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An Innovative Application On Supermarket Selection Through Using Intuitionistic Fuzzy TOPSIS Method

Feride TUĞRUL*[1]

Abstract

Multi-criteria decision making methods have recently attracted the attention of researchers and have had a large share in multidisciplinary fields. In this study, using the intuitionistic fuzzy TOPSIS method, supermarket chains were evaluated in the consumer context and the most preferred supermarket was determined. Consumers' opinions were expressed using linguistic term. The reason why the intuitionistic fuzzy TOPSIS method is preferred; it is the ability of consumers to express their opinions easily, to take into account the undecided situations with the help of intuitionistic fuzzy sets, and thus to create an objective decision making mechanism.

Keywords: Intuitionistic fuzzy sets, TOPSIS, market selection.

1.INTRODUCTION

Many scientists have been doing research on fuzzy and intuitionistic fuzzy sets for a long time. Zadeh defined fuzzy sets [1]; After fuzzy logic was defined, many researchers have been used fuzzy logic in both theoretical and application areas. Fuzzy logic provides serious convenience in many areas. When concepts such as sensitivity, indecision and hesitation came into play, it became clear that researchers needed a new field. Atanassov firstly defined intuitionistic fuzzy (IF) sets in response to these needs [2]. Since it eliminates uncertainty in many application areas, its use gives favorable results.

Multi-criteria decision-making (MCDM) processes are a challenging processes for decision-makers. Because many factors come into play while making the decision. Decision-makers want to make decisions by considering all factors at the same time. Therefore, MCDM methods make it easier for decision-makers in many ways. Many methods were described and used by decision-makers so far; TOPSIS, PROMETHEE, ELECTRE, AHP, etc.

In this study, the evaluation of supermarket chains, which are an important part of people's lives, in the context of consumers has been made. Shopping has a wide range of products such as food and beverage, cleaning materials, care products. In today's conditions, it is very convenient for people

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to act by choosing the market that suits their needs. To provide this convenience; in this study, a MCDM mechanism was established in order to evaluate the markets according to the perspective and needs of the consumers.

IF sets have been used to evaluate the situations in which consumers were undecided while reflecting their views. Consumers expressed their opinions about the markets with linguistic expressions, the values that these linguistic expressions correspond to as IF numbers are given in the tables.

The basic idea of this study is as follows: First of all, the 3 most preferred supermarkets in Turkey have been determined. Afterward, the criteria affecting the market preferences have been determined and classified. First of all, consumers' opinions about these criteria have been taken. Afterward, consumers have been asked to evaluate the markets according to the criteria. Linguistic expressions in the tables created according to the comments of the consumers are expressed by intuitionistic fuzzy numbers. These values have been evaluated within the decision-making mechanism with the IF TOPSIS method, which has a high rate of preference among MCDM methods.

According to the evaluation of the intuitionistic fuzzy TOPSIS method, a ranking has been made among the markets and the most preferred market has been determined in the context of consumers.

Market selection and evaluation has attracted the attention of many researchers. There are various researches in this field, some of them are as follows: Market segment evaluation, e-marketplace selection, competitiveness of supermarket chains, market selection in international expansion, consumer market for business, opinion of supermarket's executives, market segment evaluation with CODAS method, VIKOR method with research on fresh fruit-vegetable sector, market evaluation using by AHP and COPRAS-G method, etc. [3-10]

Today, most researchers have applications related to MCDM, especially in multidisciplinary fields. IF sets, TOPSIS, fuzzy TOPSIS and IF TOPSIS methods have been used by researchers both theoretically and in many application areas: Supplier selection, facility location selection, mobile phone selection, distance measure, developing new methods, renewable energy technologies, selecting school, furniture industry, departments' performances, selection of wind power plants, determination of physical conditions of schools, product concept selection, etc. [11-34].

In addition to these, innovative studies can be carried out in many fields by using IF sets and MCDM methods together; education, physics, geometry, algebraic structures, recycling, technology, and computers, etc.

The choices of alternatives and criteria, calculation methods, ordering method, distance measure used, equations used in the method, intuitionistic fuzzy expressions and all calculations are explained in detail.

1.1.Preliminaries

Definition 1: [2, 35] Let $X \neq \emptyset$. An intuitionistic fuzzy set A in X;

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle | \; x \epsilon X\}, \qquad (1.1)$$

$$\mu_A(x), \nu_A(x), \pi_A(x): X \rightarrow [0,1] \qquad (1.2)$$

defined membership, nonmembership and hesitation degree of the element $x \in X$ respectively.

$$\mu_A(x) + \nu_A(x) + \pi_A(x) = 1 \qquad (1.3)$$

The IF TOPSIS algorithm which are m alternatives and n criteria is as follows [29]:

Step 1 Linguistic terms are used when determining the importance of each DM.

