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SUPPLIER SELECTION BY INTEGRATED IFDEMATEL-IFTOPSIS METHOD: A CASE STUDY OF AUTOMOTIVE SUPPLY INDUSTRY

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Abstract: *Selecting the best supplier emerges as a crucial subject for all sectors to achieve long term collaborations in supply chains. This study object to select the most suitable supplier for a company engage in activities in the automotive supply industry. For this purpose, a five-stage Intuitionistic Fuzzy Multi-Criteria Decision Making (IFMCDM) model is conducted. Firstly, decision criteria are defined by literature research and expert group opinions. Secondly, the importance weights of these criteria are obtained by IF Decision Making Trial and Evaluation Laboratory (IFDEMATEL). Followingly, the most suitable supplier is assessed by IF Technique for Order Preference by Similarity to Ideal Solution (IFTOPSIS). In the fourth stage, Sensitivity Analysis is utilized to analyze the effect of differentiation in criterion. Lastly, a comparative analysis is carried out. The results of the study has pointed that "Price" is the most important criterion in supplier selection and "Supplier 4" is the best alternative for this case. Main contribution of this study is to integrate IFDEMATEL-IFTOPSIS method for the first time in automotive supplier selection literature and propose a specific decision framework. In addition, proposed model is found robust and valid.*

Key words*: Automotive Supply Industry, IFDEMATEL, Supplier Selection, IFTOPSIS.*

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1. Introduction

Enterprises working in automotive supply industry, one of the sectors in which the competitiveness is at the highest level in today's developing world, need to pay special attention to supplier selection to continue their existence. Supplier selection is agreed to be a strategically crucial subject in terms of maintaining competitive position of the companies (Banaeian et al., 2018). Enterprises need to rely on their suppliers to increase the product quality, to lower their costs, and to improve their economic activities. Therefore, the right supplier selection has a great deal of importance for all businesses (Gao et al., 2020).

Especially during the Covid-19 pandemic that has been going on for the last 1 year, it has become even more prominent that businesses choose their suppliers correctly. It has been inevitable in all sectors to ensure economic sustainability, to maintain its place in the supply chain, and to ensure coordination with stakeholders. The way to achieve this is through long term collaborations and working with the right suppliers.

Automotive industry is among the leading sectors in the economies of the industrialized countries and requires and effective supply chain management. The reason why the automotive industry is in close relation with the other sectors of the economy is that this sector has a driving force in the business circle. The sector is composed of two subsectors, namely the main and supply industry. The sector in which the vehicles are produced is called the main industry. The supply industry is the sector that provides the production and supply of the spare parts, system, equipment etc. both for the enterprises in the field of vehicle production and for the part replacement requests of the existing vehicles according to the technical characteristics the vehicles have.

Automotive sector is accepted to be in the purchaser position for the main industry branches such as iron and steel, petroleum chemicals, and rubber. Also, it is in the supplier position for the vital sectors of the economic system such as tourism, infrastructure, transportation, agriculture etc., in the sense of the vehicle types they require. Besides, this sector provides basis for the development of the defense industry and the increase in the technological level. When the ranking of the automotive industry enterprises among the top ten enterprises in Turkey's 500 Biggest Industrial Enterprises List for 2019 (ISO 500, 2019) is analyzed; it is seen that the number of automotive firms ranked in the list is (i) 4 based on the production-based sales, (ii) 2 based on the gross value added, (iii) 5 based on the export value, and (iv) 3 based on the number of employees. Taking into account all of these rankings, automotive industry is regarded as a strategic industry branch within national economies and there is an increasing trend towards this sector day by day. In addition, the automotive export of Turkey in 2019 is 31.2 billion dollars and automotive supply industry export volume is 10,618 million dollars. Supplied products are categorized as safety glass, storage battery, engine, tube and outer tires, other components and parts. Other components and parts category including vehicle body and lighting parts has the biggest share in automotive supply industry (KPMG, 2020).

With respect to related literature, supplier selection can be considered as a multi-criteria decision making (MCDM) problem for which numerous quantitative and qualitative factors (cost, price, reliability, geographical location, relations with the sellers, etc.) need to be taken into account together. Supplier selection is an intuitive decision-making problem based on Decision Makers' (DMs') opinions including ambiguity and vagueness. To handle this problem, Atanassov (1986) presented Intuitionistic Fuzzy (IF) sets which is the generalized form of Fuzzy Sets (Boran et al., 2012) to address these weaknesses associated with sufficiently expressing DMs' judgments (Wei, 2018). In other words, the main benefit of an IF set over the crisp or a traditional fuzzy set is to separate the positive and negative factors for the membership and non-membership of an element in the set (Büyüközkan et al., 2017).

In this context, this study purposes to evaluate suppliers, producing sub-industry products for a Turkish enterprise that exports and imports vehicle body and lighting parts. With this aim, a five-step Intuitionistic Fuzzy Multi-Criteria Decision Making (IFMCDM) model is preferred to reach a solution in this study. In the first step, a group of experts working as the sector managers is created and literature review is conducted to determine the mostly used criteria for supplier selection. Subsequently, IF Decision Making Trial and Evaluation Laboratory (IFDEMATEL) is utilized to obtain the relations between these criteria and determine their weights. In the third step, the alternatives are identified based on the suggestions of the enterprise for choosing the best supplier in accordance with the aim of the study. Afterwards, IF Technique for Order Preference by Similarity to Ideal Solution (IFTOPSIS) method is implied for the evaluation of these suppliers. Then, One Dimensional Sensitivity Analysis is used to reveal the impact of the changings in the criteria weights on the ranking of the alternatives. Finally a comparative analysis is conducted to validate the results.

IFDEMATEL is a powerful MCDM technique (Pilko et al., 2017), which can be effectively employed in subjective DM problems. Therefore, this method is useful in determining the importance of criteria. When there are several conflicting criteria, IFTOPSIS is utilized to rank the alternatives based on their closeness to the ideal solution and selecting a prominent one. We argue that the integrated model based on IF theory is more robust in defining DMs' judgments than the crisp or the fuzzy arithmetic based approaches.

The contributions of this paper can be summarized as follows. First, it proposes a framework for choosing and evaluating suppliers that operate in automotive supply chain. Second, it analyzes a real case of an enterprise in automotive industry and this is the first study to integrate IFDEMATEL-IFTOPSIS-One Dimensional Sensitivity Analysis into the related field. Third, this study provides and effective decision model that contributes to the cooperation of manufacturers and suppliers in their management processes. This paper is organized in five parts. Part 2 expresses the literature review. Part 3 gives brief information about IFDEMATEL, IFTOPSIS and One-Dimensional Sensitivity Analysis methods whereas Part 4 discusses supplier selection of a Turkish enterprise in automotive spare parts sector within the supply industry. At the end, Part 5 displays results and conclusions respectively.

2. Literature review

Literature review of this research consists of two subsections as "studies on supplier selection criteria" and "studies on automotive supplier selection with MCDM methods".

2.1. Studies on supplier selection criteria

Supplier selection can be expressed as a MCDM problem that can be realized with more than one criterion. There are various criteria that have both qualitative and quantitative characteristics within supplier selection problems. The most commonly utilized criteria which are used in this study according to relevant literature are summarized in Table 1.

