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Designing an Analytical Model for Assessing Supply Chain Resilience to Different Types of Risks: Case Study of Iran Petro-Chemical Industries

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ABSTRACT

The study aims to develop and validate an analytical model for assessing the resilience of supply chains in the face of system-wide and individual tier risks. To accomplish this, a multi-method research approach is employed, involving the utilization of data envelopment analysis (DEA) and fuzzy set theory. Specifically, a fuzzy network DEA model is introduced to evaluate risks across entire supply chains and their individual tiers. This model is then put to the test through a survey involving 130 respondents from select petrochemical companies in Iran. The survey results reveal significant disparities in resilience ratings between the overarching petrochemical supply chains and their specific tiers. The research findings emphasize that the resilience of a system may not necessarily reflect the resilience of its individual tiers. Conversely, high efficiency scores within supply chain tiers have only a limited impact on the overall resilience of the supply chain. The analytical model proposed in this study facilitates the evaluation of supply chain flexibility at various levels while addressing a broad spectrum of supply chain risks in the upstream, downstream, and intermediary processes.

1 Introduction

Nowadays supply chains have become one of the dominant paradigms in the world of business. Forster who many identified him as the founder of the subject of supply chains, in 1958 noted the idea that "the success of organizations depends on the efficient interaction and exchange of information, material, capital, human resources and equipment among them." Over time, this idea has become dominant and indisputable theories in the realm of business [1]. The breadth of this idea is such that today one cannot imagine an organization without considering its position in a supply chain. Many experts believe that the competition between organizations and companies over the past decades has become a rivalry between chains in the present era. In fact, a large part of the generalization and expansion of this field has taken place in the last two decades, and many international organizations such as Cisco, Dell, Nike,

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Proctor and Gamble and Zara have benefited from it [1]. Due to the role and importance of supply chain management, this concept encounters many issues and challenges. But an overview of the theoretical foundations of this field shows that issues such as information systems, marketing, financial management, logistics issues, and inter-organizational relations have been the subject of interest by researchers in this field [2]. Soni et al. [2] have looked at the most important elements in supply chain management and their issues in four stages: purchase, operation, distribution, and integration. Today, organizations are obliged to reduce the vulnerability and increase the ability to withstand supply chain due to increased uncertainty in the supply chain and the emergence of factors such as political issues, demand fluctuations, technological changes, financial instability and natural disasters spend resources to predict demand, supply and internal uncertainties. According to these uncertainties and risk factors led to the issue of risk management in the supply chain [2].

The existence of risk and failure in the supply chain can have a significant effect on short-run performance as well as a negative long-term effect on financial performance of the organization. Therefore, supply chain risk management is necessary to reduce the risks of various risks, such as uncertain economic cycles, unreliable customer demand, and unpredictable natural and human events [3]. Supply chain performance evaluation criteria have been categorized into four areas: quality, time, cost and flexibility (resiliency). In addition, they are categorized on the basis of quantitative and qualitative, cost or non-cost and focus on technical / operational / strategic levels and supply chain processes [4]. Today, enterprises face the challenges and pressures of the competitive market, including globalization, competition and cooperation, diversification of customer needs and short product life cycle, and the supply chain has been considered as an important principle. Therefore, in order to be able to achieve the company's strategic and strategic goals, it is necessary to assess the supply chain from a functional point of view, in this way, identifying strengths and weaknesses and for strengthening, improving or removing them [3]. Regarding the role of the petrochemical industry in Iran's economy, improving the supply chain performance of petrochemical industries can be an important step towards achieving the macroeconomic goals of the country's economy and due to the lack of research in the field of effective quality factors in the supply chain it is vital to examine the supply chain resilience in the petrochemical industry [4]. Risk management requires identifying, evaluating and rating various risks. Risk assessment is one of the pillars of risk management and its purpose is to measure the risks based on different indicators such as the extent of the effect and the probability of occurrence. And the results of this stage are more precise, we can say that the management process Risk with higher degree of certainty [3].

In order to accurately study the consequences of accidents that can lead to disruptions and thus have a negative impact on the supply chain system, reference models in the supply chain literature (such as the SCOR supply chain operational reference model) [5] approaches to supply chain risk assessment primarily focus on rapid identification and evaluation of risks, development of risk response strategies, and monitoring and interpretation of risk [6]. Meanwhile, with the increasing complexity and vulnerability of supply chains, more studies focus on linking the assessment of supply chain performance as part of the supply chain management [7, 8]. Many researchers attest to the importance of tolerance in the supply chain system in the face of unexpected and unexpected risks. Identifying the main risks and developing future capabilities for managing identified risks are key variables that affect the level of supply chain performance [9]. The necessity of this research can be largely due to the increasing development of multi-level systems along with the development of supply chain discussions and advanced programming topics. Today, many business organizations are organized in the form of networks of manufacturers and distributors that provide raw materials transform them into finished products and distribute them among customers. The term multi-level production / distribution networks is in fact synonymous with such networks, which are also known as supply chains, and refer to the situations in which a pen reaches different stages before reaching the final customer [9]. In a supply chain, decisions are coordinated and considering the requirements and characteristics of the various stages of the chain is very important. This importance can be explained by looking at the effect of whipping leather. Many suppliers and retailers have found that, despite the slight changes in customer demand, inventory levels and return orders have changed a lot throughout the supply chain. This increase in fluctuations along the chain is called "whip". In order to control the effects of the bullwhip effect on the chain, its agents should be identified. In a simpler formulation and considering a multi-level system, it can be argued that the optimal decision making at single levels of this chain does not lead to the optimality of the whole chain, and the achievement of overall optimization requires the exploitation of models that simultaneously aim and Constraints of all levels of the chain are considered. Accordingly, organizations in the supply chain have increasingly identified the need for planning and decision-making based on co-operation and coordination, taking into account the characteristics of each stage and the characteristics determined by the chain for its stages.

For example, the Planning, Prediction, and Procurement Modeling (CPFR) model is one of the strategies used in supply chains to improve the planning debate. The necessity of designing a model for estimating the cost function in multi-level inventory systems can be explained by the attitude to the above mentioned items. As mentioned, there are multi-level structural supply chains. Emphasis on co-operation and participation in the supply chain management due to the conflict of interests between different sectors on the one hand and the appearance of undesirable effects of bullwhip due to inconsistency between the various stages of the chain on the other. The assessment of supply chain resilience to unexpected hazards and events is an issue of importance and many researchers have reaffirmed its importance. Integrated assessment of this issue involves assessing the supply chain system as well as its components. This is important because, according to new supply chain theories, the performance of this chain is not focused solely on the performance evaluation system, but rather on each component. Given the complexity of this sector, providing a unique and indigenous model for assessing the capability of enduring supply chain risks in the field of petrochemical industry has not been studied in depth until now. It is considered as an innovative aspect of this research. This research can be considered as the first research to use the data model envelopment modeling model to evaluate the supply chain capability to risk. Since there has been no research in the research network models in order to provide improvement directions for the evaluated units, in the present study, using shorter-based approaches and considering adverse outcomes, a new approach to determining the optimal levels of each of the variables The inputs and outputs and the interface will be presented, which is the innovation of this research.

2 Theoretical Foundations

In this research, a proposed model for estimating resiliency in the context of a three-part supply chain is presented. The overall model schema is presented as Fig. 1. Here is the following. Fig. 1 represents a three-part supply chain model that includes upstream, downstream and downstream processes, and the associated risk and resilience levels, as well as the inputs and outputs between and among organizational processes.

Potentially, risks affect all three components of the supply chain and can also interfere with operational processes, which ultimately will have a devastating effect on the entire supply chain. Hence, the greater the vulnerability of the components of the supply chain (including suppliers, producers and distributors), the resilience of these components in operational matters will also be less [10]. The reliability levels for components are considered as outputs of each model process. A specific component (as the supplier) is more vulnerable to risks, and disturbances caused by these risks in a particular component can have a negative effect on the next components of the supply chain. For example, if a supplier, due to an unexpected event, would disrupt the key business processes, cannot provide the raw material of the manufacturer at the right time and hence the effect of the malicious event can be on the manufacturer's operation (from Such as declining production and rising costs) [11]. Hence, the levels of upstream supply chain components that are referred to as outputs can be considered as inputs of downstream supply chain components.

Fig. 1: Proposed Model for Assessing Supply Chain to Risks

3 Review of Literature

The contemporary era can be seen as the era of growing competition for companies in an effort to gain, maintain, and increase market share. A look at the history of business and business shows how the activities of industry and service organizations have changed from owner-managed and losing relationships to shared management and win-win relationships. The history of Supply Chain Management Discussion is back to topics such as logistics. The issue of logistics has been raised as well as the way people organize and organize various organizations. Its advanced records can be found in military activities that utilized advanced logistics and supply chains as part of their supply chain strategies. In order to accurately study the consequences of disruptions that can lead to disruptions and thus have a negative impact on the supply chain system, reference models in the supply chain literature (such as the SCOR supply chain operational reference model) [7] and approaches to supply chain risk assessment primarily focus on rapid identification and evaluation of risks, development of risk response strategies, and monitoring and interpretation of risk [6, 12].

