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A Fuzzy Delphi-BWM-TOPSIS Hybrid Approach to Assessment Suppliers Resilience

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Abstract

Identifying and evaluating the key parameters of resilience on the evaluating of suppliers in order to select the best resource supplier in the industry is very important. For this purpose, in this study, after a comprehensive review of the literature and the application of fuzzy Delphi technique and using the opinions of petrochemical upstream industry experts, six key and general parameters of supplier resilience (including key performance factors, supplier responsiveness, supplier risk reduction, supplier technical support, supplier stability, information technology management) were identified in eighteen factors. Then the weight of the parameters was determined using the best-worst method (BWM). The output of this method indicates the extraction of "supplier risk mitigation systems" and "key performance factors" as the most important parameters, respectively. Then, the five suppliers of the mentioned industry were evaluated and ranked using TOPSIS (technique for order performance by similarity to ideal solution) technique and based on the extracted weight of the parameters. The output showed that the fourth supplier was in the first place and the second supplier was in the last place. Thus, the proposed model of this research can be a good guide for upstream petrochemical industries in the successful and future evaluation of potential suppliers in order to improve supply and achieve competitive advantage and further satisfy customer needs.

Keywords: Resilience, Suppliers, Fuzzy Delphi, BWM, TOPSIS

Paper Type: Original Research

1. Introduction

A Supply Chain (SC) consists of five main elements namely suppliers, manufacturers, distributors, retailers, and customers. Recently, uncertain global risks and disruptions have affected most of the manufacturing industries which forced them to focus on SC resilience. Generally, the risks associated with SC can be classified into two categories which are operational risk and disruption risk. Operational risk refers to the inherent events that occur within a SC such as uncertainty in transportation cost, customer demand, and power outage. Disruption risk refers to the major disruptive events such as natural disasters, human-made threats, or employee strikes including pandemics, tsunamis, earthquakes, floods, fires, transport accidents, and labor strikes. These events may cause short-term or long-term negative impacts to the financial performance of SC or even economic crisis in more serious cases. To deal with the economic issues, resilience is vital to be incorporated in a SC (Leong et al. 2022). Following an earthquake in Japan in 2011, Apple was unable to produce the iPad 2 due to a lack of flash memory and an extremely thin battery (BBC News, 2011), which led to widespread supply chain disruptions. This particular event also led to the disruption of the automotive sector and retail supply chains in the UK (Hall, 2010). For this reason, in order to protect businesses, organizations must include the concept of accountability in decision-making criteria (Torabi et al., 2015). Criteria refer to the ability of suppliers to deal with risks and events that are unexpected and unpredictable and affect efficiency and speed higher than other suppliers (Mohammed et al., 2018). Severe disruptions often lead to significant reductions in production, sales, and economic outcomes. According to the World Economic Forum (2013), there are five major causes of severe supply chain disruptions, including natural disasters, adverse weather conditions, political conflicts and turmoil, terrorism, and sudden demand shocks. The occurrence of severe disruptions in public supply chains is due to certain risks of the country and the possibility of other risks. Therefore, emphasis on risk management is essential. A supply supplier is defined as "a supplier who is able to produce good quality products at economical rates and is flexible enough to adapt demand fluctuations to shorter advances in a lower risk environment without compromising environmental safety and operations" (Rajesh et al., 2015). A review of the literature reveals that quality, cost, and flexibility characteristics are key indicators in supplier selection issues (De Boer et al., 2001).