Table 1. Review of Supplier Selection Criteria

Criteria	Notation	Author(s)
Geographical Position	C_1	Aksoy and Öztürk (2011), Golmohammadi (2011), Rajesh and Malliga (2013); Dargi et al. (2014), Tosun and Akyüz (2015), Vahdani et al. (2015), Khan et al. (2016), Prakash and Barua (2016), Adalı and Işık (2017), Jiang et al. (2018)
Providing Demo Products	C_2	Eş and Kocadağ (2020)
Price	C_3	Xia and Wu (2007), Kasirian and Yusuff (2010), Kuo et al. (2010), Mafakheri et al. (2011), Amindoust et al. (2012), Huang and Hu (2013), Junior et al. (2014), Rezaei et al. (2014), Zhong and Yao (2017), Arabsheybani et al. (2018), Jain et al. (2018), Jiang et al. (2018), Feng and Gong (2020), Karabıçak et al. (2020), Öztürk and Paksoy (2020)
Guaranty	C_4	Kasirian and Yusuff (2010), Keramati et al. (2014), Khan et al. (2016), Pitchipoo et al. (2015), Jain et al. (2018)
Reliability	C_5	Huang and Keskar (2007), Kasirian and Yusuff (2010), Chang et al. (2011), Lin et al. (2011), Adalı and Işık (2017), Kumar et al. (2018), Bai et al. (2019)
Velocity	C_6	Chang et al. (2011), Öztürk and Paksoy (2020)
Service	C_7	Xia and Wu (2007), Kasirian and Yusuff (2010), Chang et al. (2011), Huang and Hu (2013), Fei et al., (2019), Gupta et al. (2019)
Mold	C_8	Karabıçak et al. (2020)
Quality	C_9	Sarkis and Talluri (2002), Xia and Wu (2007), Dağdeviren and Eraslan (2008), Lee et al. (2009), Kasirian and Yusuff (2010), Wu and Weng (2010), Shemshadi et al. (2011), Amindoust et al. (2012), Magdalena (2012), Huang and Hu (2013), Ghadimi and Heavey (2014), Hruska et al. (2014), Rezaei et al. (2014), Adalı and Işık (2017), Wan et al. (2017), Jain et al. (2018), Fei et al. (2019), Gupta et al. (2019), Hadian et al. (2020), Karabıçak et al. (2020)
Risk Factors	C_{10}	Chan and Kumar (2007), Hadian et al. (2020)
Design	C_{11}	Chan (2003), Jiang et al. (2018)
Delivery	C_{12}	Narasimhan et al. (2001), Jadidi et al. (2009), Fazlollahtabar et al. (2011), Shahroudi and Rouydel (2012), Junior et al. (2014), Arabsheybani et al. (2018), Jain et al. (2018), Vasiljević et al. (2018)
Product Return Flexibility	C_{13}	Sarkis and Talluri (2002), Awasthi et al. (2018), Eş and Kocadağ (2020), Hadian et al. (2020)
Product Performance	C_{14}	Kahraman et al. (2003), Jadidi et al. (2009), Liao et al. (2010), Fazlollahtabar et al. (2011), Vahdani et al.

		(2015), Kumar et al. (2018), Vasiljević et al. (2018), Hadian et al., 2020
Innovation	C_{15}	Chan and Chan (2004), Fazlollahtabar et al. (2011), Hashemi et al. (2018), Vasiljević et al. (2018), Hadian et al. (2020)

In line with the literature review conducted in this paper, Table 2 shows that *Price*, *Reliability*, *Service*, *Quality*, and *Delivery* are the main evaluation criteria for selecting the suppliers.

2.2. Studies on automotive supplier selection with MCDM methods

MCDM methods that are often used to solve problems with multiple conflicting criteria, are utilized to handle supplier selection problems. In current literature, there are various studies that employ MCDM methods in supplier selection. Some studies conducted in automotive industry are indicated in Table 2.

Table 2. Review of Automotive Supplier Selection Studies

Study	Method	Sensitivity analysis	Illustrative or Case Study
Kokangul and Susuz (2009)	AHP-Mathematical Programming	-	Case study
Kasirian and Yusuff (2010)	AHP and ANP	-	Case study
Zeydan et al. (2011)	Fuzzy AHP-Fuzzy TOPSIS	-	Case study
Huang and Hu (2013)	Fuzzy ANP-Goal Programming	-	Case study
Dargi et al. (2014)	Fuzzy ANP	-	Case study
Keramati et al. (2014)	QFD (Quality Function Deployment)-ANP	+	Case study
Ayağ and Samanlıoğlu (2016)	Fuzzy ANP	-	Case study
Dweiri et al. (2016)	AHP	+	Case study
Galankashi et al. (2016)	Balanced scorecard-Fuzzy AHP	-	Illustrative
Khan et al. (2016)	AHP-QFD	-	Case study
Zimmer et al. (2017)	Fuzzy AHP	+	Case study
Jain et al. (2018)	Fuzzy AHP and TOPSIS	+	Case study
Jiang et al. (2018)	Grey DEMATEL based ANP	+	Case study
Vasiljević et al. (2018)	Rough AHP, Fuzzy AHP	-	Case study
Gupta et al. (2019)	Fuzzy AHP with MABAC, WASPAS, TOPSIS	+	Case study
Suraraksa and Shin (2019)	AHP	-	Illustrative
Hadian et al. (2020)	VIKOR-AHP-BOCR	-	Case study

Manupati et al. (2021)	Fuzzy AHP-Fuzzy TOPSIS-Fuzzy VIKOR	-	Case study

According to the current literature, it is noticed that MCDM methods are oftenly implemented in automotive industry. Some of these studies prefer using only one of MCDM methods, whereas some studies prefer applying integrated and fuzzy MCDM methods. However supplier selection subject have been researched in many papers recently with MCDM methods (Qin et al., 2017; Banaeian et al., 2018; Stević et al., 2019; Biswas and Das, 2020; Stević et al., 2020; Fazlollahtabar & Kazemitash, 2021), few of them have been aimed to select supplier in automotive industries and use IFMCDM methods. To the best of authors' knowledge, there is no paper that employs Integrated IFDEMATEL-IFTOPSIS-One Dimensional Sensitivity Analysis approach to solve a case of automotive supply industry. Therefore, this study makes contribution by considering a real business case under IF environment and proposing a new framework for automotive companies to decide their suppliers upon particular criteria.

3. Methodology

In some complex decision processes such as identifying cause and effect groups that involves fuzziness in DMs' opinions or insufficient knowledge about a problem, the Fuzzy Sets Theory (Zadeh, 1965) can be utilized in decision-making processes. On the other hand, the literature suggest that fuzzy sets can be insufficient in certain cases when they are used for processing human beings' subjective judgments and the associated ambiguity such as the difficulty to formulate the degree of one alternative superior to the others (Behret, 2014). To cope with such issues, Intuitionistic Fuzzy Sets (IFS) can be employed in a practical way (Büyüközkan et al., 2017). IFS is frequently used to represent DMs' opinions and handle the inherent ambiguity in human judgments more effectively. This study applies an IFMCDM framework including IFDEMATEL-IFTOPSIS, and One-Dimensional Sensitivity Analysis for the aim of supplier selection in the automotive supply industry. This section presents these methods respectively.