Meanwhile, with the increasing complexity and vulnerability of supply chains, more studies focus on linking the assessment of supply chain performance as part of the supply chain management [12]. In recent years, several studies [13, 14] have systematically reviewed the literature on supply chain resonance, definitions, and attributes Related to this complex construction (resonance). Meanwhile, although identifying and responding more actively to supply chain risks is highly desirable [14], the uncertainty surrounding today's supply chain environment worldwide requires readiness and prompting a quick response to unpredictable events is unavoidable [14-16]. In the meantime, some researchers focused on the speed of response to these events (time) as well as on cost reduction strategies [17]. Therefore, the main concept of resiliency comes from the ability of the system to return to the post-disorder stability situation. This issue has been addressed by new disciplines such as supply chain risk management and sustainable supply chain management [18, 19]. Models and backgrounds related to Fuzzy Network Data Envelopment Analysis can be presented in Table 1.

Table 1: Models and Literature review of Fuzzy Network DEA

Criteria	Model	Case Study	Journal	Research Subject	References
Performance of safety improvements in the rail transport system	Dynamic Network Data Envelopment Analysis in a Fuzzy Network (Fuzzy DNDEA Model(	Iran Airlines	Applied Soft Computing	Dynamic network data envelopment analysis model with fuzzy inputs and outputs: An application for Iranian Airlines	[20]
Choosing the right supplier on the supply side	Combined research model hybrid DEA-boost model Multi-Object Database Model: fuzzy multi-objective DEA	Supply Chain to Select Suppliers	IFAC-Papers Online	A Hybrid DEA-boost Model in Supplier Selection for Fuzzy Variable and Multiple Objectives	[21]
Evaluation of proposed improvement solutions to enhance the supply chain efficiency	Combined programming of data envelopment analysis (GP-DEA) model		Journal of Cleaner Production	A robust fuzzy possibility programming for a new network GPDEA model to evaluate sustainable supply chains	[21]
Performance Evaluation of Medical Centers	Fuzzy data envelopment analysis and intuitive hierarchical analysis process fuzzy DEA and IF-AHP	hospitals in Istanbul	Knowledge-Based Systems	Multi-expert performance evaluation of healthcare institutions using an integrated intuitionistic fuzzy AHP&DEA methodology	[22]
China's industry service performance assessment	1-dynamic black-box data envelopment analysis (DBDA; 2-static network data envelopment analysis(SNDE);	China service industry	Applied Mathematics and Computation	Evaluation of cloud service industry with dynamic and network DEA models	[23]
Solving the design of the efficient supply chain continuity scheme by the method of weighting the target functions	DEA, MDEA		Industrial Engineering Journal	Presenting a Multi-objective Planning Model to Design a Supply Chain Networking with Producers and Distributors Efficiently	[24]
Calculating the optimistic and cynical efficiency of sustainable supply chains	Network DEA (NDEA)	Resin production plants	Computers & Operations Research	A new fuzzy DEA model for evaluation resilience of efficiency and effectiveness of suppliers in sustainable supply chain management context	[25]

Table 1: Models and Literature review of Fuzzy Network DEA

Criteria	Model	Case Study	Journal	Research Subject	References
Supply chain flexibility	Social Network Analysis (SNA) and System Dynamics Modeling (SDM)	Industrialized Construction in Hong Kong	Journal of Construction Engineering and Management	Modeling Supply Chain Resilience in Industrialized Construction: A Hong Kong Case	[26]
This paper focuses on the evaluation of supply chain operations that maximize economic returns, minimize environment impacts, and meet social expectations.	that is apt to evaluate the sustainability of a chain of business partners. In addition, the proposed mathematical model is applied to two case studies.	In Iran	Journal of Cleaner Production	A data envelopment analysis approach to evaluate sustainability in supply chain networks	[27]
Integrated data envelopment analysis	additive approach of two-stage network data envelopment analysis (DEA), the nonlinear DEA model	In China	European Journal of Operational Research	Equivalent solutions to additive two-stage network data envelopment analysis	[28]
propose a new dynamic range directional measure (RDM) for two-stage DEA models	data envelopment analysis (DEA) approach, two-stage DEA models	banking industry In Iran	Computers & Industrial Engineering	A new dynamic range directional measure for two-stage data envelopment analysis models with negative data	[29]
sustainably resilient supply chains (SCs)	novel fuzzy chance-constrained two-stage data envelopment analysis (DEA) model	three megacities In Iran	Applied Soft Computing	Sustainably resilient supply chains evaluation in public transport: A fuzzy chance-constrained two-stage DEA approach	[30]
assessing the sustainability of supply chains	new stochastic two-stage data envelopment analysis (DEA) model	In Iran	Annals of Operations Research	Developing a linear stochastic two-stage data envelopment analysis model for evaluating sustainability of supply chains: a case study in welding industry	[31]
consider efficient frontiers and the second aspect applied DEA to consider inefficient frontiers	First, using fuzzy screening system, the authors identify and remove the unqualified suppliers. Then, the authors run their proposed clustering method. This paper proposes a data envelopment analysis (DEA) algorithm to cluster suppliers.	In Iran	Journal of Enterprise Information Management	How to use fuzzy screening system and data envelopment analysis for clustering sustainable suppliers? A case study in Iran	[32]
An Agri-Fresh Food Supply Chain Network Design with Routing Optimization	modeling of traditional AFSC	ETKA Company	advances in Mathematical Finance & Applications	An Agri-Fresh Food Supply Chain Network Design with Routing Optimization: A Case Study of ETKA Company	[33]

Table 1: Models and Literature review of Fuzzy Network DEA

Criteria	Model	Case Study	Journal	Research Subject	References
Designing a Sustainable Supply Chain Model with an Emphasis on Behavioural Factors	structural equation modeling	foodstuff in Kermanshah province, iran	advances in Mathematical Finance & Applications	Designing a Sustainable Supply Chain Model with an Emphasis on Behavioral Factors for Foodstuffs in Kermanshah Province	[34]
real case study of the natural gas supply chain	Fuzzy modeling	In Iran	advances in Mathematical Finance & Applications	A Fuzzy Goal-Programming Model for Optimization of Sustainable Supply Chain by Focusing on the Environmental and Economic Costs and Revenue	[35]

According to new supply chain theories, the performance of this chain is not focused solely on performance evaluation systems, but on each component. In this study, a multivariate approach (Data Envelopment Analysis, Data Envelopment Analysis, and Linear Programming) has been used, which is a new approach to performance evaluation. In the review of the above studies, all of the studies carried out were based on data envelopment analysis, although the models and data used for this purpose were different. Since there has been no research in the research network in order to provide improvement directions for the evaluated units, in the present study, using a shortage-based approach and considering adverse outcomes, a new approach to determining the optimal levels of each of the variables Input and output and interface will be provided.

Previous studies have shown that although the efficiency of supply chain components is considered desirable, this has a limited impact on the overall efficiency of the supply chain. Therefore, the researcher believes that in order to assess the resilience (resilience) of the supply chain, it is necessary to simultaneously examine the components of the supply chain and supply chain system. Although risk assessment studies have often been performed quantitatively or in part, risk identification is very limited, and, on the other hand, the high risk exposure is not expressed based on different indicators, and therefore the risk level is critical are not related to each other and are also more concerned with case study. Therefore, the results of the review of previous studies and researches and the studies carried out show that most of the papers and researches (over 70% of them) focus on the concepts of supply chain risk management, the provision of field and case studies, and the review of literature and issues such as the application of modelling and simulation approaches are very limited[36]. Among other issues to be addressed in this study, there is a lack of research guidance on assessing risk resilience in the supply chain. So far, little research has been done to address this by developing analytical frameworks and focusing on the complex task of assessing supply chain resonance [9, 20, 21, 27]. However, many of these studies do not pay attention to the pre-disturbing phase of the supply chain system (which includes risk assessment) [37].

Although it has been proven that using these models to perform risk assessment of the supply chain is inefficient, they do not directly assess the supply chain resonance. In addition, traditional data envelopment modelling typically describes the simulation of a "black box" [38], in which the performance and the nature of the relationship between the underlying processes of the supply chain system are examined. Take up Such constraints could raise problems with the assessment of the individual levels (components) of the supply chain and the supply chain system as a whole. Network data modelling of data envelopment analysis [38] in this study has been used to overcome such barriers and limitations.

