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An Integrated Approach for Supplier Evaluation and Selection using the Delphi Method and Analytic Hierarchy Process (AHP): A New Framework

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Abstract. Supplier selection is one of the most critical processes in supply chain management (SCM). Most small and medium enterprises (SMEs) face difficulties choosing the best supplier using conventional methods. A hybrid multi-criteria decision-making (MCDM) approach is proposed in supplier selection. This proposed framework integrates the Delphi technique as a data-gathering tool and Analytic Hierarchy Process (AHP) as the MCDM methodology for data analysis; both were used to select an effective supplier. This project applies the Delphi technique, allows experts to select the main criteria, and compares the trade-offs between the available alternatives depending on the main criteria. The criteria selected were price, delivery time, online ranking, rejection rate, and flexibility. Using the AHP approach, the criteria's weights were then assigned. The highest was for the price (43.84%), followed by the rejection rate (21.81%), online ranking (19.27%), delivery time (9.44%), and flexibility (5.64%). Lastly, a new framework was suggested using the weighted criteria collection for supplier selection.

Keywords: AHP; Delphi; MCDM; Supplier selection; Supply chain

1. Introduction

The multi-criteria decision-making (MCDM) approach is a decision aid framework that can evaluate multiple conflicting criteria (Shukor et al., 2018). It is a method of operational research in which various criteria are included in decision-making conditions to give optimal solutions (Anaokar et al., 2018). MCDM looks at the paradigm in which an individual decision-maker or a group of experts contemplate a choice of action in an uncertain environment. MCDM methods were highly efficient at solving selection problems (Chatterjee et al., 2014). One of the critical selection problems is supplier selection, which involves conflicting criteria such as price, quality, and delivery time. Therefore, the need for an efficient MCDM method is required. Many MCDM approaches have been proposed to deal with such problems. Velasquez and Hester (2013) analyzed the MCDM techniques and their applicability to different areas. They identified 11 MCDM methods that have been widely applied, highlighting the need for an efficient MCDM method. In the literature, many

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researchers have used MCDM methods in the supplier selection process, such as Multi-Attribute Utility Theory (Shaik and Abdul-Kader, 2011), Analytic Hierarchy Process (AHP) (Yadav and Sharma, 2016), fuzzy set theory (Chen et al., 2006), fuzzy AHP (Chan et al., 2008), case-based reasoning (Zhao and Yu, 2011), data envelopment analysis (DEA) (Garfamy, 2006), Simple Multi-Attribute Rating Technique (Ng, 2008), Goal Programming (Choudhary and Shankar, 2014), ELECTRE method (Fahmi et al., 2016), Simple Additive Weighing (Kaur and Kumar, 2013), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Zouggari and Benyoucef, 2012). Other researchers prefer to integrate two methods and techniques to yield more robust decisions: fuzzy AHP and TOPSIS (Jain et al., 2018); AHP and Delphi (Su and Zhan, 2020); AHP and Monte Carlo Method Approach (Kristy and Zagloel, 2020); goal programming and AHP (Khorramshahgol, 2012); AHP and VIKOR (Büyüközkan et al., 2019); Analytical Network Process (ANP) and VIKOR (Abdel-Baset et al., 2019); fuzzy TOPSIS and MCGP (Liao and Kao, 2011); ELECTRE and fuzzy clustering (Azadnia et al., 2011); AHP and ELECTRE II (Wan et al., 2017); utility function and ELECTRE (de Almeida, 2007); fuzzy AHP and fuzzy multi-objective linear programming (Shaw et al., 2012); ANP and DPA (Kuo and Lin, 2012); and ANP and linear programming (Ghodsypour and O'Brien, 1998).

One of the most used methods is AHP, which was developed in 1970s by Thomas Saaty. Various researchers have implemented the AHP method in supplier selection. For example, Chan and Chan (2010) used AHP for their supplier selection to evaluate four suppliers in different countries, considering five levels. Kahraman et al. (2003) used fuzzy AHP for the supplier selection problem, using data from one Turkish enterprise, considering the most important criteria determined by a questionnaire. Ramanathan (2007) used the hybrid of AHP-DEA-TCO as his methodology in supplier selection, integrating the total cost of ownership (TCO), AHP, and DEA.