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In addition, a supplier must be sufficiently responsive to demand fluctuations (Peck, 2005; Christopher, 2010). Following supply chain resilience, the supplier should be least vulnerable to disruptions by being aware of possible risks and having well-established operations of supply chain continuity management (Squire et al., 2009; Wu et al., 2010). Suppliers should also have a R&D unit to ensure good levels of technical support and safety operations and a well-established environment to maintain sustainable competitiveness (Seuring and Müller, 2008; Mahapatra et al., 2010). Considering all these parameters in a specific framework will lead to the selection and ranking of suppliers with fluency capabilities. These parameters are discussed below. Various methods have been used to evaluate supplier resilience factors and supplier selection issues, including multi-criteria decision analysis techniques, mathematical programming, and artificial intelligence. In this regard, Liao and Kao (2011) used a combination of fuzzy TOPSIS technique and multi-objective ideal planning to solve the supplier selection problem, which allows decision makers to consider the levels of multiple ideals. Dalalah et al. (2011) used the fuzzy DEMATEL technique to evaluate and transform the relationship between causes and effects criteria into an understandable structural model. Karsak and Dursun (2014) used an approach based on integrating qualitative function development and data envelopment analysis to select the best supplier. In this study, the interdependence between supplier evaluation criteria through the structure of a quality house is introduced. Kar (2014) used the integration of fuzzy hierarchical analysis process and fuzzy ideal programming for the supplier selection problem. Lee et al. (2014) used a combination of fuzzy hierarchical analysis and fuzzy TOPSIS to determine the weight of the criteria and select the best supplier by making vague Subjective preferences from decision making. Igoulalene et al. (2015) used a hybrid approach of fuzzy multi-criteria decision analysis based on composition and consensus based on feasibility measures and fuzzy TOPSIS. You et al. (2015) used a new multi-criteria decision-making model using distance bipolar language variables and the developed VIKOR approach to select the best supplier under uncertainty and incomplete information. Govindan and Sivakumar (2016) developed an integrated multi-criteria decision-making and multi-objective linear programming approach as an aid to select the best green supplier. Ajalli et al., (2017) proposed a combined approach of of Fuzzy AHP and COPRAS to Solve the Supplier Selection Problems. results of this research, give an evaluation method for companies in order to help managers to identify and select the best suppliers. Amani et al. (2017) identified barriers to green supply chain acceptance using Fuzzy DEMATEL Technique. Extracted factors in this research were Outsourcing, technology, knowledge, finance and support. Mohammed et al. (2018) evaluated Green and Resilient Supplier Performance using AHP-Fuzzy TOPSIS Decision-Making Approach. They ranked suppliers with respect to their traditional, green and resilience (TGR) characteristics. A set of criteria/sub-criteria were identified within a unified framework and their relative importance weighted using the analytical hierarchy process (AHP) algorithm. In addition, the suppliers were evaluated and ranked based on their performance towards the identified TGR criteria using the fuzzy FTOPSIS algorithm through a real case study. The study provides a noteworthy aid to management who understand the necessity of building supply chain resilience while concurrently pursuing 'go green' responsibilities. Ajalli et al., (2019a) proposed a hybrid FSIR-TOPSIS approach for selecting of manufacturing levers. So dealing with the selected manufacturing levers and promoting them, an organization makes customers satisfied with the least cost and time. Hosseini and Khaled (2019) proposed a hybrid ensemble and AHP approach for resilient supplier selection. In this research, resilience value, obtained from ensemble methods, is coupled with additional four variables to assess the suppliers' overall performance and rank them using different supplier selection models. Finally, a case study has been performed on international plastic raw material suppliers for a U.S. based manufacturer. Ajalli et al., (2019b) presented a Combined SWARA-FVIKOR Approach for ranking suppliers. The result showed that delivery is the most important criteria's. Such, the results of FVIKOR technique showed that supplier 1 is the best supplier. This proposed approach gives an evaluation method for all of the companies in order to help managers to identify the best suppliers. Sahebjamnia (2020) has studied the selection of a resilient supplier and order allocation under conditions of uncertainty. The proposed mathematical model helps the decision makers to select supplier and allocate the optimum order quantities by considering shortage. Since the disruptive incidents are inevitable events in real world problems, the impact of disruptions on suppliers, manufactures and retailers has been considered in the proposed model. Inherent uncertainties of parameters are taken into account to increase the compatibility of the approach with realistic environments. To tackle the uncertainty and multi-objectiveness of the proposed model, interval Method and TH aggregation function is adapted. The proposed model is validated through application to a real case study in a furniture company. Results demonstrate the usefulness and applicability of the proposed model. Ajalli et al., (2021a) proposed a hybrid FSIR-TOPSIS approach for selecting of manufacturing levers. So dealing with the selected manufacturing levers and promoting them, an organization makes customers satisfied with the least cost and time.Mohammed et al. (2021) used a hybrid MCDM approach towards resilient sourcing. In this context, the resilience pillars of "flexibility" attained the highest relative weight compared to "agility", which secured the lowest weight. The results also showed "absolute" correlation among MABAC, VIKOR, and OCRA compared to "very strong" correlation between TOPSIS and the others. This research can support supply chain managers to achieve supply chain systems that reduce not only sourcing costs, but also potential losses because of disrupting threats, by building resilient supply chains. Hosseini et al. (2022) in a study, due to the importance of emergency centers and patient transport vehicles in epidemic conditions, the performance of emergency centers has been evaluated based on health protocols. The criteria were divided into preventive and operational sections by collecting opinions, health experts, standard criteria, and the Delphi method. Preventive criteria for evaluating emergency centers and operating criteria for assessing vehicles in these centers are considered. The weighting of the determined criteria was done by the triangular fuzzy aggregation method. According to the standard criteria, the emergency centers have been evaluated for a 30-day period results have been assessed as a qualitative and quantitative matrix using the PROMETHEE method. The results showed better performance of Center A (63%) due to proper performance and better compliance with protocols in both criteria (preventive and operational). e reason for the superiority of this center over Center B can be considered the better performance of this center in terms of prevention indicators and better performance of the center's vehicles (Ambulance A-1 and Ambulance A-2) in the performance index by observing the standards. Ayough et al. (2022) proposed a new interactive method based on multi-criteria preference degree functions for solar power plant site selection. This study renders a new approach that redefines the linear relations of Interactive Simple Additive Weighting (ISAW) by multi-criteria preference degree functions of Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). In the proposed approach, an initial order of alternatives is gradually improved by swapping the order of a pair of alternatives until the decision-maker becomes satisfied. To validate the proposed method, we consider a case study of site selection for solar farms. Ayough et al. (2023) presented a new integrated approach based on base-criterion and utility additive methods and its application to the supplier selection problem. A numerical example and a real case in the electronics industry have been presented to corroborate the applicability and effectiveness of the BCUA model. Sensitivity analysis and a comparative analysis of the proposed method are discussed in comparison to already existing MCDM methods, including the Fully Consistency Method (FUCOM), Ordinal Priority Approach (OPA), Level Based Weight Assignment (LBWA), and Defining Interrelationships Between Ranked Criteria (DIBR). These analyses indicate that the criteria weights and alternative rankings are robust to changing the parameters δ and λ. In addition to selecting the most suitable supplier, the model presented here can also be used in any decision-making problem with multiple attributes and alternatives, particularly when decision-makers are faced with many alternatives. Salman et al. (2023) in research used a hybrid approach using z-number DEA model and artificial neural network for resilient supplier selection. The obtained results are compared with a fuzzy DEA (FDEA) method in the form of validation and verification. Second, a sensitivity analysis is executed to show the effects of different criteria on ranking results, and the price index is identified as the most important evaluation criteria. Third, a predictive model is presented based on ANN that is able to detect the efficiency or inefficiency of suppliers with an 83% accuracy. Ajalli et al., (2024) used a hybrid approach (CFA-SWARA-MOORA) in order to modeling and evaluate the determining factors in the assessment of sustainability and resilience of the supply chain in Iran rubber industry. The output of this approach showed that all the identified factors have a positive effect on the evaluation of suppliers. Then, by using the SWARA technique and using the opinions of 40 industry experts, the weight of the factors was calculated. The output of this technique showed that the third factor of supply chain sustainability, (S3: Strategy, support and commitment of company managers) with the highest weight is ranked first in terms of importance. Also, the 7th factor of sustainability (S7: Green warehouse) with the least weight in terms of importance in the integrated performance evaluation system of suppliers was placed in the 16th ranks. At the end of the research, 7 rubber industry suppliers were evaluated using the opinions of 40 experts and using MOORA's technique. The final result of this technique showed that the fifth supplier is ranked first, and the fourth supplier is ranked last. In this way, an integrated and comprehensive approach was proposed in order to measure and evaluate the suppliers of the rubber industry in Iran.

Kiani Mavi et al. (2024) in a study, Ahmadi et al investigated the resilience of the supply chain and analyzed the efficiency of common weights with optional and uncontrollable inputs. The proposed model formulates the non-discretionary and non-controllable inputs in measuring the resilience of SCNs and provides a complete ranking with a higher discrimination power. To improve SCRes, SC managers are recommended to enhance the clustering.

Master purposes of present research is: 1. Identification the key parameters of resilience on the evaluating of suppliers at petrochemical upstream industry in Iran by using fuzzy Delphi 2. Evaluating the keys by using a new method of MCDM by topic BWM and finally ranking the suppliers of the industry based on weight and importance by using TOPSIS. So, in the present study, the best-worst method has been used to weight (prioritize) the key parameters of suppliers 'resilience, and the TOPSIS multi-criteria decision-making technique has been used to rank the suppliers' suppliant industry. The best-worst method was presented in 2015 by Rezaei, an Iranian scientist and associate professor at Technical University Delft in the Netherlands, and is one of the best methods for pairwise comparisons, which in addition to weighting the indicators, also has the ability to rank options based on indicators. The TOPSIS technique is one of the well-known methods for classical MCDM. TOPSIS technique, as one of the known classical MCDM methods, was first developed by Hwang and Yoon in year 1981 for solving a MCDM problem. The underlying logic of TOPSIS is to define the ideal solution and negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution is the solution that maximizes the cost criteria and minimizes the benefit criteria. In short, the ideal solution consists of all of best values attainable of criteria, whereas the negative ideal solution is composed of all worst values attainable of criteria. The optimal alternative is the one which has the shortest distance from the ideal solution and the farthest distance from the negative ideal solution (Wang et al., 2007; Ajalli et al., 2021a). According to above comments, the master contribution of this research is the implementation of qualitative fuzzy Delphi technique and multi-criteria decision-making techniques (BWM & TOPSIS) for identification and ranking the keys effective on resilience of suppliers at petrochemical upstream industry in Iran. The combined approach is not used in internal and international researches. In other words, the main motivation and innovation of this article is the evaluation of suppliers' resilience using a combined approach of qualitative technique and quantitative MCDM techniques, which in no research have been used to evaluate suppliers' resilience by using at the same time, these approaches have not been addressed. Such, the most important limitation in this research was the limited access to experts of company for gathering of research data. For this purpose, the basic questions of the current research are as follows:

1. What are the key factors in evaluating suppliers' resilience?

2. What is the weight and importance of the factors?

3. How the suppliers of the studied industry ranked are based on the weight of the indicators?

The rest of the article is organized as follows: In the second part, first the background is presented and then the conceptual model of research is extracted; In the third section, the research methodology is discussed; In the fourth section, the research findings include the implementation of a combined approach of BWM and TOPSIS in order to weight the parameters and rank of the suppliers in the upstream petrochemical industry are discussed; Finally, in the fifth section, conclusions and research suggestions are presented.