3.1. IFDEMATEL method

DEMATEL method, developed by Geneva Research Center of Battelle Memorial Institute (Chang & Cheng, 2011), is an effective method that provides analysis in terms of magnitude and types of the direct and indirect relations between factors (Han & Deng, 2018). DEMATEL can provide an ideal way to better understand the structural relations through analysis of total relations among components and solve congruent system problems (Li et al., 2014).

Supplier selection is a complicated system for multiple factors affecting one another. Therefore, IFDEMATEL method can be used to sort the factors influencing supplier selection and enhance the problem. The use of IFDEMATEL method in automotive supply industry will provide the evaluation of supplier selection and define causality between the criteria taken into account during the selection process.

The steps of IFDEMATEL method are described as below (Keshavarzfard & Makui, 2015; Büyüközkan et al., 2017):

Step 1: Creating Initial Direct Relation IF Matrix ($\check{X}_z$): The evaluation scale (Table 3) is used to generate a direct relation matrix for the pairwise comparisons to be realized by the experts.

Table 3. Pairwise Comparison Scale of IFDEMATEL

Numerical Values	Definitions of Linguistic Terms	μ (membership)	V (non membership)	π (hesitancy)
4	Very high effect (VH)	0.90	0.10	0.00
3	High effect (H)	0.75	0.20	0.05
2	Medium effect (M)	0.50	0.45	0.05
1	Low effect (L)	0.35	0.60	0.05
0	No effect (N)	0.00	1.00	0.00

As a result of obtained data with pairwise comparisons, direct relation IF Matrix ($(\breve{X}_z)$) is created.

Step 2: Normalized Direct Relation IF Matrix $(\breve{N}_z)$: Upon the creation of direct relations matrix $(\breve{X}_z)$, Equations (1) and (2) are utilized to obtain Normalized direct relation matrix $(\breve{N}_z)$.

$$\breve{N}_z = \text{k x } \breve{X}_z \quad (1)$$

$$k = \text{Min }\left(\frac{1}{\boldsymbol{max}\sum_{j=1}^{n}\left|\breve{X}_{zij}\right|}, \frac{1}{\boldsymbol{max}\sum_{i=1}^{n}\left|z_{\breve{X}_{zj}}\right|}\right) \qquad i \text{ and } j = 1,2,3,\ldots,n \quad (2)$$

Step 3: Calculating Total Relation IF Matrix $(\breve{T}_z)$: It is obtained by using unit matrix (I) via equation (3):

$$\breve{T}_z = \breve{N}_z + \breve{N}_z^2 + \breve{N}_z^3 + \breve{N}_z^4 + \ldots + \breve{N}_z^m = \breve{N}_z \,.\, (I - \breve{N}_z)^{-1} \quad (m \to \infty) \quad (3)$$

Step 4: Calculating Causal Relations between Factors: $(\breve{T}_z)$ matrix is used to calculate the values of *D* and *R*. *D* values obtained from sum of rows, and *R* values obtained from sum of columns of $(\breve{T}_z)$ matrix are calculated with equations (4) and (5), respectively.

$$D_i = \sum_{j=1}^{n} T_{i,j} \qquad (i=1,2,\ldots,n) \quad (4)$$

$$R_j = \sum_{i=1}^{n} T_{i,j} \qquad (i=1,2,\ldots,n) \quad (5)$$

Relations between criteria are defined according to the values of *D-R*, whereas the significance and total effects of the criteria are determined regarding to the values of *D+R*. The fact that the factor has a higher *D+R* value means that it has more interaction with other factors. Also, the criteria with positive values of *D-R* are classified in the "sender (cause) group" whereas criteria with negative values of *D-R* are in "receiver (effect) group". Positive valued criteria of *D-R* affect other criteria, in contrast negative valued criteria of *D-R* are affected by other criteria. Defuzzied membership, non-membership and hesitancy values are obtained by using the transformation formula given in Equation (6).

$$\bar{r}_{ij} = \mu_{ij} - v_{ij} + (2\alpha - 1)\pi_{ij} \quad (6)$$

Step 5: Determining Criteria Weights (W): Criteria weights are calculated with equations (7) and (8).

$$W_i = \sqrt{(D_i + R_j)^2 + (D_i - R_j)^2} \quad (7)$$

$$W_i = \frac{w_i}{\sum_i^n w_i} \quad (8)$$

3.2. IFTOPSIS method

IFTOPSIS method is applied to rank the available alternatives of this study. The steps of the method explained as follows (Boran et al., 2009):

Step 1: Constructing an IFTOPSIS Decision Matrix: It is calculated by integrating the assessments of the DMs for alternatives. In the assessment step, all opinions of the DMs are aggregated as group data in order not to lose information. The linguistic terms presented in Table 4 is utilized to reflect the DMs' preferences for each alternative.

Table 4. Linguistic Terms for Assessing Alternatives

Linguistic Term		IF Values		
		μ	υ	π
Very Poor	1	0.05	0.90	0.05
Poor	2	0.25	0.70	0.05
Fair	3	0.50	0.45	0.05
Good	4	0.75	0.20	0.05
Very Good	5	0.90	0.05	0.05

$$r_{ij} = [1 - \prod_{k=1}^{l}(1 - \mu_{ij}^{(k)})^{\lambda k}, \prod_{k=1}^{l}. \vartheta_{ij}^{(k)})^{\lambda k}, \prod_{k=1}^{l}(1 - \mu_{ij}^{(k)})^{\lambda k} - \prod_{k=1}^{l}. \vartheta_{ij}^{(k)})^{\lambda k}] \quad (9)$$

R_{ij}= (μij, ϑij, πij) , (i=1,2,…m; j=1,2,…n), where R is the member of the integrated decision matrix.

$$R = \begin{bmatrix} \mu_{11}, \vartheta_{11}, \pi_{11} & \cdots & \mu_{1n}, \vartheta_{1n}, \pi_{1n} \\ \vdots & \ddots & \vdots \\ \mu_{m1}, \vartheta_{m1}, \pi_{m} & \cdots & \mu_{11}, \vartheta_{11}, \pi_{mn} \end{bmatrix} = \begin{bmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{bmatrix} \quad (10)$$

Step 2: Calculating Normalized and Weighted IFTOPSIS Decision Matrix: These matrices are calculated by using Eq. (11-12), respectively.

$$\acute{R} = (\mu'_{ij}, \vartheta'_{ij}) = \{(x, \mu_{ij}. \mu_j, \vartheta_{ij} + \vartheta_j - \vartheta_{ij} . \vartheta_j), x \in X\} \ \Pi_{ij=} 1 - \vartheta_{ij} - \vartheta_j - \mu_{ij}.. \mu_j + \vartheta_{ij} . \vartheta_j \quad (11)$$

$$\acute{R} = \begin{bmatrix} \mu'_{11}, \vartheta'_{11}, \pi'_{11} & \cdots & \mu'_{1n}, \vartheta'_{1n}, \pi'_{1n} \\ \vdots & \ddots & \vdots \\ \mu'_{m1}, \vartheta'_{m1}, \pi'_{m1} & \cdots & \mu'_{11}, \vartheta'_{11}, \pi'_{mn} \end{bmatrix} = \begin{bmatrix} r'_{11} & \cdots & r'_{1n} \\ \vdots & \ddots & \vdots \\ r'_{m1} & \cdots & r'_{mn} \end{bmatrix} \quad (12)$$

