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Investigating the Different Layer's Risk and the Resilience of Petrochemical Industry Supply Chains and Its Function in the Analytical Model

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Abstract: *The present study aimed at investigating the risks of various layers and the resilience of petrochemical industry supply chains and its function in the analytical model. This study was developmental in terms of purpose and of descriptive- mathematical models in terms of method. In order to test the model, 50 senior and middle managers from 9 Iranian petrochemical companies were examined to rank the resilience of risks in the companies they were working. In addition, the scoring of risk and resilience of upstream, organizational and downstream processes of these companies was examined. The research tool allowing the respondents to assess the level of risk in the supply chain was derived from the Wagner and Bod's model (2008). In this study, the research tools were updated based on risk grouping. In addition, the items associated to the evaluation of supply chain resilience in this study were defined based on to the supply chain resilience criteria to the items of stability, redundancy, high-thinking, reaction, and recovery efficiency being regarded the same for all three processes. Since the variables had a various frequency distribution, in this study the threshold levels of Tabachnick and Fidell (2007) were used, such that 0.32 was equal to weak, 0.45 was appropriate, 0.55 was good, 0.63 was very good and 0.71 was excellent. The results indicated that although a supply chain system may have a higher resilience than its risks, its layers may be still at risk.*

Keywords:*Different layers' risk, resilience, supply chain, petrochemical industry.*

INTRODUCTION

Supply chain is a set of units including customers, retailers, wholesalers/distributors, manufacturers and suppliers of components/materials which directly or indirectly contribute to satisfying the needs of a customer. Accordingly, there are three main flows of product, information, and finance in the supply chain. The effective management of the supply chain needs the management of these three major flows in such a way that the supply chain is of a dynamic and diverse nature and full of the flow of information, product, and capital from the different steps of its development (Ivanov and Boris, 2013) In a supply chain, it is significant to make coordinated decisions, regarding the requirements and features of the different steps of the chain. This significance can be explained by looking at the bullwhip effect.
One of the main factors in creating this study is the inconsistency of the supply chain's steps in adopting favorable policies. When each step of the chain acts as a single-level system, independently, and without

regard to the other steps of the policy, it will have the reaction of other steps. The lack of coordination in making decisions through the supply chain from loops is closer to the customer and the supply chain of primary materials as well as components, exacerbates demand fluctuations; thus, that small volatility in the amount of customer demand has significant variability in the decisions of other steps (Kaminsky and Simchi-Levi, 2008).

The significance of this study for managing multi-level systems is summarized as follows:

First, in a competitive environment, companies are searching how to speed up their activities and operations. The issues such as globalization and expansion of networks like the Internet are vital issues affecting the provision of resources, marketing, and other issues which companies are involved with. By developing the resources and enhancing the distribution channels, companies alone cannot produce and distribute all the parts they require and their own products. In this case, it is significant that the materials and components of the suppliers are provided by implementing the processes in the companies, the output obtained in the distribution channels will reach the customer. Therefore, there should be a chain of various companies which work together to produce and supply the product. Accordingly, the supply chain discussion is raised. Companies are significantly adding to supply chains and preferring to compete as part of a supply chain against other supply chains. Defining the supply chain in a chain is possible to include all activities related to the flow of products and the conversion of materials from the step of procurement of raw materials to the step of delivery of final products to the consumer (Hamidieh and ArshadiKhamseh, 2016).

Second, supply chains always involve multi-level systems, where storage is carried out at various levels under the management and ownership of various units. Accordingly, using developed models for single-level systems in these systems will not be sufficient and the specific features of these multi-level structures indicate the significance of developing and using specific models good for them. Third, in the case of designing a model to manage multi-level systems, this system should be compatible with the features of these systems. Since the distribution networks have various features, multi-level systems in supply chains each have specific features which should be regarded in designing their respective models (this change in the features and design of distribution networks and multi-level systems can be observed in the different assumptions which various researchers have provided in their models for multi-level systems. In this regard, enough explanation is presented in the background section of the study.

The chemical industry in today's world, particularly the petrochemical industry, is one of the industries where investment is highly sensitive. the reasons as follows:

1. They need for investments. 2. They are pollutants to the environment. 3. They usually consume high energy. There is a requirement for continuous development and innovation to use new technology and enhance the quality of production. They need raw materials. Some people think that they have sufficient raw materials to invest in the petrochemical industry while most countries in this field either have no raw materials themselves or have not used their raw materials to produce petrochemicals (Vilko, 2012). Reducing international sanctions in Iran's petrochemical industry and creating new investment opportunities in the country, although it decreased our country's risk rating by 0.6%, but decreased the petrochemical industry score by 0.1 unit in the first quarter of 2014 and reached to 59. Thus, Iran is still ranked fifth in the Middle East and Africa in terms of risk-return index. Although sanctions have dropped in the petrochemical industry in comparison to the past, it has not had a significant effect on exports of these products in the first three months of this year, and although 3.6% more exports were conducted in comparison to same period last year, we are still 2.9 %lower than the average annual export of petrochemicals (Business Monitor, 2017). However, the launch of new complexes requiring $ 31 billion in investment can enhance the production level and export volumes to 55 million. Sanctions, the cancellation of contracts with foreign companies, low prices for petrochemicals in Iran being 50 %to 70 % lower than global prices and lower oil production will be the main threats to the petrochemical industry in the future. However, Iran can address such threats given the high

demand for its products and progress in gas fields and special economic and industrial areas and the import of technology in the petrochemical industry from other countries (Jafari et al., 2008).
With a 4% reduction in the size of petrochemicals exports, along with a slight increase as 1%in the value of these products, the continued decrease in feed levels particularly in the cold season of the past year, caused manufacturers in this sector to stop at the times of inactivity. The cost of this stop is estimated to be around $ 1.5 billion. However, if the country can enhance the gas share of the petrochemical sector from 7% to 25% next year, many problems will be resolved.
Iran was ranked fifth in the region with 59% of risk / return after Saudi Arabia, UAE, Qatar and Kuwait. This indicator measures the country's ranking by evaluating the efficiency of the petrochemical industry, the country's returns, the risk of the petrochemical industry, and the risk of the country. However, analyzing the scores and rankings indicates that although our country's profitability in the petrochemical industry is more than other like Saudi Arabia, our country's risk rating in the industry (10 units out of 100) is the least in the first 10 countries. On the other hand, the score for the overall economy of the country is 47.6 after Nigeria, the minimum for the first 10 countries in the region. The statistics on risk side also indicate that the country's economic risk rating is less for us than all the first 10 countries in the region. Political risk and continuous economic reduction of the country in recent years are two important factors for low risk and returns in the country. However, it is expected that Iran's position in this ranking will enhance in the years to come. At the meantime, the strict laws associated with foreign investment, financial infrastructure, redundant administrative bureaucracy for trade, sanctions problems, etc. have all had an impact on the risks of industry and economy (Boromandkakhki and Akhavan, 2018). However, the main issue of this study is that what are the various layers' risks and resilience of petrochemical industry supply chain and how is its function in the analytical model?
In this regard, the following sub-questions are raised:

1. What structure does the petrochemical supply chain have?
2. What are the input, output, and intermediate indicators between the different steps of this chain?
3. What mathematical model is used in network data envelopment analysis to evaluate the resilience of risks in this chain?
4. How is the efficiency of petrochemical companies evaluated in terms of resilience to risks based on the designed model?