Table 1 Linguistic Terms for the Importance of DMs

Linguistic Terms	IFNs
Very Important	(0.8,0.1)
Important	(0.5,0.2)
Medium	(0.5,0.5)
Bad	(0.3,0.5)
Very Bad	(0.2,0.7)

$L = l_1, l_2, \dots, l_n$ is set of decision makers. $Dl = [\mu l, \nu l, \pi l]$ is calculated as follows [36]:

$$\lambda l = \frac{\left[\mu l + \pi l\left(\frac{\mu l}{\mu l + \nu l}\right)\right]}{\sum_{l=1}^{k}\left[\mu l + \pi l\left(\frac{\mu l}{\mu l + \nu l}\right)\right]} \qquad (1.4)$$

$\lambda 1 \in [0,1]$ and $\sum_{l=1}^{k} \lambda l = 1$.

Step 2 The importance of the criteria (W) is determined in linguistic terms depending on the views of the DMs:

Table 2 Linguistic Terms for Rating the Criterion

Linguistic Terms	IFNs
Very Important	(0.9,0.1)
Important	(0.75,0.2)
Medium	(0.5,0.45)
Unimportant	(0.35,0.6)
Very Unimportant	(0.1,0.9)

When calculating the weights of the criteria, The IFWA operator is used [37]. According to linguistic terms in Table 2, the weight of criteria is calculated as:

$$w_j = IFWAr_\lambda\left(w_j^{(1)}, w_j^{(2)}, \dots, w_j^{(l)}\right) = \lambda_1 w_j^{(1)} \oplus \lambda_2 w_j^{(2)} \oplus, \dots, \oplus \lambda_k w_j^{(k)}$$

$$= \left[1 - \prod_{l=1}^{k}\left(1 - \mu_{ij}^{(l)}\right)^{\lambda l}, \left(\prod_{l=1}^{k}\left(\nu_{ij}^{(l)}\right)^{\lambda l}\right), \prod_{l=1}^{k}\left(1 - \mu_{ij}^{(l)}\right)^{\lambda l} - \prod_{l=1}^{k}\left(\nu_{ij}^{(l)}\right)^{\lambda l}\right] \qquad (1.5)$$

Step 3 Determine IF Decision Matrix (IFDM). In Table 3, the IF corresponding values of linguistic terms are given. These values are used when calculating the weights of the alternatives:

Table 3 Linguistic Terms for Rating the Alternatives

Linguistic Terms	IFNs
Very Good (VG)	(1.00,0.00)
Good (G)	(0.85,0.05)
MediumGood (MG)	(0.70,0.20)
Fair (F)	(0.50,0.50)
Medium Poor (MP)	(0.40,0.50)
Poor (P)	(0.25,0.60)
Very Poor (VP)	(0.00,0.90)

The Aggregated Intuitionistic Fuzzy Decision Matrix (AIFDM) is obtained [37]. $R^l = (r_{ij}^{(l)})_{m*n}$ is the IFDM of each DM. $\lambda = \lambda_1, \lambda_2, \dots, \lambda_k$ is the weight of the DM. $R = (r_{ij})_{m' \times n'}$

$$r_{ij} = IFWAr_\lambda\left(r_{ij}^{(1)}, r_{ij}^{(2)}, \dots, r_{ij}^{(l)}\right) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus, \dots, \oplus \lambda_k r_{ij}^{(k)}$$

$$= \left[1 - \prod_{l=1}^{k}\left(1 - \mu_{ij}^{(l)}\right)^{\lambda l}, \left(\prod_{l=1}^{k}\left(\nu_{ij}^{(l)}\right)^{\lambda l}\right), \prod_{l=1}^{k}\left(1 - \mu_{ij}^{(l)}\right)^{\lambda l} - \prod_{l=1}^{k}\left(\nu_{ij}^{(l)}\right)^{\lambda l}\right] \qquad (1.6)$$

Step 4 The S matrix is created. W with respect to IFDM (R) are defined as follows:

$$S = R \times W$$
$$R \otimes W = \left(\mu'_{ij}, \nu'_{ij}\right) = \left\{\langle \mu_{ij} \times \mu_j, \nu_{ij} + \nu_j - \nu_{ij} \times \nu_j \rangle\right\} \qquad (1.7)$$