2. Literature Review

A review of the domestic and foreign literature shows that there are few research studies on evaluating the factors of resilience and solving the problems of resource providers using quantitative and decision-making approaches. The literature review shows that there are few research studies on solving problems and the choice of resilient suppliers using quantitative approaches and decision making. In addition, in order to identify suppliers of resiliency measurement indicators, six general key parameters of reviewing literature (eighteen factors) are presented in table 1:

Table 1. General Key parameters of resilience

Row	Internal Resources	External Resources	Indicators	Keys
1	Ajalli et al., (2021c)	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Wang et al (2013);	Quality	Key Performance Factors
2	Ajalli et al., (2021c)	Ajalli et al (2021b); Rajesh et al (2015); Lee et al (2013); Yeung et al (2013);	Cost	
3	Ajalli et al., (2021c); Khodabakhsh et al (2018); Bagherzadeh Azar (2017); Jafarnejad et al (2016); Jahani (2016);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015b); Jayaram et al (2011); Hartmann et al (2011);	Flexibility	
4	Ajalli et al., (2021c); Khodabakhsh et al (2018); Ajalli et al., (2021c); Bagherzadehazar (2017); Jafarnejad et al (2016); Jahani (2016); Nazkabadi (2016); Jafarnejad et al (2015);	Ajalli (2024); Ajalli et al (2021b); Mohammad et al (2018); Purvis et al (2016); Rajesh et al (2015); Roh et al (2014); Soni et al (2014);	Velocity, Agility and Supply Chain	Supplier Accountability: Supplier responsiveness means better visibility and better supplier speed. A supplier must have a high supply chain speed such as adequate responsiveness to reduce the time elapsed from order level to delivery point.
5	Ajalli et al., (2021c); Bagherzadeh Azar (2017); Jafarnejad et al (2016);	Ajalli (2024); Ajalli et al (2021b); Kamal Ahamdi et al (2016); Rajesh et al (2015); Kyu Kim et al (2011);	Visibility of the supply chain	
6	Ajalli et al., (2021c); BagherzadehAzar (2017); Jafarnejad et al (2016);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Hofman et al (2015);	Vulnerability	Reduce the Supplier Risk: Suppliers should have the least vulnerability to disruption. They need to work with companies. Suppliers should also be better aware of possible risks and well-established operations of supply chain continuity management to reduce strong risks. Factors such as rapid technological
7	Ajalli et al., (2021c); Khodabakhsh et al (2018); Bagherzadeh Azar (2017); Jafarnejad et al (2016);	Ajalli (2024); Ajalli et al (2021b); Kamal Ahmadi et al (2016); Rajesh et al (2015); Soni et al (2014);	Collaboration among actors	

	Jaha (2016); Jafarnejad et al (2015);			change, changing customer preferences in information discovery, and increasing competition enhance affiliate marketing (Adler, 1996).
8	Ajalli et al., (2021c); Jafarnejad et al (2016);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Lavastre et al (2012); Kern et al (2012);	Risk Awareness	
9	Ajalli et al., (2021c);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015b); Gopalakrishnan et al (2012); Lavastre et al (2012);	Supply Chain Management	
10	Ajalli et al., (2021c); Jafarnejad et al (2016); Pfohl et al (2016);	Ajalli (2024); Ajalli et al (2021b); Soni et al (2014);	Risk and revenue sharing	
11	Ajalli et al., (2021c);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Lock et (2012); Pfohl et al (2011);	Technological Abilities	Technical Support Suppliers: Suppliers must be strong in technical capabilities. Also have a R&D department to ensure a good level of technical support. The technological capability of the supplier must be highly adapted to technological innovations. New technologies must be registered to maintain quality standards and reduce risks (Mahapatra et al., 2010).
12	Ajalli et al., (2021c);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015b); Kloyer et al (2012); Clegg et al (2012);	Research and development	
13	Ajalli et al., (2021c); Bagherzadeh Azar (2017); Jafarnejad et al (2016); Jahani (2016);	Ajalli (2024); Ajalli et al (2021b); Mohammad et al (2018); Kamal Ahamadi et al (2016); Carvalho et al (2012);	Redundancy	
14	Ajalli et al., (2021c); Bagherzadeh Azar (2017); Jafarnejad et al (2016);	Ajalli (2024); Ajalli et al (2021b); Carvalho et al (2012); Blackhurst et (2011); Cristofer et al (2011);	Complexity	
15	Ajalli et al., (2021c); Bagherzadeh Azar (2017); Jafarnejad et al (2016); Jafarnejad and Mohseni (2015);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Lock et al (2012); Punniyamoorthy et al (2011);	Safety	Supplier Sustainability: Suppliers must give greater priority to greener operations, taking into account safety and the environment in order to maintain sustainable competitiveness. Environmental concerns primarily include environmental protection system certification (such as ISO 14001 certification), and safety operations include the use of personal protective equipment and the maintenance of accident, hazard, and assessment records (Panyamorsi et al., 2011).
16	Ajalli et al., (2021c); Bagherzadeh Azar (2017); Jafarnejad et al (2016); Jafarnejad and Mohseni (2015);	Ajalli (2024); Ajalli et al (2021b); Rajesh et al (2015); Tate et al (2011); Chiou et al (2011);	Concerns for the environment	
17	Ajalli et al., (2021c); Ajalli et al., (2021)	Ajalli (2024); Ajalli et al (2021b); Soni et al (2011);	Knowledge Management	IT Management: In this regard, the implementation of knowledge management system, information sharing and the use of information technology throughout the supply chain has a positive effect on supply chain improvement and supplier resilience. Knowledge management means the creation and development of knowledge and understanding of the physical and information structures of the supply chain and the ability to learn from change as well as the training of other institutions. The exchange of information between members of the chain helps to reduce the risks and minimizes the consequences of phenomena such as the effect of the leather whip.
18	Ajalli et al., (2021c); Khodabakhsh et al (2018); Bagherzadeh Azar (2017); Jafarnejad et al (2016); Jahani (2016); Jafarnejad et al (2015);	Ajalli (2024); Ajalli et al (2021b); Kamal Ahamdi et al (2016); Soni et al (2014); Carvalho et al (2012); Chiang et al (2012); Cristofer et al (2011); Blackharst et al (2011);	Information sharing by using information technology	

Figure 1 shows the conceptual model of the research:

Figure 1. the conceptual model of the research

3. Methodology

The current research is applied in terms of purpose and descriptive survey in terms of data collection method. This research, like survey research, systematically describes the existing situation through a questionnaire and examines its characteristics and attributes. Data collection is done using questionnaires and interviews. The statistical population of this research in relation to the identification of supplier resilience evaluation criteria consisted of 40 experts, specialists and managers with useful experience in upstream petrochemical industries, and due to the small number of expert members of the statistical population, all experts were used for the evaluation. . This type of sampling is a non-probability method that has a random selection mode, and usually 10 to 20 experts are considered sufficient (Ajalli et al., 2021 quoted Rebar, Gersh, McNee and McCabe, 2011). In this study, after extensive literature review and identification of key parameters of supplier resilience, the opinions of 40 experts in the upstream petrochemical industry are used to compare pairs between parameters and the weight of indicators are calculated by the best-worst method. Then, using the TOPSIS ranking technique, industry suppliers are evaluated and ranked. As mentioned, the opinions of industry experts are used to evaluate the sub-criteria. The descriptive information of the mentioned industry experts is presented in Table 2:

Tale 2. Expert Information

Category	Classification	Number
Age	Less than 40 years	10
	Between 40 and 50 years	17
	Between 50 and 60 years	9
	Over 60 years	4
Work experience	Managers	13
	Deputies and Engineers	27
Level of Education	Diploma	--
	Bachelor	6
	Masters	29
	P.H.D	5
Work experience	Less than 10 years	5
	Between 10 and 20 years	15
	Between 20 and 25 years	12
	Over 25 years	8
Gender	Man	36
	Female	4

Accordingly, the following two basic questions arise:

- Question 1: What are the final parameters of resilience in the evaluation of industry suppliers based on Delphi technique in fuzzy environment?
- Question 2: Using the best-worst method, what is the importance (weight) of the key parameters of suppliers' resilience in the upstream petrochemical industry?
- Question 3: What is the ranking of industry suppliers?

Figure 2 shows the methodological diagram presented in this research:

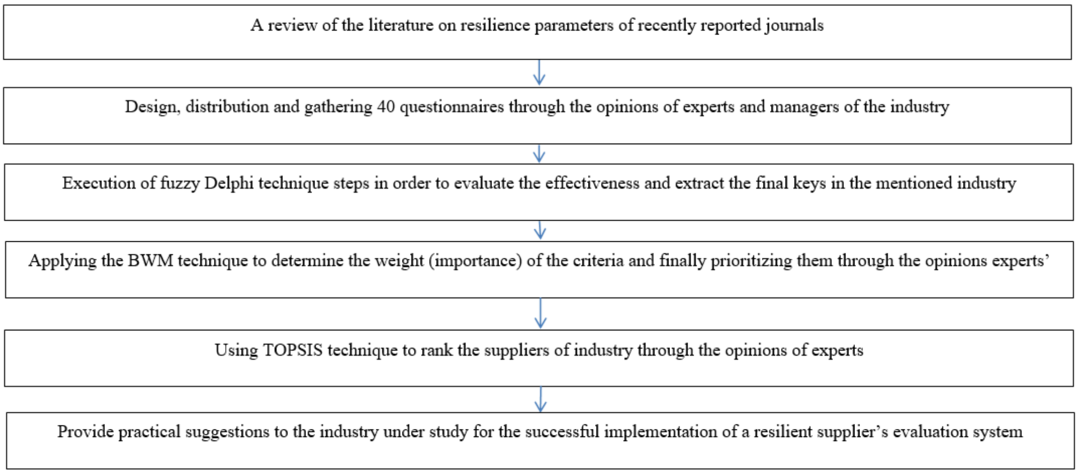

Figure 2. Research methodology diagram

4. Finding

4.1. Execution of Fuzzy Delphi Technique

In this study, researchers used fuzzy Delphi technique to localize and screen the criteria extracted from the research literature. This method is a combination of the Delphi method and the theory of fuzzy sets, which was proposed by Ishikawa et al. In 1993. The steps of the fuzzy Delphi method are as follows (Bouzon et al., 2016):

Step 1: Identify the key parameters of resilience in evaluating suppliers through a comprehensive literature review.

Step 2: Gathering the opinions of decision-making experts: In this step, after identifying the effective performance criteria in the resilience system of suppliers, a decision-making team consisting of experts related to the research topic is formed and a questionnaire is sent to determine the relevance of the identified criteria to the main research topic. The linguistic variables of Table 3 are used to express the importance of each attribute. There are several types of fuzzy numbers, such as triangular, trapezoidal, and exponential fuzzy numbers. In this research, triangular fuzzy numbers have been used many times due to their simplicity in understanding different researchers.

Table 3. Verbal Phrases to Confirm Indices (Wang et al., 2009)

Verbal Variable	Fuzzy Number
Very Little	(0,0,0.25)
Little	(0,0.25,0.5)
Medium	(0.25,0.5,0.75)
Much	(0.5,0.75,1)
Very Much	(0.75,1,1)

Step 3: Verify Important Criteria: This is done by comparing the value of the acquired value of each criterion with the threshold value. The threshold value can be determined in several ways, but using the average value of the criteria as the threshold value is one of the best methods (Bouzon et al., 2016). Experts are first asked about the relevant criteria at three levels: pessimistic (L), probable (m) and optimistic (u) as equation (1):

$$Ai = (a_L^{(i)};\ a_m^{(i)};\ a_u^{(i)}) \tag{1}$$

In which it expresses the amount of pessimism, probable opinion and expresses the optimistic opinion of each expert about each criterion.

In the next step, the geometric mean of experts' opinions on each criterion is calculated through the following equation (Bouzon et al., 2016):

As can be seen, the worst opinion among experts is related to a criterion, the geometric average is the opinion of experts about a criterion, and the most optimistic opinion among all experts is about a criterion. In the last step, decision-making on the criteria is done by using the equations (2) to differentiate the opinions of experts about each criterion.

$$a_i = (l_i * m_i * u_i) l_i = \min (a_L^{(i)}) \quad m_i = (\prod_{i=1}^{n} a_m^{(i)})^{\frac{1}{n}} \qquad u_i = \max (a_u^{(i)}) \tag{2}$$

After calculating the above values, if the defrosted value of each criterion is higher than the average of the defrosted values, the desired criterion is approved and enters the main decision stage. But if the diffused value is less, the desired criterion is rejected. In order to confirm the criteria related to the integrated system, main six criteria in 18 sub-criteria obtained from literature review (Table 3) were included in the fuzzy Delphi method questionnaire and a team of 40 experts was asked to answer the questions. Finally, after analyzing the data of the fuzzy Delphi method questionnaire, all of initial indicators were confirmed and selected as described in Table 4:

Table 4. Results of fuzzy Delphi technique

Key Parameters	Attribute	De-Fuzzy Average	Confirm or Reject
Key Performance Factors	Quality	0.679	C
	Cost	0.756	C
	Flexibility	0.690	C
Supplier Accountability	Velocity, Agility and Supply Chain	0.634	C
	Visibility of the supply chain	0.711	C
Reduce the Supplier Risk	Vulnerability	0.698	C
	Collaboration among actors	0.629	C
	Risk Awareness	0.731	C
	Supply Chain Management	0.664	C
	Risk and Revenue Sharing	0.681	C
Technical Support Suppliers	Technological Abilities	0.673	C
	Research and Development	0.728	C
	Redundancy	0.704	C
	Complexity	0.667	C
Supplier Sustainability	Safety	0.627	C
	Concerns for the Environment	0.719	C
IT Management	Knowledge Management	0.633	C
		Threshold value: 0.616	

Thus, the confirmed key parameters of the present study along with the code of each index are as follows: 1. Key Performance Factors 2. Supplier Accountability 3. Reduce the Supplier Risk 4. Technical Support Suppliers 5. Supplier Sustainability 6. IT Management

