ISSN Online: 2821-1936

Transactions on Data Analysis in Social Science

Journal Homepage: https://transoscience.ir

Supply Chain Risk Management by Risk Efficiency Index

E. Hajigol Yazdi[1]*, M.B. Fakhrzad[2]

[1, 2] Department of Industrial Engineering, Yazd University, Yazd, Iran

ARTICLE INFO

Article History:
Received 29 November 2019
Received in revised form
4 December 2019
Accepted 1 March 2020
Available online 7 March 2020

Keywords:
Supply chain network, Risk management, Risk Efficiency Index (REI), Fuzzy TOPSIS, FFMEA, FMEA, FAHP

ABSTRACT

Business competitive world is faced with various risk resources treated companies. There are many risk sources may occur in business supply chain network lead to huge loss of companies resources. Risk Identification, assessment and management is too crucial to protect the supply chain network revenue from inappropriate impact of potential risks. In this research a novel classification of identified risk in supply chain network is proposed which facilitate recognition of potential ventures in supply chain. Then, a neoteric Risk Efficiency Index (REI) presents based on hazards intensity versus resources spend to mitigate supply chain network risks. In a simple way risks are evaluated on loss criteria (outputs) and costs (inputs). REI attempts to determine which of the venture type is more destructive which is most critical to manage. According to fuzzy nature of risk, risk efficiency index is calculated Fuzzy area. First, the new approach in Fuzzy FMEA technique is applied to measure supply chain risks which show the superiority and efficiency of proposed model, then the Fuzzy AHP technique is implemented to rank risk potential resources.

1. INTRODUCTION

Supply chain network is exposed to risky situations, broadly. Companies hope to implement efficient resources with minimum loss. Zsidisin [1] defines Supply chain risk as the probability of loss is associated with inbound supply from individual supplier failures or the supply market which is preparing customer demand. It is important how firms' resources are managed drastically that the probability of catastrophic events be least. Various organizations implement different strategies to manage their supply chain risk. So, they experience different risk management performance. Behind of the risk management methods wide board, it is important to select the proper method considering various features and functionality which have a coherent representation of supply chain structure. Supply chain risk management (SCRM) models proposed in qualitative and quantitative modes. Tang [2] has a plenary review on SCRM quantitative models. David Bogataj [3] presented the frequency space to measure and control risk

*Corresponding Author: E. Hajigol Yazdi
Department of Industrial Engineering, Yazd University, Yazd, Iran

http://dx.doi.org/10.47176/TDASS/2020.23

in a supply chain. They found out linear programming model to optimize net present value of activity cells in total supply chain. Since, risk is concomitant with uncertainty and ambiguous then there are several researches in the literature handle uncertainty in supply chain risk management. Proposed a novel approach to model the supply chain management uncertainties by means of the fuzzy set theory. Lin and et al. simulate vendor managed inventory (VMI) with a fuzzy system which handle dynamic relationship in supply chain network thoroughly. Meta-heuristic methods illustrated with fuzzy set to model supply chain risk. For example, Wang and Shu implemented genetic algorithms for fuzzy data of a supply chain inventory management model. Copra and sodhi [4] stated the stability of dynamic cooperation and coordination between supply chain partners is greatly related to Supply chain Risk management. Some study implement multi criteria decision making (MCDM) models to model supply chain risks. Gaur and Ravindran used a bi-criterion mathematical programming model to assess supply chain risks in cost and service level. Kirkwood proposed a multi-attribute utility theory model using cost, quality, customer responsiveness and operating constraints criteria. Bargbarosog˘lu and Yazgac performed an AHP model to a set of 72 criteria involved supply chain management. Rabelo combined AHP with system dynamics in a model considering criteria of customer satisfaction, responsiveness, and political stability.

Xia and Chen focused on the dynamic nature of an SC risk system. The interaction and relationships between risk managerial factors presented by means of the decision model for risk management and a strategic model of a SC risk management decision-making system introduced with operational process cycle (OPC) and product life cycle (PLC). As presented different techniques was implemented for risk management. In this paper, a novel approach in supply chain risks classification proposed which is believed the risk of supply chain network has a great impact on company resources consumption. Based on this assumption a new model presented to measure supply chain risk.