Step 5 J_1 is the benefit criteria and J_2 is the cost criteria. A^+ is the IF positive ideal solution and A^- is the IF negative ideal

solution. Then A^+ and A^- are obtained as follows:

$$A^+ = (r_1'^*, r_2'^*, \dots, r_n'^*), r_j'^* = (\mu_j'^*, \nu_j'^*, \pi_j'^*), \quad j = 1,2,\dots,n \tag{1.8}$$

$$A^- = (r_1'^-, r_2'^-, \dots, r_n'^-), r_j'^- = (\mu_j'^-, \nu_j'^-, \pi_j'^-) \quad j = 1,2,\dots,n \tag{1.9}$$

Where

$$\mu_j'^* = \left\{\left(\max_i\{\mu_{ij}'\} j \in J_1\right), \left(\min_i\{\mu_{ij}'\} j \in J_2\right)\right\}$$

$$\nu_j'^* = \left\{\left(\min_i\{\nu_{ij}'\} j \in J_1\right), \left(\max_i\{\nu_{ij}'\} j \in J_2\right)\right\}$$

$$\mu_j'^- = \left\{\left(\min_i\{\mu_{ij}'\} j \in J_1\right), \left(\max_i\{\mu_{ij}'\} j \in J_2\right)\right\}$$

$$\nu_j'^- = \left\{\left(\max_i\{\nu_{ij}'\} j \in J_1\right), \left(\min_i\{\nu_{ij}'\} j \in J_2\right)\right\}$$

Step 6 Many distance measures have been defined on IF sets [38, 39]. In this step of the study, unlike other methods, the normalized Hamming measure will be used. Studies have shown that the normalized Hamming measure is the most sensitive measure of distance compared to other distance measures. Therefore, in this study, the normalized Hamming distance measure was used. Through the positive and negative ideal solutions, S_i^+ and S_i^- respectively, the separation measures of the alternatives are determined.

$$S_i^+ = \frac{1}{2n}\sum_{i=1}^{n}\left[\left|\mu_{ij}' - \mu_{ij}'^*\right| + \left|\nu_{ij}' - \nu_{ij}'^*\right| + \left|\pi_{ij}' - \pi_{ij}'^*\right|\right] \tag{1.10}$$

$$S_i^- = \frac{1}{2n}\sum_{i=1}^{n}\left[\left|\mu_{ij}' - \mu_{ij}'^-\right| + \left|\nu_{ij}' - \nu_{ij}'^-\right| + \left|\pi_{ij}' - \pi_{ij}'^-\right|\right] \tag{1.11}$$

Step 7 The closeness coefficient between the positive ideal solution and the negative ideal solution is calculated by the formula:

$$C_i^* = \frac{S_i^-}{S_i^+ + S_i^-}, \tag{1.12}$$

and $0 \le C_i^* \le 1$. The resulting value is ranked from largest to smallest. A larger C_i^* value indicates better alternative.

2. SUPERMARKET SELECTION USING THE IF TOPSIS METHOD

In this study, the 3 most preferred chain supermarkets in Turkey have been discussed. These supermarkets have been evaluated according to certain criteria by consumers. From many aspects, supermarkets have a very important role in people's lives. Chain supermarkets, on the other hand, are designed to serve the needs of people.

Supermarkets have been evaluated according to the opinions of consumers. IF sets have been used in order to consider all the ideas of the consumers while determining the opinions of the consumers. It is aimed to reflect the ideas of consumers in the most objective way, taking into account the undecided situations as well as positive and negative ideas. By using the IF TOPSIS method together with the IF sets, the distances to both the positive ideal solution and the negative ideal solution have been calculated, and a ranking has been made between the alternatives thanks to the closeness coefficient.

In this study; alternatives represent the markets and the criteria represent the issues that the markets pay attention to when choosing according to the consumers. Alternatives, criteria and explanations about them are as follows:
$M = \{M_1, M_2, M_3\}$ is the set of alternatives, namely, supermarkets. $C = \{C_1, C_2, C_3, C_4, C_5, C_6\}$ is the set of criteria.

