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Prioritization of Supply Chain Risks in Automotive Industry

Mohammad Khojasteh Ghamari
M.Sc., Department of Management, Firoozkuh Branch,
Islamic Azad University, Firoozkuh, Iran

Yacob Khojasteh
Associate Professor, Graduate School of Global Studies,
Sophia University, Tokyo, Japan

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Abstract

Supply chains are constantly exposed to various risks. An incident or uncertain event, which has positive or negative effect 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. Accordingly, the objective of this study is to prioritize the performance of supply chain risks. For this purpose we have analyzed the supply chain of a large automotive parts' supplier based on the method of fuzzy analytic network process and taking into account the opinion of specialists and experts. Fields of study for the prioritization of the supply chain risks, consist of five main components: supplier risk, manufacturer risk, distributor risk, external risk and final customer risks. In order to prioritize these fields, questionnaires were prepared and codified based on experts' opinions. Afterwards, the compiled data were analyzed and investigated in Super Decision Software. The research results indicate that among the main components, external risks have the first priority and final customer risks have the second priority. Among the sub-components, the inappropriate price sub-component has the highest rank while the supplier bankruptcy sub-component has the last priority.

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

Introduction

Today, attention to opportunities and threats, as well as evaluation of power of industries and companies dealing with present uncertainties and risks is essential. In this regard, supply chain risk management (SCRM) is of great significance. Risk management is the process of identification and evaluation of risk factors and reduction of the undesirable effects of risk. Risk assessment is one of the substantial stages of risk management and it is of utmost importance to spend resources on it in supply chain. Ignorance and even inadequate implementation of this process may cause irreparable damage to different parts of supply chain

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 in organizational management. For effective management in organizations, new management approaches and specific techniques are recommended (Browne et al., 1984; Harrison, 2001; Bowersox, 2006). Increasing competitiveness in global markets make organizations find new ways for survival. As a result they use various strategies such as outsourcing or product diversification in order to increase market share and business development. Although these strategies are effective, they cause supply chain to be vulnerable and at risk. Risk identification and management is one of the new approaches applied to strengthen and improve the effectiveness of large organizations. Nowadays, the surging global developments have prompted organizations to do research on supply chain risk management to overcome uncertainties. To achieve this goal, it is necessary to identify and rank effective risks in supply chain (Hugos, 2003; Zsidisin and Ritchie, 2009; Hessam and Savoji, 2012).

In this research, we investigate the concept of uncertainty in supply chain, identify supply chain risks, determine their effects and discuss supply chain risk management. Many companies adopt various measures, such as production outsourcing and product diversification to achieve cost advantage and market share (Baker, 2008). These measures are effective as long as we are in stable conditions. However, these measures, themselves, may cause a supply chain to suffer because it is under the influence of various types of risks, such as uncertain economic cycles, uncertain customer demand, human and natural disasters. Accordingly, the need to study various approaches and strategies to manage supply chain risk is urgent.

Since there is little research done on supply chain risk management, this study is devoted to that filed. In this paper, supply chain risk factors are classified into five categories - supplier, manufacturer, distributor, final customer, and external risks. Subsequently, using the multi-criteria decision-making technique, we prioritize these risks in the company, which is one of the suppliers of automotive industry. The studied company is one of the suppliers of automotive parts in domestic market, which began its activities in the early 80s. The company has its own domestic and international suppliers and its major products include wire category group, automotive decorative pieces group, and electronic parts group.

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 2011 in Japan 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 important (Thun and Hoenig, 2011).

A research carried out by Accenture in 2006 showed that 73 percent of organizations have experienced a significant disruption in the past five years. It took from a week to a month for 36% and more than a month for nearly 32% of the organizations to recover. Hendricks and Singhal (2003, 2005) pointed out that sales typically fall by 7 percent in the year after a major supply chain disruption while shareholder return falls by 7-8 percent, operating income falls by 42 percent and return on asset is down by 35 percent on the day a disruption occurs.

Thun and Hoenig (2011) conducted an empirical analysis of SCRM in the German automotive industry. They collected the data from 67 manufacturing plants in Germany. They investigated the vulnerability of supply chains and their impact on the supply chain, and highlighted instruments for dealing with those risks.

Blackhurst et al. (2005) conducted a study in several industries analyzing global sourcing and supply chain disruptions. They identified critical issues for disruption analysis and mitigation as well as resilient supply chain design. Craighead et al. (2007) evaluate different kinds of supply chain disruptions based on an empirical study. In addition to design characteristics, they investigate two categories of SCRM, i.e. the capabilities of recovery and warning.

