Case Report

Identification and Prioritization of Supply Chain Risks in Automotive Industries Using Fuzzy Analytic Network Approach: A Case Study

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ABSTRACT:

Supply chains are constantly exposed to various risks. An incident or uncertain event, which, in case of happening, has positive or negative effects on the objectives of a project, is called a risk. According to this identification, analysis and prioritization of risks may have a significant role in the success of the project. The purpose of risk management is to reduce the risks of non-achievement of these objectives and to identify and benefit from opportunities. The current study's objective is to prioritize the performance of supply chain risks in Cruise Company, based on the method of fuzzy analytic network process, taking into account the opinion of specialists and experts. Fields of study for the prioritization of the supply chain risks, consist of 5 main components, supplier risk, manufacturer risk, distributor risk, external risks and final customer risks. In order to prioritize these fields, some questionnaires were prepared and codified based on expert opinion. Afterwards, the compiled data was analyzed and investigated in **Super decision** software. The research result indicates that, among the main components, external risks are the first priority and final customer risks are the second priority. Among the sub-components, the inappropriate price sub-component has been allocated the first priority and, finally, the supplier bankruptcy sub-component has the last priority.

Key Words: Supply Chain, Risk, Supply Chain Risk Management, Fuzzy Analytic Network Process (FANP)

1 – INTRODUCTION

Today, attention to existing opportunities and threats in the fields of industry and commerce and evaluation of power of industries and companies dealing with present uncertainties and risks is essential and supply chain risk management is of great significance. Risk management is the process of identification and evaluation of risk factors and planning to reduce the undesirable effects of risks. Risk assessment is one of the substantial stages of risk management and, given the numerous risks as well as the need to better spend resources in the supply chain, is of utmost importance and ignoring it and even inadequate implementation of this process may cause

irreparable damage to different parts of supply chain. Risk evaluation and ranking determines risk preference based on related indices and hence the possibility of offering an appropriate response for each risk is provided.

2 – Statement of the Problem

Major developments in the business environment, such as the globalization of business and the high speed of changes in technology, have caused increase in competitiveness and difficulty of management in organizations. For effective management in organizations, new management approaches and specific techniques are recommended. Risk identification and risk

management is one of the new approaches applied to strengthen and improve the effectiveness of large organizations. On the other hand, with increasing competitiveness in global markets, organizations' attempt for survival in these markets has increased. This has led to the creation of supply chain management philosophy. Organizations use various strategies such as outsourcing or diversifying their products, in order to increase market share and business development.

Although these strategies are effective, they cause supply chain to be vulnerable and at risk. Today, the surging global developments have prompted organizations to do research on supply chain risk management in order to overcome the uncertain situations surrounding them. Suppliers must manufacture parts and materials with the best quality and lowest price. To achieve this goal, it is necessary to identify and rank effective risks in supply chain. In this research, while investigating the concept of uncertainty in supply chain, and also identifying supply chain risks and determining their effects, supply chain risk management will be discussed as one of the principal tasks of managers. Nowadays, many companies adopt various measures, such as production outsourcing and product variety, to achieve cost advantage and market share. These measures are effective as long as we are in stable conditions; however, these measures, themselves, may cause a supply chain which is under the influence of various types of risks, such as uncertain economic cycles, uncertain customer demand and human and natural disasters, to suffer numerous damages.

Thus, according to these increasing measures, the need to study various approaches and strategies for supply chain risk management is increasingly on the agenda of top companies. Risks incurred to the supply chain include different types, depending on the risk importer factor.

One of the potential risks in supply chain, are those risks incurred by suppliers. Since the concept of supply chain risk management is a relatively new research and practical concept, it is evident that, with respect to one of its subdivisions, i.e. management of supply chain risks incurred by suppliers, little research has been done.