C_1: Product quality

- Fresh produce
- Not selling defective products

- Paying attention to the expiry date of the products

C_2: Accessibility
- Excess number of branches
- Easy to reach the location
- No traffic, no parking problems

C_3: Product variety
- Easy access to every product
- Wide range of products
- Brand diversity

C_4: Economic

C_5: Access to products in the Market
- Number of employees
- Slabs, signboards for product promotion

C_6: The atmosphere of the market
- Hygiene
- Organized shelves
- Fresh environment

While determining the criteria for choosing supermarket chains, the concept of competition is remarkable for consumers. According to Levy and Weitz, they identified important factors affecting competition in the retail industry [40, 41] The steps of applying the IF TOPSIS method to the alternatives and criteria mentioned above and explained in detail are as follows:

Step 1: There are 2 DMs in this study. Decision maker 1 (DM_1): Consumer, Decision maker 2 (DM_2): Consumer. After determining the importance of DMs with linguistic variables according to Table 1; the importance of the DM_1 is "very important" and the importance of the DM_2 is "important". It has been converted into numerical data with the help of equation 1.4:

Numerical values of DM_1's importance weight: 0,55

Numerical values of DM_2's importance weight: 0,45

Step 2: Linguistic values have been assigned to each criterion by the decision makers and the importance values of the criteria were determined as linguistic expressions. Many different methods could be used when calculating weights of the criteria. One of the effective methods among these methods is controlled sets [42]. In this study, it has been preferred to use linguistic expressions. Table 4 represents the degree of importance of the criteria determined based on the opinions of the decision makers. Assigned numeric values to the linguistic expressions have been determined with the help of intuitionistic fuzzy numbers in Table 2. Using of Equation 1.5, weights of criteria are obtained values are shown in Table 5.

Table 4 Importance weights of criteria based on DMs opinion

	DM_1	DM_2
C_1	VI	VI
C_2	M	U
C_3	VI	I
C_4	I	VI
C_5	I	M
C_6	I	I

Table 5 Weights of criteria

C_1	(0.90, 0.10)
C_2	(0.44, 0.52)
C_3	(0.85, 0.14)
C_4	(0.83, 0.15)
C_5	(0.66, 0.29)
C_6	(0.75, 0.20)

The importance of the alternatives for each criterion has been determined by the DMs according to the linguistic expressions in Table 3 and has shown in Table 6.

Table 6 Importance of alternatives according to DMs

	C_1	C_2	C_3	C_4	C_5	C_6
DM_1						
M_1	G	F	VG	G	MP	P
M_2	MG	G	MG	G	G	MG
M_3	VG	F	VG	MP	MP	VG
DM_2						
M_1	G	MG	VG	G	MP	MP
M_2	G	VG	G	VG	VG	G
M_3	G	F	VG	MP	MP	G

Step 3: AIFDM has been calculated using by Equation 1.6. R matrix is obtained in Table 7.

Step 4: S matrix is obtained with the help of Equation 1.7. S matrix is obtained in Table 8.

Table 7 R Matrix

	C_1	C_2	C_3	C_4	C_5	C_6
M_1	(0.850, 0.050)	(0.602, 0.332)	(1.000, 0.000)	(0.850, 0.050)	(0.400,0.500)	(0.321, 0.553)
M_2	(0.780, 0.108)	(1.000, 0.000)	(0.780, 0.108)	(1.000, 0.000)	(1.000, 0.000)	(0.780, 0.108)
M_3	(1.000,0.000)	(0.500,0.500)	(1.000,0.000)	(0.400,0.500)	(0.400,0.500)	(1.000,0.000)

Table 8 S Matrix

	C_1	C_2	C_3	C_4	C_5	C_6
M_1	(0.765, 0.145)	(0.264, 0.674)	(0.850,0.136)	(0.709, 0.189)	(0.264, 0.644)	(0.241, 0.643)
M_2	(0.702, 0.197)	(0.438, 0.512)	(0.662, 0.229)	(0.834, 0.147)	(0.659, 0.287)	(0.585, 0.286)
M_3	(0.900,0.100)	(0.219, 0.756)	(0.849, 0.136)	(0.334, 0.573)	(0.264, 0.644)	(0.750, 0.200)

Step 5: The IF positive A^+ and negative ideal solution A^- are obtained using by Equation 1.8 and 1.9 in Table 9 and Table 10 respectively:

Table 9 The IF positive ideal solution A^+

A^+	
C_1	(0.900, 0.100)
C_2	(0.438, 0.512)
C_3	(0.849, 0.136)
C_4	(0.834, 0.147)
C_5	(0.659, 0.287)
C_6	(0.750, 0.200)

Table 10 The IF negative ideal solution A^-

A^-	
C_1	(0.702, 0.197)
C_2	(0.219, 0.756)
C_3	(0.663, 0.229)
C_4	(0.334, 0.574)
C_5	(0.264, 0.644)
C_6	(0.241, 0.643)

Step 6-7: Separation measures, namely, positive ideal solution S^+ and negative ideal solution S^- are obtained using by normalized Hamming distance measure (with by Equation 1.10 and 1.11). Also, The closeness coefficient C_i^* between the positive ideal solution and the negative

ideal solution is calculated using by Equation 1.12 in Table 11 and shown in Figure 1.