According to new chain theories, both performance systems and each component affect this chain performance. The present study uses a multi-method approach (data envelopment analysis, network envelopment data analysis, linear programming), which is a new approach in performance evaluation.

4 Analysis

In the previous sections of this paper, it explains its modelling approach by demonstrating the need to combine the traditional approach of identifying, managing, and reducing supply chain risks with modern supply chain resilience approaches that are prepared, responsive, and resuscitated. The supply chain was addressed to potential losses. In addition, in the literature, there is also the lack of quantitative evaluation models of supply chain resilience [13]. Quantitative models that can measure the supply chain and the evaluation of the resilience are also addressed.

In order to achieve the purpose of this research, a multi-method approach has been selected that allows designing and testing an analytical model for assessing supply chain risk resilience. In order to develop an analytical model for risk and evaluate the resilience in a three-stage supply chain, data envelopment analysis and fuzzy theory have been used. As discussed later in this section, in this study, data envelopment analysis enables the integration of risk and viability criteria as supply chain data and headquarters, as well as it is possible to compare the current level of vibration for different risks of supply chain with the desired levels of volatility that the decision makers are aiming for it. Additionally, data envelopment analysis provides three comparisons at the process level (as an example of the supply chain companies) and at the system level (supply chain as entity). The data envelopment analysis, introduced by Charnes et al., measures the relative efficiency of the number of n decision-maker units (DMUs) that use m data to generate output s. The disparity model for the kM decision maker, DMUk, presented by Charles, Cooper, and Rhodes (CCR), is presented as follows:

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

s.t.

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

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

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

In this model,
s the number of output variables;
m Number of input variables;
r Index of output variables (r = 1,2, ..., s);
i is the index of input variables (i = 1,2, ..., m);
j The units of the decision maker (j = 1,2, ..., n);
Y_rk The output value rM (r = 1,2, ..., s) The decision maker k;
X_ik Input value iM (i = 1,2, ..., m) The decision maker k;
u_r The output coefficient rM (r = 1,2, ..., s) in the assessment of the efficiency of the decision maker k;

v_i The i-th input factor (i = 1,2, ..., m) in the estimation of the unit's efficiency k;

And ε is a small amount of Archimedean.

Using the transformation of the Charnes and Cooper variables, the model (1) becomes a linear programming model as follows:

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

s.t.

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

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

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

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

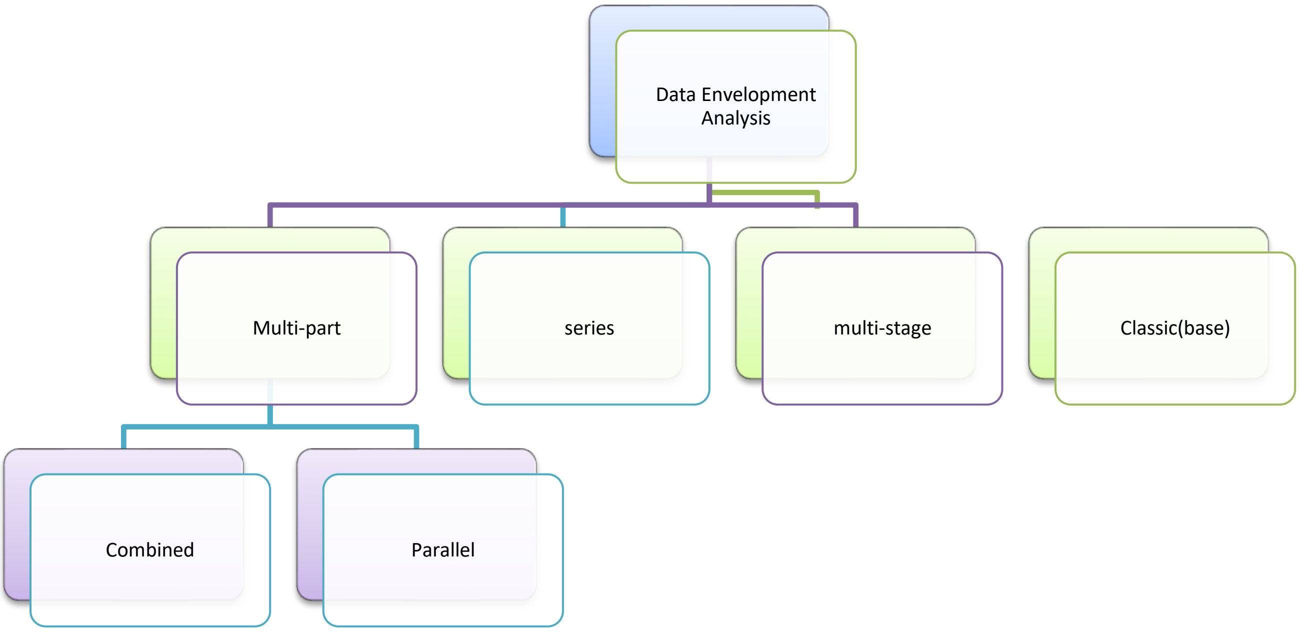

Fig. 2: Classification of Data Envelopment Analysis Models in terms of the decision maker's structure [39]

This model, which is the first model of data envelopment analysis, is called the input-axis multiplicative model. This model actually provides a nonparametric estimation of the production function, assuming that the set produces a convex set with a constant-scale return. After presenting this model, various forms of the various types of data envelopment analysis models were presented by various researchers. The present study presents a proposed model for evaluating the resilience in a three-stage supply chain as shown in Fig. Due to the network nature of the problem under study, we need to use a network of data envelopment analysis models. By developing the model number (2-4) into the Data

Envelopment Analysis Model, it is possible to calculate a risk and vibration variable in a three-stage supply chain has been provided. In addition, it has been shown that the analysis of the data network is stronger than the traditional non-network model and hence the accuracy of the model results increases [39].

4.1 Data Envelopment Analysis Network Models

Classical data envelopment analysis models consider evaluated units as a black box that converts inputs into outputs. These models do not pay attention to the structure and flow of the units. Models of the general network are based on these classical models that take into account the internal structure of the units. These models were first introduced by [36]. A general look at the data capture models can be categorized as shown in Fig. 2.

Based on Fig. 2, network data envelopment analysis is split into two multi-stage and multi-part groups. Two or more stage models are used in the assessment of the efficiency of supply chains in several organizations [28]. While multi-sectional models relate to the internal structure of an organization that is composed of different parts. This structure can be in series, parallel or combination.

Consider the two-step process shown in Fig. 3. Suppose that the DMU must be evaluated and each DMU〗 _j (j = 1,2, ..., n) has m input () and output () in the first stage. This output will then be the inputs of the second stage, and they are called interstitial products. The outputs of the second stage are shown as (). The 〖DMU〗 _j performances are defined and defined in the first and second stages respectively, where () and (), respectively, the input and output weights in the first stage and () and () respectively the input and output weights in the second stage are. Based on performance in each of the two stages, the overall efficiency of the whole process can be defined in some way.

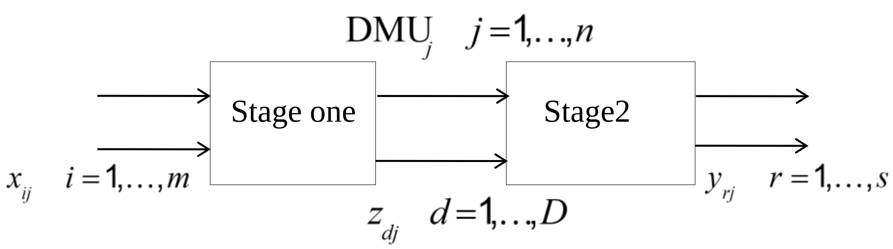

Fig. 3: Two-step process

4.2 DEA Model for Evaluating the Supply Chain Resilience to its Risks

The three-stage supply chain model, which includes upstream, organizational, and downstream processes, their associated risks and their resiliency levels (as inputs and outputs of inter-organizational processes) has been shown. Hence, the upstream levels of the supply chain layers are shown as outputs and can be considered as inputs of the lower layers.

It has been shown from the figure that the upstream risks (X-11), the external (X-12), the network (X-12) as input and the supply resiliency to (Z _1) the output of the interface of the upstream process, has an impact on the supplier operation. Similarly, organizational risks (X-21), external (X-22), network (X-23), input are considered, and the manufacturer's resiliency (Z_2) is considered as the output of the interfaces of organizational processes. Finally, the downstream risks (X_{31}), external (X_{32}), network (X_{33}), as distribution input and distribution (Y_3), as output of upstream processes have been taken. The "~" sign represents the fuzzy values of risk levels and volatility.