Wagner and Bode (2006) evaluated the supply chain risks and investigated the relationship between supply chain vulnerability and supply chain risk. Responses of 760 managers of active companies in Germany indicate that supply chain characteristics, such as a company's dependence on certain customers and suppliers, finding exclusive resources, or reliance on global supply resources, are related to the company’s exposure to supply chain risk. Overall, this study represents the first large-scale significant investigation and provides a better understanding of supply chain vulnerability.

Research Method

To achieve the main objective of this study, in the first phase, we gather information and identify major and minor factors affecting supply chain risks and effective criteria according to the experts’ verbal weight. In the second phase, the questionnaires are distributed among influential managers and experts in supply chain risks and the paired comparisons are carried out. Then, by inserting the obtained paired comparisons in the Super Decision Software, the significance of the coefficients of the main and secondary factors are determined. In the third phase, we perform the weighting of indices and ranking of sub-indices through group phase paired comparisons by entering all the obtained results in analytic network process (ANP) super matrix. Finally, in the fourth phase, the compatibility of each of the main factors and the whole system with supply chain risks characteristics are determined and the research validation is performed.

Research Methodology

Data collection tools in the current study include interview, observation and questionnaire. Four sets of questionnaires were prepared and distributed among the statistical population, which consisted of 15 company experts. The first questionnaire set included questions about the main risks and effective indices on supply chain risks, which was derived from studies conducted in this area. Then, they were distributed among 15 managers and experts of the company to determine supply chain risks. The second questionnaire set was developed and distributed in the company for paired comparisons of main criteria in relation with the objective. The third set 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. Finally the fourth set 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 stage of the questionnaire distribution, to avoid any ambiguity that may affect the responses and to facilitate the understanding of the notion of analysis, the researcher used a combination of interview and questionnaire methods and met the respondents in person. After collecting the questionnaires, the data were classified and the ANP technique was used to weigh each index.

As a result of the survey five risk factors were identified. These factors and sub-components of each factor are displayed in Figure 1. As indicated in the figure, supply chain risks consist of five major risks, each of which has several subsidiary indices with overall 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 the 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 customer. The third level demonstrates the sub-criteria and subsidiary factors related to each of the main criteria of the second level. As shown in Figure 1, the factors of each level are influenced by previous level. Thus, 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 mentioned factors, which compares each factor in pair with another factor. To this end, the respondents were asked, first, to compare the criteria with one another as binaries, then, determine and specify the preference and importance of each criterion to the other one