Step 3: Specifying the positive and negative ideal solutions: A^* refers positive ideal solution while A^- refers negative ideal solution as calculated by Eq. (13-20), respectively.

$$A^* = (r_1'^*, r_2'^*, \ldots r_n'^*), r_j'^* = (\mu_j'^*, \vartheta_j'^*, \pi_j'^*), j = 1,2, \ldots n \quad (13)$$

$$A^- = (r_1'^-, r_2'^-, \ldots r_n'^-), r_j'^- = (\mu_j'^-, \vartheta_j'^-, \pi_j'^-), j = 1,2, \ldots n \quad (14)$$

$$\mu_j'^* = \{(\max\{\mu'_{ij}\}, j \in J_1), (\min\{\mu'_{ij}\}, j \in J_2)\} \quad (15)$$

$\vartheta_j'^{*}$ = {(min { ϑ_{ij}'}, j ∈ J_1), (max { ϑ_{ij}'}, j ∈ J_2)} (16)

$\pi_j'^{*}$ = {(1- max { μ_{ij}'} – min { ϑ_{ij}'}, j ∈ J_1 (17)

= {(1- min { μ_{ij}'} – max { ϑ_{ij}'}, j ∈ J_2)

$\mu_j'^{-}$ = {(min { μ_{ij}'}, j ∈ J_1), (max { μ_{ij}'}, j ∈ J_2)} (18)

$\vartheta_j'^{-}$ = {(max { ϑ_{ij}'}, j ∈ J_1), (min { ϑ_{ij}'}, j ∈ J_2)} (19)

$\pi_j'^{-}$ = {(1- min { μ_{ij}'} – max { ϑ_{ij}'}, j ∈ J_1)} (20)

= {(1- max { μ_{ij}'} – min { ϑ_{ij}'}, j ∈ J_2)}

Step 4: Calculation of positive (S_i^*) and negative (S_i^-) difference measurements*:* Two methods such as Hamming and Euclidean can be used to obtain this measurement. In this application, Hamming method is favored as calculated follows.

$$S_i^* = \frac{1}{2}\sum_{j=1}^{n}[\, |\mu_{ij}' - \mu_j'^{*}| + |\vartheta_{ij}' - \vartheta_j'^{*}| + |\pi_{ij}'^{-} - \pi_j'^{*}|\,], i = 1,2, \ldots m \quad (21)$$

$$S_i^- = \frac{1}{2}\sum_{j=1}^{n}[\, |\mu_{ij}' - \mu_j'^{-}| + |\vartheta_{ij}' - \vartheta_j'^{-}| + |\pi_{ij}' - \pi_j'^{-}|\,], i = 1,2, \ldots m \quad (22)$$

*Step 5***:** Determination of proximity coefficient for each alternative*:* It is obtained via using the Eq. (23) below.

$$C_i^* = ((S_i^-) / (S_i^* + S_i^-)), 0 \le C_i^* \le 1, I=1,2,\ldots,m \quad (23)$$

Step 6: Ranking the alternatives*:* Alternatives are ordered according to the seniority of the proximity coefficients.

3.3. One dimensional sensitivity analysis

Sensitivity analysis is employed to examine the reliability and stability in the event of vagueness emerged by MCDM problems (Karande et al., 2016). The criteria weights in MCDM problems are usually acquired with subjective assessments of the decision makers through different techniques. Hence, conducting sensitivity analysis is a necessary stage of the decision making procedure for the certain interpretations of the obtained data. It provides *(i)* validation of the results acquired from the MCDM methods, *(ii)* detection of the most important factors creating differences in the ordering of the alternatives, and *(iii)* ranking regarding to the variations in the criteria weights (Butler et al., 1997).

This study applies one dimensional sensitivity analysis to acquire the impacts of the most important criteria on the ranking of the alternatives in case of weight differentiation. In this study, the weight of the most significant criterion is explained within an optimal interval and all the other criteria weights are identified equally so that the weight contribution limit could meet $\sum_{I=1}^{n} w_j=1$. w_j is the most important criterion and it can be decreased to 0 and enhanced to w_j'. The w_j' value that reflecting the highest criterion weights (w_{jmax}) and lowest criterion weights (w_{jmin}) is calculated with equation (16) (Karande et al., 2016).

$$w_j' = [(w_{jmax} + (n-1) \times (w_{jmin})] \quad (16)$$

4. Application

With the impact of increasing competition in supply chains, choosing the proper supplier has become more crucial for the enterprises. Automotive sector is one of the key competition instrument for the countries in terms of in this globalized world.

This study evaluates spare parts suppliers of automobiles, which are constantly active in business life. In the application part, a solution to supplier selection problem of an enterprise that sells automotive body and lighting parts is searched by IFDEMATEL-IFTOPSIS approach. This enterprise has a customer portfolio in 81 provinces of Turkey in the automotive supply industry with a 20-year experience. It is one of the biggest five enterprises in the sector with regard to market share. Accordingly, the flow chart of the application is displayed in Figure 1.

4.1. Establishing the expert group

Expert group used in this study consists of sector managers. Data about the expert group of 5 sector managers participated in supplier selection procedure is presented in Table 5.

Table 5. Information of the Expert Group

Expert Group	Title	Sector Experience (Year)	Working Company
Expert 1	General Manager	12	2
Expert 2	R&D Manager	8	3
Expert 3	Finance Manager	10	4
Expert 4	Marketing Manager	7	2
Expert 5	Purchasing Manager	7	1

4.2. Identifying the criteria

Firstly, a criteria pool is created following the literature research on supplier selection to determine the criteria utilized in this study. Then, upon the interviews conducted with the expert group, the suggested criteria are taken into consideration (Table 1).

4.3. Weighting the criteria

The weights of the criteria for supplier selection defined in the previous stage are identified by conducting IFDEMATEL method, which is also used for the analysis of the interactions between the criteria. The significance weights of the criteria are attained by evaluating the data obtained in accordance with the face-to-face interviews of expert group. According to the application steps of IFDEMATEL, decision matrix is created using Table 3. Direct Relation Matrix is displayed in Table 6 whereas interaction values between criteria and criteria weights are shown in Table 7.

