu, 2013): The quality is considered as a main criterion in most of the relevant researches for suppliers' evaluation, including performance, credit, durability, and appearance indices, etc.
- On time delivery (Aksoy and Öztürk, 2011): The on time delivery means no tardiness in receiving the products or services based on predetermined due dates.
- After-sale service (Z. Chen and Yang, 2011): It is due to periodic or required repairs or modifying the products or services and solving occurred disputes.
- Background of activity of supplier (Fadavi et al., 2013): It denotes the background and reputation of the suppliers in providing the products or services.

- Financial situation of supplying company (Z. Chen and Yang, 2011): It refers to the financial condition and solvency of the supplying company in presenting given services and or products.
- Remote communication: It denotes the ability of the suppliers to communicate with their customers by various tools like website, email, video conference, intranet, etc. Various communication tools may cause significant saves in time and cost. So, it should be considered as a criterion of supplier selection problem.
- Comprehensiveness of services: Advertisement has different approaches (publishing advertisement, TV advertisement, Phone advertisement, etc.) in which each approach has various types (for example, several quality in publishing advertisement). Each approach or type is proper for a target segment of the market. Some suppliers concentrate on an approach and the others are active in several approaches. We consider the comprehensiveness of services as a criterion in supplier selection problem. Table 2 shows the criteria that used in this research.

Table 2. Criteria that used in this research

ID	Criteria
C_1	Price of product
C_2	Quality of product
C_3	On time delivery
C_4	After-sale service
C_5	Supplier background
C_6	Financial situation
C_7	Remote communication system
C_8	Comprehensiveness of services

4-2- Data gathering technique

As mentioned, after identifying the needed criteria to rank suppliers, a hybrid approach is proposed for the decision process. In the proposed approach, the MDL technique determines the weights of the criteria. The approach uses FTOPSIS technique to evaluate the suppliers based on the obtained weights. Finally, the result of the technique is compared with another hybrid approach which uses a combination of FAHP and FTOPSIS.

So, three questionnaires are adapted to gather the needed data. The first questionnaire is designed to gather MDL required data including twenty eight pairwise comparisons between the criteria. In the second questionnaire, five predetermined suppliers are scored in terms of each criterion based on 7 linguistic variables offered in the questionnaire with each other. The linguistic variables of the second questionnaires are derived from Chen and Yang (2011). The third questionnaire is designed to gather AHP required data including twenty eight pairwise comparisons. The result of each comparison should be chosen from a 9-scale spectrum (Alvandi et al., 2011).

In order to access to the required data, the questionnaires are answered by 8 experts as decision makers, namely D_1, D_2,… D_8.

4-3- Determination of weight of criteria by MDL method

In this section, the weight of each criterion is calculated, using MDL method. A questionnaire is designed to gather MDL required data including 28 pairwise comparisons among the criteria. In each comparison, a criterion with higher preference gives score 3 and another one give score 1. If both criteria have the same preference, they give score 2. After receiving the required data, sum of obtained scores by a criterion indicates its scores.

Sum of scores of each criterion is named as total non-normalized weight. After calculating the all weights they should be normalized. Table 3 shows the non-normalized and normal weights for all criteria.

Table 3. Weight of criteria by means of MDL technique

Criteria	Non- normalized weight	Normalized weight
C_1	157	0.18
C_2	147	0.17
C_3	115	0.13
C_4	99	0.11
C_5	81	0.09
C_6	93	0.11
C_7	106	0.12
C_8	80	0.09

4-4- Ranking alternatives by MDL weights

In the second phase, the weights derived from MDL technique (Table 3) is used by FTOPSIS technique to rank alternatives. The experts use linguistic terms proposed by Chen and Yang (2011) presented in Table 4. Table 5 shows the scores of suppliers in each of criterion and Table 6 shows the weighted normalized decision matrix.

