FUZZY OPTIMIZATION AND MODELLING 3(4) (2022) 1-8

E-ISNN: 2676-7007

Contents lists available at FOMJ

Fuzzy Optimization and Modelling

Journal homepage: http://fomj.qaemshahr.iau.ir/

Paper Type: Research Paper

Coping Uncertainty in the Supplier Selection Problem Using a Scenario-Based Approach and Distance Measure on Type-2 Intuitionistic Fuzzy Sets

Ali Sorourkhah

Department of Management, Ayandegan Institute of Higher Education, Tonekabon, Iran

ARTICLEINFO

Article history:
Received 26 February 2022
Revised 16 April 2022
Accepted 01 December 2021
Available online 15 May 2022

Keywords:
Uncertainty
Supplier Selection
Scenario
Intuitionistic Fuzzy Sets
Distance Measure

ABSTRACT

Supplier selection (SS) is a process in which companies identify, evaluate, and select suppliers. The MCDM methods are often used for supplier selection in supply chain management. An unlimited number of MCDM techniques, such as analytic hierarchy process (AHP), analytic network process (ANP), the technique of order preference distance to the ideal solution (TOPSIS), etc., have been deployed to solve the supplier selection problems. Though they can manage problem complexity, MCDM techniques cannot deal with problem uncertainty. Hence, they have been combined with the fuzzy set, intuitionistic fuzzy set, etc., to provide more accurate solutions to supplier selection problems. Nonetheless, the future uncertainty related to the environmental changes is ignored in the SS literature. Therefore, we use future scenarios as criteria to select the best supplier in this study. Moreover, we applied a distance measure to rank Type-2 Intuitionistic Fuzzy Set, which is a suitable approach to deal with the vagueness of verbal judgments. A numerical example explains the 5-step proposed approach.

1. Introduction

Supplier selection *SS* is a process in which companies identify, screen, evaluate, analyze, and select suppliers [32]. The supplier selection process mainly focuses on the following tasks: a; identifying the products to be procured, b; assimilating a list of potential suppliers, c; choosing the key factors (criteria), d; forming a decision-maker team, e; selecting the most apposite supplier, and f; continuous performance evaluation of the finally selected supplier [12]. The selection of suppliers and the allocation of orders are complicated decisions, and various techniques are available to solve these problems [18]. Finding eligible suppliers with which one can form long-lasting relationships is a strategic problem, so organizations need structured and well-developed methods to evaluate candidate suppliers [2]. The MCDM methods are often used for supplier selection in supply chain management [6].

An unlimited number of MCDM techniques, such as analytic hierarchy process (AHP) [10], analytic

* Correspondig author
E-mail address: ali.sorourkhah@gmail.com (Ali Sorourkhah)

DOI: 10.30495/fomj.2022.1953705.1066

network process (ANP) [21], the technique of order preference similarity to the ideal solution (TOPSIS) [44], the decision making trial and evaluation laboratory (DEMATEL) [23], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [43], etc. have been deployed for solving the supplier selection problems in diverse manufacturing industries. It is also noticed that some of those MCDM techniques have been combined with the fuzzy set [42], intuitionistic fuzzy set [14], etc., for providing more accurate solutions to supplier election problems dealing with qualitative information [12]. Fuzzy AHP [19], fuzzy ANP [9], fuzzy TOPSIS [26], TODIM with IT2FSs (interval type-two fuzzy sets), fuzzy VIKOR [29], rough DEMATEL and the fuzzy VIKOR (FVIKOR) [45], etc. Recently, multiple methods have been integrated with DEA to create a two-step supplier evaluation and selection process with improved performance [35], while data envelopment analysis (DEA) and fuzzy DEA are among the most widely used methods in supply chain management [1]. But, all the methods mentioned above have a significant weakness related to the probable futures [39]. Using the MCDM methods, the decision-maker chooses an option/alternative that is suitable in the present time, and in many situations, the one chosen according to past information.