Cruise Company is one of the suppliers of parts for domestic automotive companies, which began its activity in the early 80s. This company has its own domestic and international suppliers and its major products in various fields include: wire category group, automotive decorative pieces group and electronic parts group. Therefore, in this study, supply chain risk factors will be classified into 5 categories of supplier, manufacturer, distributor, final customer and external risks and, subsequently, using the multi-criteria decision-making technique, we will prioritize these risks in Cruise Company, which is one of the suppliers of automotive industry.

3 – Literature Review

In a business environment characterized by high complexity and uncertainty, manufacturing companies are forced to manage their supply chains effectively in order to increase efficiency and reactivity. Catastrophes such as 9/11, hurricane Katrina, or the Tsunami in 2004 have raised the attention on this issue. Moreover, everyday issues and problems, such as loss and quality problems for suppliers, have made supply chain risk management as important (Thun and Hoenig, 2011).

3 – 1. Supply Chain Types

In traditional manufacturing companies, products would be stored in warehouses and other storage places after being manufactured and this would make supply chain more complicated. If the company uses a manufacturing business model based on order, there will be no need for the storage of manufactured products;

however, at the same time, there will be a need for the storage of raw materials and components. Consequently, it is clear that the supply chains depend on the nature of the company.

A – Accumulative Manufacturing for Storage:

Supply chain model of accumulative manufacturing for storage focuses on targeted customer demands for efficient storage of finished goods inventory in real time. This accumulation of reserves is often done through the use of an information system which is fully integrated. In this way, such a system may collect information of real time demands, which can be used for modification and development of programs and functional programs of manufacturing, and may attempt to store items which are customer requirements. These systems perform integrated activities of distribution planning, manufacturing, detailed planning, inventory control, supply coordination with multiple distribution channels, the flow of accurate information about demand, investment, inventory capacity, detailed planning of transport, and … etc.

B – Persistent Storage:

The idea for this model is based on, persistently, refilling empty inventory by working closely with suppliers or intermediaries. Therefore, a strong connection is required between order implementation process and manufacturing process. This model is the most practical model for environments with constant demand patterns.

C – Manufacturing for Order:

The notion of this model is based on order for assembling, immediately after receipt of the order. This model needs useful management of components inventories and delivery of needed supplies during supply chain. A solution to overcome this need is the multipurpose use of devices for the manufacturing of goods. One of the main advantages of this model is the perception that each customer may visualize regarding their required product. In addition, every customer receives their goods immediately.

D – Channel Assembly:

With a slight modification in the manufacturing model based on order, channel assembly is obtained. In this model, parts of each product are collected and assembled, as they move in the distribution channel. As an example, we can name some computer companies, which, in the distribution chain, buy and assemble computer parts and, then, deliver them to customers. Therefore, customer computer order needs only to be collected to be placed in a device for delivery.

E – Global Supply Chain:

A supply chain that involves suppliers and, or, customers in other countries is known as global supply chain. The main reasons why companies enter global supply chain include: lower prices of materials, services and human resources, access to products and technologies that are unavailable inside, high quality products in global markets, company's global sales strategies, intensifying of global competition caused by reducing company's expenses, the need to develop foreign presence and international trade. Some of the problems that may exist in global supply chains include: legal issues, wages and business taxes, cultural and linguistic differences, rapid changes in currency exchange rates and political instability (JafarNejad, Ahmed. 1391).

3 – 2 – Supply Chain Risk Management (SCRM)

Supply chain risk management is responsible for identification, analysis, providing appropriate approaches for accountability, control and monitoring of risks in economic and manufacturing cycles and is a process applicable for managing and controlling all the stages involved in the creation, formation, documentation and control of chain risks and assists each of the chain components to control and manage income and expenditure of the input and output(, Elahi et al, 2015, Hanifi et al,2014).

Supply chain risk management, actively, plays the main role in successful management of business processes and helps the decision-making process in most functional areas during a business activity (such as the marketing decisions regarding product delivery, management of health and safety in manufacturing operations).

