Black Sea Journal of Engineering and Science

doi: 10.34248/bsengineering.1155615

Open Access Journal
e-ISSN: 2619 – 8991

Research Article
Volume 5 - Issue 4: 146-150 / October 2022

AN EVALUATION OF SUPERMARKETS FROM THE LENS OF MULTIPLE CRITERIA: THE INTUITIONISTIC FUZZY TOPSIS METHOD

Feride TUĞRUL[1]*

[1]*Kahramanmaraş Sütçü İmam University, Faculty of Science and Arts, Department of Mathematics, 46050, Kahramanmaraş, Türkiye*

Abstract: This study is an attempt to evaluate supermarkets by both the consumer and the market researcher through the intuitionistic fuzzy TOPSIS. In this regard, the decision makers' views were expressed in linguistic terms and ranked from the most preferred supermarket to the least preferred supermarket. The satisfaction of using linguistic terms is that it gives decision makers the chance to express views that they cannot express in numerical values. Furthermore, undecided situations were interpreted through the IFS. This method, which may be easily used in many application areas, offers researchers more consistent results than the others due to its advantages. Besides, this study attempts to innovative implementation of the intuitionistic fuzzy TOPSIS method on its algorithm and mathematical basis.

Keywords: Intuitionistic fuzzy set, Market selection, Intuitionistic fuzzy TOPSIS

***Corresponding author:** Kahramanmaraş Sütçü İmam University, Faculty of Science and Arts, Department of Mathematics, 46050, Kahramanmaraş, Türkiye
E mail: feridetugrul@gmail.com (F. TUĞRUL)
Feride TUĞRUL https://orcid.org/0000-0001-7690-8080

Received: August 04, 2022
Accepted: September 07, 2022
Published: October 01, 2022

Cite as: Tuğrul F. 2022. An evaluation of supermarkets from the lens of multiple criteria: the intuitionistic fuzzy TOPSIS method. BSJ Eng Sci, 5(4): 146-150.

1. Introduction

Fuzzy logic was described by Zadeh (1965), furthermore Atanassov described intuitionistic fuzzy (IF) sets (Atanassov, 2016). Recently, there are many MCDM methods defined and have been the focus of attention for many researchers (Majumder, 2015). TOPSIS method makes a ranking built on the positive ideal and negative ideal relationship (Hwang and Yoon, 1981). Besides IF TOPSIS method is chosen since decision makers are free to express their ideas in linguistic terms. Numerous researchers have benefited from the TOPSIS method in their application areas such as supplier selection, location selection, renewable energy technologies, mobile phone selection, product concept selection, wind power plants, etc. (Boran et al., 2009; Boran, 2011; Rouyendegh, 2011; Boran et al., 2012; Rouyendegh and Saputro, 2014; Büyüközkan and Güleryüz, 2015; Efe et al., 2015; Rouyendegh, 2015; Damgacı et al., 2017; Rouyendegh et al., 2018; Rouyendegh et al., 2020). Today, the issue of market selection that meets the basic needs of people has been the focus of the attention of researchers. There are studies conducted with different methods in the related literature such as: Market segment evaluation, e-marketplace selection, the competitiveness of supermarket chains, market selection in international expansion, the consumer market for business, opinion of supermarket executives, market segment evaluation with CODAS method, VIKOR method with research on the fresh fruit-vegetable sector, market evaluation using by AHP and COPRAS-G method, etc. (Büyüközkan, 2004; Gorecka and Szałucka, 2013; Tosun, 2015; Ghorabaee et al., 2017). The intuitionistic fuzzy sets and MCDM methods were utilized by researchers in many decision making processes and applications, and very favorable results were obtained since the sensitivity makes sense (Çuvalcıoğlu, 2014; Tuğrul and Çitil, 2021; Sözeyatarlar et al., 2021; Yavuz and Şahin, 2022).