4.3 Symbol

In order to develop a resampling network model for risk assessment, this section introduces the symbols used for modelling in the section below.
Parameters
X_{11}^j Fuzzy Estimated Value Upstream Risk Upstream Processes in JM Decision Unit (Petrochemical);
X_{12}^j Fuzzy Estimated Risk External Processes Upstream Processes in the JM Decision Unit (Petrochemical);
X_{13}^j Fuzzy Estimated Value of Network Risks of Upstream Processes in the JM Decision Unit (Petrochemical);
X_{21}^j Fuzzy Estimated Risk Organizational Processes in the JM Decision Unit (Petrochemical);
X_{22}^j Fuzzy Estimated Value of External Risks of Organizational Processes in the JM Decision Unit (Petrochemical);
X_{23}^j Fuzzy Estimated Value of Network Risks of Organizational Processes in the JM Decision Unit (Petrochemical);
X_{31}^j Fuzzy Estimated Value of Downstream Risks Downstream Processes in the JM Decision Unit (Petrochemical);
X_{32}^j Fuzzy Estimated Value of External Risks Downstream Processes in the JM Decision Unit (Petrochemical);
X_{33}^j Fuzzy Estimated Value of Network Risks for Downstream Processes in the JM Decision Unit (Petrochemical);
Z_1^j Fuzzy Estimated Value of Provider Resonance in Highly Handled Processes in the JM Decision Unit (Petrochemical);
Z_2^j Fuzzy Estimated Value of Provider Resilience in Organizational Processes in the JM Decision maker (Petrochemical);
Y_3^j Fuzzy Estimated Value of Provider Resilience in Downstream Processes in the JM Decision Unit (Petrochemical).

Variables
v_{1i}: Weight of upstream types of risk ($i = 1$), external ($i = 2$) and network ($i = 1$) upstream processes in resiliency assessment;
v_{2i}: The weight of organizational risks ($i = 1$), external ($i = 2$) and network ($i = 1$) of organizational processes in the assessment of resiliency;
v_{1i}: Weight of downside risk types ($i = 1$), external ($i = 2$) and network ($i = 1$) downstream processes in resonance assessment;
w_1: Weight of supplier resonance in high-handed processes in resilient assessment;
w_2: Supply Resonant Weight in Organizational Processes in Resilience Evaluation;
u_3: Weight of supplier resilience in downstream processes in resilience assessment;

5 Modeling

5.1 Overall Performance 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 resonance. For each of the supply chain process layers, four performance scores have been calculated: the performance of upstream processes, organizational processes and downstream processes along with the overall performance of the supply chain system.

To estimate overall efficiency, consider the three-step process model as Fig. 1.

The processes inside the box are intended to be black boxes and the overall performance of the chain is formulated using classical models. According to Mandal [38] the overall performance of the DMUk supply chain system will be formulated as follows:

$$\begin{aligned}
&\tilde{E}_k = max \frac{u_3 \tilde{Y}_3^k}{\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^k} \\
&\text{s.t.} \\
&\frac{u_3 \tilde{Y}_3^j}{(\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^j)} \le 0, j = 1,2,\dots,n \\
&v_{ti}, u_3, \ge \varepsilon, i = 1,2,3;\ t = 1,2,3
\end{aligned} \tag{3}$$

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. This is the multiplication factor of the CCR deficit. By modifying the Charness-Cooper variable, the linear model is formulated as follows.

$$\begin{aligned}
&\tilde{E}_k = max\ u_3 \tilde{Y}_3^k \\
&\text{s.t.} \\
&\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^k = 1 \\
&u_3 \tilde{Y}_3^j - (\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^j) \le 0, j = 1,2,\dots,n \\
&1,2,\dots,n \\
&v_{ti}, u_3, \ge \varepsilon, i = 1,2,3;\ t = 1,2,3
\end{aligned} \tag{4}$$

5.2 Partly Functionalities

Similarly, one can assume each of the upstream, downstream and downstream processes, with regard to the input and output risks. Suppose that E_k ^ 1, E_k ^ 2, and E_k ^ 3, respectively, are to assess the upstream, downstream, and organizational processes of the petrochemical company under consideration. Consider the upstream processes. In these processes, three types of 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:

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

Similarly, organizational processes produce resilience to upstream processes as well as corporate, external, and network risks as inputs and resiliency as outputs. Using the symbols in this section, the organizational processes' motivation is formulated as follows.

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

A similar clause can be made for downstream processes. These processes generate resilience to organizational processes, along with downstream, enterprise, and network-based risk as input and output as output. As a result, the resilience of these processes is formulated as follows:

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

Considering the smaller value of the existence of the values of efficiency, relations (5) - (7) can be considered in the form of model constraints.

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

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

$$\begin{aligned} &\tilde{E}_k = max\, u_3\tilde{Y}_3^k \\ &\text{S.T.} \\ &\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^k = 1 \\ &u_3\tilde{Y}_3^j - (\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}\tilde{X}_{ti}^j) \le 0, j = 1,2,\dots,n \\ &w_1\tilde{Z}_1^j - \sum_{i=1}^{3} v_{1i}\tilde{X}_{1i}^j \le 0, j = 1,2,\dots,n \\ &w_2\tilde{Z}_2^j - (w_1\tilde{Z}_1^j + \sum_{i=1}^{3} v_{2i}\tilde{X}_{2i}^j) \le 0, j = 1,2,\dots,n \\ &u_3\tilde{Y}_3^0 - (w_2\tilde{Z}_2^j + \sum_{i=1}^{3} v_{3i}\tilde{X}_{3i}^j) \le 0, j = 1,2,\dots,n \\ &v_{ti}, u_3, w_1, w_2 \ge \varepsilon, i = 1,2,3;\ t = 1,2,3 \end{aligned} \tag{9}$$

(10)

Model (10) is a fuzzy linear programming model whose solution requires the development of specific methods. In the present study, in order to solve the fuzzy linear model, an alpha-based approach is used which is described below.

Using fuzzy sets and the α-cut approach for the proposed DEA model various approaches to solving fuzzy linear programming problems are presented by researchers. One of the most widely used methods, which is based on Hatami Mabbini, today's powerful and potent is also widely used in fuzzy data envelopment analysis, the alpha-based approach. In this approach, fuzzy numbers are replaced with their alpha slices and the problem is solved for different alpha values. By 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. Given that the fuzzy numbers considered in this study are to evaluate the types of risk and resonance indices of triangular fuzzy numbers, fuzzy slices will be considered for these numbers. For a triangular fuzzy number (l, m, u), the membership function is defined as follows.

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

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

$$\frac{x-l}{m-l} \geq \alpha \rightarrow x \geq l(1-\alpha) + \alpha m$$

and

$$\frac{u-x}{u-m} \geq \alpha \rightarrow \leq u(1-\alpha) + \alpha m$$

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

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

The relationships of the above equation show the alpha slices of input, output, and interface indices in the resiliency assessment model. By applying these cuts in the resiliency assessment model, in order to find the DMUk membership function, it is necessary to calculate the upper and lower limit of α-cut for the function E _k, ie, 〖(E_k)〗 _ α = [〖 〖(E〗 _k)〗 _ α ^ L, 〖 〖(E〗 _k)〗 _α ^ U]. Based on the models, Kao [24], and Kao and Hwang [25], the upper limit of the model 9 will be calculated using the model 19.

$$\begin{aligned}
&(E_k)_\alpha^U = max\, u_3(Y_3^k)_\alpha^U \\
&\text{s.t.} \\
&\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^k)_\alpha^L = 1
\end{aligned} \tag{12}$$

$$u_3(Y_3^k)_\alpha^L - \left(\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^k)_\alpha^U\right)$$
$$u_3(Y_3^j)_\alpha^L - \left(\sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}(X_{ti}^j)_\alpha^U\right) \le 0, j = 1,2,\dots,n, j \ne k$$
$$\hat{z}_1^k - \sum_{i=1}^{3} v_{1i}(X_{1i}^k)_\alpha^L \le 0$$
$$\hat{z}_1^j - (\sum_{i=1}^{3} v_{1i}(X_{1i}^j)_\alpha^U) \le 0, j = 1,2,\dots,n, j \ne k$$
$$\hat{z}_2^k - (\hat{z}_1^k + \sum_{i=1}^{3} v_{1i}(X_{2i}^k)_\alpha^L) \le 0$$
$$\hat{z}_2^j - (\hat{z}_1^j + \sum_{i=1}^{3} v_{1i}(X_{2i}^j)_\alpha^U) \le 0, j = 1,2,\dots,n, j \ne k$$
$$u_3(Y_3^k)_\alpha^U - (\hat{z}_2^k + \sum_{i=1}^{3} v_{1i}(X_{3i}^k)_\alpha^L) \le 0$$
$$u_3(Y_3^j)_\alpha^L - (\hat{z}_2^j + \sum_{i=1}^{3} v_{1i}(X_{3i}^j)_\alpha^U) \le 0, j = 1,2,\dots,n, j \ne k$$
$$w_1(Z_1^j)_\alpha^L \le \hat{z}_1^j \le w_1(Z_1^j)_\alpha^U, j = 1,2,\dots,n$$
$$w_2(Z_2^j)_\alpha^L \le \hat{z}_2^j \le w_2(Z_2^j)_\alpha^U, j = 1,2,\dots,n$$
$$v_{ti}, u_3, w_1, w_2 \ge \varepsilon,$$
$$i = 1,2,3; t = 1,2,3$$