3 – 3 – International Studies

Thun and Hoenig's paper is entitled "An empirical analysis of supply chain risk management in the

German automotive industry," which investigates supply chain risk management methods in the German automotive industry and its vulnerability.

The purpose of this article is the empirical analysis of supply chain risk management (SCRM) methods. The analysis is undertaken, based on a survey of 67 manufacturing companies in the German automotive industry. After investigating the vulnerability of supply chain as a whole and examining the key drivers of supply chain risk, the paper identifies supply chain risks through analyzing the possibility of their occurrence and their potential impact on supply chain.

Stephan Wagner and ChristophBode's paper is entitled "An empirical investigation into supply chain vulnerability."

A growing number of scholars and specialists placed supply chain risks on their agenda, in particular, the recent series of catastrophic events that disrupt the economy and supply chain throughout the world. Due to the increasing awareness of this important issue,

The purpose of this study was to evaluate the supply chain risks in more details and to investigate the relationship between supply chain vulnerability and supply chain risk.

Responses by 760 managers of active companies in Germany indicate that supply chain characteristics, such as the company's dependence on certain customers and suppliers, finding exclusive resources, or reliance on global supply resources, are related to a company's exposure to supply chain risk.

Overall, this study represents the first large-scale significant investigation, in this respect, and provides a better understanding of the history of supply chain vulnerability.

Research Method

In summary, four main stages in 4 phases should be followed to achieve the main objective of the study.

In the first phase, we gather information and identify major and minor factors affecting supply chain risks and effective criteria in the experts' verbal weight.

In the second phase, the paired comparisons and ratings questionnaire is edited and the said questionnaire is distributed among influential managers and experts in supply chain risks. Then, by inserting the obtained paired comparisons in the Super Decision software, the significance of the main and secondary factors coefficients are determined.

In the third phase,we will perform the weighting of indices and ranking of sub-indices through group phase paired comparisons by entering all the obtained results in ANP super matrix.

Finally, in the fourth phase, the compatibility of each of the main factors and, eventually, the whole system with supply chain risks characteristics was determined and research validation was performed.

3 – 2 – Research Methodology
3 – 2 – 1 – Introduction of data collection tools
Data collection tools in the current study include: interview and observation and questionnaire

Interview

Some interviews were done with a number of senior managers and specialists and experts on the composition and overview of the questionnaire and how it is designed. Interview questions are in the form of hypotheses and research questions and have led to the design of the research questionnaires.

Questionnaire

4 sets of questionnaires were prepared for this study and distributed among the statistical population, which consisted of 15 company experts.

The first questionnaire included questions about the main risks and effective indices on supply chain risks, which was derived from studies conducted in this area. And, to determine supply chain risks, applicable in Cruise Company, it was distributed among managers and experts of the company, including 15 people.

The second questionnaire was developed and distributed in the company, for paired comparisons of main criteria in relation with the objective, the form of which is also given at the end of this thesis.

The third questionnaire was developed and distributed for paired comparisons of main criteria with each other and the determination of the main criteria's interactions with one another.

The fourth questionnaire was developed for paired comparisons of indices with the main criteria.

The questionnaire was designed in such a way that the respondents had to choose a qualitative response for each question, from equal importance to very high or absolute importance.

In the questionnaire distribution stage, to avoid any ambiguity that may affect the responses and also to facilitate the understanding of the notion of analysis and network analysis, the researcher, using a combination of interview and questionnaire methods, met the respondents in person so that understanding the concept and contents of the questionnaire would be accelerated for the respondents. After collecting the questionnaires, the data was classified and the ANP technique was used for weighting of each index.

3 – 5 – Statistical Population

Statistical population in this study consists of two groups. The first group includes experts and specialists with sufficient knowledge about the prioritization of supply chain risks. And the second group comprises experts and specialists inside the company who has participated directly or indirectly at least in one of the supply chain processes.

Furthermore, according to studies conducted by Salremon, Lopez, Okli and Pulseki, eight to eighteen experts may be an appropriate number for the investigations in which AHP and ANP methods are used; therefore, in this study, 10 experts were selected.