The Delphi method is a "structured group communication" developed by Dalkey and Helmer (1963). This technique was defined as the method used for data gathering from subjects within their domain of expertise. Its goal is to converge their opinions about the specific issue (Hsu and Sandford, 2007). Generally, the Delphi method collects data using a series of questionnaires delivered by the investigator through multiple iterations, looking for a consensus of opinions regarding the topic at hand. An agreement is considered when 80% of the participants vote in favor of the case.

After a comprehensive review of the existing literature in the field, it was identified that different researchers used different sets of criteria. In our research, the traditional criteria (price and delivery time), semi-traditional criteria (flexibility to change and the average number of rejected parts), and nontraditional factors (online ranking) were merged. The modern era and changes in people's attitudes toward to technological developments and globalization have rendered these factors critical in selecting the suppliers. Moreover, the integration between the qualitative approach afforded by the Delphi method and the quantitative approach afforded by the AHP method will corroborate the results and reduce the risk of selecting inappropriate suppliers.

2. Materials and Methods

The research methodology comprised three steps. The first step was to determine the main critical affecting criteria through a comprehensive literature review (Table 1). The second step was to gather the data using the Delphi method with multiple iterations. The last step was to implement the AHP method to prioritize the selected criteria. Each Delphi participant was expected to be highly knowledgeable about the topic at hand. Also, the results are supposed to be well explained by the final round, as it was reviewed by its author many times, without any pressure application coming from other participants (Hsu and Sandford, 2007). The number of iterations depends on the consensus achievement; typically, it varies between three and five. After a thorough review of the relevant literature, a definitive collection of the criteria used in our research was price, delivery time, rejection number, flexibility, and online ranking.

Table 1 Selected criteria

Criteria	Description
Price	The final price of the product will be counted (fabrication cost and delivery cost)
Delivery time	The exact time of delivery
Rejection number	The average number of rejected pieces
Flexibility	The ability to make changes in the order within the last 15 days
Online ranking	Customers satisfactory for a specific supplier

2.1. *Delphi Implementation*

Based on previous studies, the average number of experts (i.e., participants) in the Delphi method is 8 and the maximum is 12. In our research, 10 experts were selected who originated from Dubai, Turkey, Malaysia, Palestine, and Sweden. Regarding reaching a consensus, it is agreed that no absolute and universal agreement exists on what constitutes as a sufficient consensus in a Delphi study. Two rounds were implemented in this research, during which feedback was solicited from the expert practitioners. They were allowed to modify their initial judgments about the problem presented in each round, given that each expert can review and assess the feedback from other experts. The analysis is performed after each round to determine whether a consensus has been reached. In cases in which some of the statements are left without an agreement, the mean of the experts' rankings were considered. A new concept was used to determine whether the obtained answers give the consensus or not, named the interquartile range (IQR). IQR must be a less or equal one. For binary (yes or no) questions, a consensus was considered to have been reached with 75% agreement.

2.2. *AHP Application*

The three most highly ranked sub-criteria were selected under each main criterion to apply AHP. The AHP comparison was done six times, the first time being between the five main criteria (to determine the global weights). Then, a comparison was made between the sub-criteria inside each main criterion (to determine the internal weights). The comparison between two elements using AHP can be performed in many ways; however, the most common method for comparing the relative importance between two alternatives is the Saaty scale. The comparative model approach where alternatives are compared under the various criteria is more accurate (Saaty, 2008). The priority was indicated by values ranging from 1 to 9, as shown in Table 2.

Table 2 The Saaty scale

Numerical	Scale
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred

Numerical	Scale
2	Equally to moderately preferred
4	Moderately to strongly preferred
6	Strongly to very strongly preferred
8	Very strongly to extremely preferred

The five steps needed to apply the AHP methodology among a set of criteria are:

1. Determining the criteria to be compared.

2. Determining the Comparison Matrix, the Priority Vector, and the Inconsistency, following Table 3.
3. Normalizing the comparison matrix by dividing each number by the sum of its column.
4. Calculating the weight of each criterion using the priority vector (Eigenvector) by calculating the average of each (raw) criterion.
5. Calculating the consistency index.

Table 3 AHP pairwise matrix

	Criterion 1	Criterion 2
Criterion 1	1	Numerical rating
Criterion 2	1/Numerical rating	1

The research methodology is shown in Figure 1.