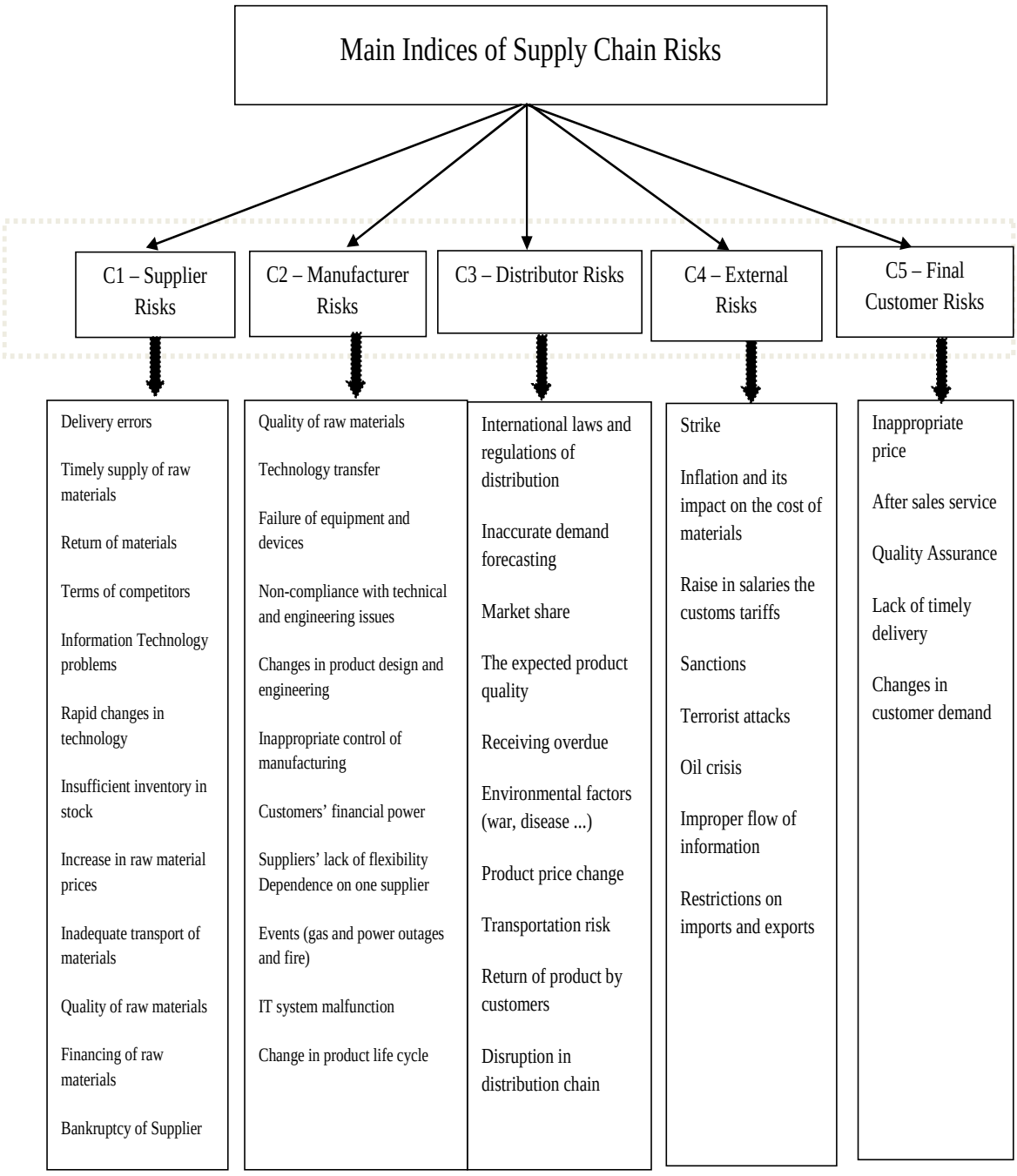

Figure 1: Main indices of supply chain risks

4. Research Conceptual Model

The research conceptual model is designed in Figure 2, based on which the criteria influencing supply chain risks in the company are determined using expert opinion. Then, the weight of each factor is determined using FANP, and in the end, supply chain risks of the company are assessed.