Selecting suitable suppliers in supply chain management requires a comprehensive evaluation process, often under uncertain conditions [20]. Reviewing published literature in the field of supplier selection shows that almost all the researchers consider some criteria and evaluate alternatives based on them [3, 5, 24, 27, 32]. Many of these studies try to cope with uncertainty by using fuzzy logic and extensions. Uncertainty has two important aspects: verbal uncertainty and future uncertainty [40]. Dealing with verbal uncertainty, Fuzzy MCDM approaches cannot address the future uncertainty because they consider the past or present experiences in the decision process [8]. Due to increasing awareness of environmental issues and environmental regulatory mandates, both private and public sectors face tremendous pressure to consider environmental aspects in their supply chain practices [25]. Therefore, to reach a reasonable decision-making method, we must consider both verbal and future uncertainty in our model. In this order, we propose a scenario-based approach, which addresses the future uncertainty, combined intuitionistic fuzzy set, which addresses the verbal uncertainty. This work will use some scenarios as criteria to assess the alternatives concerning the possible futures.

The rest of the article will be as follows: Section 2 introduces some preliminaries related to Type-2 Intuitionistic Fuzzy Sets (T2IFS), Section 3 expresses the methodology. Section 4 contains a numerical example, and section 5 will be the conclusion.

2. Preliminaries

The available information in decision-making cannot continuously be assessed using a numerical scale in actual problems. This situation makes it impossible to present the information quantitatively. Pertaining the concept of Zadeh's research paper, Atanassov [7] created phenomenally the intuitionistic fuzzy set, where he meticulously elucidates the concept of membership and non-membership function [16]. Intuitionistic fuzzy set *IFS* is an effective tool that can aid in handling such uncertain and vague information. Compared to other set theories, the IFS theory gives successful results in decision-making processes [13].

This section presents a few basics and operational principles of IFNs.

Definition 1. Type-2 Fuzzy Set (T2FS) [30]. Let X be a fixed universe. A type-2 fuzzy set $A \subseteq X$, is characterized by a fuzzy membership function μ_A as $\mu_{A: X \to [0,1]^k}$.

With the value $\mu_A(x)$ is being called a fuzzy grade and being a fuzzy set in [0, 1] (or subset K of [0, 1]).

The structure of type-2 fuzzy sets is defined as: $A = \{((x, u_A), \mu_A(x, u_A)) / x \in X, u_A \in k_X \subseteq [0,1]\}$, in which $0 \le \mu_A(x, u_A) \le 1$. $\mu_A(x, u_A)$ is named as a secondary membership function (SMF), where u_A denotes the primary membership function (PMF).

Definition 2. Variance Margin Function (VMF) [36]. The variance margin function of T2FS is defined as the difference between PMF and SMF and is denoted by ξ_A.

For T2FS *A*, $\xi_A = |u_A(x) - \mu_A(x, u_A)|$ for all *x*.

Definition 3. Intuitionistic Fuzzy Set (IFS) [7]. An Intuitionistic Fuzzy Set $A = \{(x, \mu_A(x), \vartheta_A(x)) / x \in X\}$ on the universal set *X* is characterized by a truth membership function μ_A, $\mu_A : X \to [0,1]$ and a false membership function ϑ_A, $\vartheta_A : X \to [0,1]$.

The values $\mu_A(x)$ and $\vartheta_A(x)$ represents the degree of membership and the degree of non-membership for $x \in X$ and always satisfies the condition $0 \le \mu_A(x), +\vartheta_A(x) \le 1, \forall x \in X$.