Theoretical framework

Here, with the acknowledgment of conducted studies on supply chain resilience from a systemic point of view (cited in Wieland and Carl Marcus, 2013, the goal is to progress an analytical model which can supply chain decision-makers in terms of resilience to system-level supply chain risks. In order to achieve the objective of this study, a multivariate approach was chosen which allows designing and testing an analytical model for evalauting the resilience of supply chain risks. In order to develop an analytical model for risk and assess the resilience in a three-step supply chain, data envelopment analysis and fuzzy theory were used. As will be discussed later in this chapter, in this study, data envelopment analysis allows for the integration of risk and resilience criteria as data and supply chain data as well as the possibility of comparing the current level of resilience presents for the different risks of supply chain with the desired levels of resilience which the decision-makers are aiming for. In addition, data envelope network analysis presents three comparisons at the process level (like those that supply the supply chain) and at the system level (supply chain as entity). The data envelopment analysis, introduced by Charens (1978), evaluates the relative efficiency of the number of n decision-maker units (DMUs) that use m data to generate output s. The model is a fraction of the k-th decision maker, i.e. DMUk, presented by Charles, Cooper, and Rhodes (1978) (CCR), is as follows:

$$E_k = \max \sum_{r=1}^{s} u_r Y_{rk} \Big/ \sum_{i=1}^{m} v_i X_{ik}$$

s.t.

$$\sum_{r=1}^{s} u_r Y_{rj} \Big/ \sum_{i=1}^{m} v_i X_{ij} \leq 1, j = 1,2, \dots, n \tag{1}$$

$$u_r \geq \varepsilon > 0, r = 1,2, \dots, s$$

$$v_i \geq \varepsilon > 0, i = 1,2, \dots, m,$$

In this model,
s is the number of output variables;
m is the Number of input variables;
r is the output variables index, $(r = 1,2, \dots, s)$
i is the input variables index, $(i = 1,2, \dots, m)$
j is the decision maker units index, $(j = 1,2, \dots, n)$
$Y_{rk}$is the r-th output value $(r = 1,2, \dots, s)$ of the decision maker k
$X_{ik}$is the i-th input value , $i = 1,2, \dots, m$ of the decision maker k
$u_r$is the output variable coefficient $(r = 1,2, \dots, s)$ in evaluating the efficiency of the decision maker k
$v_i$is the it-h input coefficient$(i = 1,2, \dots, m)$ in evaluating the efficiency of the decision maker k
And ε is a small Archimedes value.
Using the Charles and Cooper transformation method, model (2) becomes a linear programming model as follows:

$$E_k = \max \sum_{r=1}^{s} u_r Y_{rk}$$

s.t.

$$\sum_{i=1}^{m} v_i X_{ik} = 1$$

$$\sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, j = 1,2, \dots, n \tag{2}$$

$$u_r \geq \varepsilon > 0, r = 1,2, \dots, s$$

$$v_i \geq \varepsilon > 0, i = 1,2, \dots, m$$

This model, which is the first model of data envelopment analysis, is named multi-input input-axis model. This model actually presents a nonparametric estimate of the production function, assuming that the set can generate a convex set with a constant-scale return. After presenting this model, various forms of the various types of data envelopment analysis models were provided by various researchers. The present study presents a proposed model for evaluating resilience in a three-step supply chain according to the figure.Considering the network nature of the problem under study, we need to use a network of data envelopment analysis models. By developing the model number (2) into the data envelopment analysis model, the probability of calculating risk and resilience variables in a three- step supply chain can be provided. In addition, it has been shown that data envelopment analysis is more powerful than the conventional black-box model, and thus the reliability of the model results enhances (cited in Mandal, 2014).

Methodology

This study was developmental and evaluation based on purpose and was a descriptive study of mathematical modeling typein terms of method. The statistical population included the supply chain of active companies in the petrochemical industry. In order to select a sample, a combination of judicious methods and snowball methods were used, which was a non-probabilistic method.
The five criteria for selecting participants in this study are:

- Being key
- Identified by others
- Theoretical understanding of the subject
- Variety
- Agree to partnership

The quantitative indicators which can be considered in choosing experts are:

- Senior managers with at least 15 years of experience in direct petrochemical industry
- Middle managers with at least 8 years of experience in petrochemical industry management
- Experts and academic scholars with at least two scientific and research papers in this field.

Table 1. The specifications of the selected petrochemical companies and the number of selected experts

row	Institution/company name	Type (public / private)	Number of experts (from company / institution)
1	Bandar Imam Khomeini	public	8
2	Shazand	public	8
3	Shiraz	private	5
4	Jam	public	6
5	Tabriz	public	5
6	Isfahan	private	6
7	Qeshm	public	5
8	Maron	public	3
9	Fanavaran Technology	public	4

50 senior and middle managers from nine Iranian petrochemical companies to rank the resilience and risks of the companies they are involved in, as well as risk and resilience evaluation of the upstream, downstream and organizational companies of these companies. The study aimed at prioritizing risks and resilience of the model. In case of the workplace in person and attended to participate in completing the questionnaire in a quarterly return to evaluate the main assumptions of the model while the items associated with the risks to the upstream, downstream and organizational processes were various, items about resilience for these processes were regarded to be constant. These linear variables were converted to triangular fuzzy numbers and ranged from 1 to 9.
After defining the problem and identifying its various dimensions for data analysis in this study, the mathematical modeling was used to design the model in a network of three-level network supply chain DEA. In order to optimize the model of one of the most widely used methods, it was broadly used in fuzzy data envelopment analysis an approach based on alpha cuts. For each petrochemical company, the average fuzzy items of risk and resilience items were extracted and aggregated to realize the main risks and resilience of the supply chain of the group. Finally, MATLAB 2014b Software was used to code the model and create the associated membership function diagrams. Values (= 1α) and (= 0α) were used to identify the range and most likely values of the efficiency score. With that in mind, the upper and lower scores of the 9 supply chains are used for alphas 0 and 1 (each for three layers).

Considering that the model of this research is a type of mathematical modeling, a reliable and valid analysis is not generally considered. However, in mathematical modeling, there is a mathematical model of validity that can meet the research objectives, which naturally at the end of the research, by checking whether the goals are met, are valid. In addition, this research has a reference model, from which the model has obtained acceptable results and has been approved by the experts in the studied industries, which indicates that reasonable responses have been taken. In addition, using different alpha methods, the analysis of the fuzzy efficiency scores is reviewed and compared and the model's sensitivity is presented.

Modeling

1. **General efficiency model**

In this research, a network model has been used to assess the efficiency of upstream, downstream and downstream processes of petrochemical companies in order to assess chain resilience. For each of the supply chain process layers, four efficiency scores are calculated: upstream processes efficiency, organizational processes, and downstream processes along with the overall efficiency of the supply chain system. In order to estimate overall efficiency, the three-step process model was considered as Figure 1.