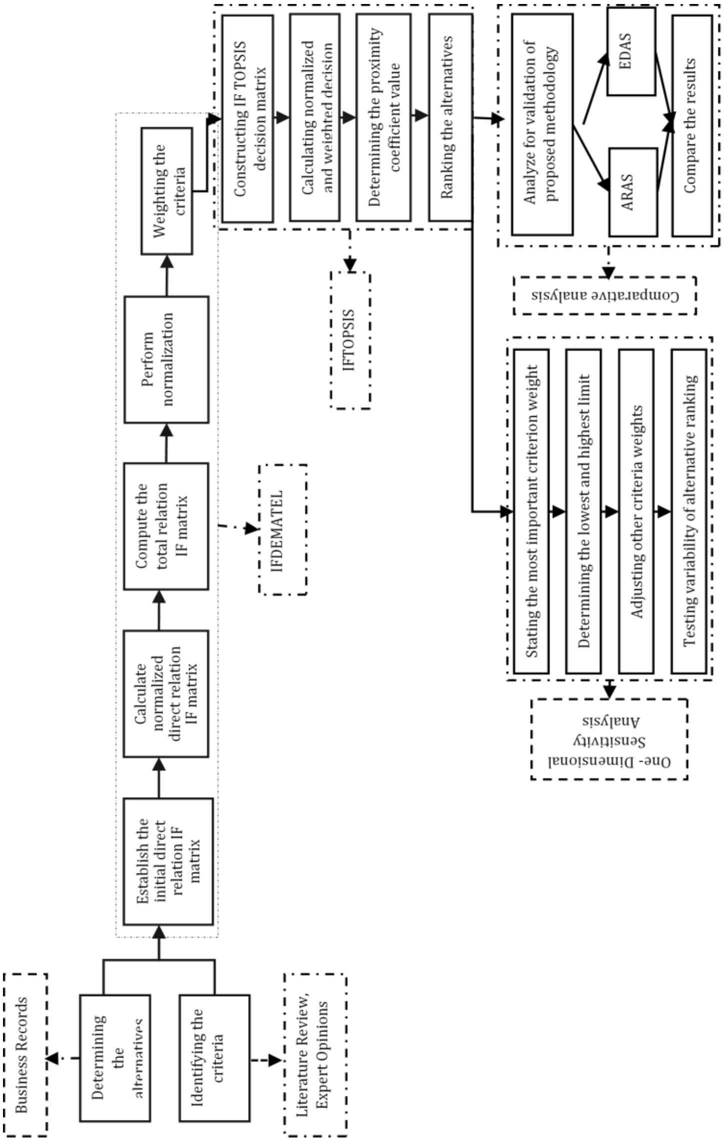


Figure 1. Application Flow Chart

Table 6. IFDEMATEL Direct Relation Matrix

Criteria	C_1			C_2			C_3			C_4			C_5		
C_1	0.90	0.10	0.00	0.50	0.45	0.05	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_2	0.84	0.12	0.04	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_3	0.14	0.81	0.05	0.07	0.88	0.05	0.90	0.10	0.00	0.35	0.60	0.05	0.50	0.45	0.05
C_4	0.55	0.40	0.05	0.41	0.54	0.05	0.90	0.10	0.00	0.90	0.10	0.00	0.84	0.16	0.00
C_5	0.50	0.45	0.05	0.38	0.57	0.05	0.78	0.22	0.00	0.81	0.19	0.00	0.90	0.10	0.00
C_6	0.47	0.48	0.05	0.38	0.57	0.05	0.90	0.10	0.00	0.78	0.22	0.00	0.87	0.13	0.00
C_7	0.70	0.25	0.05	0.65	0.30	0.05	0.90	0.10	0.00	0.87	0.13	0.00	0.81	0.19	0.00
C_8	0.50	0.45	0.05	0.47	0.48	0.05	0.90	0.10	0.00	0.78	0.22	0.00	0.90	0.10	0.00
C_9	0.28	0.67	0.05	0.21	0.74	0.05	0.90	0.10	0.00	0.44	0.51	0.05	0.55	0.40	0.05
C_{10}	0.65	0.30	0.05	0.44	0.51	0.05	0.65	0.30	0.05	0.60	0.35	0.05	0.90	0.10	0.00
C_{11}	0.84	0.16	0.00	0.65	0.30	0.05	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_{12}	0.41	0.54	0.05	0.41	0.54	0.05	0.90	0.10	0.00	0.60	0.35	0.00	0.90	0.10	0.00
C_{13}	0.78	0.22	0.00	0.70	0.25	0.05	0.90	0.10	0.00	0.78	0.22	0.00	0.90	0.10	0.00
C_{14}	0.41	0.54	0.05	0.50	0.45	0.05	0.90	0.10	0.00	0.81	0.19	0.00	0.84	0.16	0.00
C_{15}	0.60	0.35	0.05	0.60	0.35	0.05	0.90	0.10	0.00	0.75	0.20	0.05	0.84	0.16	0.00
Criteria	C_6			C_7			C_8			C_9			C_{10}		
C_1	0.90	0.10	0.00	0.84	0.12	0.04	0.81	0.16	0.03	0.90	0.10	0.00	0.90	0.10	0.00
C_2	0.90	0.10	0.00	0.90	0.10	0.00	0.84	0.12	0.04	0.90	0.10	0.00	0.90	0.10	0.00
C_3	0.35	0.60	0.05	0.35	0.60	0.05	0.44	0.51	0.05	0.70	0.25	0.05	0.65	0.30	0.05
C_4	0.78	0.22	0.00	0.70	0.25	0.05	0.78	0.22	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_5	0.50	0.45	0.05	0.44	0.51	0.05	0.60	0.35	0.05	0.84	0.16	0.00	0.75	0.20	0.05
C_6	0.90	0.10	0.00	0.65	0.30	0.05	0.84	0.16	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_7	0.90	0.10	0.00	0.90	0.10	0.00	0.84	0.16	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_8	0.65	0.30	0.05	0.65	0.30	0.05	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_9	0.44	0.51	0.05	0.14	0.81	0.05	0.47	0.48	0.05	0.90	0.10	0.00	0.35	0.60	0.05
C_{10}	0.65	0.30	0.05	0.60	0.35	0.05	0.75	0.20	0.05	0.78	0.22	0.00	0.90	0.10	0.00
C_{11}	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00	0.90	0.10	0.00
C_{12}	0.70	0.25	0.05	0.50	0.45	0.05	0.60	0.35	0.05	0.78	0.22	0.00	0.78	0.22	0.00
C_{13}	0.81	0.19	0.00	0.78	0.22	0.00	0.78	0.22	0.00	0.78	0.22	0.00	0.84	0.16	0.00
C_{14}	0.65	0.30	0.05	0.55	0.40	0.05	0.70	0.25	0.05	0.78	0.22	0.00	0.84	0.16	0.00
C_{15}	0.75	0.20	0.05	0.78	0.22	0.00	0.84	0.16	0.00	0.90	0.10	0.00	0.90	0.10	0.00
Criteria	C_{11}			C_{12}			C_{13}			C_{14}			C_{15}		
C_1	0.78	0.18	0.04	0.81	0.16	0.03	0.81	0.16	0.03	0.90	0.10	0.00	0.81	0.16	0.03
C_2	0.90	0.10	0.00	0.78	0.18	0.04	0.78	0.18	0.04	0.78	0.18	0.04	0.90	0.10	0.00
C_3	0.14	0.81	0.05	0.65	0.30	0.05	0.44	0.51	0.05	0.55	0.40	0.05	0.65	0.30	0.05
C_4	0.44	0.51	0.05	0.90	0.10	0.00	0.65	0.30	0.05	0.70	0.25	0.05	0.70	0.25	0.05
C_5	0.47	0.48	0.05	0.75	0.20	0.05	0.50	0.45	0.05	0.75	0.20	0.05	0.50	0.45	0.05
C_6	0.65	0.30	0.05	0.90	0.10	0.00	0.78	0.22	0.00	0.84	0.16	0.00	0.75	0.20	0.05
C_7	0.65	0.30	0.05	0.90	0.10	0.00	0.78	0.22	0.00	0.90	0.10	0.00	0.81	0.19	0.00
C_8	0.41	0.54	0.05	0.90	0.10	0.00	0.55	0.40	0.05	0.78	0.22	0.00	0.65	0.30	0.05
C_9	0.28	0.67	0.05	0.65	0.30	0.05	0.35	0.60	0.05	0.50	0.45	0.05	0.47	0.48	0.05
C_{10}	0.44	0.51	0.05	0.65	0.30	0.05	0.50	0.45	0.05	0.60	0.35	0.05	0.65	0.30	0.05
C_{11}	0.90	0.10	0.00	0.90	0.10	0.00	0.84	0.16	0.00	0.84	0.16	0.00	0.84	0.16	0.00
C_{12}	0.28	0.67	0.05	0.90	0.10	0.00	0.41	0.54	0.05	0.55	0.40	0.05	0.55	0.40	0.05
C_{13}	0.70	0.25	0.05	0.90	0.10	0.00	0.90	0.10	0.00	0.81	0.19	0.00	0.75	0.20	0.05
C_{14}	0.65	0.30	0.05	0.90	0.10	0.00	0.50	0.45	0.05	0.90	0.10	0.00	0.78	0.22	0.00
C_{15}	0.84	0.16	0.00	0.90	0.10	0.00	0.50	0.45	0.05	0.87	0.13	0.00	0.90	0.10	0.00