2. Materials and Methods

2.1. Material

This study utilized the 3 most preferred chain supermarkets and 1 chain local market in Turkey. These supermarkets were evaluated according to certain criteria by consumers and market researchers. From many aspects, supermarkets have a very significant role in people's lives. Chain supermarkets, on the other hand, are designed to serve the needs of people.

Alternatives and explanations about them are as follows:

- M_1: Local Market -has 7 stores and approximately 150 employees
- M_2: Supermarket Chain-has approximately 11000 stores and approximately 61000 employees
- M_3: Supermarket Chain-has approximately 2500 stores and approximately 50000 employees
- M_4: Supermarket Chain-has approximately 8500 stores and approximately 60000 employees

Criteria (Super Market) and explanations about them are as follows:

- *MC1*:Pricing
  - Greengrocer
  - Meat and meat products
  - Milk and milk products
  - Legumes
- *MC2*:Location
  - Accessibility
  - Number of stores
- *MC3*: Expiry dates of products
- *MC4*: Wide product range
- *MC5*: Freshness of products and quality of products
- *MC6*: Campaigns
  - Campaign application
  - Advertising on social media
- *MC7*: Parking facility
- *MC8*:Working principle of the staff
  - The friendliness of the staff
  - The helpfulness of the staff
  - The sufficient number of staff
- *MC9*: Clean and comfortable atmosphere
- *MC10*: Clutter-free, organized shelf-compartments
- *MC11*: Image of the market
- *MC12*: Easy access to the product in the market
  - Guide member
  - Guide signs
  - Lighting
  - Arrows
- *MC13*: Product variety
- *MC14*: Having a children's play area

2.2. Methods

Definition 1: (Atanassov, 1986; 2016) (Equation 1) *Let X ≠ Ø. An IFS* A *in* X*;*

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in X\}. \tag{1}$$

The algorithm of the IF TOPSIS method was shown in this section (Rouyendegh, 2015).

Step 1: By specifying the contribution interest of the DMs on the practice, the DM importance value was determined in linguistic terms (Wu et al., 2016).

Table 1. Expressions for DMs

Expressions	IFNs
VI	(0.8,0.1)
I	(0.5,0.2)
M	(0.5,0.5)
B	(0.3,0.5)
VB	(0.2,0.7)

The table above represents I important, VI very I, M medium, B bad, VB very bad. The value of DMs views

$Dl = [\mu l, \nu l, \pi l]$ was calculated as follows (Equation 2):

$$\lambda l = \frac{[\mu l + \pi l(\frac{\mu l}{\mu l + \nu l})]}{\sum_{l=1}^{k}[\mu l + \pi l(\frac{\mu l}{\mu l + \nu l})]} \tag{2}$$

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

Step 2: DMs indicated their opinions on the criteria in linguistic terms based on Table 2.

Table 2. Expressions for criterion evaluation

Expressions	IFNs
VI	(0.9,0.1)
I	(0.75,0.2)
M	(0.5,0.45)
U	(0.35,0.6)
VU	(0.1,0.9)

Table 2, unlike Table 1, represents U is unimportant, VU is very U. Afterwards, while calculating the criterion weight, and the IFWA operator defined by Xu (2007) was used (Equation 3).

$$w_j = IFWAr_\lambda(w_j^{(1)}, w_j^{(2)}, \ldots, w_j^{(l)}) = \lambda_1 w_j^{(1)} \oplus \lambda_2 w_j^{(2)} \oplus, \ldots, \lambda_k w_j^{(k)} \tag{3}$$

Step 3: With the help of Table 3, the views of the DMs about the alternatives were determined.