The rest of this paper is as follow: in next section, various kinds of venture a supply chain network face with it classify. Then, a new assessment method for supply chain risk measurement offered. And finally we apply fuzzy AHP to our case study data and assess potential risks according to expert’s opinions. Its noticeable our case study Data gathered from a real company in alloyed steel industry.

2. SUPPLY CHAIN RISK

Supply chain network includes suppliers, manufacturers, warehouses and clients handle risk as potential variation of outcomes that influence the decrease of value added at any activity cell in a chain. Supply chain risks have a multidimensional essence which varies by condition changes such as organization’s market share or its partners. Therefore, supply chain risk identification is an essential step in supply chain risk management. This paper propose a novel classification of supply chain potential risk which involve all concepts of risks a supply chain face with it as managerial risk, public infrastructure risk, operational risk, supply chain partner risk, transaction risk and financial risk. Proposed structure of supply chain risk presented in figure 1.

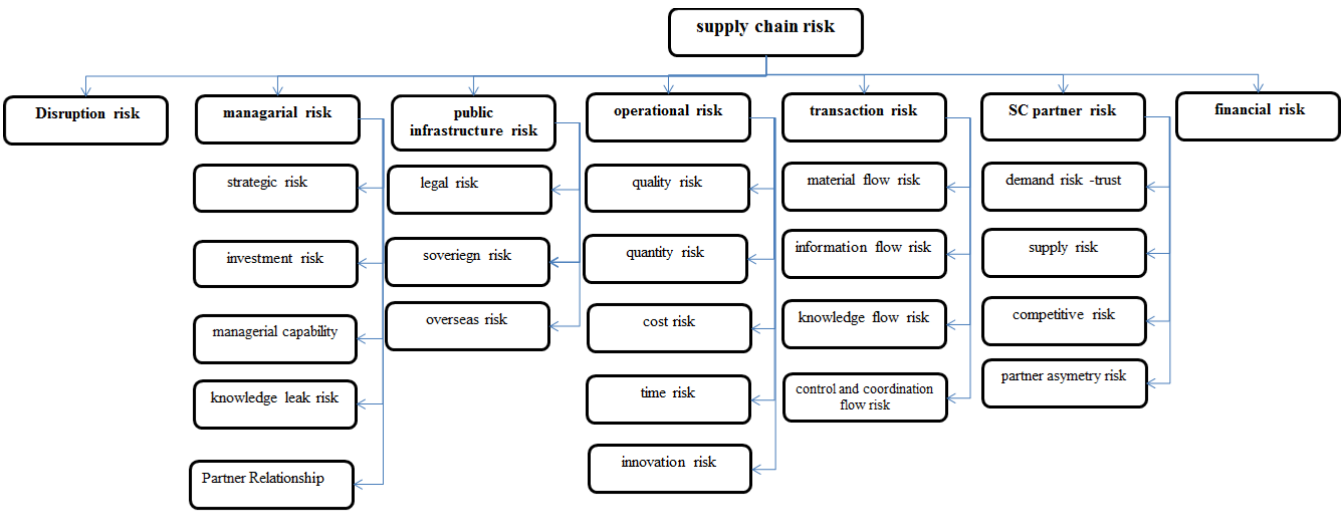

Fig. 1. supply chain risk classification

Managerial risk with the soft essence is associated with futile, wrecking or ineffective management, which disrupt in efficient organizational trends named managerial risk. In the other words, managerial risk is the risks of the improper situations presented in company due to improper managers' decision making lead to loss. Supply chain Managerial risk relate to every kind of risk occurs in supply chain macro-planning of a company such as strategic planning in supply chain management, company investment in supply chain development and improvement manner and innovation. Managerial risk concludes strategic risk, Knowledge leak risk, Investment risk, Partner Relationship management (PRM) and Managerial capabilities. Strategic risk occurs due to a weak strategic decision making in supply chain management. Knowledge leak risk fluke because of no complete control over knowledge inflows, knowledge outflows and knowledge sharing as well as continually change of partner's requirements in value chain lead to new knowledge. Investment risk can take place due to ambiguity in Investment process such as Consider Wrong investments, investment level promotion which cause because of knowledge leakage in supplier capabilities or supplier technological shortage. Managerial capabilities is the ability to provide the proper instruments to accomplish parallel tasks, to manage the hazards or Risks from a failure or threat to conquer supply chain Expectations or performance standards.