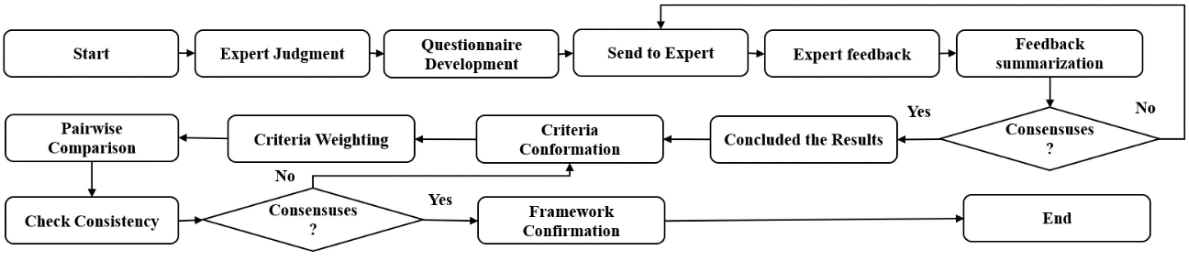

Figure 1 Schematic diagram of the research methodology

3. Results

Two iterations for Delphi implementation were enough to go for AHP implementation.

3.1. First Round

The results for the first iteration are presented in Tables 4–9.

Table 4 First iteration (product price)

Product Price	1	2	3	4	5	Description
Q1	4	3	3	3.25	4	1 = The product price (per single unit)
Q3	5	4	4.75	5	5	2 = Willing to give a discount
IQR	1	1	1.75	1.75	1	3 = Willing to give discounts for next purchases
Consensus status:	C	C	T	T	C	4 = Willing to maintain the price over time
Mean:	4.5	3.6	3.7	3.9	4.3	5 = Warranty: (after-sale service for free)
C = Consensus; T = Conflict						

The results: Two rankings will undergo a second round

Table 5 First iteration (delivery time)

Delivery Time	1	2	3	4	5	Description
Q1	3	4	4	4	3	1 = The supplier located in a near location
Q3	3.75	5	5	5	4	2 = Possibility of delivery
IQR	0.75	1	1	1	1	3 = Possibility of "just in time" delivery
Consensus status:	C	C	C	C	C	4 = Accuracy in timing.
Mean:	3.3	4.3	4.4	4.6	3.5	5 = Following the packaging standard
C = Consensus; T = Conflict						

A consensus was reached in all cases; therefore, a second round was not required

Table 6 First iteration (rejection rate)

Rejection Rate	1	2	3	4	5	6	Description
Q1	3	3	3.25	4	4	3	1 = The availability of the supplier documentation of previous statistics?
Q3	4	4	4	4.75	4.75	4	2 = Rejection rates for previous purchases?
IQR	1	1	0.75	0.75	0.75	1	3 = Number of past businesses/years of work?
Consensus status:	C	C	C	C	C	C	4 = Conforming to the standards
Mean:	3.5	3.3	3.7	4.3	4.2	3.6	5 = Customer satisfaction level?
C = Consensus; T = Conflict							6 = Free of legal claims/lawsuits?

A consensus was reached in all cases; therefore, a second round was not required

Table 7 First iteration (Online ranking)

Online ranking	1	2	3	4	5	Description
Q1	3.25	4	4	4	3	1 = Availability of the online ranking?
Q3	5	4.75	4.75	5	4	2 = Use of new technologies & and continuous improvement
IQR	1.75	0.75	0.75	1	1	3 = Possibility to retain good performance?
Consensus status:	T	C	C	C	C	4 = The speed of online responsiveness
Mean:	3.9	4.1	4.2	4.3	3.5	5 = Environmentally friendly level
C = Consensus; T = Conflict						

The results: One ranking will undergo a second round.

Table 8 First iteration (Product price)

Flexibility	1	2	3	4	5	Description
Q1	4	3	3	-	-	1 = Possibility to change the order before 15–20 days of supply?
Q3	4	4	4	-	-	2 = Capability to change the product details by max 20%.
IQR	0	1	1	-	-	3 = Capability to supply multiple products?
Consensus status:	C	C	C	-	-	
Mean:	4.1	3.6	3.6	-	-	
C = Consensus; T = Conflict						

A consensus was reached in all cases; therefore, a second round was not required

Table 9 First iteration (Relating questions)

