Management and Production Engineering Review
Volume 12 • Number 3 • September 2021 • pp. 129–140
DOI: 10.24425/mper.2021.137685

Evaluation and Ranking the Resilient Suppliers with the Combination of Decision Making Techniques

Mehdi Ajalli[1], Nima Saberifard[2], Babak Zinati[2]

[1] *Bu-Ali Sina University, Department of Management, Hamedan, Iran*
[2] *Islamic Azad University, Department of Industrial Management, Rasht Branch, Rasht, Iran*

Received: 26 June 2019
Accepted: 07 May 2021

Abstract
Supply chain management emerged as the ultimate management strategy to ensure the competitive advantages of companies in their markets. Suppliers are considered as inevitable sources of external risks in modern supply chains. In this respect, resonance is essential for the ability to adapt in resonance to disturbances and to restore in choosing suppliers. As suppliers of critical resources are vulnerable, choosing better suppliers to create resilience, and thereby reducing the risks in the supply chain as a whole. In recent years, emphasis has been placed on supply chain resilience and resilient suppliers, but few studies have been conducted on the evaluation and selection of resilient suppliers with multi-criteria decision making models. The main purposes of this study are a broad review of the literature on the resilient factor, factorization, efficiency of key factors in the reliance of suppliers and the ranking of resilient suppliers using the combined approach of SWARA and WASPAS. For this purpose, after a comprehensive review of Literature interview with the experts of petrochemical upstream industry, six key factors and overall resilience of suppliers were identified in eighteen factors. Then the weight of the dimensions was determined by using the SWARA method. The output of the method showed that supplier accountability and key performance factors were the most important factors in assessing the resilience of suppliers. Using the supporting method, five resilient suppliers were evaluated based on six dimensions and the final ranking of suppliers was determined. With this ranking, the industry will be a major step towards improving supply chain and increasing suppliers' resilience to address disruptions and risks, improve supply and achieve competitive advantage and satisfy the consumers' needs.

Keywords
Key dimensions of resilience of suppliers, SWARA technique, WASPAS method, ranking.

Introduction

The problem and decision making process and the selection of suppliers play a key role in supply chain management, because purchasing involves more than 50 percent of the company's costs. Selection and evaluation of suppliers is the process of finding suppliers capable of timely and high quality products and reasonable prices. But the selection of suppliers is a challenging concept, which involves evaluating quantitative indicators that are vague and limited in formulation. The choice of suppliers is an important issue of multi criteria decision making and includes two main tasks: 1. Determine the desired criteria; 2. Compare suppliers' worthiness. The traditional criteria associated with the selection of suppliers are divided in two quantitative categories. The suppliers' quantitative criteria include transferring costs, order and purchase costs, delivery times and defect rates, while qualitative criteria include product quality, warranties, claimed policies, performance history. Technical capability, geographic location and working relationship. Despite this importance, other evaluation criteria such as timely and reliable delivery that affect productivity and efficiency on a production environment and overall costs should be considered. Ha & Krishman (2008) emphasized 23 parameters used by decision makers in assessing provides. They presented these metrics and suggested several other criteria. Besides, most traditional business metrics include quality, cost and delivery.

***Corresponding author**: dr Mehdi Ajalli – Bu-Ali Sina University, Department of Management, Hamedan, Iran, e-mail: mehdiajalli@gmail.com*

In recent years, the concept of resilience has been widely used to explore the behavior of underlying disorders and several resilience measures have been proposed. The concept of resilience is the ability of a supply chain company to be resilient and simultaneously improving against disruptions in the supply chain management perspective. Supply disturbances can impose significant losses to the entire supply chain by cutting off the supply flows.

For example, a devastating earthquake in the center of Taiwan in September 1999, severe consequences for many manufacturing organizations and industries as a total loss of industrial production had left about 1/2 billion dollars.

Petrochemical supply chains are factors that are heavily sensitive to disturbances. Because of its activity in a field with rapid technological changes and uncertainties in its activities, this industry is subject to a wide range of disruptions that can reduce the competitiveness of customer satisfaction and ultimately reduce its profitability. For this purpose, one of the main requirements of this document is the use of suppliers that are able to meet the lowest cost and time and the most reliable. In this context, one of the main measures to achieve the goals of the industry is to take advantage of resilient suppliers that are able to meet the demand of the company.

In this study, the combination of SWARA and WASPAS is used to weigh the factors and ranking of the suppliers in petrochemical industry, considering that there is no internal or external research on the resilience of the suppliers using the combined approach, the importance of this study and the need to increase the ranking of industry suppliers is expanding.

The following article is organized as follows:

In section two, the background and history of studies have been discussed. In section three, the key dimensions for the selection of resilient suppliers have been extracted. In the fourth part of the research, methodology presented. In section five, the proposed approach is a combination of the WASPAS and SWARA. In section six, the analysis and the findings of the study included the calculation of the weight of factors using WASPAS technique and finally, in section seven, conclusions and suggestions for future research are presented.

Literature review

A review of internal and external literature suggests that there are a few research studies on solving resonant supply problems using quantitative approaches and decision making. It is also revealed that there was neither internal nor external research on the evaluation and ranking of suppliers with the combination of SWARA and WASPAS approach.