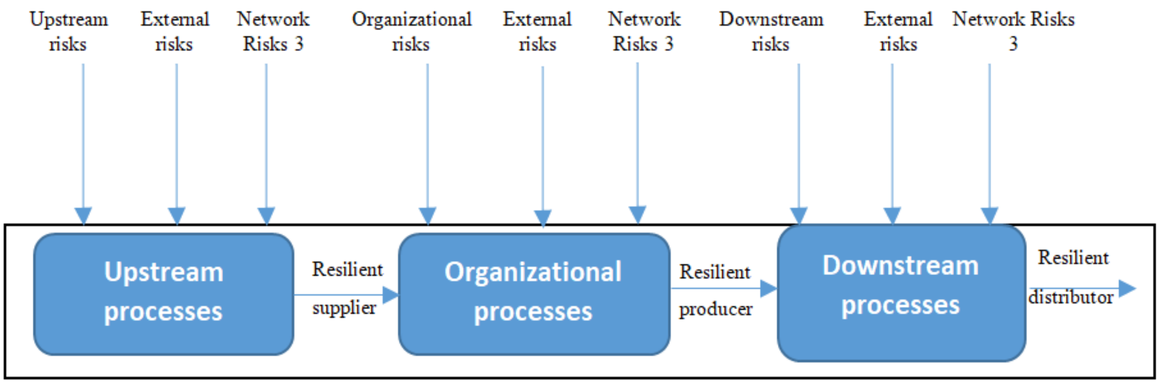

Figure 1. Three-step model of processes

In Figure 1, the processes inside the box are considered as black boxes and the overall efficiency of the chain is formulated using classical models. According to Cao and Huang (2008), the overall efficiency of the DMUk supply chain system will be formulated as follows:

$$\tilde{E}_k = \max \frac{u_3 \tilde{Y}_3^k}{\sum_{t=1}^{3} \sum_{i=1}^{3} v_{ti} \tilde{X}_{ti}^k}$$

s.t.

$$\frac{u_3 \tilde{Y}_3^j}{(\sum_{t=1}^{3} \sum_{i=1}^{3} v_{ti} \tilde{X}_{ti}^j)} \leq 0, j = 1,2, \dots, n \qquad (3)$$

$$v_{ti}, u_3, \geq \varepsilon, i = 1,2,3; \; t = 1,2,3$$

In the above model, the objective function seeks to maximize the overall efficiency of DMUk, and the constraints of the problem indicate that the efficiency of all decision-making units should be less than one. Which is the same as the fractional CCR model. By modifying the Charness-Cooper variable, the linear model is formulated as follows.

$$\tilde{E}_k = \max u_3 \tilde{Y}_3^k \qquad (4)$$

s.t.

$\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\widetilde{X}_{ti}^{k}=1$

$u_3\widetilde{Y}_3^{j} - (\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\widetilde{X}_{ti}^{j}) \leq 0, j = 1,2,\dots,n$

$1,2,\dots,n$

$v_{ti}, u_3, \geq \varepsilon, i = 1,2,3;\ t = 1,2,3$

2. **Partial efficiency**

Similarly, one can resign each of the upstream, downstream and downstream processes with regard to the input risks and output resilience. Assume that $\widetilde{E}_k^1$, $\widetilde{E}_k^2$، and $\widetilde{E}_k^3$ are respectively the resilience of upstream, downstream and downstream processes of the k-th petrochemical company is under review.Consider the upstream processes. In these processes, three upstream, organizational and network risks are defined as input and resilience as output. Accordingly, the efficiency of this part of the system can be defined as follows:

$$\widetilde{E}_k^1 = w_1^*\widetilde{Z}_1^k \Big/ \sum_{i=1}^{3} v_{1i}^*\widetilde{X}_{1i}^k \tag{5}$$

Similarly, organizational processes produce resilience to upstream processes as well as corporate, external and network risks as inputs and resilience as output. Resilience of organizational processes is formulated as follows.

$$\widetilde{E}_k^2 = w_2^*\widetilde{Z}_2^k \Big/ w_1^*\widetilde{Z}_1^k + \sum_{i=1}^{3} v_{2i}^*\widetilde{X}_{2i}^k \tag{6}$$

A similar provision can be made for downstream processes. These processes generate resilience to organizational processes, along with downstream, enterprise, and network risks as inputs and generate as outputs. As a result, the resilience of these processes is formulated as follows:

$$\widetilde{E}_k^3 = u_3^*\widetilde{Y}_3^k \Big/ w_2^*\widetilde{Z}_2^k + \sum_{i=1}^{3} v_{3i}^*\widetilde{X}_{3i}^k \tag{7}$$

With respect to the constraints of less than one in the values of efficiency, relations (5) - (6) can be considered as model constraints.

$$\begin{aligned} & w_1^*\widetilde{Z}_1^k \Big/ \sum_{i=1}^{3} v_{1i}^*\widetilde{X}_{1i}^k \leq 1 \\ & w_2^*\widetilde{Z}_2^k \Big/ w_1^*\widetilde{Z}_1^k + \sum_{i=1}^{3} v_{2i}^*\widetilde{X}_{2i}^k \leq 1 \\ & u_3^*\widetilde{Y}_3^k \Big/ w_2^*\widetilde{Z}_2^k + \sum_{i=1}^{3} v_{3i}^*\widetilde{X}_{3i}^k \leq 1 \end{aligned} \tag{8}$$

By linearizing the above constraints and adding them to model (4), the final model for the evaluation of petrochemical processes resilience is formulated as follows.

$$\widetilde{E}_k = \max u_3\widetilde{Y}_3^k \tag{9}$$

S.T.

$$\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^{k} = 1$$

$$u_3\tilde{Y}_3^j - (\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^{j}) \le 0, j = 1,2,\dots,n$$

$$w_1\tilde{Z}_1^j - \sum_{i=1}^{3} v_{1i}\tilde{X}_{1i}^{j} \le 0, j = 1,2,\dots,n$$

$$w_2\tilde{Z}_2^j - (w_1\tilde{Z}_1^j + \sum_{i=1}^{3} v_{2i}\tilde{X}_{2i}^{j}) \le 0, j = 1,2,\dots,n$$

$$u_3\tilde{Y}_3^0 - (w_2\tilde{Z}_2^j + \sum_{i=1}^{3} v_{3i}\tilde{X}_{3i}^{j}) \le 0, j = 1,2,\dots,n$$

$$v_{ti}, u_3, w_1, w_2 \ge \varepsilon, i = 1,2,3;\ t = 1,2,3$$

Model (9) is a fuzzy linear programming model whose solution requires the development of specific methods. In the present study, to solve the fuzzy linear model, an alpha-based approach is used, which is described below.

3. Using fuzzy sets and α-cut approach for proposed DEA network model

Various approaches have been proposed for solving fuzzy linear programming problems by researchers. One of the most widely used methods, which, according to HatamiMarbini, EmruzNegad and Tavana (2014), is widely used in fuzzy data envelopment analysis, is an alpha-based approach. In this approach, fuzzy numbers are replaced with their alpha cuts and the problem is solved for different alpha values. According to the definition, the alpha cut of a fuzzy set contains all elements of the reference set, whose membership in the reference set is at least equal to the value of α (cited in Soni et al, 2014). Given the fact that the fuzzy numbers in this study are intended to evaluate the types of risk and resilience indices of triangular fuzzy numbers, fuzzy cuts will be considered for these numbers. For a triangular fuzzy number (l, m, u), the membership function is defined as follows.

$$\mu = \begin{cases} 0, x \le l \\ \dfrac{x-l}{m-l}, l \le x \le m \\ \dfrac{u-x}{u-m}, m \le x \le u \\ 0, x \ge u \end{cases}$$

Considering the definition of the alpha cut for the membership function, we have:

$$\frac{x-l}{m-l} \ge \alpha \to x \ge l(1-\alpha) + \alpha m$$

And

$$\frac{u-x}{u-m} \ge \alpha \to \le u(1-\alpha) + \alpha m$$

As a result, the alpha cut of the triangular fuzzy number contains all the values at the interval [l (1 -α) + αm, u (1-α) + αm]. By applying the above definition to triangular fuzzy numbers of risk types and resiliency indices, the alpha cuts of the above indices are calculated as follows.