Relating Questions	1	2	3	4	5	6	7	Description
Q1	4	3	4	4	4	3.25	4	1 = Availability of online tracking of the delivery statement
Q3	4	4	5	4	5	4.75	5	2 = Maintaining the same price in case of changing the order details?
IQR	0	1	1	0	1	1.5	1	3 = Responsibility for the rejected products due to bad delivery conditions?
Consensus status:	C	C	C	C	C	T	C	4 = Willing to deliver on time in case of having changes in the order (before 15-20 days)?
Mean:	4.1	3.5	4.6	4.2	4.2	4	4.2	5 = Willing to refund the cost of rejected parts?
								6 = To read the (honest) customers' online feedback
								7 = How important is it to be able to contact the right person for changes to the design?
C = Consensus; T = Conflict								

The results: One ranking will undergo a second round

As shown in the above Tables, the product price, online ranking, and related questions required an additional iteration.

3.2. Second Round

Following the qualitative analysis, a second round was performed. In this round, the participants were informed of the conclusions reached in the first round (after removing the answers that had already received consensus). Afterwards, closed-ended questions formed from the information obtained in round one were given to them, allowing them to revise their answers. The result for the answers with conflict is shown in Table 10.

Table 10 Second round results

Q1	3	3.25	4	4	Description
Q3	4	4	4.75	5	1 = Willing to give attractive discounts for the next purchases
IQR	1	0.75	0.75	1	2 = willing to maintain the price over time (for future purchases)
Consensus status:	C	C	C	C	3 = Availability of the online ranking?
Mean:	3.6	3.9	4.1	4.3	4 = To read the (honest) customers online feedback
C = Consensus; T = Conflict					

All of the statements reached a consensus. Three sub-criteria were analyzed to have more accurate results using the AHP method, as shown in Figure 2. Table 11 and Table 12 show the Comparison Matrix and the Normalized Matrix.

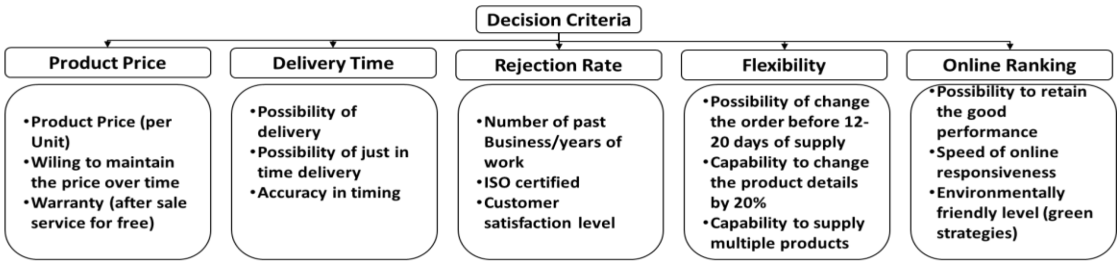

Figure 2 Criteria tree

Table 11 Pairwise matrix between the five main criteria

	Price	Delivery time	Rejection rate	Flexibility	Online ranking
Price	1.00	5.00	3.00	7.00	5.00
Delivery time	1/5	1.00	5.00	3.00	1/3
Rejection rate	1/3	1/5	1.00	5.00	5.00
Flexibility	1/7	1/3	1/5	1.00	3.00
Online ranking	1/5	3.00	1/5	1/3	1.00
Sum	1.88	9.53	9.40	16.33	14.33

Table 12 Normalized matrix of the five main criteria

	Price	Delivery time	Rejection rate	Flexibility	Online ranking
Price	0.53	0.52	0.32	0.43	0.35
Delivery time	0.11	0.10	0.53	0.18	0.02
Rejection rate	0.18	0.02	0.11	0.31	0.35
Flexibility	0.08	0.03	0.02	0.06	0.21
Online ranking	0.11	0.31	0.02	0.02	0.07

The weight of each criterion was calculated by using the priority vector (Eigenvector), as shown in Table 13.