Table 4. The used linguistic terms

Linguistic term	Score
Very poor (VP)	(0,0,0.1)
Poor (P)	(0,0.1,0.3)
Medium poor (MP)	(0.1,0.3,0.5)
Fair (F)	(0.3,0.5,0.7)
Medium good (MG)	(0.5,0.7,0.9)
Good (G)	(0.7,0.9,1.0)
Very good (VG)	(0.9,1.0,1.0)

Table 5. Scores of suppliers in each criterion

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.74,0.91,0.99)	(0.55,0.75,0.91)	(0.46,0.79,0.92)	(0.35,0.57,0.78)	(0.45,0.66,0.84)	(0.37,0.59,0.78)	(0.54,0.74,0.89)	(0.66,0.84,0.96)
A2	(0.38,0.6,0.8)	(0.49,0.69,0.88)	(0.72,0.9,0.99)	(0.33,0.49,0.69)	(0,0.58,0.84)	(0.28,0.5,0.71)	(0.38,0.61,0.79)	(0.66,0.84,0.96)
A3	(0.6,0.86,0.97)	(0.58,0.79,0.94)	(0.56,0.67,0.73)	(0.55,0.8,0.95)	(0.69,0.9,0.97)	(0.43,0.64,0.83)	(0.38,0.78,0.87)	(0.74,0.91,0.99)
A4	(0.77,0.97,1)	(0.6,0.77,0.93)	(0.53,0.74,0.91)	(0,0.28,0.49)	(0.55,0.75,0.91)	(0.31,0.65,0.74)	(0.38,0.64,0.83)	(0.67,0.86,0.96)
A5	(0.34,0.56,0.76)	(0.59,0.79,0.95)	(0.46,0.66,0.86)	(0.53,0.72,0.9)	(0.44,0.64,0.85)	(0.5,0.71,0.88)	(0.29,0.52,0.73)	(0.32,0.53,0.74)

Table 6. Weighted normalized decision matrix in MDL-TOPSIS approach

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.1,0.13,0.14)	(0.07,0.09,0.11)	(0.06,0.09,0.11)	(0.04,0.07,0.09)	(0.06,0.09,0.12)	(0.04,0.07,0.09)	(0.07,0.1, 0.12)	(0.07,0.09,0.11)
A2	(0.05,0.08,0.11)	(0.06,0.08,0.11)	(0.09,0.11,0.12)	(0.04,0.06,0.08)	(0,0.08, 0.12)	(0.03,0.06, 0.09)	(0.05,0.08, 0.1)	(0.07,0.09,0.11)
A3	(0.08,0.12,0.14)	(0.07,0.09,0.11)	(0.07,0.08,0.09)	(0.07,0.1,0.11)	(0.1,0.13, 0.14)	(0.05,0.08, 0. 1)	(0.05,0.1, 0.11)	(0.08,0. 1, 0.11)
A4	(0.11,0.14,0.14)	(0.07,0.09,0.11)	(0.06,0.09,0.11)	(0,0.03,0.06)	(0.08,0.11, 0.13)	(0.04,0.08, 0.09)	(0.05,0.08, 0.11)	(0.07,0.09,0.11)
A5	(0.05,0.08,0.11)	(0.07,0.09,0.11)	(0.06,0.08,0.1)	(0.06,0.09,.11)	(0.06,0.09, 0.12)	(0.06,0.09, 0.11)	(0.04,0.07,0.09)	(0.04,0.06, 0.08)

Table 7 shows the Fuzzy PIS (FPIS) and Fuzzy NIS (FNIS). The price of product is a negative factor which indicates that in calculating FPIS and FNIS the minimum and maximum values should be considered respectively.

Table 7. Positive and negative ideal solutions in MDL-TOPSIS approach

	C1	C2	C3	C4	C5	C6	C7	C8
FPIS	(0.05,0.08,0.11)	(0.7,0.09,0.11)	(0.09,0.11,0.12)	(0.07,0.1, 0.11)	(0.1,0.13, 0.14)	(0.06,0.09, 0.11)	(0.07,0.1, 0.12)	(0.08,0.1, 0.11)
NPIS	(0.11,0.14,0.14)	(0.06,0.08,0.11)	(0.06,0.08, 1)	(0,0.03, 0.06)	(0,0.08, 0.12)	(0.03,0.06, 0.09)	(0.04,0.07, 0.09)	(0.04,0.06, 0.08)

The distance between two triangular fuzzy numbers is determined by Eq. 2. The distances of each supplier from FPIS and FNIS are calculated by the following formula:

$$D_i^+ = \sum_j^n d(v_{ij}, FPIS_j),\ \ i = 1,2,...,m,$$
$$D_i^- = \sum_j^n d(v_{ij}, FNIS_j),\ \ i = 1,2,...,m. \qquad (3)$$

Which v_{ij} indicates the score of supplier i in j^{th} criterion, FPISj and FNISj are the positive and negative ideal solution in j^{th} criterion, respectively and D_i^+ and D_i^- are the distance of each supplier from FPIS and FNIS, respectively. Also *n* and *m* are the number of criteria and suppliers, respectively. Table 8 shows the distance of each supplier from FPIS and Table 9 shows the distance of each supplier from FNIS.