Definition 4. Operators on IFS [17]. If *A* and *B* are to IFS of the set *X*, then:

$$A \cap B = \{(x, \min(\mu_A(x), \mu_B(x)), \max(\vartheta_A(x), \vartheta_B(x))) / x \in X\},$$

$$A \cup B = \{(x, \max(\mu_A(x), \mu_B(x)), \min(\vartheta_A(x), \vartheta_B(x))) / x \in X\}.$$

Definition 5. Type-2 Intuitionistic Fuzzy Set (T2IFS) [36]. A type-2 intuitionistic fuzzy set (*P*) in the universal set *X* is defined as:

$$P = \{(x, \mu_p(x), \vartheta_p(x)), g_x(\mu_p), h_x(\vartheta_p) / x \in X, \mu_p \in K_x^1, \vartheta_p \in K_x^2\},$$

where μ_p and ϑ_p are called as PMF and PNMF of $x \in X$ while $g_x(\mu_p)$ and $h_x(\vartheta_p)$ are the membership grades of the PMF and PNMF named as SMF and SNMF respectively where $\mu_p \in K_x^1 \subseteq [0,1]$ and $\vartheta_p \in K_x^2 \subseteq [0,1]$.

For computational convenience, this pair is denoted as $P = \{x(\mu_p, g_x(\mu_p), \vartheta_p, h_x(\vartheta_p))\}$, and named type-2 intuitionistic fuzzy number (T2IFN).

Definition 6. Variance Margin Function of T2IFS [36]. The variance margin function (VMF) of T2IFS is defined as the difference between PMF and PNMF, SMF, and SNMF. It is denoted by ξ and η, i.e., fore T2IFS *P*, variance margin functions are:

$$\xi_p(x) = |u_p(x) - g_x(u_p)|, \text{ and } \eta_p(x) = |\vartheta_p(x) - h_x(\vartheta_p)|, \text{ for all } x \in X.$$

Definition 7. Jaccard Distance [28]. Jaccard distance is a measure of dissimilarity between two sets, given by:

$$d_J = (P,Q) = 1 - J(P,Q),$$

where $J(P,Q) = \frac{|P \cap Q|}{|P \cup Q|}$, is the Jaccard similarity coefficient.

Definition 8. Jaccard Distance Measure between T2IFSs [4]. Let $P=\left\{\mu_p(x)g_x(\mu_p),\vartheta_p(x),h_x(\vartheta_p)\right\}$, and $Q=\left\{\mu_Q(x)g_x(\mu_Q),\vartheta_Q(x),h_x(\vartheta_Q)\right\}$ be two T2IFSs. The Jaccard distance between P and Q denoted by $d_{J(P,Q)}$ is defined as follows considering PMF, PNMF, SMF, SNMF, and VMF:

$$d_{J(P,Q)}=1-\frac{\left|\left\{\min(\mu_p(x),\mu_Q(x)),\min(g_x(\mu_p),g_x(\mu_Q)),\min(\xi_p(x),\xi_Q(x)),\max(\vartheta_p(x),\vartheta_Q(x)),\max(h_x(\vartheta_p),h_x(\vartheta_Q)),\max(\eta_p(x),\eta_Q(x))\right\}\right|}{\left|\left\{\max(\mu_p(x),\mu_Q(x)),\max(g_x(\mu_p),g_x(\mu_Q)),\max(\xi_p(x),\xi_Q(x)),\min(\vartheta_p(x),\vartheta_Q(x)),\min(h_x(\vartheta_p),h_x(\vartheta_Q)),\min(\eta_p(x),\eta_Q(x))\right\}\right|}.$$

Definition 9. Rating T2IFSs [4]. Let P be any T2IFS. The distance from the Ideal T2IFS $I=(1,1,0,0)$ is given by:

$$d_{J(P,I)}=1-\frac{\left|\left\{\min(\mu_p(x),1),\min(g_x(\mu_p),1),\min(\xi_p(x),\xi_I(x)),\max(\vartheta_p(x),0),\max(h_x(\vartheta_p),0),\max(\eta_p(x),\eta_I(x))\right\}\right|}{\left|\left\{\max(\mu_p(x),1),\max(g_x(\mu_p),1),\max(\xi_p(x),\xi_I(x)),\min(\vartheta_p(x),0),\min(h_x(\vartheta_p),0),\min(\eta_p(x),\eta_I(x))\right\}\right|}. \quad (1)$$

Hence the set having less distance will be of more prior to the set having more distance:

1. If $d_J(P,I) < d_J(Q,I)$, then P > Q.
2. If $d_J(P,I) > d_J(Q,I)$, then P < Q.
3. If $d_J(P,I) = d_J(Q,I)$, then P = Q.