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. Rajesh & Ravi (2015) have identified five key dimensions as: “Key Performance Factors”, “Supplier Accountability”, “Reduce the Supplier Risk”, “Technical Support Suppliers” and “Supplier Stability” for assessing supplier resilience. In current study, after extensive overreview of literature and iterview by experties of the industry, the concepts of “knowledge management” and “knowledge sharing and use of information technology” were extracted from internal and external studies. Therfore the sixth dimension as “IT MANAGEMENT” is considered in this study. In order to identify resiliency measurement indicators and ranking the suppliers of industry, six general key dimensions of reviewing literature (eighteen factors) and interviewing experts in upstream petrochemical industries are presented in Table 1.

Table 1
Key factors for selecting suppliers in resilient supply chains (2004–2021)

No.	External Resources	Indicators	Keys
1	Ajalli et al., 2021; Dyer & Hatch, 2004; Rajesh & Ravi, 2015; Talib et al., 2011; Wang et al., 2013; Xie et al., 2011; Zeydan et al., 2011	Quality	Key Performance Factors
2	Ajalli et al., 2021; Friedl & Wagner, 2012; Helper & Sake, 2012; Li, 2013; Rajesh & Ravi, 2015; Yeung et al., 2013	Cost	
3	Ajalli et al., 2021; Chung et al., 2010; Gosling et al., 2010; Hartmann & De Grahl, 2011; Jayaram et al., 2011; Liao et al., 2010; Rajesh & Ravi, 2015	Flexibility	

Table 1 [cont.]

No.	External Resources	Indicators	Keys
4	Ajalli et al., 2021; Azevedo et al., 2010; Bode et al., 2011; Chiang et al., 2012; Christopher & Holweg, 2011; Mohammed et al., 2018; Pettit et al., 2011; Purvis et al., 2016; Rajesh & Ravi, 2015; Roh et al., 2014; Soni et al., 2014	Velocity, Agility and Supply Chain	Supplier Accountability
5	Ajalli et al., 2021; Awaysheh & Klassen, 2010; Caridi et al., 2010; Christopher & Holweg, 2011; Holmström et al., 2010; Kamal & Parast, 2016; Lee et al., 2009; Ponomarov & Holcomb, 2009; Rajesh & Ravi, 2015	Visibility of the supply chain	
6	Ajalli et al., 2021; Rajesh & Ravi, 2015; Whipple & Roh (2010); Wagner & Neshat (2010); Chan & Larsen (2010); Zhang et al., 2009;	Vulnerability	Reduce the Supplier Risk
7	Ajalli et al., 2021; Ha et al., 2011; Kamal & Parast, 2016; Lager & Frishammar, 2010; Park et al., 2010; Rajesh & Ravi, 2015; Soni et al., 2014; Spiegler et al., 2012; Squire et al., 2009; Wagner & Neshat, 2010	Collaboration among actors	
8	Blome & Schoenherr, 2011; Foerstl et al., 2010; Kern et al., 2012; Lavastre et al., 2012; Matook et al., 2010; Rajesh & Ravi, 2015;	Risk Awareness	
9	Gopalakrishnan et al., 2012; Lavastre et al., 2012; Pagell &Wu, 2009; Pfohl et al., 2010; Rajesh & Ravi, 2015; Tang & Musa, 2011	Supply Chain Management	
10	Pfohl et al., 2010; Soni et al., 2014	Risk and revenue sharing	
11	Rajesh & Ravi, 2015; Locke & Romis, 2012; Martínez-Noya & García-Canal, 2011; Ivarsson & Alvstam, 2011; Pfohl et al., 2010; Mahapatra et al., 2010; Torres-Fuchslocher, 2010	Technological Abilities	Technical Support Suppliers
12	Clegg et al., 2012; Cousins et al., 2011; Kloyer & Scholderer, 2012; Pfohl et al., 2010; Rajesh & Ravi, 2015; Schiele et al., 2011; Wang et al., 2013	Research and development	
13	Carvalho et al., 2012; Kamal & Parast, 2016; Mohammed et al., 2018; Pfohl et al., 2010; Zsidisin & Wagner, 2010	Redundancy	
14	Ajalli et al., 2021; Blackhurst et al., 2005; Carvalho et al., 2012; Christopher & Holweg, 2011; Lee et al., 2009; Pettit et al., 2010; Pfohl et al., 2010;	Complexity	
15	Ajalli et al., 2021; Dyer & Hatch, 2004; Locke & Romis, 2012; Punniyamoorthy et al., 2011; Rajesh & Ravi, 2015; Tate et al., 2011;	Safety	Supplier Stability
16	Ajalli et al., 2021; Chiou et al., 2011; Hsu et al., 2011; Kyu et al., 2011; Lee et al., 2009; Rajesh & Ravi, 2015;	Concerns for the environment	
17	Ajalli et al., 2021; Blackhurst et al., 2005; Lee et al., 2009; Soni et al., 2014	Knowledge Management	IT Management
18	Ajalli et al., 2021; Blackhurst et al., 2005; Carvalhoo et al., 2012; Chiang et al., 2012; Christopher & Holweg, 2011; Kamal & Parast, 2016; Soni et al., 2014	Information sharing by using information technology	

Materials and methods

In this research, after extracting key dimensions in the evaluation and selection of suppliers of upstream petrochemical industries, the view of ten industry experts were used to compare the pairs between indices and calculating their weight by using SWARA method. Ultimately, industry suppliers rank by using WASPAS method. Therefore, this research is a quantitative research (SWARA and WASPAS method). Accordingly, two basic questions are raised:

Q1: What are the key dimensions in assessing suppliers of resilience to upstream petrochemical industries?