Table 8. Distance of each supplier from FPIS

	C1	C2	C3	C4	C5	C6	C7	C8	S_i^+
D_1^+	0.04	0	0.2	0.03	0.03	0.02	0	0.01	0.15
D_2^+	0	0.01	0	0.03	0.07	0.03	0.02	0.01	0.17
D_3^+	0.03	0	0.03	0	0	0.01	0.01	0	0.08
D_4^+	0.05	0	0.02	0.06	0.02	0.02	0.02	0.01	0.2
D_5^+	0	0	0.03	0.01	0.03	0	0.03	0.04	0.14

Table 9. Distance of each supplier from FNIS

	C1	C2	C3	C4	C5	C6	C7	C8	S_i^-
D_1^-	0.01	0.01	0.01	0.04	0.04	0.01	0.03	0.03	0.18
D_2^-	0.05	0	0.03	0.03	0	0	0.01	0.03	0.15
D_3^-	0.02	0.01	0.01	0.06	0.07	0.02	0.02	0.04	0.25
D_4^-	0	0.01	0.01	0	0.05	0.01	0.01	0.03	0.12
D_5^-	0.05	0.01	0	0.06	0.04	0.03	0	0	0.19

The relative closeness coefficient of i^{th} supplier (CC_i) is calculated by Eq. 4 and the results are shown in Table 10.

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \qquad i = 1,2,\ldots,m \qquad (4)$$

Table 10. Relative closeness coefficient of suppliers in MDL-TOPSIS approach

Rank	CC_i	suppliers
3	0.545	A_1
4	0.469	A_2
1	0.758	A_3
5	0.375	A_4
2	0.576	A_5

5- FAHP-FTOPSIS method

Fuzzy AHP method is a systematic approach which uses the concepts of fuzzy set theory to determine the weight of criteria and alternatives (Taylan et al., 2015). In this section we use a hybrid approach by integration of FAHP and FTOPSIS to rank suppliers. The aim is comparing the result of MDL-FTOPSIS with FAHP-FTOPSIS one.

5-1- Determination of criterion weight by FAHP

The experts use the linguistic variables given in Table 11 to complete the FAHP matrix.

Table 11. Linguistic terms for ranking alternatives

Linguistic term	Score
Extremely strong	(9,9,9)
Intermediate	(7,8,9)
Very strong	(6,7,8)
Intermediate	(5,6,7)
Strong	(4,5,6)
Intermediate	(3,4,5)
Moderately strong	(2,3,4)
Intermediate	(1,2,3)
Equally strong	(1,1,1)

The result of pairwise comparisons is shown in Table 12.

Table 12. Integrated matrix of pairwise comparisons using geometric average

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	(1,1,1)	(1.86,2.45,3.56)	(3.29,4.34,5.37)	(0.54,1.27,1.67)	(0.29,0.35,0.44)	(3.03,4.09,5.12)	(1.53,1.95,2.39)	(0.23,0.27,0.34)
C_2	(0.28,0.41,0.53)	(1,1,1)	(1.12,1.34,1.56)	(1.79,2.17,2.64)	(0.51,0.62,0.76)	(0.43,0.66,0.82)	(1.09,1.31,1.54)	(2.33,3.34,4.35)
C_3	(0.19,0.23,0.3)	(0.64,0.75,0.89)	(1,1,1)	(0.47,0.53,0.63)	(0.27,0.31,0.37)	(1.57,1.9,2.23)	(2.33,3.11,3.85)	(3.34,4.35,5.36)
C_4	(0.6,0.79,1.85)	(0.38,0.46,0.56)	(1.59,1.89,2.13)	(1,1,1)	(3.25,3.8,4.24)	(1.82,2.25,2.62)	(0.2,0.25,0.33)	(0.21,0.27,0.38)
C_5	(2.27,2.86,3.45)	(1.32,1.61,1.96)	(2.7,3.23,3.7)	(0.24,0.26,0.31)	(1,1,1)	(0.87,1.07,1.3)	(0.88,1.03,1.22)	(1.45,1.85,2.24)
C_6	(0.19,0.24,0.33)	(1.22,1.52,2.33)	(0.45,0.53,0.64)	(0.38,0.44,0.55)	(0.77,0.93,1.15)	(1,1,1)	(0.91,1.18,1.5)	(2.45,3.22,3.96)
C_7	(0.42,0.51,0.65)	(0.65,0.76,0.92)	(0.26,0.32,0.43)	(3.03,4,5)	(0.82,0.97,1.14)	(0.67,0.85,1.1)	(1,1,1)	(1.62,2.06,2.45)
C_8	(2.94,3.7,4.35)	(0.23,0.3,0.43)	(0.19,0.23,0.3)	(2.63,3.7,4.76)	(0.45,0.54,0.69)	(0.25,0.31,0.41)	(0.41,0.49,0.62)	(1,1,1)