3. Methodology

To select the best supplier, we propose the following steps:

Step 1: List all the suppliers as problem alternatives $A=[a_1, a_2,\ldots, a_n]$, and define future scenarios $S=[s_1, s_2,\ldots, s_m]$. These qualitative scenarios are routinely built considering two variables, or they can be the organization's strategies, etc. Furthermore, we can create them using the matrix approach introduced by [38].

Step 2: Form the decision matrix D according to membership and non-membership grade values shown in Table 1. A given element of this matrix a_{ij} shows how will the ith alternative work if the jth scenario happens.

Step 3: Calculate distance measures $d_J(d_{ij})$ using equation (1).

Step 4: Compute the overall assessment of alternatives OA (A_i) by using:

$$OA_i=\sum_{1}^{m}W.d_j,\ i=1,2,\ldots,n,\ j=1,2,\ldots,m. \quad (2)$$

Table 1. Membership and non-membership grade values [4]

Grades	Membership value	Grades	Non-membership value
Very poor	*0*	Very poor	*1*
Poor	*0.2*	Poor	*0.7*
Medium poor	*0.4*	Medium poor	*0.5*
Fair	*0.5*	Fair	*0.4*
Medium good	*0.7*	Medium good	*0.2*
Good	*0.9*	Good	*0.1*
Very good	*1*	Very good	*0*

Step 5: Choose the best alternative by ranking the overall assessment of each alternative. The set having less distance will be of more prior to the set having more distance.

4. Numerical Example

Sorourkhah et al. applied a Robustness Analysis approach to the strategy selection problem at Saipa Automotive Research and Innovation Center [37]. They concluded that four strategies, the concentric diversification, the retrenchment, the divestiture, and the market development, are the most robust ones. Consider this organization wants to select a supplier. As the firm strategy is not specifically determined, there is future uncertainty in the supplier selection problem. Therefore, we use the proposed approach to deal with uncertainty. In this order, we consider the organization strategies as future scenarios and evaluate the suppliers with respect to them. Suppose that there are three different suppliers (A_1, A_2, and A_3), four future scenarios (Sn_1, Sn_2, Sn_3, and Sn_4), and the decision matrix *D* showing the performance of any supplier (*i=1,2,3*) in a given scenario (*j=1,2,3,4*) as a_{ij} given in Table 2.

Table 2. The decision matrix

	Sn_1				Sn_2				Sn_3				Sn_4			
	PMF	SMF	PNMF	SNMF	PMF	SMF	PNMF	SNMF	PMF	SMF	PNMF	SNMF	PMF	SMF	PNMF	SNMF
A_1	0/9	1	0/1	0	0/5	0/4	0/5	0/5	0/7	0/5	0/2	0/4	0/4	0/4	0/5	0/5
A_2	0/5	0/4	0/4	0/5	0/4	0/4	0/5	0/5	0/5	0/5	0/4	0/4	0/7	0/5	0/2	0/4
A_3	0/7	0/7	0/2	0/2	0/5	0/5	0/4	0/4	0/4	0/5	0/5	0/4	0/2	0/2	0/7	0/7
I	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

Now, applying equation (1), we obtain the distance measure matrix as given in Table 3.