4.2. Determining the Weight of Key Suppliers' Resilience Parameters by BWM

In this part of the research, the importance of each of the 10 identified factors is calculated based on the SWARA method. Fuzzy values are used so as to make the results closer to the real world. The resulting decision matrix from experts' point of view for implementing the SWARA algorithm is shown in Table 3. This matrix is formed based on the relative average of the opinions of 10 experts participating in this research after defuzzifying the results listed in Table 2 according to the defined spectrum. The best-worst method is a multi-criteria comparison-based decision-making method that compares the best criterion with other criteria and other criteria with the worst criterion. The goal is to find the optimal weights and adaptation rates through a simple linear optimization model created with the comparison system (Rezaei et al., 2016). The BWM technique is one of the newest and most efficient multi-criteria decision-making techniques, which is used to weigh the factors and decision criteria. In multi-criteria decision-making methods, including the AHP method, decision-making indicators and criteria and sub-criteria can be ranked by pairwise comparisons and analysis of experts' opinions, and they are ordered from the most preferred and most important to the least important. But in the Best Worst Method, the best and worst indicators and criteria are determined by the decision maker, and then a paired comparison is made between each of these two indicators, which are the best and worst, with other indicators. Then the problem becomes a linear programming problem in such a way that the weights of the indicators are obtained in such a way that the absolute differences of the weights are minimized. Among the prominent features of the BWM method, which is one of the new multi-criteria decision-making techniques, compared to other existing MCDM techniques, the following can be mentioned: Feature 1: fewer pairwise comparisons Feature 2: achieving more consistent pairwise comparisons. In the literature, some studies have used this new multi-criterion decision-making approach. In this study, by preparing a questionnaire for the best-worst method and distributing them among upstream petrochemical industry experts, the weights of key suppliers' equity factors were calculated. The following are the steps of this method to calculate the weight of parameters (Rezaei, 2015; Rezaei, a2015):

Step 1: Determining the set of decision criteria $\{\boldsymbol{c_1}\ \boldsymbol{c_2} \ldots \boldsymbol{c_n}\}$ by decision makers and extracting the most important and least important factor from the experts' point of view:

The set of criteria in this research are the same six key parameters of supplier equity that were extracted from literature review and interviews with industry experts. Also, the third parameter (supplier risk reduction) was determined as the most important criterion and the fifth parameter (supplier stability) was determined as the least important criterion by experts.

Step 2: Determine the preference of the best criterion among other criteria in the form of numbers 1 to 9 (1: equal importance, 9 most important) to express the value of the criteria: The result of selecting the best criterion over other criteria is shown as $A_B = (a_{B1}\ a_{B2}\ \ldots a_{Bn})$ a vector that a_{Bj} the preference of criterion B Shows (best criterion) relative to criterion j and $a_{BB} = 1$.

In the present study, to determine this vector, experts were asked to determine the preference of the most important factor over other factors from 1 to 9, and finally the average of the collected data was obtained and the results of Table 5 were obtained:

Table 5. Preference of the most important factor over other factors

The most important factor (F3)		Key Factors
2.5	F1	Key Performance Factors
4.8	F2	Supplier Accountability
1	F3	Reduce the Supplier Risk
7.9	F4	Technical Support Suppliers
8.8	F5	Supplier Sustainability
5.9	F6	IT Management

Step 3: Determine the preference of each of the other criteria over the worst criteria: In this case, numbers from 1 to 9 are assigned. The worst vector over other criteria is represented as $A_W = (a_{1W}\ a_{2W}\ \ldots a_{nW})^T$ by the fact that $a_{jW}$the preference of the vector j over the worst criterion is W. To determine this vector, follow the previous step and the results of Table 6 were obtained:

Table 6. Preference of other factors over the least important factor

The worst criteria (F5)	
8.6	F1
6.8	F2
8.8	F3
5.9	F4
1	F5
5.3	F6

Step 4: Find the optimal weights ($\boldsymbol{w_1^* w_2^* \ldots w_n^*}$): Solve the following problem; get the optimal weights for the criteria. To determine the optimal weights of the criteria, the largest absolute difference $\{|w_B - a_{Bj}w_j|;\ |w_j - a_{jw}w_w|\}$ Must be minimized for each j as equation (3):

$$\begin{aligned}
&\min \max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right| ; \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \\
&\text{s.t.} \\
&\sum_j w_j = 1 \\
&w_j \geq 0 \quad \text{for all } j
\end{aligned} \tag{3}$$

This model will be solvable after being converted into the linear programming equations as (4) (Rezaei, b2015):

$$\begin{aligned}
&\min \xi \\
&\text{s.t.} \\
&|w_B - a_{Bj} w_j| \leq \xi; \ \text{for all } j \\
&|w_j - a_{jw} w_w| \leq \xi; \ \text{for all } j \\
&\sum_j w_j = 1 \\
&w_j \geq 0 \quad \text{for all } j
\end{aligned} \tag{4}$$

By solving this problem, optimal weights ($w_1^* w_2^* \dots w_n^*$) and optimal values ξ^* are obtained. It is defined as the ratio (rate) of compatibility of the comparison system. ξ^* Closer to zero indicates greater compatibility of the comparison system provided with decision makers. The equation (5) is used to evaluate the compatibility of comparisons (Rezaei et al., 2016):

$$Consistency\ Ratio = \frac{\xi^*}{Consistency\ Index} \tag{5}$$

The consistency index is obtained from Table 7. A lower compatibility ratio means more reliability of comparisons.

Table 7. Consistency Index (Rezaei, 2015a)

a_{BW}	1	2	3	4	5	6	7	7	9
Consistency Index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.74	5.23

In this research, by solving the above models using LINGO 15 software, the optimal and final weight of each of the key parameters ($w_1^* w_2^* \dots w_n^*$) is obtained. It should be noted that the above model was solved with 9 variables and 19 constraints in 11 replications and the results of this step are shown in Table 8:

Table 8. Final weights of key factors

Final rank		Parameter
2	0.23	F1
3	0.12	F2
1	0.44	F3
5	0.073	F4
6	0.035	F5
4	0.097	F6
0.134072		the amount of ξ^*
5.078		Consistency Index
0.01208		Consistency rate

According to the solution of the linear programming model of the best-worst method, it can be seen that "supplier risk reduction systems" and "key performance factors including quality, cost and flexibility" were recognized as the most important factors, respectively. The compatibility rate is also at an acceptable level.