The rank of each supplier is calculated by the method proposed by Chen and Young (2011). Table 13 shows the defuzzified normalized weight of each criterion.

Table 13. Defuzzified normalized weight of each criterion

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Non normalized weight	1	0.58	0.69	0.58	0.77	0.42	0.58	0.54
Normalized weight	0.19	0.11	0.13	0.11	0.15	0.08	0.11	0.1

5-2- Ranking alternatives by FAHP weights

In the second phase, the weights derived from FAHP (Table 13) are used by FTOPSIS technique to rank the alternatives. Table 14 shows the weighted normalized decision matrix.

Table 14. Weighted decision making matrix by FAHP- FTOPSIS

	C1	C2	C3	C4	C5	C6	C7	C8
A1	(0.14,0.17,0.19)	(0.0.6,0.08,0.1)	(0.06,0.1,0.12)	(0.04,0.06,0.08)	(0.07,0.1,0.13)	(0.03,0.05,0.06)	(0.06,0.08,0.1)	(0.07,0.08,0.1)
A2	(0.07,0.11,0.15)	(0.05,0.08,0.1)	(0.09,0.12, 0.13)	(0.04,0.05,0.08)	(0,0.09,0.13)	(0.02,0.04,0.06)	(0.04,0.07,0.09)	(0.07,0.08,0.1)
A3	(0.11,0.16,0.18)	(0.06,0.09,0.1)	(0.07,0.09,0.09)	(0.06,0.09,0.1)	(0.1,0.14,0.15)	(0.03,0.05,0.07)	(0.04,0.09,0.1)	(0.07,0.09,0.1)
A4	(0.15,0.18,0.19)	(0.07,0.08,0.1)	(0.07,0.1,0.12)	(0,0.03,0.05)	(0.08,0.11,0.14)	(0.02,0.05,0.06)	(0.04,0.07,0.09)	(0.07,0.09,0.1)
A5	(0.06,0.11,0.14)	(0.06,0.09,0.1)	(0.06,0.09,0.11)	(0.06,0.08,0.1)	(0.07,0.1,0.13)	(0.04,0.06,0.07)	(0.03,0.06,0.07)	(0.03,0.05,0.07)

Table 15 shows FPIS and FNIS. The other steps of the FTOPSIS are shown in tables 16-18.

Table 15. Fuzzy positive and negative ideal solutions in FAHP-FTOPSIS approach

	C1	C2	C3	C4	C5	C6	C7	C8
FPIS	(0.06,0.11,0.14)	(0.07,0.08,0.1)	(0.09,0.12,0.13)	(0.06,0.09,0.1)	(0.1,0.14,0.15)	(0.04,0.06,0.07)	(0.06,0.08,0.1)	(0.07,0.09,0.1)
NPIS	(0.15,0.18,0.19)	(0.05,0.08,0.1)	(0.06,0.09,0.11)	(0,0.03,0.05)	(0,0.09,0.13)	(0.02,0.04,0.06)	(0.03,0.06,0.08)	(0.03,0.05,0.07)

Table 16. Distance of each supplier from FPIS

	C1	C2	C3	C4	C5	C6	C7	C8	S_i^+
D_1^+	0.06	0.01	0.03	0.02	0.03	0.01	0	0.01	0.17
D_2^+	0.01	0.01	0	0.03	0.07	0.02	0.01	0.01	0.16
D_3^+	0.05	0.01	0.03	0	0	0.01	0.01	0	0.11
D_4^+	0.06	0	0.02	0.06	0.02	0.01	0.01	0	0.18
D_5^+	0	0.01	0.03	0.01	0.03	0	0.02	0.04	0.14