Q2: what is the ranking of industry suppliers based on key extractive dimensions?

Figure 1, shows the psychological flowchart presented in this study.

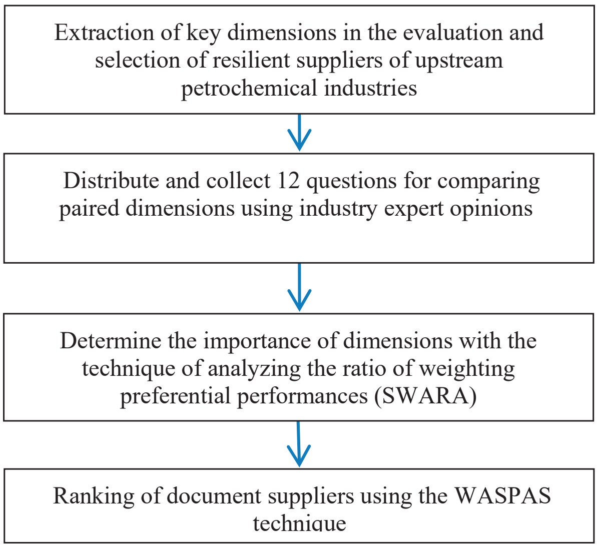

Fig. 1. The flowchart of research psychological

Step-wise Weight Assessment Ratio Analysis (SWARA)

As stated above, the SWARA method is the subjective method for determining the weight of the indices by experts, which after ranking them, we can calculate their weight. The weight of each factors, indicates its importance.

The executive steps of SWARA method are as follows (Zavadskas et al., 2013a; 2013b; Zolfani et al., 2013; Aghdaie et al., 2013):

Step one: The percentage of comments by each indicator is calculated by dividing the number of comments of that indicator into the number of experts. Rank the indicators in descending order by the percentage of comments.

Step two: Create a new table in which indicators are removed in order of priority; that is, the indicator that has ranked one in the first column, the indicator that has ranked two in the second column and continue in this order. In the next steps, the first indicator is the one that id ranked in column one. Others are like this ranking.

Step three: Calculate the relative differences in the view of each indicator relative to the next indicator (s_j), which is equal to the difference in the percentage of comments from each indicator relative to its previous index. This value is not calculated for the first index. So the relative importance of the first index is written in relation to the second index in the column for the second index.

Step four: We can calculate the growth parameter (k_j) in this way: for the indicator with the rank one equals one, and for the other indicators, the sum of one and relative importance of s_j is related to its indicator.

$$k_j = 1 + s_j, \quad j \neq 1.$$

Step five: The importance of retrieving q_j the index is equal to 1, which for the next indicator is equal to the result of dividing q_j the previous indicator k_j into that indicator.

$$q_j = \frac{q_{j-1}}{k_j}, \quad j \neq 1.$$

Step six: By dividing q_j of each indicator to total indicators, q_j, the weight of each indicator is obtained.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j}.$$

WASPAS method

Currently, several multi criteria decision making methods are available to help organizations choose the best options. Each selection basically consists of four main stages: 1. Options; 2. Indicators; 3. The importance of the weight of each indicator; 4. Performance measures of the options, taking into account different indicators. These types of arbitrary structures are well suited for using multi criteria decision making techniques. Therefore, the main purpose of any multi criteria decision making approach is to select the best option from a set of possible option in the presence of different parameters. This research is trying to use and justify the decision of a multi criteria decision making approach called WASPAS method (Chakraborty & Zavadskas, 2014). WASPAS is one of the effective multi criteria decision making techniques that were first introduced in 2012 and has the ability to accurately evaluate options in all of the selection issues. The WASPAS method is a combination of two well-known multi criteria decision making approaches called weighted sum model and Weight product model and uses the matrix decision and weight indicators as inputs and ranking options. Multi criteria decision making problem begins with the following evaluation matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix},$$

m is the number of candidates, n is the number of evaluation criteria, x_{ij} is the performance of the i with the j criterion.

To apply this method, first of all, it is necessary to linear normalization the elements of the decision matrix using the following two equations:

For helpful indicators (positive):

$$\overline{x}_{ij} = \frac{x_{ij}}{\max_{ix_{ij}}}.$$

For useless indicators (negative):

$$\overline{x}_{ij} = \frac{\min_{ix_{ij}}}{x_{ij}}.$$

Here, $\overline{x}_{ij}$ is the normal value of x_{ij}.