4.3. Ranking Suppliers using TOPSIS

In this study, in order to rank of suppliers in the Petrochemical Upstream Industries, TOPSIS decision-making technique including the following six steps has been used:

- Conversion of the D decision-making matrix to the ND matrix based on Euclidean norm.

$$r_{ij} = \frac{r_{ij}}{(\sum_{i=1}^{m} r_{ij})^{1/2}} \quad (j = 1, \dots, n)$$

In order to implement the first step, first the decision matrix was extracted from the opinions of 40 experts of the industry and finally the final aggregation matrix was presented as Table 9:

Table 9. Collective matrix of expert opinions

Decision-Making Matrix (DMM)	C1	C2	C3	C4	C5	C6
A1	8	6	7	9	8	9
A2	5	6	6	6	6	5
A3	6	7	7	8	7	8
A4	10	9	8	10	8	9
A5	5	8	7	8	6	6
weight of key factors	0.23	0.12	0.44	0.073	0.035	0.097
Alpha	15.81	16.31	15.72	18.57	15.78	16.94

In the table 8, the integration matrix of expert opinions is obtained through simple mediation of expert opinions regarding each criterion and alternative. Also, the weight of the main parameters extracted from the final output of the BWM technique is given. Alpha is equal to the square root of the sum of experts' opinions in each column related to the criterion, which is the normal decision matrix in the next table by dividing the experts' opinions by alpha. The following is a ND matrix in Table 10:

Table 10: Normal Decision-Making Matrix

Normalized DM	C1	C2	C3	C4	C5	C6
A1	0.5060	0.3679	0.4454	0.4845	0.5070	0.5313
A2	0.3162	0.3679	0.3818	0.3230	0.3802	0.2951
A3	0.3795	0.4292	0.4454	0.4307	0.4436	0.4722
A4	0.6325	0.5518	0.5090	0.5384	0.5070	0.5313
A5	0.3162	0.4905	0.4454	0.4307	0.3802	0.3542

- The matrix of the balanced scale is obtained by assuming the vector was equation (6):

$$V = N_D . W \tag{6}$$

Where V is the balanced scale matrix and W is the diameter matrix of the weights obtained for the criteria. Table 11 shows the balanced ND decision making:

Table 11. The Weighted NDM

Weighted NDM	C1	C2	C3	C4	C5	C6
A1	0.1164	0.0441	0.1960	0.0354	0.0177	0.0515
A2	0.0727	0.0441	0.1680	0.0236	0.0133	0.0286
A3	0.0873	0.0515	0.1960	0.0314	0.0155	0.0458
A4	0.1455	0.0662	0.2240	0.0393	0.0177	0.0515
A5	0.0727	0.0589	0.1960	0.0314	0.0133	0.0344

Identify the solution to the positive ideal and the solution to the negative ideal as follows:

$$A^+ = \{(\max V_{ij}, J \in j_1), (\min V_{ij}, J \in j_2), i = 1,2, \dots, m\}$$

$$A^- = \{(\min V_{ij}, J \in j_1), (\max V_{ij}, J \in j_2), i = 1,2, \dots, m\}$$

$A_i^+ = \{v_1^+, v_2^+, \ldots, v_n^+\}$

$A_i^- = \{v_1^-, v_2^-, \ldots, v_n^-\}$

For the positive elements of the criteria: $j_1 = \{j = 1,2, \ldots . n\}$

For the negative elements of the criteria: $j_2 = \{j = 1,2, \ldots . n\}$

According to the above relations, the values of the positive ideal solution and the negative ideal solution are calculated and given in Table 12:

Table 12. the values of the positive and negative ideal solution

A+	0.1455	0.0662	0.2240	0.0393	0.0177	0.0515
A-	0.0727	0.0441	0.1680	0.0236	0.0133	0.0286

- Calculation of distances based on Euclidean norm as equations (7):

$$d_i^+ = \left\{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2\right\}^{1/2}, (i= 1,2,\ldots,m) \quad d_i^- = \left\{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\right\}^{1/2} \qquad (7)$$

Considering the above relations, the distance between positive and negative ideas is presented in Table 13:

Table 13. the distance between positive and negative ideas

Distances	d+	d-
A1	0.0462	0.0581
A2	0.0985	0.0000
A3	0.0670	0.0376
A4	0.0000	0.0985
A5	0.0807	0.0331

- Calculate the relative proximity of the option to the ideal solution as equation (8):

$$c_i = \frac{d_i^-}{(d_i^- + d_i^+)}, (i = 1,2, \ldots, n) \qquad (8)$$

If $A_i = A_i^+$ then $d_i^+ = 0$

So, the closer the option is to the ideal solution, the closer it will be to one.

According to the above relation, the relative proximity of the options to the ideal solution is calculated and given in Table 14:

Table 14. the relative proximity of the options to the ideal solution

Proximity	CC
A1	0.5570
A2	0.0000
A3	0.3594
A4	1.0000
A5	0.2909

- Ranking options: At this stage, the options (suppliers) are ranked based on c_i as the values from largest to smallest. The results are shown in table 15:

Table 15. Ranking Suppliers

	Rank
A1	2
A2	5
A3	3
A4	1
A5	4

5. Conclusions

Unexpected worldwide disruptions brought various challenges to supply chain management thus manipulating the research direction towards resilience. Since the supplier is one of the important supply chain elements, the challenges can be overcome through resilient supplier selection. Supplier selection is a multi-criteria decision-making problem where several criteria are involved (Leong et al. 2022). The ultimate goal of supplier selection is to select the right suppliers according to the supply chain resilience capabilities of the companies. As suppliers are unavoidable vital resources, choosing a better supplier will help create liquidity to reduce supply chain risks as a whole. For this purpose, identifying and extracting the key factors of supplier resilience and evaluating the factors and selecting the most important factors and the sequence between them will be very useful. To achieve these goals, in this study, first, with a comprehensive review of the literature and interviews with upstream petrochemical industry experts, 6 key and general factors were identified. Then, using the opinions of industry experts and using the fuzzy Delphi approach, the criteria identified from the literature were re-examined and finally all the criteria were approved. Then, using the BWM technique, the weights of the criteria were calculated, and finally, the suppliers were evaluated and ranked by using the TOPSIS technique and the opinions of the relevant experts.

The analytical results of the techniques were obtained as follows:

- Based on the fuzzy Delphi technique, all six key parameters in supplier resilience were confirmed in terms of effectiveness.
- Based on the BWM, the factor of "supplier risk reduction" with higher final weight was extracted as the most important factor in supplier equity.
- Based on the TOPSIS, the fourth supplier was in the first place and the second supplier was in the last place.

Based on the results, suggestions for future research can be made as follows:

- In connection with the evaluation of supply chain resilience, more studies were done and used the data envelopment analysis technique and other techniques.
- Considering that it is very important to use any system to identify the obstacles and to implement it, then in the next research it can be identified the key barriers to implementing the supply chain resilience system in the upstream petrochemical industry with other related industries and national ones and appropriate solutions to address these barriers and promote this system.
- Using confirmatory factor analysis, it evaluated and tested 6 key and general extractive factors in the industry and, if effective, approved these factors to improve supplier resilience.
- Using other techniques such as SWARA, hierarchical analysis process, etc., re-evaluate and calculate the weight of the indicators and compare it with the output of this research.
- Using the interpretive structural modeling approach, it evaluated the relationships between key parameters and extracted the factor leveling model.
- The structural interpretation modeling approach has been used to explain the relationships between indicators as well as their classifying. By using the structural equation modeling approach, the proposed structural model is tested and analyzed.

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References

Abraz, S. (2007). Identifying and Prioritizing Effective Factors in Managing Supply Chain Management Using Network Analysis Technique (Case study: Sman Khodro), Master's degree in industrial engineering at Islamic Azad University, Najaf Abad (In Persian).

Adler, L., (1966). Symbiotic marketing. Harv. Bus. Rev. 44 (6), 59e71.

Ajalli, M. (2024). Conceptual modeling of determining factors in the assessment of sustainability and resilience of the supply chain: a study of rubber industry suppliers in Iran. Journal of Rubber Research, 27, 259–274.

Ajalli, M., Azimi, H., Mohammadi Balani, A., Rezaei, M. (2017). Application of Fuzzy AHP and COPRAS to Solve the Supplier Selection Problems. Int. J Sup. Chain. Mgt, Vol. 6, No. 3, September.