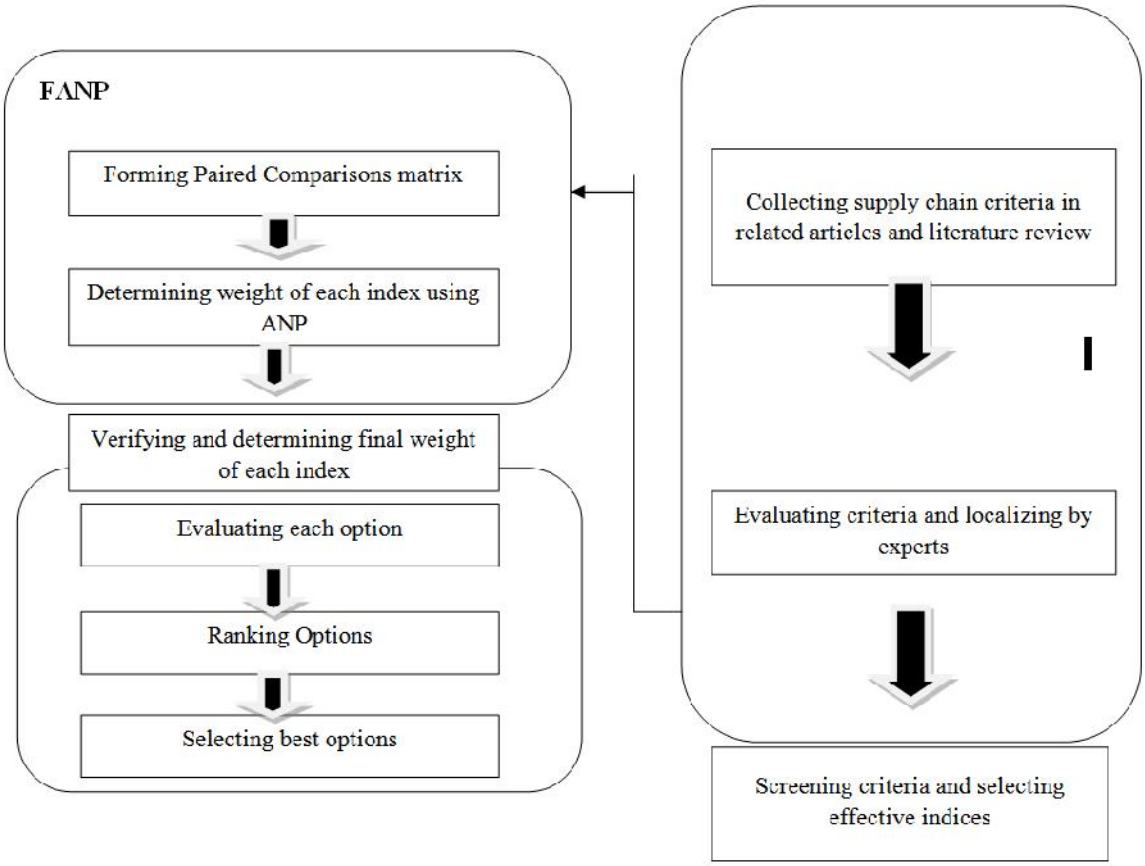

Figure 2: Research conceptual model

Designing a Model for Assessment of Supply Chain Risks

In the first stage, the components of supply chain risks 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 four main steps: 1) Model formation and structuring, 2) Providing priority vector and paired comparison matrices, 3) Formation of super matrix, and 4) Selection of the best option. This procedure is described in the following steps:

The first step is model formation and problem structuring. The research model is a combination of the existing models. The relevant model was developed after reciprocating process among academic and administrative experts and the study of the corresponding documentation and research. Finally, the validity of the model was approved.

Model Components

For the identification of the components, in the first step, a primary list of the components and sub-components was extracted from literature based on various researchers' perspectives. Afterwards, experts and specialists modified the identified components. Since we evaluate supply chain risks using expert opinion, in the second step 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 questionnaires, the main and subsidiary risks, which are effective in the 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 company, as demonstrated in Figure 3.

To obtain the weights 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. The results of performed investigations have been received based on fuzzy evaluations. The decision-making group consisted of ten managers and experts. Thus, the paired comparison matrices were the results of geometric mean obtained as a result of paired comparison conducted by this group.

To conduct 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.

$$Z_{ij}^{k} = \left(\sqrt[k]{l_1 l_2 l_3 \dots l_k} \text{ and } \sqrt[k]{m_1 m_2 m_3 \dots m_k} \text{ and } \sqrt[k]{u_1 u_2 \dots u_k}\right)$$

The results obtained after receiving the weight of all the sub-components compared to their main components are presented in Matrix C as follows:

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			

Figure 3: Assessment of supply chain risks

Table 1: Final weights of each effective component and sub-component 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	5	0.0389	C3
20	3	0.0063	C3-2			
17	2	0.0069	C3-3			
21	4	0.0048	C3-4			
28	6	0.0028	C3-5			
23	5	0.0034	C3-6			
13	4	0.0108	C4-1	1	0.1803	C4
4	3	0.0361	C4-2			
2	1	0.0817	C4-3			
3	2	0.0517	C4-4			
1	1	0.0868	C5-1	2	0.158	C5
5	2	0.0333	C5-2			
7	3	0.0191	C5-3			
14	4	0.0108	C5-4			
16	5	0.0079	C5-5			

C =

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

According to the results, experts have considered external risks as the most significant component in the assessment of supply chain risks. After that, final customer risk play the most important role in the supply chain risk assessment process. Further, the sub-component C5-1 inappropriate price is the most substantial sub-component. The results are shown in Table 1.

Conclusion

Lack of or inadequate management of supply chain risks can lead to negative consequences, such as prolongation of timing and delays, the increase in prices, etc. Risk ranking is one of the main elements of risk management, which provides the possibility of offering an appropriate and on time response to risks. In this paper, by presenting a model, while designing a comprehensive breakdown structure of supply chain risk and 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 to design a valid and scientific model for supply chain risks assessment. In the designed model, the benefits of hierarchical structure available among risk factors have been used and the intended model has been designed. The outputs of the model may assist managers to plan the reduction of risk periodically and evaluate a company's improvement and weakness conditions tangibly and comprehensibly. The network analytic method has provided reliable results and risk ranking with this method is conducted based on their significance in relation with each other. This model has been used as the company's case study about supply chain. Thus, external risks were identified as the highest ones and were introduced as the most critical risks of the set. According to the obtained results, external factors impose the highest risk on the supply chain with the weight of around 0.1803. The second factor is customer that imposes high risk on the supply chain with the weight of 0.158. Supplier has a significance of 0.0743, which is in the third place. The manufacturer is in the fourth place with the weight of 0.0485, and the last place is the distributor with the lowest weight of 0.0389.

Further inappropriate price is in the category of sub-components of customer risk and has the first rank in chain risks. Sanctions, import and export restrictions are in the category of external risks and have the second and third ranks respectively in the project risks. Transportation risk is in the category of distributor risks and has the twenty-eighth rank in the project risks. Finally, supplier bankruptcy is in the category of supplier risk with the last rank in supply chain risks.

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