The statistical population of this study includes 15 people ranging from employees, experts and managers of Cruise Company.

Explanation of Components and Sub-Components

With the carried out studies and researches, stated in numerous books and articles, it was noted that the supply chain risks are under various factors and standards, which may be used during, before and after the operations occur.

Then, after conducting interviews and surveys with experts, the number of these factors was reduced to 5 cases, by which the system would be evaluated by measuring the intensity and weakness of such factors. These factors and sub-components of each factor have been displayed in figure 1 – 3. As indicated in the figure, supply chain risks consist of 5 major risks, each of which has several subsidiary indices and are, overall, up to 47 criteria.

The first step in the process of paired comparisons is to create a graphical representation of the problem, in which the objective, criteria, and sub-criteria will be shown. The first level demonstrates the objective, which is the prioritization of Cruise Company's supply chain risks. The second level of the hierarchical structure consists of five main factors influencing the supply chain risk, which includes:

Risks of supplier, manufacturer, distributor, external and final customer

The third level demonstrates the sub-criteria and subsidiary factors related to each one of the main criteria of the second level. As is seen in figure 1 – 3, every level comprises factors influenced by previous level and thus, as achieving the main objective of the research in the first level is affected by the main criteria of the second level, the second level criteria are, in turn, influenced by the subsidiary criteria of the third level. In order to determine the weight and priority of the factors and criteria listed in the figure's hierarchical structure, a question has been developed for each of the said factors, which compares each factor in pair with another factor.

To this end, the respondents were asked to compare the criteria with one another as binaries and determine and specify the preference and

importance of each criterion to the other one being compared with.

3 – 6 – Research Analytical Model

Every field research needs a research model to reveal, in a suitable format of analytical tools, variables and their relationships among them.

According to Kiwi and Compound model, each variable is a concept which, in turn, is divided into several dimensions and each dimension into several features or components and each component into a number of indices; the last level is quantifying the concepts (variables).
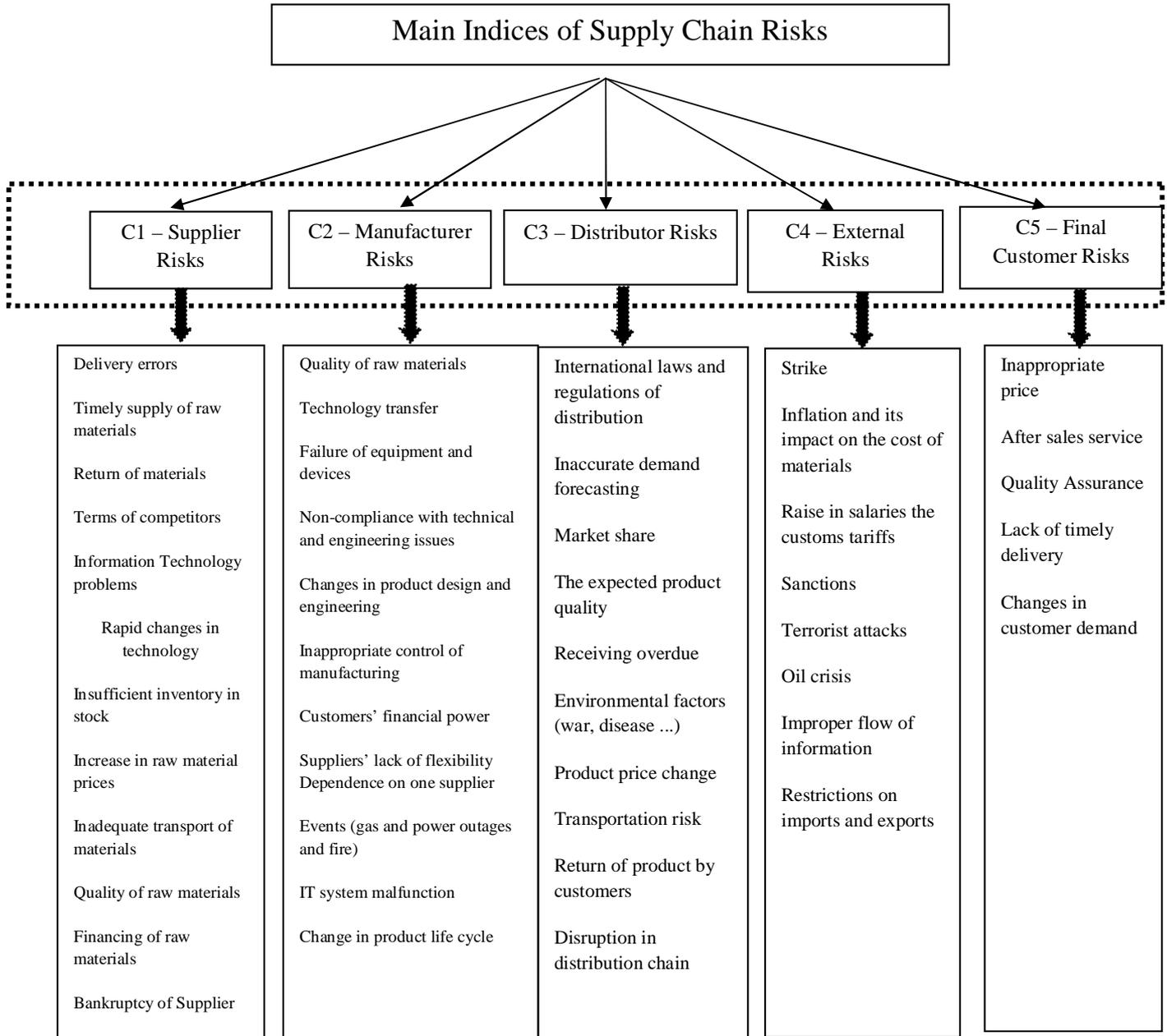