Ajalli, M., Homayounfar M., Zinati B., Saberifard N. (2021a). Evaluating and ranking the green suppliers by combining the path analysis and decision technics, Logistics Thought Scientific Publication, Volume 20, Issue 78 - Serial Number 20, December, Pages 153-183.

Ajalli, M., Mozaffari, M. M., & Asgharisarem, A. (2019a). A hybrid FSIR-TOPSIS approach for selecting of manufacturing levers. Management and Production Engineering Review, 10, 69-82.

Ajalli, M., Mozaffari, M.M., Salahshori, R. (2019b). Ranking the Suppliers using a Combined SWARA-FVIKOR Approach, Int. J Sup. Chain. Mgt, Vol. 8, No. 1, February.

Ajalli, M., Saberifard, N., Zinati, B. (2021b). Evaluation and Ranking the Resilient Suppliers with the Combination of Decision Making Techniques, Management and Production Engineering Review, Volume 12, Number 3, September, pp. 129–140, DOI: 10.24425/mper.2021.137685.

Ajalli, M., Safari. H., and Mozaffari, M.M. (2021c). Analyzing Key Dimensions of Suppliers Resilience Using a Combined Approach of Path Analysis and Fuzzy DEMATEL, Iranian Journal Trade Studies (IJTC) Quartery, 24, 96, 61–96.

Amani, M., Ashrafi, A., Dehghan, H. (2017). "Obstacles to green supply chain acceptance using fuzzy DEMATELtechnique", Journal of Information Technology Management Studies, 91(15), pp. 147-179.

Ayough, A., Boshruei, S., & Khorshidvand, B. (2022). A new interactive method based on multi-criteria preference degree functions for solar power plant site selection. Renewable Energy, 195, 1165-1173.

Ayough, A., Shargh, S. B., & Khorshidvand, B. (2023). A new integrated approach based on base-criterion and utility additive methods and its application to the supplier selection problem. Expert Systems with Applications, 221, 119740.

Bagherzadeh, A., (2017). Designing a Concept Model for Rescuing Supply Chain by National Iranian Oil Company, P.H.D in industrial management, University of Tehran (In Persian).

BBC News, 18 Mar (2011). Japan disaster: Supply shortages in three months. BBC News. (accessed 11.02.17).

Blackhurst, J., Craighead, C.W., Elkins, D., Handfield, R.B., 2005. An empirically derived agenda of critical research issues for managing supply-chain disruptions. Int. J. Prod. Res. 43 (19), 4067e4081.

Bouzon, M., Govindan, K., Rodriguez, C. M. T., & Campos, L. M. S. (2016). Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. Resources, Conservation and Recycling, 108, 182–197.

Carvalho, H., Barroso, A. P., Machado, V. H., Azevedo, S., & Cruz-Machado, V. (2012). Supply chain redesign for resilience using simulation. Computers & Industrial Engineering, 62(1), 329-341.

Chiang, C., Kocabasoglu-Hillmer, C. and Suresh, N. (2012), "An empirical investigation of the impact of strategic sourcing and flexibility on firm's supply chain agility", International Journal of Operations & Production Management, Vol. 32 No. 1, pp. 49-78.

Chiou, T.Y., Chan, H.K., Lettice, F., Chung, S.H., (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. Transp. Res. Part E: Logist. Transp. Rev. 47 (6), 822e836.

Christopher, M., & Holweg, M. (2011). "Supply Chain 2.0": managing supply chains in the era of turbulence. International Journal of Physical Distribution & Logistics Management, 41(1), 63-82.

Christopher, M., (2010). Logistics and Supply Chain Management. Financial Times/ Prentice Hall.

Clegg, B., Chandler, S., Binder, M., Edwards, J., (2012). Governing inter-organisational R&D supplier collaborations: a study at Jaguar Land Rover. Prod. Plan. Control 24 (8e9), 818e836.

Dalalah, D., Hayajneh, M., & Batieha, F. (2011). A fuzzy multi-criteria decision making model for supplier selection. Expert Systems with Applications, 38(7), 8384–8391.

De Boer, L., Labro, E., Morlacchi, P., (2001). A review of methods supporting supplier selection. Eur. J. Purch. Supply Manag. 7 (2), 75e89.

Govindan, K., Sivakumar, R., (2016). Green supplier selection and order allocation in a low-carbon paper industry: integrated multi-criteria heterogeneous decision making and multi-objective linear programming approaches. Ann. Oper. Res. 238, 243–276.

Hall, J., 16 Apr (2010). Volcanic Ash Cloud Leaves Shops Facing Shortages of Fruit, Vegetables and Medicine. The Daily Telegraph.

Hartmann, E., De Grahl, A., (2011). The flexibility of logistics service providers and its impact on customer loyalty: an empirical study. J. Supply Chain Manag. 47 (3), 63e85.

Holmstr€om, J., Ala-Risku, T., Auramo, J., Collin, J., Eloranta, E., Salminen, A., (2010). Demand-supply chain representation: a tool for economic organizing of industrial services. J. Manuf. Technol. Manag. 21 (3), 376e387.

Hosseini SeyedAmir, Choukolaei Hassan Ahmadi, Ghasemi Dardaei-beiragh Peiman, Helia, Sherafatianfini Soheil, and Adel Pourghader Chobar (20220. Evaluating the Performance of Emergency Centers during Coronavirus Epidemic Using Multi-Criteria Decision-Making Methods (Case Study: Sari City), Discrete Dynamics in Nature and Society, Volume 2022, Article ID 6074579, 13 pages.

Hosseini, S., Khaled, A.A. (2019). A hybrid ensemble and AHP approach for resilient supplier selection. Journal of Intelligent Manufacturing, 30, 207–228.

Igoulalene, I., Benyoucef, L., & Kumar Tiwari, M. (2015). Novel fuzzy hybrid multi-criteria decision making approaches for the strategic supplier selection problem. Expert Systems with Applications, 42(7), 3342–3356.

Jafarnejad, Ahamad, & Mohseni, Maryam (2015), Provide Framework for Improving Supply Chain Performance, Scientific journal of supply chain management, year 17, number 48 (In Persian).

Jafarnejad, Ahmad, Kazemi, Alie & Alireza Arab (2016), Identification and Prioritization of Suppliers' Resilience Assessment Indicators Based on The Best – The /worst Method, Industrial Management Outlook, Number 23, P. 159-186 (In Persian).

Jahani (2006), Designing a Supply chain Anchoring Model with an SEM Approach, M.A Industrial Management, Tarbiat Modarres University, Tehran (In Persian).

Jayaram, J., Xu, K., Nicolae, M., (2011). The direct and contingency effects of supplier coordination and customer coordination on quality and flexibility performance. Int. J. Prod. Res. 49 (1), 59e85.

Kamalahmadi, M., & Parast, M. M. (2016). A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. International Journal of Production Economics, 171, 116-133.

Kar, A. K. (2014). Revisiting the supplier selection problem: An integrated approach for group decision support. Expert Systems with Applications, 41(6), 2762–2771.

Karsak, E. E., & Dursun, M. (2014). An integrated supplier selection methodology incorporating QFD and DEA with imprecise data. Expert Systems with Applications, 41(16), 6995–7004.

Kern, D., Moser, R., Hartmann, E., Moder, M., (2012). Supply risk management: model development and empirical analysis. Int. J. Phys. Distrib. Logist. Manag. 42 (1), 60e82.