Table 3. The distance measure matrix

	Sn_1	Sn_2	Sn_3	Sn_4
A_1	0/046	0/325	0/314	0/36
A_2	0/357	0/36	0/36	0/307
A_3	0/272	0/36	0/36	0/272

If *W=(0.25,0.25,0.25,0.25)*, then, using equation (2), we have:

A_1= 0/261, A_2= 0/346, and A_3= 0/316, consequently;

$$A_1 > A_3 > A_2.$$

5. Conclusions

Organizations need to assess their suppliers for long-term partnerships [33]. Supplier selection is a strategic process in organizations and plays a critical role in their success [34]. The importance of supplier selection can be proved by the humungous extent of researches conducted based on the applications of various MCDM methods under both certain and uncertain manufacturing environments [12]. In recent years, attempts have been made to mitigate such issues by enhancing different practices. In these practices, a given number of suppliers is evaluated based on quantitative and qualitative parameters taken into account by the MCDM methods employed in studies [1].

Nowadays, a high degree of uncertainty is associated with these decision-making processes [25]. Generally, the decision- making problems under uncertainties are enormously studied under the fuzzy domain [15]. The SS literator shows that many researchers tried to cope with uncertainty by combining the FS with a given MCDM method. While environmental uncertainty is emphasized in the supplier selection literature [11], these methods do not address it [41]. Hence, we proposed a scenario-based approach to consider future uncertainty by examining the suppliers' performance in future scenarios. Moreover, to deal with verbal uncertainty, we used the IFS theory. In most situations, the attributes in decision- making problems can be recognized as IFSs [22, 31]. Compared with other MCDM and FMCDM methods, this simple method considers both aspects of uncertainty.

This work has some limitations needed to address by researchers in the future. According to a single attribute, the alternatives are examined in future scenarios; how much good do they work? Decision-makers need to investigate more attributes. Meanwhile, it seems that the other extensions of FS, like interval-valued sets, neutrosophic sets, etc., can produce better results. In our subsequent work, we want to apply neutrosophic sets.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Alavi, B., Tavana, M., & Mina, H. (2021). A dynamic decision support system for sustainable supplier selection in circular economy. *Sustainable Production and Consumption,* 27, 905-920.
2. Alikhani, R., Torabi, S.A., & Altay, N. (2019). Strategic supplier selection under sustainability and risk criteria. *International Journal of Production Economics,* 208, 69-82.
3. Alkahtani, M., & Kaid, H. (2018). Supplier selection in supply chain management: a review study. *Int. J. Bus. Perform. Supply Chain Model.,* 10, 107-130.
4. Anusha, V., & Sireesha, V. (2022). A new distance measure to rank type-2 intuitionistic fuzzy sets and its application to multi-criteria group decision making. *International Journal of Fuzzy System Applications (IJFSA),* 11(1), 1-17.
5. Aouadni, S., Aouadni, I., & Rebaï, A. (2019). A systematic review on supplier selection and order allocation problems. *Journal of Industrial Engineering International,* 15(1), 267-289.
6. Asadabadi, M.R. (2018). The stratified multi-criteria decision-making method. *Knowledge-Based Systems,* 162, 115-123.
7. Atanassov, K.T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems,* 20(1), 87-96.
8. Aydemir, S.B., & Kaya, T. (2021). TOPSIS method for multi-attribute group decision making based on neutrality aggregation operator under single valued neutrosophic environment: A case study of airline companies. In F. Smarandache and M. Abdel-Basset, *Neutrosophic Operational Research: Methods and Applications* (pp. 471-492). Cham: Springer International Publishing.
9. Bakeshlou, E.A., Khamseh, A.A., Asl, M.A.G., Sadeghi, J., & Abbaszadeh, M. (2017). Evaluating a green supplier selection problem using a hybrid MODM algorithm. *Journal of Intelligent Manufacturing*, 28(4), 913-927.
10. Bhat, S.A., Singh, A., & Qudaimi, A.A. (2021). A new pythagorean fuzzy analytic hierarchy process based on interval-valued pythagorean fuzzy numbers. *Fuzzy Optimization and Modeling Journal,* 2(4), 38-51.
11. Chai, J., & Ngai, E.W.T. (2020). Decision-making techniques in supplier selection: Recent accomplishments and what lies ahead. *Expert Systems with Applications,* 140, 112903.
12. Chakraborty, S., Chattopadhyay, R., & Chakraborty, S. (2020). An integrated D-MARCOS method for supplier selection in an iron and steel industry. *Decision Making: Applications in Management and Engineering,* 3(2), 49-69.
13. Çuvalcıoğlu, G., & Varol, S.U. (2021). Decision making progress for serving restaurants using intuitionistic fuzzy set theory via controlled sets *Journal of Universal Mathematics,* 4(2), 296-325.
14. Da Silva, I.A., Bedregal, B., Bedregal, B., & Santiago, R.H.N. (2021). An interval-valued atanassov's intuitionistic fuzzy multi-attribute group decision making method based on the best representation of the WA and OWA operators. *Journal of Fuzzy Extension and Applications,* 2(3), 239-261.
15. Das, A.K., & Granados, C. (2022). IFP-intuitionistic multi fuzzy N-soft set and its induced IFP-hesitant N-soft set in decision-making. *Journal of Ambient Intelligence and Humanized Computing*.
16. Das, S.K., & Edalatpanah, S.A. (2020). A new ranking function of triangular neutrosophic number and its application in integer programming. *International Journal of Neutrosophic Science,* 4(2), 82-92.
17. De, S.K., Biswas, R., & Roy, A.R. (2000). Some operations on intuitionistic fuzzy sets. *Fuzzy Sets and Systems,* 114(3), 477-