Figure 3 – 1

3 – 7 – Research Conceptual Model

According to studies conducted and presented in this paper, research conceptual model is designed in figure 3 – 2, based on which the criteria influencing supply chain risks in Cruise Company are determined, using expert opinion and, afterwards, weight of each factor is determined, using FANP, and, in the end, supply chain risks of the company are assessed.
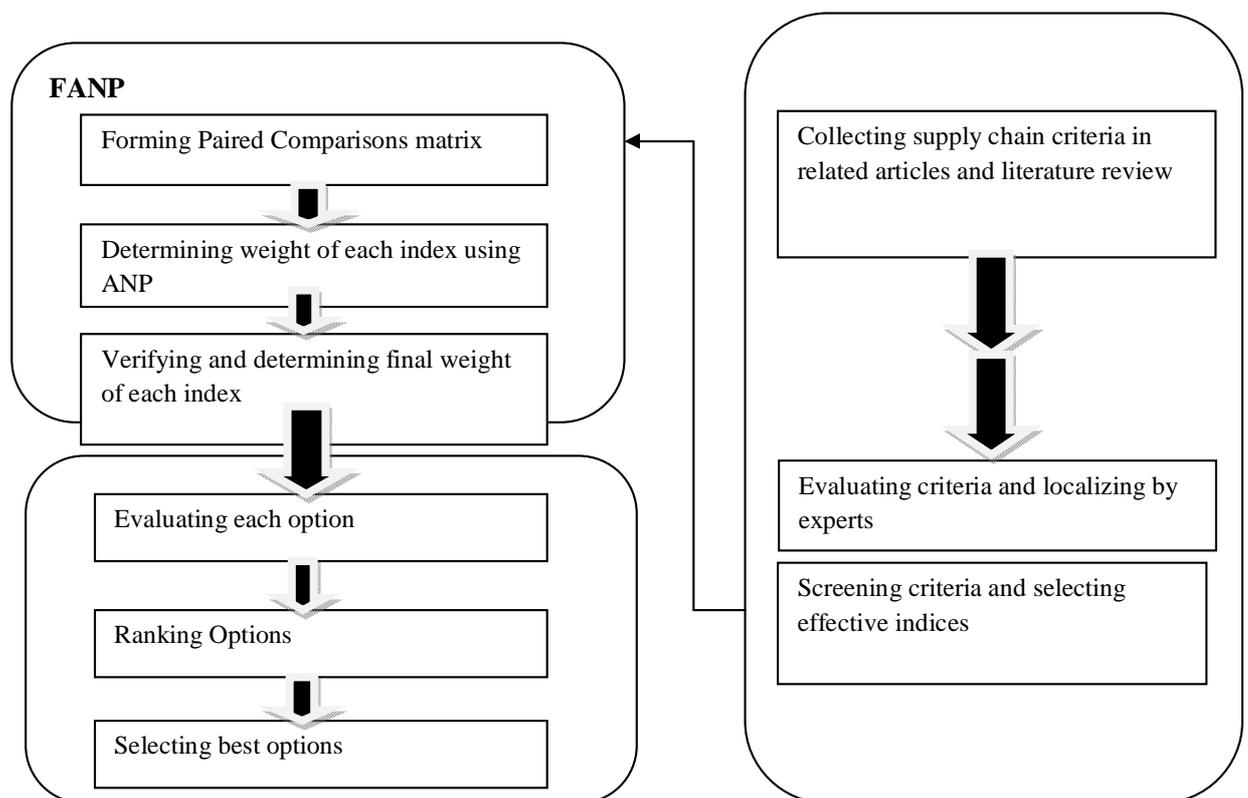
FANP