Table 7. Interaction Values Between Criteria and Criteria Weights

Criteria	D+R	D-R	Group	Weights
C_1	1.3005	-0.8638	Receiver	0.0732
C_2	1.5456	-1.2483	Receiver	0.0931
C_3	1.5331	1.372	Sender	0.0965
C_4	1.0581	0.0033	Sender	0.0496
C_5	1.143	0.6956	Sender	0.0627
C_6	1.0237	-0.1667	Receiver	0.0486
C_7	1.0709	-0.5629	Receiver	0.0567
C_8	1.1143	-0.0228	Receiver	0.0522
C_9	1.6249	1.2369	Sender	0.0957
C_{10}	1.1539	0.6403	Sender	0.0618
C_{11}	1.1966	-0.9701	Receiver	0.0722
C_{12}	1.1959	0.6468	Sender	0.0637
C_{13}	1.3408	-0.5723	Receiver	0.0683
C_{14}	1.154	0.1043	Sender	0.0543
C_{15}	1.0379	-0.2923	Receiver	0.0505

As seen in Table 7, the most significant criterion for supplier selection in automotive supply industry is *Price (C_3).* Following; *Quality (C_9)*, and *Providing Demo Products (C_2)* are the other most important criteria regarding to their significance weights. *Speed (C_6)* is found as the least important criterion for supplier selection. According to D+R values, *Quality (C_9)* criterion has the highest interaction in terms of the degree of impact between criteria. Other criteria having high interaction are respectively *Providing Demo Products (C_2)* and *Price (C_3).* Considering the sending group, *Price (C_3)* criterion has the highest effect on other criteria. In addition, the most affected criterion is *Providing Demo Products (C_2)*, whereas the least affected criterion is *Mold (C_8).* These criteria relations as a result of IFDEMATEL analysis are illustrated in Figure 2.

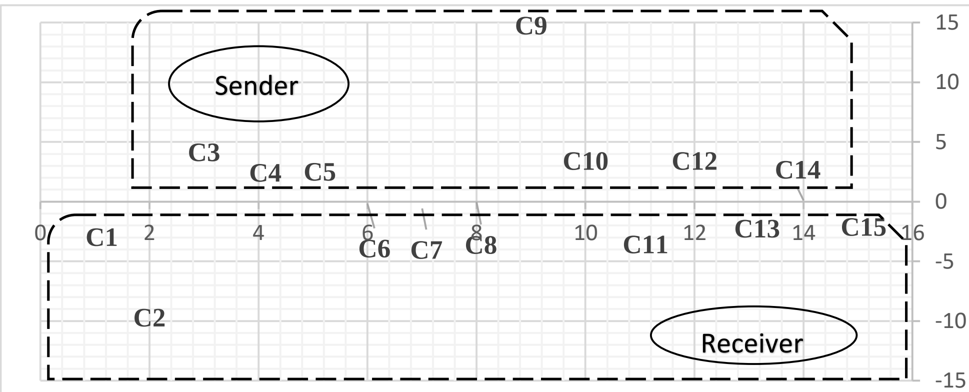


Figure 2. Criteria Relations of IFDEMATEL Analysis

4.4. Determining the alternatives

In line with the purpose of deciding optimal supplier, 5 suppliers that the mentioned company has worked at different times are chosen as the alternatives of this study, rest upon the opinions of the decision makers. Thus, the alternatives are called *S_1, S_2, S_3, S_4, and S_5* to keep their names confidential.

4.5. Supplier selection for automotive supply industry

IFTOPSIS method is utilized for supplier selection and the criteria weights displayed in Table 7 are used while applying the method. The decision makers are required to evaluate each supplier for each criterion for building the decision matrix. In the evaluation process, Table 4 is used. IFTOPSIS Decision matrix is composed with the mean values of the evaluations made by each decision maker. Data of decision matrix of the alternatives are presented in Table 8, while the order of the suppliers is shown in Table 9.

Table 8. IFTOPSIS Decision Matrix

Criteria	A_1			A_2			A_3			A_4			A_5		
C_1	0.65	0.30	0.05	0.45	0.50	0.05	0.60	0.35	0.05	0.50	0.45	0.05	0.65	0.30	0.05
C_2	0.60	0.35	0.05	0.35	0.60	0.05	0.45	0.50	0.05	0.65	0.30	0.05	0.30	0.65	0.05
C_3	0.25	0.70	0.05	0.75	0.20	0.05	0.60	0.35	0.05	0.65	0.30	0.05	0.65	0.30	0.05
C_4	0.75	0.20	0.05	0.55	0.40	0.05	0.55	0.40	0.05	0.60	0.35	0.05	0.60	0.35	0.05
C_5	0.81	0.14	0.05	0.60	0.35	0.05	0.65	0.30	0.05	0.75	0.20	0.05	0.84	0.11	0.05
C_6	0.70	0.25	0.05	0.60	0.35	0.05	0.60	0.35	0.05	0.78	0.17	0.05	0.60	0.35	0.05
C_7	0.75	0.20	0.05	0.45	0.50	0.05	0.35	0.60	0.05	0.65	0.30	0.05	0.60	0.35	0.05
C_8	0.50	0.45	0.05	0.60	0.35	0.05	0.70	0.25	0.05	0.30	0.65	0.05	0.55	0.40	0.05
C_9	0.78	0.17	0.05	0.45	0.50	0.05	0.50	0.45	0.05	0.50	0.45	0.05	0.75	0.20	0.05
C_{10}	0.60	0.35	0.05	0.81	0.14	0.05	0.75	0.20	0.05	0.75	0.20	0.05	0.35	0.60	0.05
C_{11}	0.50	0.45	0.05	0.40	0.55	0.05	0.30	0.65	0.05	0.65	0.30	0.05	0.30	0.65	0.05
C_{12}	0.70	0.25	0.05	0.70	0.25	0.05	0.70	0.25	0.05	0.84	0.11	0.05	0.50	0.45	0.05
C_{13}	0.13	0.82	0.05	0.81	0.14	0.05	0.60	0.35	0.05	0.60	0.35	0.05	0.40	0.55	0.05
C_{14}	0.78	0.17	0.05	0.75	0.20	0.05	0.50	0.45	0.05	0.55	0.40	0.05	0.17	0.78	0.05
C_{15}	0.30	0.65	0.05	0.55	0.40	0.05	0.25	0.70	0.05	0.50	0.45	0.05	0.17	0.78	0.05