$$
\begin{aligned}
&(X_{11})_\alpha = [(X_{11})_\alpha^L, (X_{11})_\alpha^U] = [(1-\alpha)X_{11}^1 + \alpha X_{11}^2, \alpha X_{11}^2 + (1-\alpha)X_{11}^3] \\
&(X_{12})_\alpha = [(X_{12})_\alpha^L, (X_{12})_\alpha^U] = [(1-\alpha)X_{12}^1 + \alpha X_{12}^2, \alpha X_{12}^2 + (1-\alpha)X_{12}^3] \\
&(X_{13})_\alpha = [(X_{13})_\alpha^L, (X_{13})_\alpha^U] = [(1-\alpha)X_{13}^1 + \alpha X_{13}^2, \alpha X_{13}^2 + (1-\alpha)X_{13}^3] \\
&(X_{21})_\alpha = [(X_{21})_\alpha^L, (X_{21})_\alpha^U] = [(1-\alpha)X_{21}^1 + \alpha X_{21}^2, \alpha X_{21}^2 + (1-\alpha)X_{21}^3] \\
&(X_{22})_\alpha = [(X_{22})_\alpha^L, (X_{22})_\alpha^U] = [(1-\alpha)X_{22}^1 + \alpha X_{22}^2, \alpha X_{22}^2 + (1-\alpha)X_{22}^3] \\
&(X_{23})_\alpha = [(X_{23})_\alpha^L, (X_{23})_\alpha^U] = [(1-\alpha)X_{23}^1 + \alpha X_{23}^2, \alpha X_{23}^2 + (1-\alpha)X_{23}^3] \\
&(X_{31})_\alpha = [(X_{31})_\alpha^L, (X_{31})_\alpha^U] = [(1-\alpha)X_{31}^1 + \alpha X_{31}^2, \alpha X_{31}^2 + (1-\alpha)X_{31}^3] \\
&(X_{32})_\alpha = [(X_{32})_\alpha^L, (X_{32})_\alpha^U] = [(1-\alpha)X_{32}^1 + \alpha X_{32}^2, \alpha X_{32}^2 + (1-\alpha)X_{32}^3] \\
&(X_{33})_\alpha = [(X_{33})_\alpha^L, (X_{33})_\alpha^U] = [(1-\alpha)X_{33}^1 + \alpha X_{33}^2, \alpha X_{33}^2 + (1-\alpha)X_{33}^3] \\
&(Z_1)_\alpha = [(Z_1)_\alpha^L, (Z_1)_\alpha^U] = [(1-\alpha)Z_1^1 + \alpha Z_1^2, \alpha Z_1^2 + (1-\alpha)Z_1^3] \\
&(Z_2)_\alpha = [(Z_2)_\alpha^L, (Z_2)_\alpha^U] = [(1-\alpha)Z_2^1 + \alpha Z_2^2, \alpha Z_2^2 + (1-\alpha)Z_2^3] \\
&(Y_3)_\alpha = [(Y_3)_\alpha^L, (Y_3)_\alpha^U] = [(1-\alpha)Y_3^1 + \alpha Y_3^2, \alpha Y_3^2 + (1-\alpha)Y_3^3],
\end{aligned}
\tag{10}
$$

The relations of the above equation show the alpha cuts of the input, output, and interface indices in the resilience assessment model.By applying these cuts to the resiliency assessment model and in order to find the overall network functionality (DMUk) membership function, the upper and lower limits **α**-cut should be calculated for function $\tilde{\mathbf{E}}_{\mathbf{k}}$, i.e. $(\mathbf{E_k})_\alpha = [(\mathbf{E_k})_\alpha^L, (\mathbf{E_k})_\alpha^U]$. Based on the models of Cao and Liu (2000), Cao (2006), and Cao and Liu (2011), the upper limit of model (3) is calculated using the model (6) (Byars& Rue, 2011).

$$(E_k)_\alpha^U = \max u_3 (Y_3^k)_\alpha^U$$

s.t.

$$\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^k)_\alpha^L = 1$$

$$u_3(Y_3^k)_\alpha^L - \left(\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^k)_\alpha^U\right) \le 0$$

$$u_3(Y_3^j)_\alpha^L - \left(\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^j)_\alpha^U\right) \le 0, j = 1,2,\dots,n, j \ne k$$

$$\hat{z}_1^k - \sum_{i=1}^{3} v_{1i}(X_{1i}^k)_\alpha^L \le 0$$

$$\hat{z}_1^j - (\sum_{i=1}^{3} v_{1i}(X_{1i}^j)_\alpha^U) \le 0, j = 1,2,\dots,n, j \ne k$$

$$\hat{z}_2^k - (\hat{z}_1^k + \sum_{i=1}^{3} v_{1i}(X_{2i}^k)_\alpha^L) \le 0$$

$$\hat{z}_2^j - (\hat{z}_1^j + \sum_{i=1}^{3} v_{1i}(X_{2i}^j)_\alpha^U) \le 0, j = 1,2, \dots, n, j \ne k$$

$$u_3(Y_3^k)_\alpha^U - (\hat{z}_2^k + \sum_{i=1}^{3} v_{1i}(X_{3i}^k)_\alpha^L) \le 0$$

$$u_3(Y_3^j)_\alpha^L - (\hat{z}_2^j + \sum_{i=1}^{3} v_{1i}(X_{3i}^j)_\alpha^U) \le 0, j = 1,2, \dots, n, j \ne k$$

$$w_1(Z_1^j)_\alpha^L \le \hat{z}_1^j \le w_1(Z_1^j)_\alpha^U, j = 1,2, \dots, n$$

$$w_2(Z_2^j)_\alpha^L \le \hat{z}_2^j \le w_2(Z_2^j)_\alpha^U, j = 1,2, \dots, n$$

$$v_{ti}, u_3, w_1, w_2 \ge \varepsilon,$$

$$i = 1,2,3; t = 1,2,3$$

After calculating optimal values for, $\mathbf{u_3^*}$, $\mathbf{w_1^*}$, $\mathbf{w_2^*}$, $\mathbf{\hat{z}_1^*}$ و $\mathbf{\hat{z}_2^*}$, and $\mathbf{v_{ti}^*}$, Model (6) provides the efficiencies for the entire network and three levels of process according to the following formula:

$$(E_k)_\alpha^U = u_3^*(Y_3^k)_\alpha^U \Big/ \sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}^*(X_{ti}^k)_\alpha^L$$

$$(E_k^1)_\alpha^U = \hat{z}_1^{*k} \Big/ \sum_{i=1}^{3} v_{1i}^*(X_{1i}^k)_\alpha^L$$

$$(E_k^2)_\alpha^U = \hat{z}_2^{*k} \Big/ (\hat{z}_1^{*k} + \sum_{i=1}^{3} v_{2i}^*(X_{2i}^k)_\alpha^L) \qquad (12)$$

$$(E_k^3)_\alpha^U = u_3^*(Y_3^k)_\alpha^U \Big/ (\hat{z}_2^{*k} + \sum_{i=1}^{3} v_{3i}^*(X_{3i}^k)_\alpha^L)$$

Formulating the α-cut lower limit for the proposed model's efficiency requires a two-objective function of the model (3) to become fuzzy. Hence, the modified two-edged version of the model (3) is formulated and the lower limit of α-cut is calculated overall efficiency, along with the efficiency of the three upstream, organizational and lower-level processes. The two-dimensional model of model number (3) for the total decision-making units (DMUk) is calculated as follows by Cao and Huang (2008).

$$\tilde{E}_k = \min \theta - \varepsilon((\sum_{t=1}^{3}\sum_{i=1}^{3} s_{ti}^v) + s_1^w + s_2^w + s_3^u)$$

s.t.