Forming Paired Comparisons matrix

Determining weight of each index using ANP

Verifying and determining final weight of each index

Evaluating each option

Ranking Options

Selecting best options

Collecting supply chain criteria in related articles and literature review

Evaluating criteria and localizing by experts

Screening criteria and selecting effective indices

Figure 3 – 2

4 – 1 – Designing a Model for Assessment of Supply Chain Risks

Accordingly, in this research after literature review of supply chain risks and studying the experiences of developed countries in this field, in the first stage, its components were identified and a hierarchical framework was drawn for the identified components. Subsequently, in the second stage, based on the identified components, a model was developed for the assessment and implementation of supply chain risks, using ANP technique in the target company.

The ANP method comprises 4 main steps. The first step: Model formation and structuring, the second step: Providing priority vector and paired comparison matrices, the third step: Formation of super matrix, the fourth step: Selection of the best option (Azar and Rajab Zadeh, 2010: 163).

This procedure is described in the following steps:

4 – 1 – 1 – First Step: Model formation and Structuring the Problem

The research model is a combination of the existing models. The relevant Model, after reciprocating process among academic and administrative experts and the study of existing documentation and research conducted in this field, was evaluated and modified. Some of the items, which were not available in the study environment, were removed and some components, which would somehow be useful, have been equalized. Finally, the validity of the model was approved by everyone.

Model Components:

For the identification of components, in the first step, a primary list of components and sub-components was extracted from research literature based on various researchers' perspectives. Afterwards, the identified components were modified by experts and specialists. Next, since, in this study, we evaluate supply chain risks, using expert opinion, the unnecessary factors in the company were excluded from the primary factors. Then, using expert opinions and interviews with specialists related to the company's supply chain, which included 15 people, these factors were localized and 43 factors were identified under subdivision of the following risks: Supplier, Manufacturer, Distributor, External, and Final customer. After collecting the first questionnaire, the main and subsidiary risks which are effective in Cruise Company were ranked by the company's experts and managers.