Table 9. Order of the Suppliers

Order	Alternatives	Proximity Value
1	S_4	0.6452
2	S_2	0.5868
3	S_3	0.4873
4	S_1	0.4531
5	S_5	0.4407

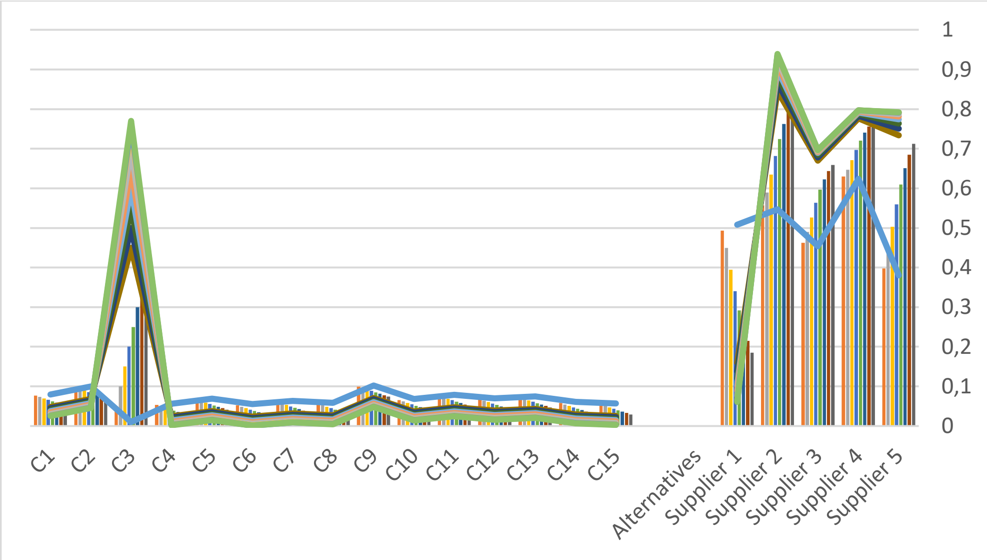
According to the ranking obtained by IFTOPSIS method, S_4 has the best supplier performance in pursuant of the criteria, whereas S_5 has the worse supplier performance among all the suppliers of this decision problem.

4.6. Sensitivity analysis

One dimensional sensitivity analysis is employed to analyze the sensitivity of differentiation of criteria weights. With reference to the findings of this research, C_3 *(Price)* is the most important criterion with its highest precedence weight value of 0.096501. In the sensitivity analysis, criteria weight is set freely at an optimal interval, and the weights of all the other criteria are equally increased and decreased. Accordingly, the most important criterion's weight is decreased to 0.01 and increased to the upper limit. Regarding to Appendix-Table A1, the weight of criterion C_3 cannot be upraised over 0.77. If it is increased over 0.77, the least important criterion gets a negative value. In this context, the weight of the criterion C_3 is kept within the interval of $0.01 \leq C_3 \leq 0.77$ and new weight values shown in Appendix-Table A1 are obtained. Changes in criteria weights are illustrated in Graph 1.

As a conclusion of the sensitivity analysis, changes in the alternatives ranking have been observed according to the weights obtained. Appendix Table A2 shows the changes in the alternatives. As seen in Appendix-Table A2, if the weight of the criterion C_3 is decreased to 0.01 and increased to 0.23, there is no change in the order of the best supplier. On condition that the criterion C_3 is increased over 0.23, then the result of the best supplier selection differs.

Figure 3. Sensitivity Analysis



Furthermore as seen in Figure 3, if the weight of the criterion C_3 is increased over 0.23, then the best supplier changes from Supplier 4 (S_4) to Supplier 2 (S_2). The main reason of this difference is that S_2 has the best value of the criterion C_3 in the evaluations made by the experts.

4.7. Comparative analysis

For testing the validity of proposed methodology comparative analysis with other MCDM methods is carried out in this section. EDAS (Evaluation Based on Distance from Average Solution) and ARAS (Additive Ratio Assessment) methods recently used in related studies, applied to rank the automotive suppliers mentioned in this study. Obtained results are summarized in Table 10.

Table 10. Results of Comparative Analysis

Order	EDAS Result	EDAS Value	ARAS Result	ARAS Value
1	S_4	0.776	S_4	0.877
2	S_2	0.539	S_2	0.850
3	S_1	0.478	S_1	0.849
4	S_3	0.252	S_5	0.801
5	S_5	0.173	S_3	0.791

According to the rankings, results of ARAS and EDAS methods are very similar to each other, only the last row indicates a change. Also, in comparison with the results of the IFDEMATEL-IFTOPSIS method in the study, it is seen that the order of the third rank supplier (S_3) has changed, but the best performing suppliers remain in the same ranking. S_4 is the best and S_2 is the second in all methods, so the results appear to be valid.

5. Conclusion and Discussion

Fierce competition environment in the automotive supply industry obligates the enterprises in spare parts sector to put more emphasis on supplier selection decisions to survive. Therefore, providing spare parts at the right time from the right supplier directly affects both the interests and competitive power of the enterprises in the market. From this point of view, supplier selection process in which various criteria play a crucial role, is seen as one of the necessary decision processes for the enterprises. Additively, in recent Covid-19 pandemic period, correct cooperation and selection in supply chain management has gained more importance both economically and socially.

This paper contributes to the related field by suggesting an IFMCDM model to find out the best supplier in the automotive supply industry through considering the fuzziness and ambiguity of DMs' opinions. Also, a case study of an enterprise supplying automotive spare parts is conducted effectively. Within this framework, firstly, a group of experts working as the sector managers is created. Following, a criteria pool is composed in line with a literature review about criteria utilized for supplier selection. Then, upon the interviews realized with the expert group, the criteria to be used for the selection of the suppliers are clarified. Then, IFDEMATEL is applied to obtain both the relations between the criteria and the weights of these criteria for supplier selection. In the last stage, IFTOPSIS method is performed to identify the best supplier.