484.
18. Dutta, P., Jaikumar, B., & Arora, M.S. (2021). Applications of data envelopment analysis in supplier selection between 2000 and 2020: A literature review. *Annals of Operations Research*.
19. Ecer, F. (2022). Multi-criteria decision making for green supplier selection using interval type-2 fuzzy AHP: A case study of a home appliance manufacturer. *Operational Research,* 22(1), 199-233.
20. Fallahpour, A., Wong, K.Y., Rajoo, S., Fathollahi-Fard, A.M., Antucheviciene, J., & Nayeri, S. (2021). An integrated approach for a sustainable supplier selection based on Industry 4.0 concept. *Environmental Science and Pollution Research*.
21. Giannakis, M., Dubey, R., Vlachos, I., & Ju, Y. (2020). Supplier sustainability performance evaluation using the analytic network process. *Journal of Cleaner Production,* 247, 119439.
22. Gohain, B., Chutia, R., & Dutta, P. (2022). Distance measure on intuitionistic fuzzy sets and its application in decision-making, pattern recognition, and clustering problems. *International Journal of Intelligent Systems,* 37(3), 2458-2501.
23. Gören, H.G. (2018). A decision framework for sustainable supplier selection and order allocation with lost sales. *Journal of Cleaner Production,* 183, 1156-1169.
24. Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *Journal of Cleaner Production,* 98, 66-83.
25. Gupta, S., Soni, U., & Kumar, G. (2019). Green supplier selection using multi-criterion decision making under fuzzy environment: A case study in automotive industry. *Computers & Industrial Engineering,* 136, 663-680.
26. Kannan, D., Jabbour, A.B.L.d.S., & Jabbour, C.J.C. (2014). Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of Operational Research,* 233(2), 432-447.
27. Karsak, E.E., & Dursun, M. (2016). Taxonomy and review of non-deterministic analytical methods for supplier selection. *International Journal of Computer Integrated Manufacturing,* 29(3), 263-286.
28. Levandowsky, M., & Winter, D. (1971). Distance between sets. *Nature,* 234(5323), 34-35.
29. Liu, A., Xiao, Y., Lu, H., Tsai, S.-B., & Song, W. (2019). A fuzzy three-stage multi-attribute decision-making approach based on customer needs for sustainable supplier selection. *Journal of Cleaner Production,* 239, 118043.
30. Mendel, J.M. (2001). *Uncertain rule-based fuzzy logic system: Introduction and new directions*. (2). Springer, Cham.
31. Mohan, S., Kannusamy, A.P., & Samiappan, V. (2020). A new approach for ranking of intuitionistic fuzzy numbers. *Journal of Fuzzy Extension and Applications,* 1(1), 15-26.
32. Naqvi, M.A., & Amin, S.H. (2021). Supplier selection and order allocation: A literature review. *Journal of Data, Information and Management,* 3(2), 125-139.
33. Nezhadroshan, A.M., Fathollahi-Fard, A.M., & Hajiaghaei-Keshteli, M. (2021). A scenario-based possibilistic-stochastic programming approach to address resilient humanitarian logistics considering travel time and resilience levels of facilities. *International Journal of Systems Science: Operations & Logistics,* 8(4), 321-347.