After calculating the optimal values for v_ti ^ *, u_3 ^ *, w_1 ^ *, w_2 ^ *, z_1 ^ * and z_2 ^ *, the model 12 provides the performance for the whole network and the three process levels according to the following formula: Suggests:

$$(E_k)_\alpha^U = u_3^*(Y_3^k)_\alpha^U \Big/ \sum_{t=1}^{3}\sum_{i=1}^{3} v_{ti}^*(X_{ti}^k)_\alpha^L$$
$$(E_k^1)_\alpha^U = \hat{z}_1^{*k} \Big/ \sum_{i=1}^{3} v_{1i}^*(X_{1i}^k)_\alpha^L$$
$$(E_k^2)_\alpha^U = \hat{z}_2^{*k} \Big/ (\hat{z}_1^{*k} + \sum_{i=1}^{3} v_{2i}^*(X_{2i}^k)_\alpha^L) \tag{13}$$
$$(E_k^3)_\alpha^U = u_3^*(Y_3^k)_\alpha^U \Big/ (\hat{z}_2^{*k} + \sum_{i=1}^{3} v_{3i}^*(X_{3i}^k)_\alpha^L)$$

The formulation of the lower limit of α-cut performances of the proposed model in Figure 3 requires a dual function of the model 16 to become fuzzy. Consequently, the two-edged and transformed version of the 16-model is formulated and the bottom-line α-cut is calculated as the overall efficiency, along with the performance 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 Pettit et al. [24].

$$
\begin{aligned}
&\tilde{E}_k = \min \theta - \varepsilon((\sum_{t=1}^{3}\sum_{i=1}^{3} s_{ti}^{v}) + s_1^w + s_2^w + s_3^u)\\
&\text{s.t.}\\
&\theta \tilde{X}_{1i}^{k} - \sum_{j=1}^{n} \alpha_j \tilde{X}_{1i}^{j} - \sum_{j=1}^{n} \beta_j \tilde{X}_{1i}^{j} - s_{1i}^{v} = 0, i = 1,2,3\\
&\theta \tilde{X}_{2i}^{k} - \sum_{j=1}^{n} \alpha_j \tilde{X}_{2i}^{j} - \sum_{j=1}^{n} \gamma_j \tilde{X}_{2i}^{j} - s_{2i}^{v} = 0, i = 1,2,3\\
&\theta \tilde{X}_{3i}^{k} - \sum_{j=1}^{n} \alpha_j \tilde{X}_{3i}^{j} - \sum_{j=1}^{n} \delta_j \tilde{X}_{3i}^{j} - s_{3i}^{v} = 0, i = 1,2,3\\
&\sum_{j=1}^{n} \beta_j \tilde{Z}_1^j - \sum_{j=1}^{n} \gamma_j \tilde{Z}_1^j - s_1^w = 0\\
&\sum_{j=1}^{n} \gamma_j \tilde{Z}_2^j - \sum_{j=1}^{n} \delta_j \tilde{Z}_2^j - s_2^w = 0\\
&\sum_{j=1}^{n} \alpha_j \tilde{Y}_3^j + \sum_{j=1}^{n} \delta_j \tilde{Y}_3^j - s_3^u = \tilde{Y}_3^k\\
&\alpha_j, \beta_j, \gamma_j, \delta_j, s_{ti}^{v}, s_1^w, s_2^w, s_3^u \geq 0, j = 1,2,\dots,n; i = 1,2,3; t = 1,2,3
\end{aligned}
\tag{14}
$$

Accordingly, the lower limit of α-cut of the overall efficiency model (number 21) will be as follows:

$$
\begin{aligned}
&(E_k)_\alpha^L = \min \varepsilon((\sum_{t=1}^{3}\sum_{i=1}^{3} s_{ti}^{v}) + s_1^w + s_2^w + s_3^u)\\
&\text{s.t.}\\
&\theta (X_{1i}^k)_\alpha^U - \left[\alpha_k \left(X_{1i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j \left(X_{1i}^j\right)_\alpha^L\right] - \left[\beta_k \left(X_{1i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \beta_j \left(X_{1i}^j\right)_\alpha^L\right] - s_{1i}^{v}\\
&\qquad = 0, i = 1,2,3\\
&\theta (X_{2i}^k)_\alpha^U - \left[\alpha_k \left(X_{2i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j \left(X_{2i}^j\right)_\alpha^L\right] - \left[\gamma_k \left(X_{2i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \gamma_j \left(X_{2i}^j\right)_\alpha^L\right] - s_{2i}^{v}\\
&\qquad = 0, i = 1,2,3\\
&\theta (X_{3i}^k)_\alpha^U - \left[\alpha_k \left(X_{3i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \alpha_j \left(X_{3i}^j\right)_\alpha^L\right] - \left[\delta_k \left(X_{3i}^k\right)_\alpha^U + \sum_{j=1, j\neq k}^{n} \delta_j \left(X_{3i}^j\right)_\alpha^L\right] - s_{3i}^{v}\\
&\qquad = 0, i = 1,2,3\\
&\sum_{j=1}^{n} \beta_j z_1^j - \sum_{j=1}^{n} \gamma_j z_1^j - s_1^w = 0\\
&\sum_{j=1}^{n} \gamma_j z_2^j - \sum_{j=1}^{n} \delta_j z_2^j - s_2^w = 0
\end{aligned}
\tag{15}
$$

$$\left[\alpha_k (Y_3^k)_\alpha^L + \sum_{j=1, j\neq k}^{n} \alpha_j (Y_3^j)_\alpha^U\right] + \left[\delta_k (Y_3^k)_\alpha^L + \sum_{j=1, j\neq k}^{n} \delta_j (Y_3^j)_\alpha^U\right] - s_3^u = (Y_3^k)_\alpha^L$$
$$(Z_1^j)_\alpha^L \leq z_1^j \leq \left(Z_1^j\right)_\alpha^U, j = 1,2, \dots, n$$
$$(Z_2^j)_\alpha^L \leq z_2^j \leq \left(Z_2^j\right)_\alpha^U, j = 1,2, \dots, n$$
$$\alpha_j, \beta_j, \gamma_j, \delta_j, s_{ti}^v, s_1^w, s_2^w, s_3^u \geq 0, j = 1,2, \dots, n; i = 1,2,3; t = 1,2,3$$

By obtaining the optimal solution of model number (22), the values of sti ^ (* v), s_1 ^ (* w), s_2 ^ (* w), s_3 ^ (* u) are given to vti ^ *, w_1 ^ *, w_2 ^ *, u_3 ^ * and hence, the low system efficiency and low performance levels of upstream, organizational and downstream processes are calculated at the α-cut level as follows:

$$(E_k)_\alpha^L = u_3^* (Y_3^k)_\alpha^L \Big/ \sum_{t=1}^{3} \sum_{i=1}^{3} v_{ti}^* (X_{ti}^k)_\alpha^U$$
$$(E_k^1)_\alpha^L = w_1^* z_1^{*k} \Big/ \sum_{i=1}^{3} v_{1i}^* (X_{1i}^k)_\alpha^U$$
$$(E_k^2)_\alpha^L = w_2^* z_2^{*k} \Big/ (w_1^* z_1^{*k} + \sum_{i=1}^{3} v_{2i}^* (X_{2i}^k)_\alpha^U) \qquad (16)$$
$$(E_k^3)_\alpha^L = u_3^* (Y_3^k)_\alpha^L \Big/ (w_2^* z_2^{*k} + \sum_{i=1}^{3} v_{3i}^* (X_{3i}^k)_\alpha^U)$$

The variable values of α in models of (12) and (15) are 0 and 1, respectively. These values are important and used to report on the outcome of these two models. If alpha is zero (α = 0), then the range of all possible performance scores for different alpha values is determined. Additionally, at alpha level 1 (α = 1), the most probable performance scores are obtained for decision-making units. Therefore, using performance scores for different alpha values and communicating below and above these performance scores, the membership function of the fuzzy resiliency levels of the 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 / viability ratios between the decision-making units and the diverse processes of the environment. In the next section, the proposed DEA network fuzzy model is tested using 150 intermediate and senior managers of nine Iranian petrochemical companies.