As a result of this research, the most important criterion for supplier selection is revealed as *Price (0.0965),* followed by *Quality (0.0957)*, *Providing Demo Products (0.0931),* and *Geographical Location (0.0732)* respectively. When the findings are compared with the previous studies in related literature, it is seen that weight values of the criteria are parallel with them. The order of priority for the criterion *Price* which is selected as the most important criterion, is in line with the studies Xia and Wu (2007), Kuo et al. (2010), Mafakheri et al. (2011), Amindoust et al. (2012), Zhong and Yao (2017). Besides, in this case of the study, Supplier 4 is identified as the best supplier among alternatives through evaluating with IFTOPSIS method. In addition, with respect to the sensitivity and comparative analyzes this result came out to be valid and robust in other MCDM methods.

An important limitation of MCDM techniques is the fact that as the criteria weights change, the results of the research might differ. According to the findings of one dimensional sensitivity analysis presented to minimize the effect of mentioned limitation, it is determined that the weight of the most significant criterion can not be increased over 0.77 and if it is increased over 0.77, the least important criterion will have a negative value. Furthermore, if the weight of the criterion C_3 is reduced to 0.01 and increased to 0.23, there is no change in the order of the best supplier. In case this value is over 0.23, then the result of the best supplier changes from S_4 to S_2.

In this paper, the information acquired from a group of 5 experts who have had business relations with suppliers, yet there is no information exchange with other enterprises in the same sector. Because this study is concentrated on the case of an enterprise in automotive supply industry. Therefore, a limitation of this paper is that the inferences of this study represent only one enterprise in the spare parts sector in which this study is carried out. Besides, due to the subjectivity in the base of integrated IFDEMATEL-IFTOPSIS method, the results could be different in case different supplier selection criteria are included in or excluded from this study is another limitation.

The conclusion of this research are shared with the decision makers involved in this study, and it is seen that the findings show parallelism with the enterprise behaviors. Thus, an effective and usable decision-making approach is provided for a real case. Also, suppliers analyzed in this research, try to maintain the spare parts in accordance with the requests of the enterprise in question.

In future, a contribution may provide to the literature by examining the criteria used in this paper with Delphi method or similar methods that ensure consensus in line with the opinions of the experts working in spare parts sector. Another future research recommendation may be a study that proposes a new model for supplier selection by including various enterprises in automotive supply industry in Turkey. Last but not least, another future study could contribute to the literature in a way that determines the relations between criteria and helps the enterprises in automotive supply industry for supplier selection by integrating different MCDM methods and fuzzy logic approaches.

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Appendix

Table A1. Weights of Criteria in the Range of 0.01-0.78

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
Available Weights	*.0732*	*.0932*	*.0965*	*.0496*	*.0628*	*.0486*	*.0567*	*.0523*	*.0958*	*.0619*	*.0723*	*.0638*	*.0684*	*.0544*	*.0506*
.01	.0794	.0994	.0100	.0558	.0689	.0548	.0629	.0585	.1020	.0681	.0784	.0700	.0746	.0605	.0568
.05	.0766	.0965	.0500	.0530	.0661	.052	.0601	.0556	.0991	.0652	.0756	.0671	.0717	.0577	.0539
.10	.0730	.0929	.1000	.0494	.0625	.0484	.0565	.0520	.0955	.0616	.0720	.0635	.0681	.0541	.0503
.15	.0694	.0894	.1500	.0458	.0589	.0448	.0529	.0485	.0920	.0581	.0684	.0600	.0646	.0505	.0468
.20	.0658	.0858	.2000	.0422	.0554	.0413	.0494	.0449	.0884	.0545	.0649	.0564	.0610	.0470	.0432
025	.0623	.0822	.2500	.0387	.0518	.0377	.0458	.0413	.0848	.0509	.0613	.0528	.0574	.0434	.0396
.30	.0587	.0787	.3000	.0351	.0482	.0341	.0422	.0377	.0813	.0474	.0577	.0492	.0538	.0398	.0360
.35	.0551	.0751	.3500	.0315	.0447	.0305	.0386	.0342	.0777	.0438	.0541	.0457	.0503	.0362	.0325
.40	.0516	.0715	.4000	.0280	.0411	.0270	.0351	.0306	.0741	.0402	.0506	.0421	.0467	.0327	.0289
.45	.0480	.0679	.4500	.0244	.0375	.0234	.0315	.0270	.0705	.0366	.0470	.0385	.0431	.0291	.0253
.50	.0444	.0644	.5000	.0208	.0339	.0198	.0279	.0235	.0670	.0331	.0434	.0350	.0396	.0255	.0218
.55	.0408	.0608	.5500	.0172	.0304	.0163	.0244	.0199	.0634	.0295	.0399	.0314	.0360	.0220	.0182
.60	.0373	.0572	.6000	.0137	.0268	.0127	.0208	.0163	.0598	.0259	.0363	.0278	.0324	.0184	.0146
.65	.0337	.0537	.6500	.0101	.0232	.0091	.0172	.0127	.0563	.0224	.0327	.0242	.0288	.0148	.0110
.70	.0301	.0501	.7000	.0065	.0197	.0055	.0136	.0092	.0527	.0188	.0291	.0207	.0253	.0112	.0075
.75	.0266	.0465	.7500	.0030	.0161	.0020	.0101	.0056	.0491	.0152	.0256	.0171	.0217	.0077	.0039
.76	.0258	.0458	.7600	.0022	.0154	.0013	.0094	.0049	.0484	.0145	.0249	.0164	.0210	.0070	.0032
.77	.0251	.0451	.7700	.0015	.0147	.0005	.0086	.0042	.0477	.0138	.0241	.0157	.0203	.0062	.0025
.78	.0244	.0444	.7800	.0008	.0139	-.0002	.0079	.0035	.0470	.0131	.0234	.0150	.0196	.0055	.0018

Table A2. Ranking Value of Alternatives in the Range of 0.01-0.78

Weight	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
.01	.5082	.5465	.4536	.6239	.3803
.05	.4930	.5568	.4626	.6296	.3977
.10	.4495	.5897	.4897	.6468	.4446
.15	.3943	.6348	.5265	.6711	.5029
.20	.3401	.6816	.5638	.6971	.5596
.21	.3299	.6906	.5708	.7021	.5702
.22	.3199	.6994	.5776	.7070	.5805
.23	.3103	.708	.5841	.7117	.5904

Weight	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
.24	.3009	.7164	.5905	.7163	.6001
.25	.2918	.7246	.5965	.7208	.6094
.30	.2503	.7624	.6229	.7404	.6511
.35	.2150	.7948	.6433	.7558	.6852
.40	.1851	.8225	.6587	.7676	.7125
.45	.1595	.8463	.6700	.7764	.7342
.50	.1376	.8667	.6784	.7829	.7510
.55	.1186	.8844	.6845	.7876	.7641
.60	.1022	.8998	.6889	.7911	.7740
.65	.0879	.9133	.6921	.7936	.7814
.70	.0754	.9250	.6944	.7955	.7870
.75	.0646	.9354	.6961	.7968	.7910
.76	.0626	.9373	.6964	.7970	.7916
.77	.0607	.9391	.6966	.7972	.7922
.78	.0588	.9409	.6969	.7974	.7928

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