$$\theta\tilde{X}_{1i}^k - \sum_{j=1}^{n} \alpha_j \tilde{X}_{1i}^j - \sum_{j=1}^{n} \beta_j \tilde{X}_{1i}^j - s_{1i}^v = 0, i = 1,2,3$$

$$\theta\tilde{X}_{2i}^k - \sum_{j=1}^{n} \alpha_j \tilde{X}_{2i}^j - \sum_{j=1}^{n} \gamma_j \tilde{X}_{2i}^j - s_{2i}^v = 0, i = 1,2,3 \qquad (13)$$

$$\theta\tilde{X}_{3i}^k - \sum_{j=1}^{n} \alpha_j \tilde{X}_{3i}^j - \sum_{j=1}^{n} \delta_j \tilde{X}_{3i}^j - s_{3i}^v = 0, i = 1,2,3$$

$$\sum_{j=1}^{n} \beta_j \tilde{Z}_1^j - \sum_{j=1}^{n} \gamma_j \tilde{Z}_1^j - s_1^w = 0$$

$$\sum_{j=1}^{n} \gamma_j \tilde{Z}_2^j - \sum_{j=1}^{n} \delta_j \tilde{Z}_2^j - s_2^w = 0$$

$$\sum_{j=1}^{n} \alpha_j \tilde{Y}_3^j + \sum_{j=1}^{n} \delta_j \tilde{Y}_3^j - s_3^u = \tilde{Y}_3^k$$

$$\alpha_j, \beta_j, \gamma_j, \delta_j, s_{ti}^v, s_1^w, s_2^w, s_3^u \geq 0, j = 1,2,\dots,n; i = 1,2,3; t = 1,2,3$$

Accordingly, the lower limit of α-cut of the overall efficiency model (8) will be as follows:

$$(E_k)_\alpha^L = min\, \varepsilon((\sum_{t=1}^{3}\sum_{i=1}^{3} s_{ti}^v) + s_1^w + s_2^w + s_3^u)$$

s.t.

$$\theta(X_{1i}^k)_\alpha^U - \left[\alpha_k\left(X_{1i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j\left(X_{1i}^j\right)_\alpha^L\right] - \left[\beta_k\left(X_{1i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \beta_j\left(X_{1i}^j\right)_\alpha^L\right] - s_{1i}^v = 0, i = 1,2,3$$

$$\theta(X_{2i}^k)_\alpha^U - \left[\alpha_k\left(X_{2i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j\left(X_{2i}^j\right)_\alpha^L\right] - \left[\gamma_k\left(X_{2i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \gamma_j\left(X_{2i}^j\right)_\alpha^L\right] - s_{2i}^v = 0, i = 1,2,3$$

$$\theta(X_{3i}^k)_\alpha^U - \left[\alpha_k\left(X_{3i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j\left(X_{3i}^j\right)_\alpha^L\right] - \left[\delta_k\left(X_{3i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \delta_j\left(X_{3i}^j\right)_\alpha^L\right] - s_{3i}^v = 0, i = 1,2,3 \qquad (14)$$

$$\sum_{j=1}^{n} \beta_j z_1^j - \sum_{j=1}^{n} \gamma_j z_1^j - s_1^w = 0$$

$$\sum_{j=1}^{n} \gamma_j z_2^j - \sum_{j=1}^{n} \delta_j z_2^j - s_2^w = 0$$

$$\left[\alpha_k(Y_3^k)_\alpha^L + \sum_{j=1, j\neq k}^{n} \alpha_j (Y_3^j)_\alpha^U\right] + \left[\delta_k(Y_3^k)_\alpha^L + \sum_{j=1, j\neq k}^{n} \delta_j (Y_3^j)_\alpha^U\right] - s_3^u = (Y_3^k)_\alpha^L$$

$$(Z_1^j)_\alpha^L \leq z_1^j \leq \left(Z_1^j\right)_\alpha^U, j = 1,2,\dots,n$$

$$(Z_2^j)_\alpha^L \leq z_2^j \leq \left(Z_2^j\right)_\alpha^U, j = 1,2,\dots,n$$

$$\alpha_j, \beta_j, \gamma_j, \delta_j, s_{ti}^v, s_1^w, s_2^w, s_3^u \geq 0, j = 1,2,\dots,n; i = 1,2,3; t = 1,2,3$$

With the optimal solution of model number (9), the values $\boldsymbol{s_{ti}^{*v}}, \boldsymbol{s_1^{*w}}, \boldsymbol{s_2^{*w}}, \boldsymbol{s_3^{*u}}$ were allocated to $\boldsymbol{v_{ti}^*}$, $\boldsymbol{w_1^*}$, $\boldsymbol{w_2^*}$, $\boldsymbol{u_3^*}$. Thus, the lower limits of system efficiency and low efficiency e levels of upstream, organizational and downstream processes, in the cut-off, are calculated as follows:

$$(E_k)_\alpha^L = u_3^*(Y_3^k)_\alpha^L \Big/ \sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}^*(X_{ti}^k)_\alpha^U$$

$$(\mathrm{E}_\mathrm{k}^1)_\alpha^\mathrm{L} = \mathrm{w}_1^*\mathrm{z}_1^{*\mathrm{k}} \Big/ \sum_{\mathrm{i}=1}^{3} \mathrm{v}_{1\mathrm{i}}^*(\mathrm{X}_{1\mathrm{i}}^\mathrm{k})_\alpha^\mathrm{U}$$

$$(\mathrm{E}_\mathrm{k}^2)_\alpha^\mathrm{L} = \mathrm{w}_2^*\mathrm{z}_2^{*\mathrm{k}} \Big/ (\mathrm{w}_1^*\mathrm{z}_1^{*\mathrm{k}} + \sum_{\mathrm{i}=1}^{3} \mathrm{v}_{2\mathrm{i}}^*(\mathrm{X}_{2\mathrm{i}}^\mathrm{k})_\alpha^\mathrm{U}) \qquad (15)$$

$$(\mathrm{E}_\mathrm{k}^3)_\alpha^\mathrm{L} = \mathrm{u}_3^*(\mathrm{Y}_3^\mathrm{k})_\alpha^\mathrm{L} \Big/ (\mathrm{w}_2^*\mathrm{z}_2^{*\mathrm{k}} + \sum_{\mathrm{i}=1}^{3} \mathrm{v}_{3\mathrm{i}}^*(\mathrm{X}_{3\mathrm{i}}^\mathrm{k})_\alpha^\mathrm{U})$$

The values of α in models (6) and (9) are 0 and 1, respectively.These values are important and are used to report on the outcome of these two models. If alpha is zero (α = 0), then the range of all possible efficiency scores for different alpha values is determined. In addition, at the alpha-1 level (α = 1), the most probable efficiency scores are obtained for decision-making units.Hence, using efficiency scores for different alpha values and establishing the lower and upper limits of these efficiency scores, the membership function of the fuzzy resilience levels of supply chain risks is determined. This leads to the calculation of risk and system resilience (the entire supply chain) and the assessment of the supply chain layers and, finally, the risk / resilience ratios between the decision-making units and the various processes of the environment.

Results

In Table 2, the upper and lower scores of the supply chain are used for zero and one alpha (three for each layer).