Table 3. Expressions for alternative assessment

Expressions	IFNs
VG	(1.00,0.00)
G	(0.85,0.05)
MG	(0.70,0.20)
F	(0.50,0.50)
MP	(0.40,0.50)
P	(0.25,0.60)
VP	(0.00,0.90)

With these values, Intuitionistic Fuzzy Decision Matrix (IFDM) was acquired. Table 3 indicates that VG is very G, G is good, MG is medium G, F is fair, P is poor, MP is medium P and VP is very P. Aggregated IFDM was acquired with the help of the IFWA operator (Equation 4).

$$R^{(l)} = (r_{ij}^{(l)})_{m*n} \text{ is the IFDM.}$$
$$R = (r_{ij})_{m \times n}$$
$$r_{ij} = IFWAr_\lambda(r_{ij}^{(1)}, r_{ij}^{(2)}, \ldots, r_{ij}^{(k)}) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus, \ldots, \lambda_k r_{ij}^{(k)} \tag{4}$$

Step 4: *S* matrix was determined as seen in Equation 5.

$$S = R \otimes W \tag{5}$$

Step 5 The ideal solution means close to positive and far from negative. A^+ (Equation 6) and A^- (Equation 7) are formed in which J_1: benefit and J_2: cost criteria:

$$A^{+} = (r_1^{'*}, r_2^{'*}, \ldots, r_n^{'*}), r_j^{'*} = (\mu_j^{'*}, \nu_j^{'*}, \pi_j^{'*}), j = 1,2,\ldots,n \quad (6)$$

$$A^{-} = (r_1^{'-}, r_2^{'-}, \ldots, r_n^{'-}), r_j^{'-} = (\mu_j^{'-}, \nu_j^{'-}, \pi_j^{'-}), j = 1,2,\ldots,n \quad (7)$$

where;

$$\mu_j^{'*} = \{(\max_i \{\mu_{ij}^{'}\} j \in J_1), (\min_i \{\mu_{ij}^{'}\} j \in J_2)\} \quad (8)$$

$$\nu_j^{'*} = \{(\min_i \{\nu_{ij}^{'}\} j \in J_1), (\max_i \{\nu_{ij}^{'}\} j \in J_2)\} \quad (9)$$

$$\mu_j^{'-} = \{(\min_i \{\mu_{ij}^{'}\} j \in J_1), (\max_i \{\mu_{ij}^{'}\} j \in J_2)\} \quad (10)$$

$$\nu_j^{'-} = \{(\max_i \{\nu_{ij}^{'}\} j \in J_1), (\min_i \{\nu_{ij}^{'}\} j \in J_2)\} \quad (11)$$

Step 6: Researchers utilized many different methods to calculate separation measures (Szmidt and Kacprzyk, 2000; Çitil, 2019).This study varies across other research since the normalized Hamming distance was used. Separation measures, S_i^{+} and S_i^{-} respectively, were gained as in Equations 12 and 13:

$$S_i^{+} = \frac{1}{2n} \sum_{i=1}^{n} [\,|\mu_{ij}^{'} - \mu_{ij}^{'*}| + |\nu_{ij}^{'} - \nu_{ij}^{'*}| + |\pi_{ij}^{'} - \pi_{ij}^{'*}|\,] \quad (12)$$

$$S_i^{-} = \frac{1}{2n} \sum_{i=1}^{n} [\,|\mu_{ij}^{'} - \mu_{ij}^{'-}| + |\nu_{ij}^{'} - \nu_{ij}^{'*-}| + |\pi_{ij}^{'} - \pi_{ij}^{'-}|\,] \quad (13)$$

Step 7: C_i^{*} was calculated by the Equation 14:

$$C_i^{*} = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}, \text{and } 0 \le C_i^{*} \le 1 \quad (14)$$

A higher value of C_i^{*} represents the better alternative.