The petrochemical companies surveyed are:

1. Kharkov Petrochemical Company
2. Isfahan Petrochemical Company
3. Shazand Petrochemical Company
4. Bandar Imam Petrochemical Company
5. Shiraz Petrochemical Company
6. Tabriz Petrochemical Company
7. Khorasan Petrochemical Company
8. Kermanshah Petrochemical Company
9. Bisotun Petrochemical Company

5.3 Tools for Research and Data Collection

The main method used to collect the data needed for the present study is the history, theoretical background and library documents related to the subject, which can be used from their findings and findings at different stages of the research. To sample and present the performance evaluation model, we can use a chained or snowball sampling method (which means identifying people who are qualified and have valuable information for the selected individuals). The construction of the research model is used to select the sample from the combination of purposeful judging methods and snowball method, which is a non-probabilistic method. In this way, the work begins with people who are experts in the field and have the necessary criteria, and, while inquiring questions, they are asked to be introduced to other experts in this field. Therefore, apart from the first few people who are directly elected by the researcher on the basis of the criteria in question, other experts are selected in addition to the criteria of excellence by other experts. On the other hand, sampling adequacy will be achieved by theoretical sampling method. In this method, the sampling continues to the extent that the model reaches the limit of production and saturation. The initial test of the model indicates the acceptable level of internal sustainability, with Cronbach's alpha higher than 0.8 [21] and the convergent validity is above 0.7 [40].

In addition, all load variables were above 0.45 and no evidence of cross-reference loading was found. Since variables have a different frequency distribution, this study employed Tabachnick and Fidel's Threshold Levels, such that: 0.32 equal to the weak, 0.45 suitable, 0.55 good, 0.63 Very good and 0.71 was considered excellent. Considering that the sample size was 150, this number had the necessary capability to achieve meaningful results [41]. In order to test the model, 150 senior and middle managers from 9 Iranian petrochemical companies, in order to rank the risk resilience of the companies they were employed, as well as risk and risk assessment of upstream, organizational and the downside of these companies was examined. In the first place, the purpose of this study was to prioritize risk and model viability. The minimum, maximum and average work experience of the participants in this test was 3, 15, and 6.5 years, respectively. The demographic information of individuals is shown in Table 2.

Table 2: Demographic Information of participants n=130

	No	**%of whole**	**% Aggregate percentage**
Sex			
Woman	22	17	17
Man	108	83	100
Total	130	100	
Age			
30<	7	6	6
30-60	84	67	72
60>	35	28	100
Total	126	100	
Petrochemistry			
Khark	9	7	7
Esfahan	15	12	19
Shazand	17	13	33
Bandare Emam	11	9	41
Shiraz	13	10	52
Tabriz	20	16	67
Khorasan	16	13	80
Kermanshah	11	9	89
Bistoon	14	11	100
Total	126	100	

6 Results

Respondents were asked to take linear (from very little to very high) to assess inputs, outputs and intermediaries referred to in Figure 1. Respondents evaluated all the risk and viability items of the industrial supply chain that they were working on. Table 7 shows the number of respondents per supply chain. In order to evaluate the main assumptions of the model, while the items related to the risk of upstream, downstream and downstream processes, items related to the resilience of these processes were considered constant. These linear variables, in turn, were converted to triangular fuzzy numbers (TFNs) and range from 1 to 9. The reason for the use of triangular fuzzy numbers is the ease of calculation, extensive application in articles and research in the field of decision making and better understanding of users. To this end, the responses of respondents to the questionnaires were collected according to the verbal scale:

Very low (1, 1, 3)

Bottom (1, 3, 5)

Desirable (3, 5, 7)

Top (5, 7, 9)

Very high (7, 9, 9).

For example, if the respondent assesses one of the risk items (for example, the dependency of production on a supplier), the corresponding triangular fuzzy number will be (5, 7, 9). According to Pettit et al. [9], for each petrochemical company, the average fuzzy risk and fluctuation items were extracted and aggregated to achieve the main risk and resilience of the supply chain of the group. The average values of inputs, outputs, and input and output interfaces of the model referred to in Figure 7 are shown in Table 8.

The 2014b version of MacBooks software was used to codify the model and create the corresponding membership map diagrams. As previously mentioned, the values of $\alpha = 1$ and $\alpha = 0$ were used to determine the range and the most probable values of the performance score. With that in mind, in Table 9, the upper and lower grades of the supply chain are used for zero and one alpha (each for three layers).

7 Conclusion

As it is seen in this section, in the first section, the descriptions and precise explanations of the problem under consideration were considered, its necessity and its dimensions. After the statement of the problem, the goals and questions of the research were presented, then the general stages of the problem, the statistical society of the research and the methods for collecting and analysing the research data were presented. The second part examines the theoretical foundations of the research. In this section, a first review of the concepts of supply chain management, supply chain risks and supply chain resilience, along with the methods used in the research, was then presented and compared to the research background (research background). The explanation of the research method in the third section was introduced and the principles of the methodology of this research were introduced.

In the fourth part, the first mathematical model of the research was designed based on the principles developed in the first and second sections and after the design of the research model; we decided to determine the optimal answer. In this section, we will discuss the results of our research and its findings, as well as introduce research constraints and provide suggestions for future research.

Table 3: Average triangular fuzzy numbers extracted for inputs, outputs and intermediate inputs / outputs of the three-tier supply chain

Petrochemistry	X11	X12	X13	X21	X22	X23	X31	X32	X33	Z1	Z2	Y3
Khark	(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)	(2.1,3.4,5.3)	(3,4.4,5.9)
Esfahan	(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)	(3.4,5,6.6)	(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)
Shazand	(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)
Bandare emam	(3.4,5,6.5)	(2.8,4.3,5.9)	(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)
Shiraz	(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)	(3.4,4.6,6.3)	(3.5,5,6.4)	(3,4.6,6.4)	(4,5.8,7.1)
Tabriz	(3.1,4.6,6.4)	(3.5,5.3,7.1)	(3.3,4.8,6.4)	(2.9,4.5,6.5)	(5.4,7.4,8.4)	(3.1,4.8,6.3)	(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)
Khorasan	(2.9,4.3,6.1)	(3.6,5.5,7.1)	(4,5.5,6.8)	(2.9,4.3,6.1)	(4.1,5.9,7.3)	(3.9,5.4,6.6)	(4,6,7.5)	(3.1,4.9,6.6)	(2.8,4.4,6.1)	(3.1,4.6,6.5)	(3.8,5.4,6.9)	(3,4.4,6)
Kermanshah	(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)	(3.3,4.9,6.6)	(3.3,4.5,6)
Biston	(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)	(3.4,5.1,6.7)	(3.9,5.8,7.5)	(3.2,4.5,6.4)	(3.5,5.1,6.6)

7.1 Analysis of the Results

In addition to the results reported in Table 9, the value chain associated with the "Shazand" petrochemical company showed the highest overall exposure to risk, so that its efficiency score (E_k = 0.70) was in alpha1. Subsequently, the supply chain for the port of Imam (E = 0.68) and Tabriz petrochemical supply chain (E_k = 0.60) were next in terms of volatility. These results indicate that there is a relatively high degree of viability for the supply chain risk in these companies. Also, 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 shown in Table 3, these scores do not necessarily have to match the overall performance 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, based on this, the calculation of the efficiency scores in these values of the total fuzzy efficiency score will be determined.

For example, although Khorasan's petrochemical chain is in fourth place, in terms of resiliency toward the risk of organizational processes (E_k ^ 2 = 0.78) compared to three other supply chains (ranked first to Third, there is a better situation. The comparison of membership functions is shown in Fig. 9. In another example, the supply chain for the Isfahan Petrochemical Complex, which is ranked fifth, has the second highest score (E_k ^ 1 = 0.74) in terms of the efficiency of upstream processes. As shown in Table 9, there are significant differences in the performance of the three main layers for the three superior supply chains. The Imam Bandar Petrochemical Supply Chain has been attributed due to a higher risk to the organizational and downstream processes of the Shazand Petrochemical Supply Chain. Also, the Tabriz petrochemical supply chain is ranked first in the supply chain resilience to downstream risks. the performance scores of the three best-performing supply chains (including Shazand Petrochemicals, Bandar Imam Petrochemicals and Tabriz Petrochemicals) are shown. According to the results of Table 5, the relative efficiency of the whole and the layers of the units considered are summarized in Table 5.