Table 13 Weighting matrix of the five main criteria

Eigenvector & Weight Calculations							
	P	D	R	F	O	E	W
P	0.47	0.38	0.53	0.28	0.53	0.44	43.84%
D	0.12	0.10	0.09	0.11	0.06	0.09	9.44%
R	0.16	0.19	0.18	0.39	0.18	0.22	21.81%
F	0.09	0.05	0.03	0.06	0.06	0.06	5.64%
O	0.16	0.29	0.18	0.17	0.18	0.19	19.27%

*P = Price; D = Delivery time; R = Rejection rate; F = Flexibility; O = Online ranking; E = Eigenvector; W = Weight

The consistency was determined using the followings steps:

1. Calculate the consistency index CI, using Equation 1, where n is the number of criteria in the comparison (Saaty, 2016).

$$\text{CI} = \frac{\text{Max Eigen value} - n}{n-1} \quad (1)$$

2. Divide its value by the random consistency index, which is stated by Saaty depending on the value of n.
3. Calculate the Consistency Ratio (CR) using Equation 2, wherein a value below 10% was considered consistent (CI is the Consistency Index and RI is the Random Consistency Index).

$$\text{CR} = \frac{CI}{RI} < 0.1\sim10\% \quad (2)$$

The results display consistency, as shown in Table 15.

Table 14 Random consistency index introduced by Saaty (1980)

n	3	4	5	6	7	8	9	10	11	12	13
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56

Table 15 Consistency index for the five main criteria

Consistency Index Calculation			
	Eigenvector	Sum	Eigenvector *sum
Price	0.44	2.12	0.93
Delivery time	0.09	10.50	0.99
Rejection rate	0.22	5.64	1.23
Flexibility	0.06	18.00	1.01
Online ranking	0.19	5.67	1.09
Max Eigen value			5.26

$$\text{CI} = \frac{5.26 - 5}{5 - 1} = 0.06$$

$$\text{CR} = \frac{0.06}{1.12} = 0.0572 < 10\%$$

3.3. AHP Pairwise for the Sub-Criteria

As shown in Figure 2, the AHP pairwise was conducted for each criterion to determine the internal weights. For example, the pairwise comparison for the product price was developed and normalized, after which the weights were calculated for the price, as shown in Tables 16–19.

Table 16 Pairwise comparison for the price

Pairwise Comparison for the Price			
Price	A	B	C
A	1	7	4
B	1/7	1	1/3
C	¼	3	1
Sum	1.39	11.00	5.33

Table 17 Normalized matrix for the price

Normalized matrix for the Price			
Price	A	B	C
0.72	0.72	0.64	0.75
0.10	0.10	0.09	0.06
0.18	0.18	0.27	0.19

Table 18 Weight calculations for the price

Weight Calculations					
Price	A	B	C	Eigenvector	Percentage
A	0.72	0.64	0.75	0.7	70.14%
B	0.1	0.09	0.06	0.09	8.53%
C	0.18	0.27	0.19	0.21	21.32%

Table 19 Consistency ratio for the price

Price	Eigenvector	Sum	Eigenvector *Sum
A	0.70	1.39	0.98
B	0.09	11.00	0.94
C	0.21	5.33	1.14
Max Eigen value	-	-	3.05
CI	-	-	0.03
RCI	0.58	-	-
CR	-	-	0.05 Consistent

3.4. Framework Development

Based on the results, a new framework was proposed to increase the opportunity of the supplier selection process. The final framework is shown in Table 20.

Table 20 Final framework for supplier selection

Main criteria	Sub-criteria	Internal weight	Global weight	Percentage
Price 43.80%	Single unit price	0.70	0.308	30.75%
	Maintaining the price over time	0.09	0.037	3.74%
	Free warranty	0.21	0.093	9.35%
Delivery Time 9.40%	Possibility of delivery	0.41	0.038	3.83%
	Possibility of JIT delivery	0.11	0.011	1.09%
	Accuracy in timing	0.48	0.045	4.53%
Rejection Rate 21.80%	Years of work	0.11	0.025	2.51%
	(ISO certified)	0.41	0.088	8.84%
	Customer satisfaction level	0.48	0.105	10.46%
Flexibility 5.60%	Possibility to change the order	0.16	0.009	0.89%
	Capability to change the product details	0.19	0.011	1.05%
	Capability to supply multiple products	0.66	0.037	3.69%
Online Ranking 19.30%	Expectation to retain good performance	0.13	0.024	2.43%
	The speed of online responsiveness	0.46	0.088	8.82%
	Environmentally friendly level	0.42	0.080	8.02%
				100%

4. Conclusions

A new framework was developed by integrating the Delphi method and the AHP method. Five main criteria were identified: price, delivery time, rejection number, flexibility, and online ranking. The questionnaire given to the experts was designed in a specific way to develop the pairwise matrix. Saaty's Scale of Relative Importance was used to prioritize the factors. Two runs were conducted using the Delphi method for the experts to reach a consensus. The results show the effectiveness of the integrated framework, and the factors were ranked by percentage as follows: price (43.84%), rejection rate (21.81%), online ranking (19.27%), delivery time (9.44%), and flexibility (5.64%).