In the end, an appropriate model was designed for the investigation and assessment of supply chain risks in the said company, as

Supply Chain Risks

Supplier risks	Manufacturer risks	Distributor risks	External risks	Final customer risks
Delivery errors	Failure of equipment and devices	Inaccurate demand forecasting	Strike	Inappropriate price
Lack of timely supply of raw materials	Non-compliance with technical and engineering issues	Market share	Inflation and its impact on the cost of materials	After sales service
Quality of raw materials	Changes in product design and engineering	The expected product quality	Sanctions	Quality Assurance
Increase in raw material prices	Inappropriate control of manufacturing	Product price change	Restrictions on imports and exports	Lack of timely delivery
Insufficient inventory in stock	Dependence on one supplier	Transportation risk		Changes in customer demand
Rapid changes in technology	Events (gas and power outages and fire)	Disruption in distribution chain		
Supplier bankruptcy	IT system malfunction			

Decision Network Formation

Decision network, in this study, has 3 levels. In order to calculate the extent super matrix and assess the inconsistency rate, this network is modeled using Super Decision software.

4 – 1 – 2 – Second Step: paired comparisons of main and subsidiary factors

To obtain the weight of the main factors and sub-factors of their subset, paired Comparisons between the given points are needed. Thus, some questionnaires were given to each of the experts for paired comparisons of each factor, an example of which is provided in the appendix.

4 – 1 – 2 – 1 – paired comparisons of main components:

The results of performed investigations have been done by experts, based on fuzzy evaluations. The decision making group included 10 people of managers and experts; thus, the paired comparisons matrices were the results of geometric mean obtained from paired comparisons of these 10 people.

2. Geometric mean calculation of total comments by K experts:

For conducting paired comparisons in the group, after obtaining a fuzzy paired comparisons table for each expert, the following equation is used to assess the combined opinions of people and achieve the final tables of paired comparisons was used to obtain the final table:

$$= (\sqrt[k]{l_1 l_2 l_3 \ldots l_k} \text{ and } \sqrt[k]{m_1 m_2 m_3 \ldots} \text{ and } \sqrt[k]{u_1 u_2 \ldots})$$

After achieving the weight of all the sub-components compared to their main components, the obtained results are as described in Matrix C:

$$C = \begin{bmatrix}
0.0626 & 0 & 0 & 0 & 0 \\
0.3053 & 0 & 0 & 0 & 0 \\
0.1932 & 0 & 0 & 0 & 0 \\
0.185 & 0 & 0 & 0 & 0 \\
0.1319 & 0 & 0 & 0 & 0 \\
0.0922 & 0 & 0 & 0 & 0 \\
0.0297 & 0 & 0 & 0 & 0 \\
0 & 0.3154 & 0 & 0 & 0 \\
0 & 0.1349 & 0 & 0 & 0 \\
0 & 0.061 & 0 & 0 & 0 \\
0 & 0.0653 & 0 & 0 & 0 \\
0 & 0.3041 & 0 & 0 & 0 \\
0 & 0.0601 & 0 & 0 & 0 \\
0 & 0.0592 & 0 & 0 & 0 \\
0 & 0 & 0.3767 & 0 & 0 \\
0 & 0 & 0.1631 & 0 & 0 \\
0 & 0 & 0.1777 & 0 & 0 \\
0 & 0 & 0.1222 & 0 & 0 \\
0 & 0 & 0.0732 & 0 & 0 \\
0 & 0 & 0.0871 & 0 & 0 \\
0 & 0 & 0 & 0.0601 & 0 \\
0 & 0 & 0 & 0.2004 & 0 \\
0 & 0 & 0 & 0.453 & 0 \\
0 & 0 & 0 & 0.2865 & 0 \\
0 & 0 & 0 & 0 & 0.5496 \\
0 & 0 & 0 & 0 & 0.211 \\
0 & 0 & 0 & 0 & 0.1208 \\
0 & 0 & 0 & 0 & 0.0683 \\
0 & 0 & 0 & 0 & 0.0502
\end{bmatrix}$$

4 – 1 – 5 – The fifth step: analysis of the obtained weights

According to the results obtained from this research, as seen in table 4 – 27, experts have considered external risks as the most significant component effective in the assessment of supply chain risks. After that, final customer risks components play the most important role in the supply chain risk assessment process. Moreover, the sub-component C5-1 inappropriate price is also, among all the other sub-components, the most substantial sub-component, based on expert opinion.