3. Results

For this study, the views of 3 decision makers were taken into account. DM_1: Market researcher, DM_2 and DM_3: Consumer. After specifying the importance of DMs with linguistic variables according to Table 1, it was converted into numerical data with the help of Equation (2) and was shown in Table 4 as follows:

Table 4. Importance of DMs

DM_1	DM_2	DM_3
VI	I	I
λ_1	λ_2	λ_3
0.383561644	0.308219178	0.308219178

Decision makers specified when determining the weights for criteria as follows:

Table 5. Weights of Criteria

Criteria	DM_1	DM_2	DM_3
MC_1	VI	VI	U
MC_2	M	I	U
MC_3	VI	VI	VI
MC_4	VI	I	I
MC_5	VI	M	VI
MC_6	I	I	M
MC_7	I	U	VI
MC_8	I	VI	I
MC_9	VI	U	VI
MC_{10}	VI	M	VI
MC_{11}	VI	U	VI
MC_{12}	VI	I	I
MC_{13}	VI	I	I
MC_{14}	I	U	VI

The views of the DMs were given in Table 6-7-8. For each criterion, decision makers evaluated all alternatives separately.

Table 6. Values of alternatives for criteria according to decision maker 1

DM_1	M_1	M_2	M_3	M_4
MC_1	G	MG	MP	G
MC_2	MG	VG	MP	G
MC_3	VG	VG	VG	G
MC_4	G	MG	MG	G
MC_5	VG	MP	G	P
MC_6	P	VG	G	VG
MC_7	MP	G	MP	G
MC_8	G	MP	MG	MP
MC_9	MG	G	VG	G
MC_{10}	P	MG	G	MG
MC_{11}	G	MG	VG	MG
MC_{12}	P	MG	G	G
MC_{13}	VG	MG	VG	G
MC_{14}	VG	P	VG	P

Table 7. Values of alternatives for criteria according to decision maker 2

DM_2	M_1	M_2	M_3	M_4
MC_1	MG	MG	MP	VG
MC_2	MG	VG	P	VG
MC_3	VG	VG	VG	G
MC_4	MG	VG	MG	VG
MC_5	VG	MG	MG	MG
MC_6	P	G	MG	VG
MC_7	MP	G	MP	G
MC_8	MG	MP	MG	MP
MC_9	MP	G	MG	G
MC_{10}	P	P	F	P
MC_{11}	MG	VG	MG	VG
MC_{12}	P	MG	G	G
MC_{13}	VG	MG	F	VG
MC_{14}	F	F	F	F

Table 8. Values of alternatives for criteria according to decision maker 3

DM_3	M_1	M_2	M_3	M_4
MC_1	VG	VG	G	VG
MC_2	MG	VG	MG	VG
MC_3	VG	VG	VG	G
MC_4	G	MG	VG	MG
MC_5	VG	MP	VG	MP
MC_6	P	G	VG	G
MC_7	MP	G	MP	G
MC_8	MG	MP	G	MP
MC_9	MP	G	VG	G
MC_{10}	MG	MG	G	MG
MC_{11}	G	MG	VG	MG
MC_{12}	P	G	VG	G
MC_{13}	VG	F	VG	F
MC_{14}	VG	P	VG	P

R matrix was created with the help of Equation (4). Afterwards, the S matrix was obtained using Equation (5). A^+ and A^- solutions were calculated using Equations (6) and (7) and shown in Table 9.

Table 9. The if positive and negative ideal solution

Criteria	A^+	A^-
MC_1	(0.8219,0.1737)	(0.5003,0.3769)
MC_2	(0.5622,0.3829)	(0.2704,0.6290)
MC_3	(0.9000,0.1000)	(0.7650,0.1450)
MC_4	(0.8241,0.1533)	(0.6710,0.2182)
MC_5	(0.8358,0.1589)	(0.3946,0.4989)
MC_6	(0.6905,0.2568)	(0.1726,0.7027)
MC_7	(0.6349,0.2653)	(0.2988,0.6133)
MC_8	(0.6249,0.2601)	(0.3246,0.5808)
MC_9	(0.8219,0.1737)	(0.4439,0.4644)
MC_{10}	(0.6541,0.2445)	(0.3632,0.5186)
MC_{11}	(0.8219,0.1737)	(0.6693,0.2371)
MC_{12}	(0.8241,0.1533)	(0.2060,0.6613)
MC_{13}	(0.8241,0.1533)	(0.5347,0.3779)
MC_{14}	(0.7469,0.2266)	(0.2526,0.6653)

S^+ and S^- for alternatives determined using Equation (12) and (13) using the normalized Hamming measure are shown in Table 10, respectively. The closeness coefficient values were calculated by using the Equation (14) and are shown in Table 10. In addition, the graphs of the C_i^* are shown in Figure 1.