References

Abdel-Baset, M., Chang, V., Gamal, A., Smarandache, F., 2019. An Integrated Neutrosophic ANP and VIKOR Method for Achieving Sustainable Supplier Selection: A Case Study in Importing Field. *Computers in Industry,* Volume 106, pp. 94–110

Anaokar, G.S., Khambete, A.K., Christian, R.A., 2018. Evaluation of a Performance Index for Municipal Wastewater Treatment Plants using MCDM – TOPSIS. *International Journal of Technology*, Volume 9(4), pp. 715–726

Azadnia, A.H., Ghadimi, P., Saman, M.Z.M., Wong, K.Y., Sharif, S., 2011. Supplier Selection: A Hybrid Approach Using ELECTRE and Fuzzy Clustering. *In:* International Conference on Informatics Engineering and Information Science, Volume 252, Springer, Berlin, Heidelberg, pp. 663–676

Büyüközkan, G., Göçer, F., Karabulut, Y., 2019. A New Group Decision Making Approach with IF AHP and IF VIKOR for Selecting Hazardous Waste Carriers. *Measurement*, Volume 134, pp. 66–82

Chan, F.T., Chan, H.K., 2010. An AHP Model for Selection of Suppliers in the Fast-Changing Fashion Market. *The International Journal of Advanced Manufacturing Technology*, Volume 51(9-12), pp. 1195–1207

Chan, F.T., Kumar, N., Tiwari, M.K., Lau, H.C., Choy, K., 2008. Global Supplier Selection: A Fuzzy-AHP Approach. *International Journal of Production Research*, Volume 46(14), pp. 3825–3857

Chatterjee, P., Mondal, S., Chakraborty, S., 2014. A Comprehensive Solution to Automated Inspection Device Selection Problems using ELECTRE Methods. *International Journal of Technology*, Volume 5(2), pp. 193–208

Chen, C.T., Lin, C.T., Huang, S.F., 2006. A Fuzzy Approach for Supplier Evaluation and Selection in Supply Chain Management. *International Journal of Production Economics*, Volume 102(2), pp. 289–301

Choudhary, D., Shankar, R., 2014. A Goal Programming Model for Joint Decision Making of Inventory Lot-Size, Supplier Selection and Carrier Selection. *Computers & Industrial Engineering*, Volume 71, pp. 1–9

Dalkey, N., Helmer, O., 1963. An Experimental Application of the Delphi Method to the Use of Experts. *Management Science*, Volume 9(3), pp. 458–467

De Almeida, A.T., 2007. Multicriteria Decision Model for Outsourcing Contracts Selection based on Utility Function and ELECTRE Method. *Computers & Operations Research*, Volume 34(12), pp. 3569–3574

Fahmi, A., Kahraman, C., Bilen, Ü., 2016. ELECTRE I Method using Hesitant Linguistic Term Sets: An Application to Supplier Selection. *International Journal of Computational Intelligence Systems*, Volume 9(1), pp. 153–167

Ghodsypour, S.H., O'Brien, C., 1998. A Decision Support System for Supplier Selection using an Integrated Analytic Hierarchy Process and Linear Programming. *International Journal of Production Economics*, Volume 56, pp. 199–212

Garfamy, R.M., 2006. A Data Envelopment Analysis Approach based on Total Cost of Ownership for Supplier Selection. *Journal of Enterprise Information Management*, Volume 19(6), pp. 662–678

Hsu, C.C., Sandford, B.A., 2007. The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation*, Volume 12(10), pp. 1–8

Jain, V., Sangaiah, A.K., Sakhuja, S., Thoduka, N., Aggarwal, R., 2018. Supplier Selection using Fuzzy AHP and TOPSIS: A Case Study in the Indian Automotive Industry. *Neural Computing and Applications*, Volume 29(7), pp. 555–564

Kahraman, C., Cebeci, U., Ulukan, Z., 2003. Multi-Criteria Supplier Selection using Fuzzy AHP. *Logistics Information Management*, Volume 16(6), pp. 382–394