In the technique of foundation, a common criterion of optimality is the pursuit of the optimal alternative. The first criterion of optimality is the mean weight success rate similar to that of the WSM model. This technique is a valid multi criteria decision making approach for evaluating a number of options against a number of decision criteria. Based on the WSM method (MacCrimon, 1968), the relative importance of the I option is calculated as follows:

$$R_i^{(1)} = \sum_{j=1}^{n} N_{ij} \times W_j .$$

Here, W_j is the weight of j, in other words, given the WM model (Miller & Starr, 1969), the overall ratio of the i option is calculated as follows:

$$R_i^{(2)} = \prod_{j=1}^{n} N_{ij}^{w_j}.$$

Execution Algorithm

In brief, the implementation of this technique consists of five steps:

Step one: the formation of a normal weighted decision matrix ($Wn_{ij}^{(1)}$) by weight trapping if indices (W_j) in the linear matrix (N_{ij}):

$$Wn_{ij}^{(1)} = N_{ij} \times W_j.$$

Step two: calculate the total weight of normal matrix line as follows:

$$R_i^{(1)} = \sum_{j=1}^{n} Wn_{ij}^{(1)}.$$

Step three: the formation of a normal weighing matrix ($Wn_{ij}^{(2)}$): we make a linear normal matrix for the weights of the indexes:

$$Wn_{ij}^{(2)} = N_{ij}^{w_j}.$$

Step four: the calculation of the product is a normal weighed matrix line ($R_i^{(2)}$):

$$R_i^{(2)} = \prod_{j=1}^{n} Wn_{ij}^{(2)}.$$

Step five: calculate the mean scores of normal weight (R_i^1) and jaundice and power matrices (R_i^2) as follows and prioritize options in descending order R_i:

$$R_i = \frac{R_i^{(1)} + R_i^{(2)}}{2}.$$

This index is a common criterion for the multiplicative and addictive methods (Zavadskas et al., 2013a; 2013b).

In order to increase the accuracy and effectiveness of ranking in the multi criteria decision making approach WASPAS, a general equation for determining the relative importance of the option i has been developed as follows:

$$R_i = \gamma R_i^1 + (1-\gamma) R_i^2$$
$$= \gamma \sum_{j=1}^{n} N_{ij} \times W_j + (1-\gamma) \prod_{j=1}^{n} N_{ij}^{w_j} \quad (= 0, 0.1, \ldots, 1).$$

Now, we can rank the options based on the best value R, so that the options are the most R and the best options. When the γ value is zero, the WASPAS methods converted to WPM method and when its one, WASPAS method converted to WSM method. So far, the WASPAS method has had little application in the researches, that one of the most important researches being the selection of the location (Zolfani et al., 2013) and domain engineering civilization issues (Staniunas et al., 2013).

Results

Calculate the weight key dimensions of the suppliers' resilience with SWARA

The SWARA method is the subjective method for determining the weight if indicators by using experts' opinion, which then calculates the indicators and their weight after ranking them (Ajalli & Mozaffari, 2018). In this research, the key indicator in the assessment of resilience of suppliers of upstream petrochemical industries was extracted, as shown in Table 2.

Then, using SWARA technique, we evaluate these dimensions. For this purpose, ten industry experts (Table 3) in this field evaluated the dimensions. The weight of each criterion indicates its importance.

Table 2
Key dimensions in assessing resilient suppliers

Extractive Dimensions	Sign
Key factors of supplier performance	R1
Supplier accountability	R2
Supplier risk	R3
Technical support suppliers	R4
Supplier stability	R5
IT management	R6

Table 3
Information about experts

<table>
<tr><th>Number</th><th>Classification</th><th>Group</th></tr>
<tr><td>4</td><td>Managers</td><td rowspan="2">Work Experience</td></tr>
<tr><td>6</td><td>Deputies and Engineers</td></tr>
<tr><td>1</td><td>B.A</td><td rowspan="3">Level of education</td></tr>
<tr><td>7</td><td>M.A</td></tr>
<tr><td>2
10</td><td>P.H.D
Male</td></tr>
<tr><td>–</td><td>Female</td><td>Gender</td></tr>
</table>

For this purpose, after extracting the comments from each of the news about the identified dimensions, the initial weight of the dimensions were extracted and in fact each of the experts were asked to prioritize each of them separately as these five indicators, and in order to calculate the relative importance of these criteria, the number of priorities for each indicator is proportional to the opinions of the experts. For example, the first index is twice replaced in priority one, twice in priority two, four times in priority three, once in priority four and once in priority five. After prioritizing the dimensions by the experts, calculate the weight of each, the number of priorities for each index multiplied by the difference in the highest score and the corresponding score.

Table 4 shows the final calculation related to the weight and importance of each of the indicators analyzed using EXCEL software, which can be dimensioned based on the weight of last column.

As it is shown, suppliers' accountability as the most important indicator and supplier sustainability as the least important indicator in the assessment of resilient suppliers in the upstream petrochemical industry has been identified.

Ranking the suppliers resilient industry with WASPAS method

Steps one and two: First, the decision matrix of the linear normal of the suppliers is extracted according to the dimensions in Table 5.

Then all the qualitative dimensions of Table 6 converted to quantitative dimensions as Table 6.

The normal linear decision matrix is obtained as Table 7.