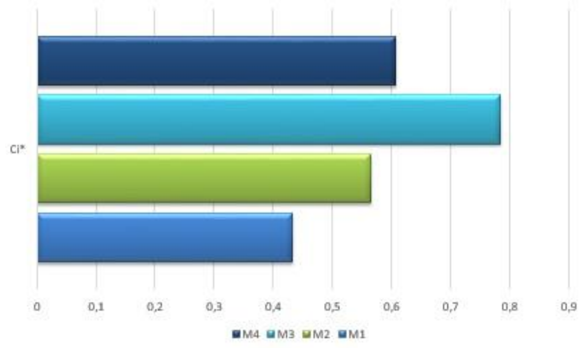

Figure 1. Closeness coefficient values

Table 10. Values of separation measures and closeness coefficient

	S^+	S^-	C_i^*
M_1	0.18685	0.14246	0.43261
M_2	0.14167	0.18463	0.56584
M_3	0.06945	0.25203	0.78395
M_4	0.12779	0.19758	0.60725

High C_i^* value means that that alternative is preferred more. According to Figure 1 and closeness coefficient values, the order of the supermarkets from the most preferred to the least preferred in terms of consumers is as follows: M_3, M_4, M_2 and M_1.

4. Discussion and Conclusion

This study investigated the markets preferred by the consumers with the help of the IF-based TOPSIS method. While evaluating the markets, it has been handled from the perspective of both market researchers and consumers. Expressing their ideas in linguistic terms provided a freer decision making action for decision makers. Thanks to intuitionistic fuzzy sets, the study aimed to get the most efficient result by making sense of the sensitivities. The reason for using the TOPSIS is that the DMs may easily state their ideas with the help of linguistic terms, not numerical values. The study will offer various approaches the literature in many markets and marketing fields. At the same time, it will guide researchers in the field of application. The number of consumers in the study may be increased by changing, different decision makers may be added, and the number of supermarkets may be increased. This application may be developed in different supermarkets and by other methods over different criteria. By establishing a wide-ranging decision-making mechanism thanks to this method, it may be ensured that the sector across the country and the world may meet customer demands quickly and facilitate their workload.

Author Contributions

All task was done by the single author: F.T. (100%). The author reviewed and approved the manuscript.

Conflict of Interest

The author declared that there is no conflict of interest.

Acknowledgements

The author declared that has not received any financial support for the research, authorship or publication of this study.

References

Atanassov KT. 1986. Intuitionistic fuzzy set. Fuzzy Sets Syst, 20(1): 87-96.

Atanassov KT. 2016. Intuitionistic fuzzy sets. Int J Bioautomation, 20(S1): 1-6.

Boran FE, Boran K, Menlik T. 2012. The evaluation of renewable energy technologies for electricity generation in turkey using intuitionistic fuzzy TOPSIS. Energy Sour Part B: Econ Plan Pol, 7(1): 81-90.

Boran FE, Genç S, Kurt M, Akay D. 2009. A Multi-Criteria Intuitionistic fuzzy group decision making for supplier selection with TOPSIS Method. Expert Syst App, 36(8): 11363-11368.

Boran FE. 2011. An integrated intuitionistic fuzzy multi criteria decision making method for facility location selection. Math Comp App, 16(2): 487-496.