Table 4 – 27: final weight of each of the effective components and sub-components based on fuzzy ANP analytic method

Final rank	Rank in category	Overall weight of sub-components of limited matrix	Sub-components	Final rank	Overall weight of main components of limited matrix	Main components
22	6	0.0047	C1-1	3	0.0743	C1
6	1	0.0227	C1-2			
11	2	0.0144	C1-3			
12	3	0.0137	C1-4			
15	4	0.0098	C1-5			
18	5	0.0069	C1-6			
29	7	0.0022	C1-7			
8	1	0.0153	C2-1	4	0.0485	C2
19	3	0.0065	C2-2			

25	5	0.003	C2-3			
24	4	0.0032	C2-4			
9	2	0.0147	C2-5			
26	6	0.0029	C2-6			
27	7	0.0029	C2-7			
10	1	0.0147	C3-1			
20	3	0.0063	C3-2			
17	2	0.0069	C3-3			
21	4	0.0048	C3-4	5	0.0389	C3
28	6	0.0028	C3-5			
23	5	0.0034	C3-6			
13	4	0.0108	C4-1			
4	3	0.0361	C4-2			
2	1	0.0817	C4-3	1	0.1803	C4
3	2	0.0517	C4-4			
1	1	0.0868	C5-1			
5	2	0.0333	C5-2			
7	3	0.0191	C5-3	2	0.158	C5
14	4	0.0108	C5-4			
16	5	0.0079	C5-5			

5 – 2 – The obtained results:

Lack of or inadequate management of supply chain risk can lead to negative consequences, such as prolongation of timing and delays, the increase in prices and …. Risk ranking is one of the main elements of risk management and provides the possibility of offering an appropriate and timely response to risks. In this study, by presenting a model, while designing a comprehensive breakdown structure of supply chain risk and also introducing a set of assessment indices, a comprehensive questionnaire was planned. The designed break down structure is an appropriate model for determining the set of supply chain risk factors.

This research has been conducted in order to design a valid and scientific model for supply chain risks assessment. In the designed model, the benefits of hierarchical structure available among risks factors have been used and the intended model has been designed. The quantitativeness of this model's outputs assists the company's managers to plan the reduction of risks periodically and evaluate the company's

improvement and weakness conditions tangibly and comprehensibly. The network analytic method has provided reliable results and risks ranking with this method is conducted based on their significance in relation with each other and the closeness of effect and impressions of risks. This validity is due to the possibility of considering several indices at the same time, the exchange between indices, flexibility of the method and also its results being analytic. This model has been used in the discussion of Cruise Company's supply chain as a case study, thus, external risks were allocated the highest risk rank and were introduced as the most critical risks of this set.

According to the obtained figures and numbers, external risks impose the highest risk to the supply chain so that, in the obtained analyses, this figure is around 0.1803 and after that, customer imposes the highest risk to the supply chain, the weight of which equals 0.158. Supplier, in all our five level supply chain, has a significance of 0.0743 with respect to the available risk in supply chain, which is in the third place. In the fourth place is the manufacturer with the risk of 0.0485 and, in the

last place is the distributor with the lowest risk of 0.0389.

The results obtained from the study of factors effective on supply chain risks are as follows:

Inappropriate price is in the category of sub-components of customer risk and has been assigned the first rank in chain risks.

Sanctions and import and export restrictions are in the category of external risk and have the second and third ranks in the project risks.

Transportation risk is the category of distributor risks and has the twenty eighth rank in the project risks.

Supplier bankruptcy is in the category of supplier risk and has been allocated the last rank in supply chain risks.

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