Subsequently, multiplicative weighted normal linear decision matrix was obtained from the product of Table 6 in factors weight, and the sum of the rows of the normalized weighted multiplicity matrix were extracted in Table 8.

Steps three and four:
At these stages, the normal linear decision matrix (Table 7) is minimizing Pain of weight power of indicators to obtain the normalized strength–weight matrix (Table 9). Such, Line multiplication of the normalized strength–weight matrix is extracted in the last column of Table 9.

Step five:
Finally, the average of score of the multiplicative weighted normal linear decision matrix and the normalized strength–weight matrix (the average values of last column of Table 8 and Table 9 for any alternative) and ranking alternatives were obtained as Table 10.

Table 4
Final calculations related to the weight and importance of key dimensions

Indicator	Sj	$K_j = S_j + 1$	W_j	Q_j	Rank
Supplier Accountability (R2)	–	1	1	0.262	1
Key performance Factors (R1)	0.297	1.297	0.771	0.202	2
Supplier risk (R3)	0.207	1.207	0.639	0.167	3
Technical support Suppliers (R4)	0.180	1.180	0.541	0.142	4
IT Management (R6)	0.162	1.162	0.466	0.122	5
Supplier Stability (R5)	0.153	1.153	0.404	0.106	6

Table 5
Decision matrix with qualitative dimensions

Indicators Alternatives	Supplier Accountability	Key Performance Factors	Supplier Risk	Technical Support Suppliers	IT Management	Supplier Stability
	R_1^+	R_2^+	R_3^+	R_4^+	R_5^+	R_6^+
A1	Very High	Average	High	Lov	Average	High
A2	Average	High	Average	High	High	Average
A3	Very High	High	Low	Low	Average	Very High
A4	Low	Very High	Very High	Very High	Very High	Average
A5	High	Average	Average	High	Low	Low

Table 6
Decision matrix with quantitative values

Indicators Alternatives	Supplier Accountability	Key Performance Factors	Supplier Risk	Technical Support Suppliers	IT Management	Supplier Stability
	R_1^+	R_2^+	R_3^+	R_4^+	R_5^+	R_6^+
A1	9	5	7	3	5	7
A2	5	7	5	7	7	5
A3	9	8	3	3	5	9
A4	3	9	9	9	9	5
A5	7	5	5	7	3	3

Table 7
Normal linear decision matrix

Indicators Alternatives	Supplier Accountability	Key Performance Factors	Supplier Risk	Technical Support Suppliers	IT Management	Supplier Stability
	R_1^+	R_2^+	R_3^+	R_4^+	R_5^+	R_6^+
A1	1	0.556	0.429	0.333	0.600	0.778
A2	0.556	0.212	0.600	0.778	0.778	0.600
A3	1	0.212	1	0.333	0.600	1
A4	0.333	1	0.333	1	1	0.600
A5	0.778	0.556	0.600	0.778	0.333	0.333
Weight	$w_1 = 0.202$	$w_2 = 0.262$	$w_3 = 0.167$	$w_4 = 0.142$	$w_5 = 0.106$	$w_6 = 0.122$

Table 8
The multiplicative weighted normal linear decision matrix and the sum of the matrix rows

Indicators Alternatives	Supplier Accountability	Key Performance Factors	Supplier Risk	Technical Support Suppliers	IT Management	Supplier Stability	Sum of the rows
	R_1^+	R_2^+	R_3^+	R_4^+	R_5^+	R_6^+	
A1	0.202	0.146	0.072	0.047	0.064	0.095	0.626
A2	0.112	0.056	0.100	0.111	0.083	0.073	0.535
A3	0.202	0.056	0.167	0.047	0.064	0.122	0.658
A4	0.067	0.262	0.056	0.142	0.106	0.073	0.706
A5	0.157	0.146	0.100	0.111	0.035	0.041	0.590

Table 9
The normalized strength – weight matrix and the multiplication of the matrix line

Indicators Alternatives	Supplier Accountability	Key Performance Factors	Supplier Risk	Technical Support Suppliers	IT Management	Supplier Stability	Line multiplication
	R_1^+	R_2^+	R_3^+	R_4^+	R_5^+	R_6^+	
A1	1	0.858	0.868	0.855	0.947	0.970	0.585
A2	0.888	0.666	0.918	0.965	0.974	0.940	0.480
A3	1	0.666	1	0.855	0.947	1	0.539
A4	0.801	1	0.832	1	1	0.940	0.627
A5	0.951	0.858	0.918	0.965	0.890	0.875	0.563

Table 10
Average of final scores and ranking of alternatives

Factors	Final Ranking	Ranking
A1	0.6055	2
A2	0.5075	5
A3	0.5985	3
A4	0.6665	1
A5	0.5765	4

Conclusions and recommendations

The problem and decision making process and the selection of suppliers play a key role in supply chain management, because purchasing involves more than 50 percent of the company's costs (Mohammad et al., 2017a). Selection and evaluation of suppliers is the process of finding suppliers capable of timely and high quality products and reasonable prices. But the selection of suppliers is a challenging concept, which involves evaluating quantitative indicators that are vague and limited in formulation. The choice of suppliers is an important issue of multi criteria decision making and includes two main tasks: 1. Determine the desired criteria; 2. Compare suppliers' worthiness. The traditional criteria associated with the selection of suppliers are divided in two quantitative categories. The suppliers' quantitative criteria include transferring costs, order and purchase costs, delivery times and defect rates, while qualitative criteria include product quality, warranties, claimed policies, performance history. Technical capability, geographic location and working relationship (Barker, 2016).