Büyüközkan G, Güleryüz S. 2015. An application of intuitionistic fuzzy topsis on mobile phone selection. IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), August 2-5, 2015, Rockville, US, pp: 1-8.

Büyüközkan G. 2004. Multi-Criteria decision making for e-marketplace selection. Internet Res, 14(2): 139-154.

Çitil M. 2019. Application of the Intuitionistic fuzzy logic in education. Commun Math App, 10(1): 131-143.

Çuvalcıoğlu G. 2014. Some properties of controlled set theory. Notes on Intuitionistic Fuzzy Set, 20(2): 37-42.

Damgacı E, Boran K, Boran FE. 2017. Evaluation of Turkey's renewable energy using intuitionistic fuzzy TOPSIS method. J Polytech, 20(3): 629-637.

Efe B, Boran FE, Kurt M. 2015. Ergonomic product concept selection using intuitionistic fuzzy TOPSIS. Suleyman Demirel Univ J Eng Sci Design, 3(3): 433-440.

Ghorabaee MK, Amiri M, Zavadskas EK, Hooshmand R, Antucheviciene J. 2017. Fuzzy extension of the CODAS method for multi-criteria market segment evaluation. J Busin Econ Manag, 18(1): 1-19.

Gorecka D, Szałucka M. 2013. Country market selection in international expansion using multicriteria decision aiding methods. Mult CritDec Making, 8: 32-55.

Hwang CL, Yoon K. 1981. Methods for multiple attribute decision making. In: Multiple Attribute Decision Making. Springer, Heidelberg, Berlin, Germany, pp: 58-191.

Majumder M. 2017. Multi criteria decision making. Chapter 2, Springer, Heidelberg, Berlin, Germany, pp: 35-47.

Rouyendegh BD, Saputro TE. 2014. Supplier selection using integrated fuzzy TOPSIS and MCGP: a case study. Procedia-Soc Behav Sci, 116: 3957-3970.

Rouyendegh BD, Yıldızbaşı A, Arıkan ÜZ. 2018. Using intuitionistic fuzzy TOPSIS in site selection of wind power plants in Turkey. Adv Fuzzy Sys, 2018: 6703798. DOI: 10.1155/2018/6703798.

Rouyendegh BD, Yıldızbaşı A, Üstünyer P. 2020. Intuitionistic fuzzy TOPSIS method for green supplier selection problem. Soft Comp, 24(3): 2215-2228.

Rouyendegh BD. 2011. The DEA and intuitionistic fuzzy TOPSIS approach to departments' performances: a pilot study. J App Math, 2011: 712194. DOI: 10.1155/2011/712194.

Rouyendegh BD. 2015. Developing an integrated ANP and intuitionistic fuzzy TOPSIS model for supplier selection. J Test Eval, 43(3): 664-672.

Sözeyatarlar M, Şahin M, Yavuz E. 2021. Statistical relations measures. J Universal Math, 4(2): 283-295.

Szmidt E, Kacprzyk J. 2000. Distances between intuitionistic fuzzy sets. Fuzzy Sets Syst, 114: 505-518.

Tosun N. 2017. Target market selection in fresh fruit-vegetable sector using fuzzy VIKOR method. J Manag Mark Logis, 4(4): 465-471.

Tuğrul F, Çitil M. 2021. A new perspective on evaluation system in education with intuitionistic fuzzy logic and PROMETHEE algorithm. J Univ Math, 4(1): 13-24.

Wu Y, Zhang J, Yuan J, Geng S, Zhang H. 2016. Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: a case of China. Energy Convers Manag, 113: 66-81.

Xu ZS. 2007. Intuitionistic fuzzy aggregation operators. IEEE Transact Fuzzy Sys, 15: 1179-1187.

Yavuz E, Şahin M. 2022. Semiparametric regression models and applicability in agriculture. BSJ Agri, 5(2): 160-166.

Zadeh LA. 1965. Fuzzy Sets. Info Cont, 8: 1361-1375.