Khodabakhsh et al (2018), A research entitled "Identification and Ranking of Supply Chain Resilience in Critical Situations with Non-Opening Defense Approach", Year 9, Number 1, Successive 33, P. 25-36 (In Persian).

Kiani Mavi, R., Kiani Mavi, N., Hosseini Shekarabi, S.A. et al. (2024). Supply Chain Resilience: A Common Weights Efficiency Analysis with Non-discretionary and Non-controllable Inputs. Glob J Flex Syst Manag (2024).

Kloyer, M., Scholderer, J., (2012). Effective incomplete contracts and milestones in market-distant R&D collaboration. Res. Policy 41 (2), 346e357.

Kyu Kim, K., Yul Ryoo, S., Dug Jung, M., (2011). Inter-organizational information systems visibility in buyeresupplier relationships: the case of telecommunication equipment component manufacturing industry. Omega 39 (6), 667e676.

Lavastre, O., Gunasekaran, A., Spalanzani, A., (2012). Supply chain risk management in French companies. Decis. Support Syst. 52 (4), 828e838.

Lee, A.H., Kang, H.Y., Hsu, C.F., Hung, H.C., (2009). A green supplier selection model for high-tech industry. Expert Syst. Appl. 36 (4), 7917e7927.

Lee, J., Cho, H., & Kim, Y. S. (2014). Assessing business impacts of agility criterion and order allocation strategy in multi-criteria supplier selection. Expert Systems with Applications, 42(3), 1136–1148.

Leong, W.Y.; Wong, K.Y.; Wong, W.P. A New Integrated Multi-Criteria Decision-Making Model for Resilient Supplier Selection. Appl. Syst. Innov. 2022, 5, 8. https:// doi.org/10.3390/asi5010008.

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, 38(9), 10803–10811.

Locke, R.M., Romis, M., (2012). Improving work conditions in global supply chains. MIT Sloan Manag. Rev. 48.

Mahapatra, S.K., Narasimhan, R., Barbieri, P., (2010). Strategic interdependence, governance effectiveness and supplier performance: a dyadic case study investigation and theory development. J. Oper. Manag. 28 (6), 537e552.

Mohammed Ahmed, Harris Irina, Soroka Anthony, Mohamed Naim and Ramjaun Tim, (2018). Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach, ICORES 2018 - 7th International Conference on Operations Research and Enterprise Systems.

Mohammed, A.; Yazdani, M.; Oukil, A.; Santibanez Gonzalez, E.D.R. (2021). A Hybrid MCDM Approach towards Resilient Sourcing. Sustainability, 13, 2695.

Nazlabadi, (2016), The Relationship Between Supply Chain Performance and Supply Chain Resilience, Master's thesis in industrial management, Tehran, Higher education and research institute of management and planning (In Persian).

Peck, H., (2005). Drivers of supply chain vulnerability: an integrated framework. Int. J. Phys. Distrib. Logist. Manag. 35 (4), 210e232.

Pfohl, H.C., K€ohler, H., Thomas, D., (2010). State of the art in supply chain risk management research: empirical and conceptual findings and a roadmap for the implementation in practice. Logist. Res. 2 (1), 33e44.

Punniyamoorthy, M., Mathiyalagan, P., Parthiban, P., (2011). A strategic model using structural equation modeling and fuzzy logic in supplier selection. Expert Syst. Appl. 38 (1), 458e474.

Purvis, L., Spall, S., Naim, M. and Spiegler, V. (2016). Developing a resilient supply chain strategy during 'boom' and 'bust', Production Planning & Control, 27:7-8, 579-590.

Rajesh, R., & Ravi, V. (2015). Supplier selection in resilient supply chains: a grey relational analysis approach. Journal of Cleaner Production, 86, 343-359.

Ravanestan Kazem, Aqajani, Hasanali, Safaighadikelai, Abdolhamid, & Yahyaizadehfar, Mahmood, (2017), Designing a Resilient Model in Iran Khodro Supply Chain with the Approach of Structural Modeling and Delphi Techniques, Industrial management journal of Islamic Azad University, Sanandaj, Year 12, Number 40 (In Persian).

Ravanestan, Kazem, Aghajani, Hasanali, Safaighadikelaii, Abdolhamid, & Yahyaiifar, Mahmud, (2017), Determining and Weighting Resiliency Strategies in Iran Khodro Supply Chain, Industrial Management outlook, Number 25, P. 145-172 (In Persian).

Rezaei, J. (2015a). Best-worst multi-criteria decision-making method. Omega, 53, 49-57.

Rezaei, J. (2015b). Best-worst multi-criteria decision-making method: Some properties and a linear model. Omega.

Rezaei, J., Nispeling, T., Sarkis, J., & Tavasszy, L. (2016b). A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. Journal of Cleaner Production.

Roh, J., Hong, P., Min, H., (2014). Implementation of a responsive supply chain strategy in global complexity: the case of manufacturing firms. Int. J. Prod. Econ. 147 (Part B), 198e210.

Sahebjamnia N. (2020). Resilient supplier selection and order allocation under uncertainty, Scientia Iranica E, Volume 27, Issue 1, Transactions on Industrial Engineering (E). January and February, Pages 411-426.

Salman Nazari-Shirkouhi, Mahdokht Tavakoli, Kannan Govindan, Saeed Mousakhani (2023). A hybrid approach using Z-number DEA model and Artificial Neural Network for Resilient supplier Selection, Expert Systems with Applications, Volume 222, 119746.

Seuring, S., Müller, M., (2008). From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. 16 (15), 1699e1710.

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. Computers & Industrial Engineering, 74, 11-25.

Squire, B., Cousins, P.D., Lawson, B., Brown, S., (2009). The effect of supplier manufacturing capabilities on buyer responsiveness: the role of collaboration. Int. J. Oper. Prod. Manag. 29 (8), 766e788.

Tate, W.L., Dooley, K.J., Ellram, L.M., (2011). Transaction cost and institutional drivers of supplier adoption of environmental practices. J. Bus. Logist. 32 (1), 6e16.

Torabi, S.A., Baghersad, M., Mansouri, S.A., (2015). Resilient supplier selection and order allocation under operational and disruption risks. Transportation Research Part E 79, 22–48.

Wang T.-C., Chang T.-H., (2007). Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment, Expert Systems with Applications 33, 870–880.

Wang, S.Y., Chang, S.L., Wang, R.C., (2009). Assessment of supplier performance based on product-development strategy by applying multigranularity linguistic term sets. Omega 37 (1), 215e226.

Wang, W., Plante, R.D., Tang, J., (2013). Minimum cost allocation of quality improvement targets under supplier process disruption. Eur. J. Oper. Res. 228 (2), 388e396.

World Economic Forum. (2013). Building Resilience in Supply Chains: Report. Switzerland: World Economic Forum.

Wu, D.D., Zhang, Y., Wu, D., Olson, D.L., (2010). Fuzzy multiobjective programming for supplier selection and risk modeling: a possibility approach. Eur. J. Oper. Res. 200 (3), 774e787.

Yeung, K., Lee, P.K., Yeung, A.C., Cheng, T.C.E., (2013). Supplier partnership and cost performance: the moderating roles of specific investments and environmental uncertainty. Int. J. Prod. Econ. 144 (2), 546e559.

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.