Disturbances in the supply chain come from both internal and external sources. In most cases, suppliers are considered as inevitable sources of external risks. Suppliers' selection is a multi-criteria decision making problem and includes quantitative and qualitative indicators. Selection of suppliers, taking into account more prioritization of the risks associated with issues, will reduce the supply chain vulnerability.

In this research, after a review of the literature and history of internal and external studies and interview with the experts of upstream petrochemical industries, the key factors of supply chain resonance were extracted. The weight of the factors was determined by using the SWARA method as a new approach in multi criteria decision making. Following of from WASPAS technology, the resilient suppliers of the industry ranked and the most resilient suppliers identified and delivered to the industry. Comparing the final results of this sturdy, the following results can be obtained from the output of major internal studies:

- In the study of Jafarnezhad et al. (2006) and his colleagues, using the best-the worst technique, agility, redundancy and observation of indicators were identifies as the most important indicators of the resilient assessment of Orand company.
- The variables of flexibility, management culture, cooperation risk, redundancy and agility were extracted in the order of the most important variables in supply chain resonance, in the master's thesis presented by Jahani (2006).

In this research, the suppliers' response as the most important factor in the evaluation of resilient suppliers and sustainability factor in the last priority were important. Based on the above results, the following suggestions can be introduced:

- 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.
- 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.

References

Aghdaie, M.H., Hashemkhani, Z.S., Derakhti A., Zavadskas, E.K., and Morshed Varzandeh M.H. (2013). *Decision making on business issues with foresight perspective; An application of new hybrid MCDM model in shopping mall locating*, Expert Syst. Appl., 40, 17, 7111–7121.

Ajalli, M. and Mozaffari M.M. (2018). *Appraisal the Key Factors of SCQM using a Combined Approach of SWARA-FISM*, International Journal of Supply Chain Management, 7, 4, 13–21.

Ajalli, M., Safari. H., and Mozaffari, M.M. (2021). *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.

Awaysheh, A. and Klassen, R.D. (2010). *The impact of supply chain structure on the use of supplier socially responsible practices*, Int. J. Oper. Prod. Manag., 30, 12, 1246–1268.

Azevedo, S.G., Carvalho, H., Cruz-Machado, V., and Grilo, F. (2010). *The influence of agile and resilient practices on supply chain performance: an innovative conceptual model proposal*, in: Innovative processes and solutions in logistics and SCM: Emerging trends, concepts and technologies, Verlag GmbH & Co. KG, pp. 265–281.

Barker, K. (2016). *An Approach for Modeling Supplier Resilience*, Proceedings of the Thirteenth Annual Acquisition Research Symposium Thursday Sessions Volume II.

Blackhurst, J., Craighead, C.W., Elkins, D., and Handfield, R.B. (2005). *An empirically derived agenda of critical research issues for managing supply-chain disruptions*, Int. J. Prod. Res., 43, 19, 4067–4081.

Blome, C. and Schoenherr, T. (2011). *Supply chain risk management in financial crisesda multiple case-study approach*, Int. J. Prod. Econ., 134, 1, 43–57.

Bode, C., Wagner, S.M., Petersen, K.J., and Ellram, L.M. (2011). *Understanding responses to supply chain disruptions: insights from information processing and resource dependence perspectives*, Acad. Manag. J., 54, 4, 833–856.

Caridi, M., Crippa, L., Perego, A., Sianesi, A., and Tumino, A. (2010). *Do virtuality and complexity affect supply chain visibility?*, Int. J. Prod. Econ., 127, 2, 372–383.

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

Chakraborty S. and Zavadskas E.K. (2014). *Applications of WASPAS Method in Manufacturing Decision Making*, Informatica, 25, 1, 1–20.

Chan, S. and Larsen, G.N. (2010). *A framework for supplier-supply chain risk management: tradespace factors to achieve risk reductiond. Return on investment*, In: IEEE International Conference on Technologies for Homeland Security (HST), pp. 29–34.

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, 32, 1, 49–78.

Chiou, T.Y., Chan, H.K., Lettice, F., and 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, 822–836.

Christopher, M., and 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.

Chung, W., Talluri, S., and Narasimhan, R. (2010). *Flexibility or cost saving? Sourcing decisions with two suppliers*, Decision Science, 41, 3, 623–650.

Clegg, B., Chandler, S., Binder, M., and Edwards, J. (2012). *Governing inter-organisational R&D supplier collaborations: a study at Jaguar Land Rover*, Prod. Plan. Control, 24, 8-9, 818–836.

Cousins, P.D., Lawson, B., Petersen, K.J., and Handfield, R.B. (2011). *Breakthrough scanning, supplier knowledge exchange and new product development performance*, J. Prod. Innov. Manag., 28, 6, 930–942.

Dyer, J.H. and Hatch, N.W. (2004). *Using supplier networks to learn faster*, MIT Sloan Manag. Rev., 45, 3, 57–63.