34. Rezaei, A., Rahiminezhad Galankashi, M., Mansoorzadeh, S., & Mokhatab Rafiei, F. (2020). Supplier selection and order allocation with lean manufacturing criteria: An integrated MCDM and bi-objective modelling approach. *Engineering Management Journal,* 32(4), 253-271.
35. Santos Arteaga, F.J., Ebrahimnejad, A., & Zabihi, A. (2021). A new approach for solving intuitionistic fuzzy data envelopment analysis problems. *Fuzzy Optimization and Modeling Journal,* 2(2), 46-57.
36. Singh, S., & Garg, H. (2017). Distance measures between type-2 intuitionistic fuzzy sets and their application to multicriteria decision-making process. *Applied Intelligence,* 46(4), 788-799.
37. Sorourkhah, A., Azar, A., Babaie-Kafaki, S., & Shafiei Nik Abadi, M. (2017). Using Weighted-robustness analysis in strategy selection (Case study: Saipa Automotive Research and Innovation Center). *Industrial Management Journal,* 9(4), 665-690. (In Persian).
38. Sorourkhah, A., Babaie-Kafaki, S., Azar, A., & Shafiei-Nikabadi, M. (2018). Matrix approach to robustness analysis for strategy selection. *International Journal of Industrial Mathematics,* 10(3), 261-269.
39. Sorourkhah, A., Babaie-Kafaki, S., Azar, A., & Shafiei-Nikabadi, M. (2019). A fuzzy-weighted approach to the problem of selecting the right strategy using the robustness analysis (Case study: Iran Automotive Industry). *Fuzzy Information and Engineering,* 11(1), 39-53.
40. Sorourkhah, A., & Edalatpanah, S.A. (2021). Considering the criteria interdependency in the matrix approach to robustness analysis with applying fuzzy ANP. *Fuzzy Optimization and Modeling Journal,* 3(2), 22-33.
41. Sorourkhah, A., & Edalatpanah, S.A. (2022). Using a combination of matrix approach to robustness analysis (MARA) and fuzzy DEMATEL-based ANP (FDANP) to choose the best decision. *International Journal of Mathematical, Engineering and Management Sciences,* 7(1), 68-80.
42. Tuncalı Yaman, T., & Akkartal, G.R. (2022). How warehouse location decisions changed in medical sector after pandemic? A fuzzy comparative study. *Journal of Fuzzy Extension and Applications,* 3(1), 81-95.
43. You, X.-Y., You, J.-X., Liu, H.-C., & Zhen, L. (2015). Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information. *Expert Systems with Applications,* 42(4), 1906-1916.

44. Zhang, C. (2018). Research of the selection of green material suppliers based on entropy- TOPSIS model. *IOP Conference Series: Materials Science and Engineering*, 394, 052063.
45. Zhang, J., Yang, D., Li, Q., Lev, B., & Ma, Y. (2020). Research on sustainable supplier selection based on the rough DEMATEL and FVIKOR methods. *Sustainability*, 13, 88.

Sorourkhah, A. (2022). Coping Uncertainty in the Supplier Selection Problem Using a Scenario-Based Approach and Distance Measure on Type-2 Intuitionistic Fuzzy Sets. *Fuzzy Optimization and Modeling Journal*, 3(4), 1-8.

https://doi.org/ 10.30495/fomj. 2022.1953705.1066

Received: 26 February 2022 Revised: 16 April 2022 Accepted: 15 May 2022