Kaur, P., Kumar, S., 2013. An Intuitionistic Fuzzy Simple Additive Weighting (IFSAW) Method for Selection of Vendor. *IOSR Journal of Business and Management*, Volume 15(2), pp. 78–81

Khorramshahgol, R., 2012. An Integrated Strategic Approach to Supplier Evaluation and Selection. *International Journal of Information Technology & Decision Making*, Volume 11(01), pp. 55–76

Kristy, C.N., Zagloel, T.Y., 2020. An Integrated Analytical Hierarchy Process and Monte Carlo Method Approach for Supplier Selection in Construction's Supply Chain. In: *3rd Asia Pacific Conference on Research in Industrial and Systems Engineering 2020*, pp. 300–304

Kuo, R.J., Lin, Y.J., 2012. Supplier Selection using Analytic Network Process and Data Envelopment Analysis. *International Journal of Production Research*, Volume 50(11), pp. 2852–2863

Liao, C.N., Kao, H.P., 2011. An Integrated Fuzzy TOPSIS and MCGP Approach to Supplier Selection in Supply Chain Management. *Expert Systems with Applications*, Volume 38(9), pp. 10803–10811

Ng, W.L., 2008. An Efficient and Simple Model for Multiple Criteria Supplier Selection Problem. *European Journal of Operational Research*, Volume 186(3), pp. 1059–1067

Ramanathan, R., 2007. Supplier Selection Problem: Integrating DEA with the Approaches of Total Cost of Ownership and AHP. *Supply Chain Management: An International Journal*, Volume 12(4), pp. 258–261

Saaty, T.L., 2016. The Analytic Hierarchy and Analytic Network Processes for the Measurement of Intangible Criteria and for Decision-Making. Multiple Criteria Decision Analysis. *International Series in Operations Research & Management Science*, Volume 233, pp. 363–419. Springer, New York, NY

Saaty, T.L., 2008. Decision Making with the Analytic Hierarchy Process. *International Journal of Services Sciences*, Volume 1(1), pp. 83–98

Saaty, T.L., 1980. Multicriteria Decision Making: *The Analytic Hierarchy Process*. McGraw-Hill, New York (2nd impr. 1990, RSW Publishing, Pittsburgh)

Shaik, M., Abdul-Kader, W., 2011. Green Supplier Selection Generic Framework: A Multi-Attribute Utility Theory Approach. *International Journal of Sustainable Engineering*, Volume 4(1), pp. 37–56

Shaw, K., Shankar, R., Yadav, S.S., Thakur, L.S., 2012. Supplier Selection using Fuzzy AHP and Fuzzy Multi-Objective Linear Programming for Developing Low Carbon Supply Chain. *Proceeding*, Volume 39(9), pp. 8182–8192

Shukor, J.A., Omar, M.F., Kasim, M.M., Jamaludin, M.H., Naim, M.A., 2018. Assessment of Composting Technologies for Organic Waste Management. *International Journal of Technology*, Volume 9(8), pp. 1579–1587

Su, T., Zhan, F., 2020. Supplier Selection and Evaluation System of Delphi Method and Analytic Hierarchy Process. *In:* IOP Conference Series: Materials Science and Engineering, Volume 768, pp. 1–6

Velasquez, M., Hester, P.T., 2013. An Analysis of Multi-Criteria Decision-Making Methods. *International Journal of Operations Research*, Volume 10(2), pp. 56–66

Wan, S.P., Xu, G.L., Dong, J.Y., 2017. Supplier Selection using ANP and ELECTRE II in Interval 2-Tuple Linguistic Environment. *Information Sciences*, Volume 385, pp. 19–38

Yadav, V., Sharma, M.K., 2016. Multi-Criteria Supplier Selection Model using the Analytic Hierarchy Process Approach. *Journal of Modelling in Management*, Volume 11(1), pp. 326–354

Zhao, K., Yu, X., 2011. A Case-Based Reasoning Approach on Supplier Selection in Petroleum Enterprises. *Expert Systems with Applications*, Volume 38(6), pp. 6839–6847

Zouggari, A., Benyoucef, L., 2012. Simulation Based Fuzzy TOPSIS Approach for Group Multi-Criteria Supplier Selection Problem. *Engineering Applications of Artificial Intelligence*, Volume 25(3), pp. 507–519