Foerstl, K., Reuter, C., Hartmann, E., and Blome, C. (2010). *Managing supplier sustainability risks in* *a dynamically changing environment. Sustainable supplier management in the chemical industry*, J. Purch. Supply Manag., 16, 2, 118–130.

Friedl, G. and Wagner, S.M. (2012). *Supplier development or supplier switching?*, Int. J. Prod. Res., 50, 11, 3066–3079.

Gopalakrishnan, K., Yusuf, Y.Y., Musa, A., Abubakar, T., and Ambursa, H.M. (2012). *Sustainable supply chain management: a case study of British Aerospace (BAe) Systems*, Int. J. Prod. Econ., 140, 1, 193–203.

Gosling, J., Purvis, L., and Naim, M.M. (2010). *Supply chain flexibility as a determinant of supplier selection*, Int. J. Prod. Econ., 128, 1, 11–21.

Ha, B.C., Park, Y.K., and Cho, S. (2011). *Suppliers' affective trust and trust in competency in buyers: its effect on collaboration and logistics efficiency*, Int. J. Oper. Prod. Manag., 31, 1, 56–77.

Ha, S.H. and Krishnan, R. (2008). *A hybrid approach to supplier selection for the maintenance of a competitive supply chain*, Expert Sys. with Appl., 34, 1303–1311.

Hartmann, E. and 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, 63–85.

Helper, S.R. and Sake, M. (2012). *Supplier relations in Japan and the United States: are they converging?*, MIT Sloan Manag. Rev., 36, 3, 77–85.

Holmström, J., Ala-Risku, T., Auramo, J., Collin, J., Eloranta, E., and Salminen, A. (2010). *Demand-supply chain representation: a tool for economic organizing of industrial services*, J. Manuf. Technol. Manag., 21, 3, 376–387.

Hsu, C.W., Kuo, T.C., Chen, S.H., and Hu, A.H. (2011). *Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management.* J. Clean. Prod., 56, 1, 164–172.

Ivarsson, I., and Alvstam, C.G. (2011). *Upgrading in global value-chains: a case study of technology-learning among IKEA-suppliers in China and Southeast Asia*, J. Econ. Geogr., 11, 4, 731–752.

Jafarnezhad Chaghooshi, A., Kazemi, A., and Arab, A. (2006). *Identification and Prioritization of Supplier's Resiliency Evaluation Criteria Based on BWM*, J. Industrial Management Outlook, 6, 3, 159–186 (In Persian).

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

Jayaram, J., Xu, K., and 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, 59–85.

Kamal A.M. and 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.

Kern, D., Moser, R., Hartmann, E., and Moder, M. (2012). *Supply risk management: model development and empirical analysis*, Int. J. Phys. Distrib. Logist. Manag. 42, 1, 60–82.

Kloyer, M. and Scholderer, J. (2012). *Effective incomplete contracts and milestones in market-distant R&D collaboration*, Research Policy, 41, 2, 346–357.

Kyu K.K., Yul Ryoo, S., and Dug Jung, M. (2011). *Inter-organizational information systems visibility in buyeresupplier relationships: the case of telecommunication equipment component manufacturing industry*, Omega, 39, 6, 667–676.

Lager, T. and Frishammar, J. (2010). *Equipment supplier/user collaboration in the process industries: in search of enhanced operating performance*, J. Manuf. Technol. Manag., 21, 6, 698–720.

Lavastre, O., Gunasekaran, A., and Spalanzani, A. (2012). *Supply chain risk management in French companies*, Decis. Support Syst., 52, 4, 828–838.

Lee, A.H., Kang, H.Y., Hsu, C.F., and Hung, H.C. (2009). *A green supplier selection model for high-tech industry*, Expert Syst. Appl., 36, 4, 7917–7927.

Li, C. (2013). *Sourcing for supplier effort and competition: design of the supply base and pricing mechanism*, Manag. Sci., 59, 6, 1389–1406.

Liao, Y., Hong, P., and Rao, S.S. (2010). *Supply management, supply flexibility and performance outcomes: an empirical investigation of manufacturing firms*, J. Supply Chain Manag., 46, 3, 6–22.

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

MacCrimon, K.R. (1968). *Decision Making among Multiple Attribute Alternatives: A Survey and Consolidated Approach*, Rand memorandum, RM-4823-ARPA.

Mahapatra, S.K., Narasimhan, R., and Barbieri, P. (2010). *Strategic interdependence, governance effectiveness and supplier performance: a dyadic case study investigation and theory development*, J. Oper. Manag., 28, 6, 537–552.

Martínez-Noya, A. and García-Canal, E. (2011). *Technological capabilities and the decision to outsource/outsource offshore R&D services*, Int. Bus. Rev., 20, 3, 264–277.

Matook, S., Lasch, R., and Tamaschke, R. (2009). *Supplier development with benchmarking as part of a comprehensive supplier risk management framework*, Int. J. Oper. Prod. Manag., 29, 3, 241–267.

Miller, D.W. and Starr, M.K. (1969). *Executive Decisions and Operations Research*, Prentice-Hall, Englewood Cliffs.