Table 2: Average triangular fuzzy numbers extracted for inputs, outputs and input / output interfaces of the three-layer supply chain

Petrochemistry	x_{11}	x_{12}	x_{13}	x_{21}	x_{22}	x_{23}	x_{31}	x_{32}	x_{33}	z_1	z_2	y_3
Jam	(3,5,5.3,7)	(4,5,8,7.4)	(4.1,5.8,7.1)	(3.6,5.5,7)	(4.4,6.1,7.8)	(4.1,6,7.4)	(2.5,4,5.9)	(3.1,4.6,6.1)	(2.9,4.1,5.9)	(2.6,3.9,5.6)	(2.1,2.4,5.3)	(3,4.4,5.9)
Bandar emam	(2.9,4.5,6.1)	(2.6,4.1,6.1)	(3.9,5.4,6.8)	(2.1,3.4,5.1)	(2.8,4,5.8)	(3.5,5.1,6.5)	(2.4,5,6.6)	(2.8,4.4,6.3)	(3.6,5.5,6.9)	(3.9,5.5,7)	(2.8,4.3,6.1)	(3.8,5.4,6.9)
Esfahan	(3.5,5.1,6.8)	(3.5,5.1,6.9)	(4.3,6,7.3)	(3.4,5,6.6)	(3.3,5.3,7)	(3.1,4.6,6.1)	(2.4,4.1,6)	(3.3,5,6.8)	(3,4.4.,6)	(4,5.5,6.9)	(3.5,5.1,7)	(3.9,5.6,7.1)
Shiraz	(3.4,5,6.5)	(2.7,4.3,5.9)	(3.9,5.4,6.9)	(3.8,5.6,7.1)	(3.1,4.8,6,3)	(4.3,6.3,7.8)	(4,5.9,7.4)	(4,6.7.3)	(3.1,4.9,6.6)	(2.8,4,5.8)	(4,5.8,7.1)	(4.8,6.6,8.1)
Qeshm	(2.8,4,5.6)	(3.5,4.9,6.5)	(4.4,6,7.5)	(2.4,3.8,5.8)	(3.3,4.9,6.6)	(4.1,6,7.5)	(3,8,5.1,6.5)	(3.4,4.9,6.4)	(3.4,4.6,6.4)	(3.5,5,6.4)	(3,4.6,6.4)	(4,5.8,7.1)
Shazand	(3.1,4.6,6.4)	(3.5,4.6,6.4)	(3.3,4.8,6.4)	(2.9,4.5,6.5)	(5.4,7.4,8.4)	(2.1,4.8,6.3)	(3.3,4.9,6.5)	(2.3,3.4,5.1)	(3.1,4.9,6.4)	(4.3,5.9,7)	(2.4,4.5,9)	(2.9,4.6,6.5)
Tabriz	(2.9,4.3,	(3.6,5.5,	(4.5,5.6,	(2.9,4.3,	(4.1,5.9,	(3.9,5.4,	(4,6,7.5)	(3.1,4.9,	(2.8,4.4,	(3.1,4.6,	(3.8,5.4,	(3.3,4.5

	6.1)	7.1)	8)	6.1)	7.4)	6.6)		6.6)	6.1)	6.5)	6.9)	,6)
Maroun	(2.9,4.5,6.1)	(2.9,4.1,5.9)	(2.9,4.5,6.3)	(4.1,6.1,7.8)	(3.8,5,6.3)	(3.4,4.8,6.4)	(3.1,4.5,6.3)	(3,4.9,6.8)	(3.6,5.4,6.9)	(2.3,3.6,5.5)	(4.3,4.9,6.6)	(3.3,4.5,5.6)
Fanavaran	(4,5.6,7)	(3.3,4.7,6.4)	(4,5.8,7.5)	(3.4,5.1,6.8)	(3.7,5.5,7.2)	(3.7,5.5,6.9)	(3.2,4.6,6.1)	(3.4,4.8,6.5)	(3.4,5.16.7)	(3.9,5.8,7.5)	(3.2,4.5,6.4)	(3.5,5.1,6.6)

Along with the reported results in the chain of value chain related to "Bandar Imam" petrochemicals showed the maximum overall resilience with risk, so that its efficiency score $\widetilde{E}_k = 0.76$ in alpha was 1. Then, there were Shazandpetrochemical supply chain $\widetilde{E}_k = 0.69$ and Shiraz petrochemical supply chain$\widetilde{E}_k = 0.63$ in the next levels in terms of resilience. These results indicate is a relatively high degree of resilience to the supply chain risk in these companies. Furthermore, the results for each layer of the value chain are compared to each other in order to rank the efficiency of each of the value chain layers.As indicated in Table 3, these scores do not necessarily have to match the overall efficiency rating of the value chain. Given that the values of α = 0 and α = 1 determine the left, right and middle of the triangular fuzzy numbers, based on this, the calculation of the efficiency scores in these values of the total fuzzy efficiency score will be determined. For example, although the "Jam" petrochemical chain is in fourth place, in terms of resilience to the risk of downstream processes ($\widetilde{E}_k^2 = 0.58$), was at a better status Compared to the other two supply chains (which rank second and third). In another example, Qeshm petrochemical supply chain, ranked seventh, has the second-highest score ($\widetilde{E}_k^1 = 0.84$) in terms of the efficiency of downstream processes. As shown in the table, there are significant differences in the efficiency of the three main layers for the three best-performing supply chains. Shazand petrochemical supply chain which is ranked second, has allocated a higher resilience to risk than the upstream processes ofBandar Imam petrochemical supply chain which ranked first. Ina ddition, Tabriz Petrochemical Supply Chain is ranked first in the supply chain resilience to organizational risks.

Table 3: Fuzzy efficiency scores in the three-layer supply chain

	a=0					a=1			
petrochemistry	Total ranking	Total (LB,UB)	Layer 1 (LB,UB)	Layer 2 (LB,UB)	Layer 3 (LB,UB)	Total (LB,UB)	Layer 1 (LB,UB)	Layer 2 (LB,UB)	Layer 3 (LB,UB)
Jam	4	(0,2,1)	(0,05,0,76)	(0,09,0,54)	(0,51,0,68)	(0,58,0,58)	(0,06,0,06)	(0,11,011)	(0,58,0,58)
Bandar Imam	1	(0,27,1)	(0,07,0,74,)	(0,12,0,82)	(0,49,0,97)	(0,76,0,76)	(0,09,0,09)	(0,15,0,15)	(0,97,0,97)
Esfahan	6	(0,27,1)	(0,06,0,86)	(0,18,0,88)	(0,29,0,61)	(0,46,0,46)	(0,09,0,09)	(0,18,0,18)	(0,46,0,46)
Shiraz	3	(0,34,1)	(0,05,0,88)	(0,20,0,95)	(0,13,0,56)	(0,63,0,63)	(0,06,0,06)	(0,21,0,21)	(0,34,0,34)
Qeshm	7	(0,30,1)	(0,06,0,83)	(0,15,0,57)	(0,28,0,88)	(0,44,0,44)	(0,08,0,08)	(0,16,0,16)	(0,84,0,84)
Shazand	2	(0,21,1)	(0,08,0,90)	(0,10,0,38)	(0,19,1)	(0,69,0,69)	(0,10,0,10)	(0,13,0,13)	(0,53,0,53)
Tabriz	5	(0,21,1)	(0,06,0,80)	(0,18,0,53)	(0,33,0,91)	(0,48,0,48)	(0,08,0,08)	(0,21,0,21)	(0,7,0,7)
Maroon	9	(0,24,1)	(0,05,0,64)	(0,10,0,66)	(0,19,0,88)	(0,36,0,36)	(0,05,0,05)	(0,16,0,16)	(0,58,0,58)
FAnavaran	8	(0,23,1)	(0,07,0,92)	(0,16,0,76)	(0,18,0,70)	(0,44,0,44)	(0,08,0,08)	(0,16,0,16)	(0,46,0,46)

Table 3: Fuzzy efficiency scores in the three-layer supply chain according to the results of Table 4, the relative efficiency of the total and the layers of the units are summarized in accordance with the table.