Table 11 Separation measures and closeness coefficient values

	S^+	S^-	C_j^*
M_1	0.22325	0.11937	0.34840
M_2	0.09177	0.24942	0.73102
M_3	0.19004	0.14911	0.43967

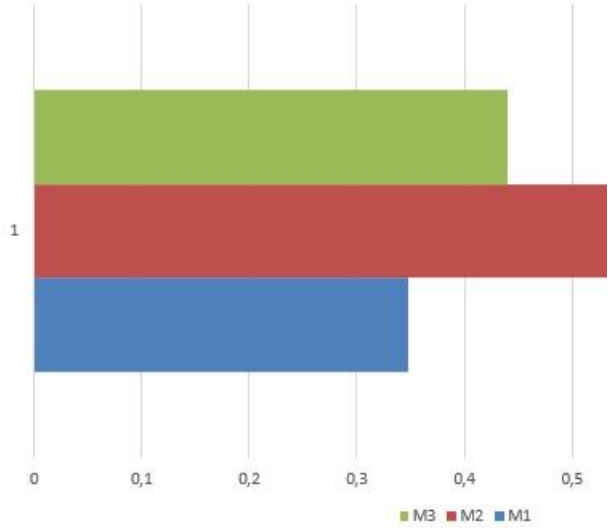

Figure 1 The Closeness Coefficient Values

When the values in Table 11 are examined, For the alternative to be good, the closeness coefficient is expected to be high. In other words, as the closeness coefficient value increases, the success of that alternative among all alternatives increases. Accordingly, the ranking among the alternatives is as follows: $M_2 - M_3 - M_1$.

According to this MCDM mechanism, which is prepared based on the opinions of consumers; the most preferred market is the M_2 market. In addition, according to consumers, the M_3 market is more preferred than the M_1 market.

3.CONCLUSION AND SUGGESTION

In this study, an application was made to the selection of supermarket chains in the context of consumers by using the intuitionistic fuzzy TOPSIS method. Purpose of the study; to evaluate the supermarket chains, which is a highly competitive market, according to the opinions of the consumers and to determine the most preferred market. For this purpose, consumers' ideas were evaluated as linguistic expressions and expressed with intuitionistic fuzzy numbers. According to this system, which is created by considering the needs, wishes and preferences of the consumers, the competition between the markets is reflected in the consumer. Supermarket chains should act in this direction by determining the factors that consumers pay special attention to in market selection.

By using the IF TOPSIS method, the distance to both the positive and negative ideal solution was calculated. While calculating the separation measures between the positive and negative ideal solutions, the normalized Hamming measure was used. According to the calculated closeness coefficient, a ranking was obtained among the markets from the best to the worst, and the most preferred market was determined.

If want to talk about another advantage of this method; it is very difficult for decision-makers to always express their views with numerical values. Therefore, decision-makers may both feel better and make more objective comments when expressing their ideas in linguistic terms. For these reasons, advantageous results were emerged by making use of the IF TOPSIS method, which gives decision-makers the chance to express their ideas in linguistic terms.

This study is an exemplary study in the multidisciplinary field. The method used in the study; it may be used in all application areas. This method will guide researchers who want to use an algorithm based on the ideas of decision makers while selecting, evaluating and ranking by using a MCDM

mechanism. In the continuation of this study; a more comprehensive study may be obtained with different market chains. The IF TOPSIS method may be compared with other MCDM methods such as PROMETHEE, ELECTRE, AHP, etc. The criteria may be expanded by making a study on the factors of preference of supermarket chains.

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Authors' Contribution
The authors contributed equally to the study.

The Declaration of Ethics Committee Approval
This study does not be necessary ethical committee permission or any special permission.

The Declaration of Research and Publication Ethics
The author(s) declared that they comply with the scientific, ethical, and citation rules of Sakarya University Journal of Science in all processes of the study and that they do not make any falsification on the data collected. Besides, the author(s) declared that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered and this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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