Mohammed, A., Harris, I., Soroka, A., Mohamed, N., and Ramjaun, T. (2018). *Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach*, ICORES 2018 – 7th International Conference on Operations Research and Enterprise Systems.

Park, J., Shin, K., Chang, T.W., and Park, J. (2010). *An integrative framework for supplier relationship management*, Ind. Manag. Data Syst., 110, 4, 495–515.

Pettit, T.J., Fiksel, J., and Croxton, K.L. (2010). *Ensuring supply chain resilience: development of a conceptual framework*, Journal of Business Logistics, 31, 1, 1–21.

Pfohl, H.C., Köhler, H., and 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*, Logistics Research, 2, 1, 33–44.

Ponomarov, S.Y. and Holcomb, M.C. (2009). *Understanding the concept of supply chain resilience*, Int. J. Logist. Manag., 20, 1, 124–143.

Punniyamoorthy, M., Mathiyalagan, P., and Parthiban, P. (2011). *A strategic model using structural equation modeling and fuzzy logic in supplier selection*, Expert Syst. Appl., 38, 1, 458–474.

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. and Ravi, V. (2015). *Supplier selection in resilient supply chains: a grey relational analysis approach*, Journal of Cleaner Production, 86, 343–359.

Roh, J., Hong, P., and 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), 198–210.

Schiele, H., Veldman, J., and Hüttinger, L. (2011). *Supplier innovativeness and supplier pricing: the role of preferred customer status*, Int. J. Innov. Manag., 15, 1, 1–27.

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

Spiegler, V.L., Naim, M.M., and Wikner, J. (2012). *A control engineering approach to the assessment of supply chain resilience*, International Journal of Production Research, 50, 21, 6162–6187.

Squire, B., Cousins, P.D., Lawson, B., and Brown, S. (2009). *The effect of supplier manufacturing capabilities on buyer responsiveness: the role of collaboration*, Int. J. Oper. Prod. Manag., 29, 8, 766–788.

Staniunas, M., Medineckienė, M., Zavadskas, E.K., and Kalibatas, D. (2013). *To modernize or not: ecological-economical assessment ofmulti-dwelling houses modernization*, Archives of Civil andMechanical Engineering, 13, 1, 88–98.

Talib, F., Rahman, Z., and Qureshi, M.N. (2011). *A study of total quality management and supply chain management practices*, Int. J. Prod. Perform. Manag., 60, 3, 268–288.

Tang, O. and Musa, N.S. (2011). *Identifying risk issues and research advancements in supply chain risk management*, Int. J. Prod. Econ., 133, 1, 25–34.

Tate, W.L., Dooley, K.J., and Ellram, L.M. (2011). *Transaction cost and institutional drivers of supplier adoption of environmental practices*, J. Bus. Logist., 32, 1, 6–16.

Torres-Fuchslocher, C. (2010). *Understanding the development of technologyintensive suppliers in resource-based developing economies*, Res. Policy, 39, 2, 268–277.

Wagner, S.M. and Neshat, N. (2010). *Assessing the vulnerability of supply chains using graph theory*, Int. J. Prod. Econ., 126, 1, 121–129.

Wang, W., Plante, R.D., and Tang, J. (2013). *Minimum cost allocation of quality improvement targets under supplier process disruption*, Eur. J. Oper. Res. 228, 2, 388–396.

Whipple, J.M. and Roh, J. (2010). *Agency theory and quality fade in buyer-supplier relationships*, Int. J. Logist. Manag., 21, 3, 338–352.

Xie, G., Yue, W., Wang, S., and Lai, K.K. (2011). *Quality investment and price decision in a risk-averse supply chain*, Eur. J. Oper. Res., 214, 2, 403–410.

Yeung, K., Lee, P.K., Yeung, A.C., and 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, 546–559.

Zavadskas, E.K., Antucheviciene, J., Šaparauskas, J., and Turskis, Z. (2013a). *Multi-criteria assessment of facades' alternatives: peculiarities of ranking methodology*, Procedia Engineering, 57, 107–112.

Zavadskas, E.K., Antucheviciene, J., Saparauskas, J., and Turskis, Z. (2013b). *MCDM methods WASPAS and MULTIMOORA: verification of robustness of methods when assessing alternative solutions*, Economic Computation and Economic Cybernetics Studies and Research, 47, 2, 5–20.

Zeydan, M., Çolpan, C., Çobanoğlu, C. (2011). *A combined methodology for supplier selection and performance evaluation*, Expert Syst. Appl., 38, 3, 2741–2751.

Zhang, Y., Lindell, M.K., and Prater, C.S. (2009). *Vulnerability of community businesses to environmental disasters*, Disasters, 33, 1, 38–57.

Zolfani, S.H., Aghdaie, M.H., Derakhti, A., Zavadskas, E.K., and Varzandeh, M.H.M. (2013). *Decision making on business issues with foresight perspective; an application of new hybrid MCDM model in shopping mall locating*, Expert Systems with Applications, 40, 17, 7111–7121.

Zsidisin, G.A. and Wagner, S.M. (2010). *Do perceptions become reality? The moderating role of supply chain resiliency on disruption occurrence*, Journal of Business Logistics, 31, 2, 1–20.