Table 4: Fuzzy efficiency scores in the three-layer supply chain

petrochemistry	Total ranking	Total	Layer 1	Layer 2	Layer 3
Jam	4	(0,2,0,58,1)	(0,05,0,06,0,76)	(0,09,0,11,0,543)	(0,51,0,58,0,68)
Bandar Imam	1	(0,27,0,76,1)	(0,07,0,09,0,74)	(0,12,0,15,0,82)	(0,50,0,97,0,97)
Esfahan	6	(0,27,0,46,1)	(0,06,0,09,0,86)	(0,18,0,18,0,88)	(0,29,0,46,0,61)
Shiraz	3	(0,34,0,63,1)	(0,05,0,06,0,88)	(0,20,0,21,0,95)	(0,13,0,34,0,56)
Qeshm	7	(0,30,0,44,1)	(0,06,0,08,0,84)	(0,15,0,16,0,57)	(0,28,0,84,0,88)
Shazand	2	(0,21,0,69,1)	(0,08,0,10,0,90)	(0,10,0,13,0,38)	(0,19,0,53,1)
Tabriz	5	(0,21,0,48,1)	(0,06,0,07,0,8)	(0,18,0,21,0,53)	(0,33,0,7,0,91)
Maroon	9	(0,24,0,36,1)	(0,05,0,05,0,64)	(0,10,0,16,0,66)	(0,19,0,58,0,88)
FAnavaran	8	(0,23,044,1)	(0,07,0,08,0,91)	(0,16,0,16,0,76)	(0,18,0,46,0,70)

From Table 3 and 4, although a supply chain system may be highly resilient to its risk managers, its layers are still at risk, and this requires that the resilience model be used appropriately to cover all risks. If these risks are not decerased properly and at the right time, they can affect supply chain resilience and provide potential for supply chain vulnerability. Thus, although a supply chain may be at a favorable level in terms of overall resilience and risk response, it should still be sensitive to its vulnerabilities and vulnerabilities in different layers. According to new supply chain theories, the efficiency of this chain is not focused solely on efficiency evaluation systems, but on each component. Therefore, assessment of supply chain resilience against unexpected risks and events is an important issue. Risk and failure in the supply chain can have a significant effect on short-run efficiency as well as a negative long-run effect on financial efficiency of the organization. Therefore, supply chain risk management is necessary to decrease the risks of various risks, such as uncertain economic cycles, uncertain customer demand, and unpredictable natural and human events, and many researchers have emphasized its importance. Integrated assessment of this issue involves evaluating the supply chain system as well as its components. This is significant because, according to new supply chain theories, the efficiency of this chain is not focused merely on the efficiency evaluation system, but on each component.

Research questions

1. What structure does the petrochemical supply chain have?

Based on the figure below, the three-part supply chain model includes upstream, organizational, and downstream processes, and the levels of risk and resilience associated with them, as well as the inputs and outputs between and among the processes of the organization. The following figure shows the three-part supply chain model, including upstream, downstream and downstream processes, and their related risk and resilience levels, as well as inputs and outputs between and among organizational processes. Potentially, risks affect all three components of the supply chain, and can interfere with operational processes, which ultimately will have a devastating effect on the entire supply chain. Thus, the greater the vulnerability of the components of the supply chain (including suppliers, manufacturers and distributors), the resilience of these components in operational matters will be less. After studying different sources related to the factors or concepts affecting the processes of supply chain of the petrochemical industry in the country and comparing it globally to finalize it to provide a comprehensive model appropriate to the processes of the indigenous supply of this industry, and to convene different meetings with experts Related and with the modeling of the reference model and the suitable changes in it, the list of the following as a factor or related concepts for use and implementation, considering the problems of the supply chain in the country, is proposed in the framework of the SCOR model.

Table 5- Factors related to supply chain processes in the petrochemical industry based on expert opinion

Upstream processes (supplier)	Organizational processes (manufacturer)	Downstream processes (distributor)
Upsteram risks	Oragnziational risks	Downsteram risks
Output risks	Output risks	Output risks
Network risks	Network risks	Network risks
Supplier resilience	Manufacturer resilience	distributer resilience

Therefore, the process of this industry's work is at the upstream level (supplier) or manufacturer level, and ultimately the downstream (distributor) level having its own complexity requirements, which in this context need not be detailed or their specific distinction. The use of the SCOR model is a graph of the overall workflow of the supply chain process of the petrochemical industry, as indicated in Figure (2).

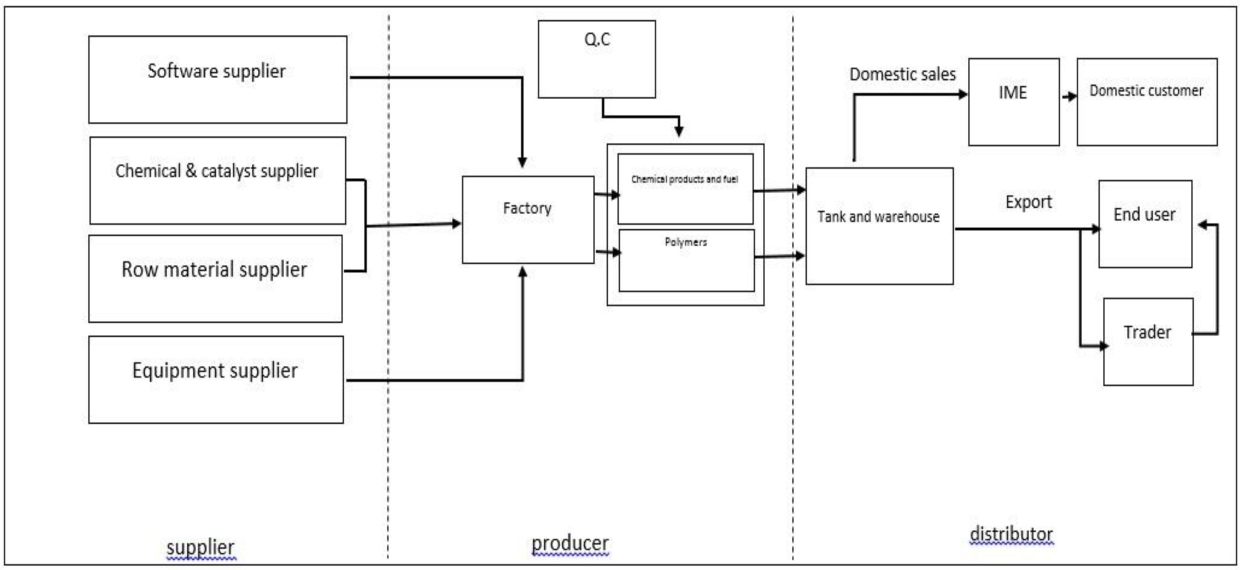

Chart 2: Generality of the process of the supply chain of the petrochemical industry

2. What are the input, output, and intermediate indicators between the different steps of this chain?

In the following, a three- step supply chain model that includes upstream, organizational and downstream processes, their associated risks and their resilience levels (as inputs and outputs of inter-organizational processes) it has been shown. Hence, the resilience levels of the upstream layers of the supply chain are shown as outputs and can be considered as inputs of the downstream layers. Fig. 3. As shown in the figure, upstream risks $(\tilde{X}_{11})$, output $(\tilde{X}_{12})$, network $(\tilde{X}_{13})$, as the input and resilience of supplier $(\tilde{Z}_1)$ as the interface output of the upstream process affects the supplier operations. This resilience is in fact the output of upstream processes and the intermediate inputs of organizational processes. For this reason, organizational risks $(\tilde{X}_{21})$, output (($\tilde{X}_{22}$), and network $(\tilde{X}_{23})$, were regarded as input and the manufacturer resilience $(\tilde{Z}_2)$ was considered as the As the output of the interfaces of organizational processes or a mediator role, the role of the output of these processes and the input of downstream processes. Finally, considering the manufacturer resilience as an intermediate input and downstream risk $(\tilde{X}_{31})$, output $(\tilde{X}_{32})$, and network $(\tilde{X}_{33})$were considered as the input and manufacturer resilience $(\tilde{Y}_3)$ was considered as the output of downstream processes the sign "~" Represents fuzzy values of risk and resilience levels.