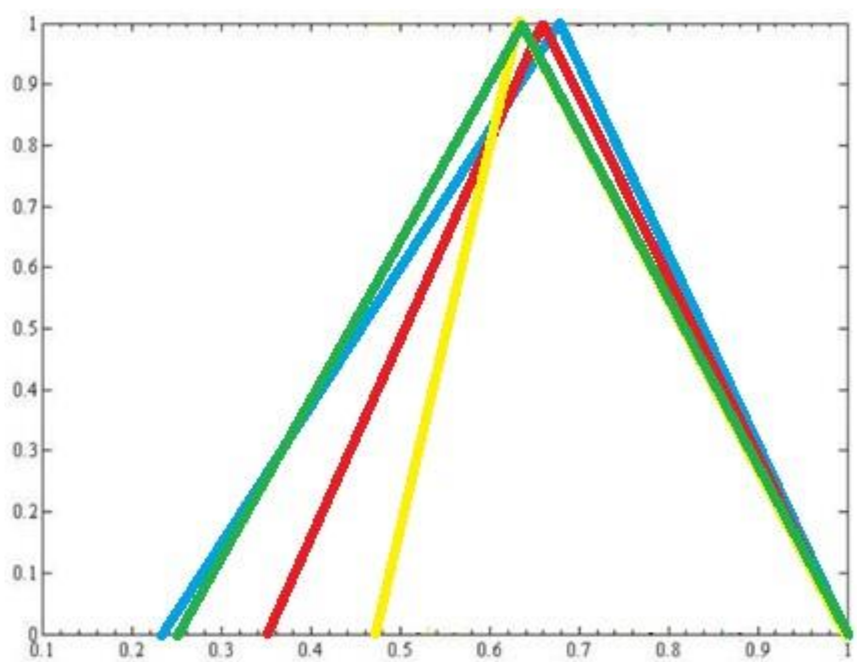

Fig. 4**:** Comparing the scores (values) of the efficiency of supply chain organizational processes in Shazand Petrochemical Complex, Bandar Imam, Tabriz, Khorasan

■Shazand Petrochemisty ■Bandare Emam ■Tabriz Petrochemistry ■Khorasan Petrochemistry

Table 4: α values for the fuzzy performance scores in the three-tier supply chain

		α=0				α=1			
Petro-chemis-try	Total rank-ing	Total (LB,UB)	Tire 1 (LB,UB)	Tire 2 (LB,UB)	Tire3 (LB,UB)	Total (LB,UB)	Tire1 (LB,UB)	Tire 2 (LB,UB)	Tire 3 (LB,UB)
Khark	٧	(0.14,1.00)	(0.18,0.46)	(0.17,0.52)	(0.14,0.47)	(0.33,0.33)	(0.30,0.30)	(0.27,0.27)	(0.34,0.34)
Esfahan	٥	(0.16,1.00)	(0.25,0.92)	(0.06,0.24)	(0.36,0.66)	(0.53,0.53)	(0.76,0.76)	(0.18,0.18)	(0.59,0.59)
Shazand	١	(0.23,1.00)	(0.66,0.93)	(0.49,0.76)	(0.12,0.85)	(0.68,0.68)	(0.88,0.88)	(0.65,0.65)	(0.58,0.58)
Bandare Emam	٢	(0.35,1.00)	(0.12,0.44)	(0.50,0.85)	(0.71,1.00)	(0.64,0.64)	(0.44,0.44)	(0.72,0.72)	(0.91,0.91)
Shiraz	٨	(0.09,1.00)	(0.03,0.34)	(0.05,0.36)	(0.06,0.34)	(0.30,0.30)	(0.30,0.30)	(0.27,0.27)	(0.33,0.33)
Tabriz	٣	(0.47,1.00)	(0.17,0.52)	(0.25,0.51)	(0.78,1.00)	(0.58,0.58)	(0.31,0.31)	(0.46,0.46)	(1.00,1.00)
Khorasan	٤	(0.25,1.00)	(0.06,0.20)	(0.54,0.82)	(0.64,1.00)	(0.60,0.60)	(0.13,0.13)	(0.76,0.76)	(0.86,0.86)
Kerman-shah	٩	(0.09,1.00)	(0.02,0.21)	(0.06,0.25)	(0.14,0.49)	(0.22,0.22)	(0.12,0.12)	(0.15,0.15)	(0.41,0.41)
Biston	٦	(0.17,1.00)	(0.15,0.54)	(0.06,0.30)	(0.46,1.00)	(0.37,0.37)	(0.38,0.38)	(0.13,0.13)	(0.70,0.70)

Table 5: Values for fuzzy performance scores in the three-tier supply chain

Petrochemistry	Overall rating	Total	Layer	Layer	Layer
Kharak	7	(٠,١٤، ٠,٣٣، ١)	(٠,١٨، ٠,٣، ٠,٤٦)	(٠,١٧، ٠,٢٧، ٠,٥٢)	(٠,١٤، ٠,٣٤، ٠,٤٧)
Esfahn	5	(٠,١٦، ٠,٥٣، ١)	(٠,٢٥، ٠,٧٦، ٠,٩٢)	(٠,٠٦، ٠,١٨، ٠,٢٤)	(٠,٣٦، ٠,٥٩، ٠,٦٦)
Shazand	1	(٠,٢٣، ٠,٦٨، ١)	(٠,٦٦، ٠,٨٨، ٠,٩٣)	(٠,٤٩، ٠,٦٥، ٠,٧٦)	(٠,١٢، ٠,٥٨، ٠,٨٥)
Bandar Emam	2	(٠/۳۵، ٠/۶۴، ١)	(٠,١٢، ٠,٤٤، ٠,٤٤)	(٠,٥ ،٠,٧٢، ٠,٨٥)	(٠,٧١، ٠,٩١، ١)
Shiraz	8	(٠/٠٩، ٠/٣، ١)	(٠,٠٣، ٠,٣، ٠,٣٤)	(٠,٠٥، ٠,٢٧، ٠,٣٦)	(٠,٠٦، ٠,٣٣، ٠,٣٤)
Tabriz	3	(٠,٤٧، ٠,٥٨، ١)	(٠,١٧، ٠,٣١، ٠,٥٢)	(٠,٢٥، ٠,٤٦، ٠,٥١)	(٠,٧٨، ١، ١)
Khorasan	4	(٠,٢٥، ٠,٦، ١)	(٠,٠٦، ٠,١٣، ٠,٢)	(٠,٥٤، ٠,٧٦، ٠,٨٢)	(٠,٦٤، ٠,٨٦، ١)
KERMANSHSAH	9	(٠,٠٩، ٠,٢٢، ١)	(٠,٠٢، ٠,١٢، ٠,٢١)	(٠,٠٦، ٠,١٥، ٠,٢٥)	(٠,١٤، ٠,٤١، ٠,٤٩)
BISTOON	6	(٠/١٧، ٠/٣٧، ١)	(٠,١٥، ٠,٣٨، ٠,٥٤)	(٠,٠٦، ٠,١٣، ٠,٣)	(٠,٤٦، ٠,٧، ١)

In Fig. 4, the values of the three superior value chain layers are shown. The function of the Shazand Petrochemical Supply Chain, shown in blue, is more efficient in terms of upstream processes, and in terms of downstream and organizational processes, lower efficiency than Bandar Imam Petrochemical and Tabriz Petrochemical ". On the other hand, Shazand petrochemical supply chain and Bandar-e-Imam petrochemical plant are close to each other in terms of the efficiency of organizational processes. The breakdown of the three main supply chain inefficiencies is shown in Table 6. This inefficient separation helps identify the variables that need to change to reach the desired level, at inputs and exits. In Table 6, the numbers (bold) represent the highest percentage change for each variable in the three supply chains. As seen in this table, upstream risks, by influencing upstream processes (-10.09%), pose the greatest threat to Bandar Imam's petrochemical supply chain. The same pattern can be seen in the Shazand petrochemical supply chain, which has the highest impact on foreign risks (-3.18%), and in Tabriz petrochemicals, the most risk of supply-side risk is Manufacturer-manufacturer (-12.86%).

The low magnitude of the volatility reported for upstream processes indicates that the petrochemical plant "Tabriz" (5.99%) has the lowest level of fluctuations in upstream processes, among the top three petrochemicals. An examination of this shows that in the Tabriz petrochemical supply chain, the network risks and communications between suppliers and producers have created the most concern among activists. In addition, the upgrading of Tabriz's petrochemical processes can be enhanced by investing more in variables that affect the supply chain resilience, such as human capital resources, organizational capital resources, and inter-organizational and physical resources. The performance values of the Imam Bandar Petrochemical Supply Chain Layer Strips indicate that the efforts to improve the thermal conductivity should include upstream and downstream processes. In addition, comparing the results with superior petrochemical patterns indicates that the primary focus of Bandar Imam's petrochemicals should be on reducing the risks associated with upstream and downstream processes. The results of Table 6 and Fig. 3 show that although a supply chain system may have a high degree of visibility over its risks, but its layers are still at risk. And this requires that the fluctuation model be used appropriately to cover all risks. If these risks do not decrease properly and at the right time, they can have an effect on supply chain resilience and provide potential for supply chain resiliency. Hence, while a supply chain may be in the general level of overall vibration and risk response, it should also be sensitive to its vulnerabilities and vulnerabilities in different layers.