Table 17. Distance of each supplier from FNIS

	C1	C2	C3	C4	C5	C6	C7	C8	S_i^-
D_1^-	0.01	0.01	0.01	0.03	0.04	0.01	0.02	0.03	0.16
D_2^-	0.07	0	0.03	0.03	0	0	0.01	0.03	0.17
D_3^-	0.03	0.01	0.01	0.06	0.07	0.01	0.02	0.04	0.25
D_4^-	0	0.01	0.01	0	0.05	0.01	0.01	0.04	0.13
D_5^-	0.07	0.01	0	0.05	0.04	0.02	0	0	0.19

Table 18. Relative closeness coefficient of suppliers in FAHP-FTOPSIS approach

Rank	CC_i	suppliers
4	0.485	A_1
3	0.515	A_2
1	0.694	A_3
5	0.419	A_4
2	0.576	A_5

5-3- Comparison of MDL-FTOPSIS and FAHP-FTOPSIS

Figure 1 compares the obtained results from MDL-FTOPSIS and FAHP-FTOPSIS approaches. As can be seen, the alternatives' ranking in both methods is very close together. The hybrid approaches utilize the benefits of their containing methods. MDL-FTOPSIS tries to use benefits of fuzzy theory, MDL technique and TOPSIS method, but FAHP-FTOPSIS utilizes fuzzy theory, AHP and TOPSIS method.

AHP has a main weakness in the pairwise comparisons in which the decision maker should remember previous scoring records when assign a score to the current pairwise comparison. For example, suppose we assigned number 3 in the pairwise comparison between the elements A and B, and number 3 between elements B and C. So, in the pairwise comparison between elements A and C, we should remember our previous scores and consider number of 5 or 7. On the other words, the difference between elements should be considered in the pairwise comparisons. Paying attention to the size of differences among qualitative variables is a confusing task and increase human errors, especially when the number of elements going to high, but in MDL technique, the size of differences between elements is not important and numbers 1, 2, and 3 are used in pairwise comparisons. So, human errors in scoring the pairwise comparisons are reduced significantly.

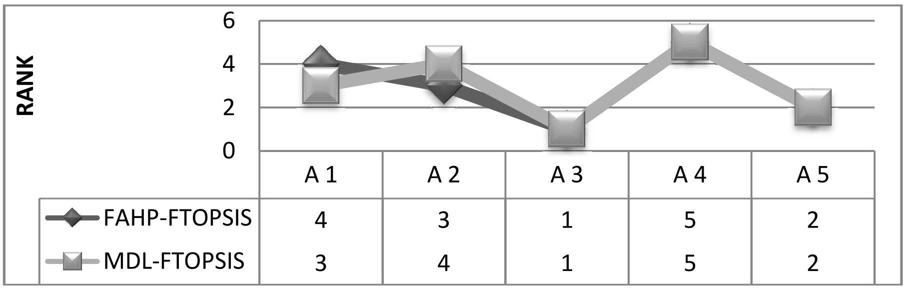

Fig1. Comparison of MDL-FTOPSIS and FAHP-FTOPSIS results

6- Summary and conclusion

Recently supplier selection has been a common problem in each industry. The problem is a MCDM problem and many researches has discussed about supplier selection. So, various models and methods are proposed to solve it. Recently hybrid methods are commonly used to solve the problem. Hybrid approaches try to utilize benefits of their containing methods. It is relatively difficult for the decision maker to simultaneously determine the true value of multi-value criteria in methods such as AHP, especially in cases with several criteria. In order to tackle this problem, an improved digital logic method were developed which uses three values {1,2 and 3} to compare pairs of criteria. For criteria with lower priority, equal priority and higher priority, the numbers 1, 2 and 3 are considered, respectively. In this paper we introduced a new hybrid approach utilizing fuzzy theory, MDL and TOPSIS methods. The result of the proposed approach is compared with another hybrid approach utilizing fuzzy theory, AHP and TOPSIS methods on a real case study in advertising supply chain. Also two new criteria to evaluate the supplier are introduced.

Merging MDL with other MCDM techniques such as PROMETHEE, ELECTERE and VIKOR could be considerable scope for future research. Utilizing Other fuzzy approaches like using trapezoidal fuzzy numbers to describe the uncertainties, employing the suggested method in other MCDM problems like choosing employees or material selection and using the MDL-FTOPSIS in selecting suppliers in other areas of industry are other topics for future studies.

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