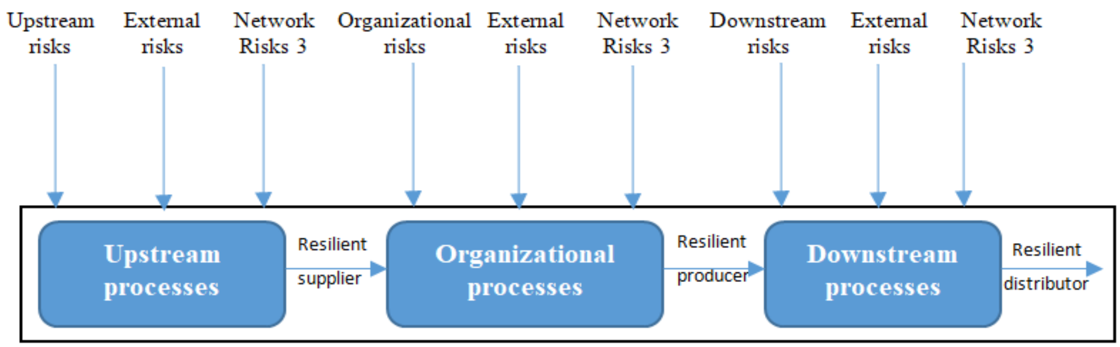

Figure 3- Three-step Supply Chain Model

3. What mathematical model is used in network data envelopment analysis to evaluate the resilience of risks in this chain?

In the present study, a network model was used to evaluate the resilience of supply chain, a network model was used for analyzing the efficiency of upstream, organizational, and downstream processes of petrochemical companies. For each layer of supply chain processes, four efficiency scores are measured. Efficiency of upstream, organizational, and downstream processes along with the overall efficiency of the supply chain system. The entire process of the system is considered as a black box and the whole chain efficiency is formulated using the Cao and Huang model of model number (16), in which the objective function seeks to maximize the total decision units. The constraints of the problem indicate that the effectiveness of all decision-making units should be less than one.

Partial efficiencies

Similarly, one can judge the resilience of each of the upstream, downstream and downstream processes with regard to the input risks and output resiliency. In the upstream processes, three categories of upstream, organizational, and network-defined risks as input and resilience are defined as output, as formulated in model 5. Similarly, organizational processes generate upstream processes, along with organizational, output, and network risks as inputs and resilience as outputs. resilience of organizational processes is formulated as model 6.A similar provision is made in relation to downstream processes, these processes generate resilience to organizational processes, along with downstream, enterprise, and network risk as input and resilience as outputs. As a result, the resilience of these processes is formulated in accordance with Model 7. Given the smaller value than the existence of the efficiency values, relations 5 - 7 can be considered as the form of the limitations of model 8. By linearizing the above constraints and adding them to the model 4, the ultimate model 8 for calculating the resilience of petrochemical processes has been formulated, being a fuzzy linear programming model, which we can extract layer components from this model. The solution to this model requires the development of specific methods, given that the data collected is of a fuzzy type. Based on the principles of the systems of uncertainty, the solution obtained was uncertain. In the present study, in order to solve the fuzzy linear model, an alpha-based approach to fuzzy problem solving is used. Different approaches were proposed by researchers to solve the fuzzy linear programming problems. One of the most practical approaches is the alpha-based approach. In this approach, fuzzy numbers are replaced by their alpha cuts and the problem is solved for various alpha values. Alpha cutting A fuzzy set consists of all elements of the reference set, whose membership in the reference set is at least equal to the alpha value. Regarding the use of triangular fuzzy numbers, by solving the designed model at the levels $\alpha = 0$ and $\alpha = 1$, the lower and upper constraints and the middle efficiency of the petrochemical companies were obtained.

4. How is the efficiency of petrochemical companies evaluated in terms of resilience to risks based on the designed model?

In order to evaluate the efficiency of companies, index data is collected through a questionnaire. For this purpose, a questionnaire was distributed among 50 senior and middle managers of the petrochemical industry. Then, the average opinions of each petrochemical expert in the relevant index were measured based on table (4). In the next step, the designed model is solved using MATLAB software and the results are obtained. By referring to the table in the overall rating column, the rank of each petrochemical company is from 1 to 9 along with the reported results in the chain of value chain related to "Bandar Imam" indicated the highest overall resilience with risk. These results indicate that there is a relatively high degree of resilience to the supply chain risk in these companies. However, the results for each value chain layer are compared to each other in order to rank the efficiency of each of the value chain layers. As shown in Table (3), these scores do not necessarily have to match the overall efficiency rating of the value chain. Given that the values of $\alpha = 0$ and $\alpha = 1$ determine the left, right and middle of the triangular fuzzy numbers, accordingly, the calculation of the efficiency scores in these values of the total fuzzy efficiency score will be determined. As indicated in the table, there are significant differences in the efficiency of the three main layers for the three upstream supply chains. The Shazand Petrochemical Supply Chain, which is ranked second, was rescued to a higher risk than the upstream petrochemical supply chain, Bandar Imam, which ranked first. In addition, Tabriz petrochemical supply chain is ranked first in the supply chain resilience with organizational risks. Meanwhile, regarding the output of the models in the table, the efficiency of this model, both aspects of the supply chain system and its components, is integrated and it was proved that the discussion of the whole system and separate components should be regarded. We need to evaluate the whole set and the components, and for different components or separate layers we can have a specific related proposal. Table 4 indicates the efficiency scores of the three best supply chains (including the Imam Port Band, Shazand Petrochemical Complex and Shiraz Petrochemical Complex).

Conclusion

According to the results obtained in the model, the results of the supply chain results of the three companies with a higher value chain than identifying variables with higher risks in different layers and to reach the desired level can be applied at inputs and outlets make the necessary changes. Since potentially, the risk affects all three components of the supply chain and can interfere with operational processes, which ultimately will have a damaging impact on the entire supply chain. Thus, the extent to which the components of the supply chain involving suppliers, manufacturers, and distributors), the resilience of these components in the operational affairs will be lower, component reliability levels are considered as outputs of each model process that are considered as inputs for the next process. In a particular component (as the supplier) it is more vulnerable to risks, the disruption of these risks in a particular component can have a negative impact on the next components of the supply chain, for example, if a supplier is due to unexpected events It can lead to disruptions in the key business processes, it is not possible to provide the manufacturer's raw materials at the right time, and hence the impact of the malicious event can affect the manufacturer's operations (such as reducing production and increasing costs). And according to Table 4, which shows that although a supply chain system may be risk averse to its managers, its layers are still at risk. Based on the results of Table 4 below, in the upstream risks, the most serious threat to the supply chain of all three petrochemicals, namely, Bandar Imam Khomeini, Shazand and Shiraz, is. In Imam Khomeini's petrochemicals, the most threatened is the first layer and the second layer, while in the third layer, the risks are highly good. In this context, the investment needs to be made in the upstream and organizational process. In the Shazand petrochemicals, the biggest threat to the first layer is the requirement to invest a lot on the supplier's layer, and in the third-ranked petrochemical company "Shiraz", it is still the most concern for the first layer requiring more investment while in the first layer between these three petrochemicals, the biggest threat is to Shiraz petrochemicals, while in the second layer, Shazand petrochemicals are more vulnerable and in the third layer, although all three are in a better condition, but the petrochemicals "Shiraz" is more vulnerable than the others. Finally, the results suggest that although a supply chain system may have a higher risk than the other risks while its layers are still at enhanced risk.

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