7.2 Conclusion

This study has also been confronted with limitations. First, if both groups were the main risk and their criteria were formulated in the model, more accurate results were obtained. In this case, we can use the Kao Dynamic Data Envelopment Analysis Model [36] or the Meng Dual-Level Coverage model [42]. This leads to increased visibility in specific risk sources that may have the most devastating impact on supply chain resilience. In this research, the simplest type of three-layer supply chain was used for risk modeling and resiliency and indirect effects were not included in the model. Nevertheless, data network analysis can be able to model parallel networks as well as sets of more than three layers of networks [39]. For example, if supply resiliencies affect both the producer and the distributor, this can be modeled using a parallel structure and when multiple suppliers or distributors, they work in series, in parallel and parallel structures, can be tested by a network model.

The model chosen for this research does not explicitly measure the effects of malware damage and feedback among agents (or core processes) within the system. This could be one of the limitations of this research. The research model, also due to time delay, is not capable of evaluating dynamic and nonlinear behavior. Future research can be done by focusing on these dimensions. We believe that this can be achieved through the use of dynamic modeling or hybrid simulation approach. Multi-simulation modeling approaches can be done through simulation engines such as Enigmatic, and this can be used to create and test supply chain evaluation resonance models. In addition, the accuracy of the assessment of supply chain resilience can be increased through the integration of supply chain trends, and the rehabilitation and restructuring capabilities of the company's resources, which has recently been defined in the general framework for assessing supply chain resilience [43]. The proposed model of research has been tested and approved to evaluate the supply chain continuity of Iran's petrochemicals. In order to increase the external validity of this model, future studies can be used to test the model in other countries and regions, and to measure the system's resilience and supply chain resilience in other environments.

Future research can also be done by focusing on describing the applied dimensions of performance evaluation and supply chain resilience. In these studies, we can use other approaches to improve the assessment of the resilience at different levels of the supply chain (moving from a systematic approach to an organizational approach to the supply chain). For example, structural models can be used to communicate between supply chain risk variables on the one hand and supply chain resiliency variables on the other. These models should be empirically evaluated in different industrial and service platforms to measure the severity of the impact of each risk group on supply chain resilience. In addition, the results of this study indicate that risk assessment in the supply chain layers is not the same in different industries, and this necessitates further research on the proposed model.

The resilience of the supply chain is a prerequisite for the survival and continuity of the supply chain activity, which today faces a wide variety of risks, both globally and nationally. Skills in identifying the locations that need to be invested in them in order to increase the supply chain resilience will lead to an increase in the speed of the supply chain to changes that result in lower [10]. However, it is difficult to identify the main sources of risk that need to be addressed and corrected, which makes it difficult to identify risk processes. Given the general theory of systems and the supply chain theory as presented by Chopra and Meindl [46], this study states that in order to achieve a better understanding of supply chain risk aversion, the resiliency must be evaluated both at the level of each layer and at the macro level of the supply chain. This two-sided approach towards supply chain resilience leads to an overview of the negative effects and risks of each layer as well as the supply chain as a whole.

In order to achieve the aforementioned goal, the fuzzy model of data envelopment analysis network has been used. This model has the functions of the previous models and, in addition, it is able to analyze and compare the supply chain's resilience to risk in two levels: 1) For each of the supply chain layers and 2) For the entire supply chain as a complex system.

In this regard, 150 managers of 9 Iranian petrochemicals were selected to answer the questionnaires. The results of the research show that the proposed model of data envelopment analysis (fuzzy network) has been able to provide an acceptable prediction of supply chain luminosity at the level of the layers and at the macro level of the supply chain. Experimental results show that this model can provide practical recommendations to managers of these nine petrochemicals in relation to supply chain risks in Iran. However, since the model used in this study has high flexibility and can be applied in other areas, the results of this model can be generalized to other industries.

Table 6: Projection changes for input and output variables according to the modeling (% change)

	Additional Upper Risks 1	Excess external risks	Additional Network Risks	Lack of resilient supplier 2
Upstream processes Shazand Petrochemical Co. Bandar-e Emam petroleum Tabriz Petrochemical Company				
	-7.32	-3.18	0.00	0.00
	-10.09	0.00	-5.99	6.08
	0.00	0.00	-12.86	5.99
	Additional Upper Risks 1	Excess external risks	Additional Network Risks	Lack of resilient supplier 2
Organizational processes Shazand Petrochemical Co. Bandar-e Emam petroleum Tabriz Petrochemical Company				
	-7.06	-1.87	-1.66	0.00
	-5.84	-1.44	-2.58	0.00
	-3.66	0.00	-9.87	3.49
	Additional lower risks	Excess external risks	Additional Network Risks	Lack of resilient supplier 2
Downstream processes Shazand Petrochemical Co. Bandar-e Emam petroleum Tabriz Petrochemical Company				
	0.00	-3.69	-4.92	0.98
	-1.45	0.00	0.00	6.02
	-1.65	0.00	-1.65	1.44

1. Increased values indicate a decrease in the percentage of inputs compared to the effective level.
2. Decreased values indicate an increase in the percentage of outputs compared to the effective level. Italic (diagonal) values represent the highest probability of occurrence of each variable

Also, the results of the research show that the level of vibration of the entire supply chain does not necessarily correlate with the level of vibration of its layers. Similarly, high levels of volatility in the supply chain layers also do not imply that the total supply chain fluctuation is high. This is consistent with the results of studies on the nonlinear behavior of the supply chain behavior. Risks that pose the greatest threat to the continuity of the supply chain are risks that are likely to occur, but they have a great impact instead. The lack or lack of background data on rare events affecting the supply chain often results in considerable damage to the core and value chain processes of the supply chain. This has made the supply chain researchers, instead of relying on previous data, to consider designing simulation models that use fictitious data, and relying on the expertise of process owners and other proprietors have a high degree of experience in dealing with these processes, anticipating and analyzing the potential effects of potential malicious events.

The analytical model used in this study allows the use of specialized knowledge to perform dual-wavelengths throughout the entire supply chain as well as each of its layers. In this regard, it should be noted that assessing the overall vulnerability of the supply chain, which is a measure of the vulnerability of the entire supply chain to risks, has many limitations in identifying the main threats to which the supply chain business processes with them They are facing. The analytical model used in this study allows the use of specialized knowledge to perform dual-wavelengths throughout the entire supply chain as well as each of its layers. In this regard, it should be noted that assessing the overall vulnerability of the supply chain, which is a measure of the vulnerability of the entire supply chain to risks, has many limitations in identifying the main threats to which the supply chain business processes with them They are facing. Our study, through the creation of a proposed model for measuring supply chain resilience, as well as comparing performance scores in the nine different petrochemicals, has provided a proper explanation of the state of resilience in the main industries of Iran. This comparison allows managers to compare their environmental conditions, identify differences between them, and ultimately adopt strategies to better integrate their processes.

In summary, our research findings confirm that supply chain analysts and decision makers should consider both system approaches (the entire supply chain) and the layers (each layer) Supply chain). From a top-down perspective, such an approach leads to the exploration of the supply chain structure and its risks, both internally and externally. From the bottom up point, the threats related to the flow of input, output flow, resources and key deliverables related to the supply chain partners should be considered, and from this perspective, the overall level of supply chain resilience should be calculated. Hence, achieving a genuine metric for measuring and measuring supply chain resilience can only be achieved if risk assessment, with emphasis on the overall risk assessment of the supply chain and its components, is achieved. This allows monitoring of any differences and partial deviations in the components and supply chain layers, which in turn will lead to timely identification and corrective action to reduce the risk of the chain.

Finally, the proposed research model is tested and approved to evaluate the resilience of nine Iranian petrochemical supply chains. It was impossible to study in a wider range. Therefore, future studies suggest testing the model in other countries and regions and measuring system resilience and supply chain resilience in other environments to increase the external validity of this model. In addition, future research can describe the practical dimensions of supply chain performance and resilience evaluation. These studies use other approaches to improve resilience evaluation at different levels of the supply chain (moving from a systemic approach to an organizational approach to the supply chain). For example, structural models correlate both supply chain risk and resilience variables. These models are experimentally evaluated in different industrial and service contexts to measure the intensity of the impact of each risk group on supply chain resilience. In addition, according to the results, risk evaluation in supply chain layers is not similar in different industries, which necessitates further studies on the proposed model.

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