Operational risk is the probability of losses due to failures in company's internal processes because of disruptions occurs in main supply chain procedure. As Bessel mentioned, operational risk define as "the risk of loss resulting from inadequate or failed internal processes, people and systems, or from external events". Operational risk directly related to the production. A product is admissible when four characteristics observe in it; conclude high quality, proper quantity, competitive cost and proper lead time. Any failure in each dimension occurs due to operational risks. Operational processes directly influence performance because of an adjustment of strategies and tactics as well as vibrant operational conditions. Operational risks consist of Quality risk, Cost risk, Quantity risk, Time risk, Innovation risk.

Supply chain partner risk establish from multi major supply chain network partners as supplier, manufacturer, customer and competitors. The kind and level of relationship between each colleague may be a source of risk occurrence. Identification of trades between partners verify by company in order to secure the supply chain and risk mitigation. Supply chain partner risks conclude Supplier risk, Customer risk, Competitor risk, Relationship asymmetry risk.

Public infrastructure risk a firm face, with initialize from external factors imply on company operation. Social and industrial provisions cause Public infrastructure risks include Legal risk, overseas risk and sovereign risk. Legal risk is probability of the potential loss arising from the uncertainty of legal proceedings, such as firm legal disability to enter into a contract, bankruptcy, tax regulation changes and potential legal proceedings. Overseas risk considers the possibility of loss occurrence due to abroad relationship existence caused not complete security in business. Relationships overseas are more difficult to manage, because for example cultural and political factors, distance and language diversities. Sovereign risk assesses the risk associated with giving up control when going overseas, including potential political instability, strikes, and stringent government regulations.

Transportation risk assesses the extent to which carriers can have problems in the physical movement of goods. This can include the infrastructure present in the host country, port capacities, cranes and other material handling equipment available, and qualified human resources. Transportation risk can be presented according to material, information, knowledge and partners coordination flow. Breakage during transport, Low quality transport, Lack of personnel, equipment, and vehicle and storage space in different stages of transition and Insolvency of logistics provider are examples of transportation risks. On the other hand, some failure could be occurred according to coordination and collaboration with upstream and downstream partners. On the other hand, Information flows between supply chain networks make relationship more accurate and transparent. The inaccurate information and knowledge sharing is a bottleneck in designing many supply chain network strategies.

Financial risk occurs when firm doesn't have sufficient ability to meet financial obligation due to supply chain network procurements. financial risk is the probability of loss inherent in financing methods which lead to firm's economic value-added decline financial risk conclude various kinds of risk such as credit risk, the risk to the company of its customers not paying for goods or services or defaulting on loans, foreign exchange, Volatility, Liquidity, Inflation risks, etc. Similar to general risk management, financial risk management requires identifying its sources, measuring it, and plans to address them.

Disruption risk considers the likelihood that the supply chain can fall victim to such attacks. Disruption risks are referred to the major disruptions caused by natural and man-made failures such as earthquakes, floods, hurricanes and terrorist Attacks or economic crises such as currency evaluation or strikes. In most cases, while the probability of occurrence of catastrophic events is small, the business impact associated with such events can be extremely damaging [5].

3. PROPOSED RISK ASSESSMENT METHODOLOGY

In this paper a new method is presented to assess and manage supply chain risks. It's considerable that every kinds of venture probe to occur in company take a set of resources as system inputs. Each level of hazard happens with various level of loss whereas various level of resources. Consider different catastrophic events took place in a manufacturing system. The failure dimension arise from each event may be different. The main aim of this paper is minimizing risks in supply chain per each resource unit implement in supply network for reducing impact of potential hazards. Each kind of risk measure attends to its nature and related to firm's resources implement to manage risk. In this manner we introduce a novel methodology for risk assessment named Risk Efficiency Index (REI). A risky function depicts of a combination firm's risks and resources. Risks the company faced fountain from firm negative operations. Then the various combinations of actual events occur in firms lead to different level of risk occurs. Such a function must the minimum risk which can be achieved with any combination of input.

The risks are evaluated on loss criteria (outputs) and cost criteria (inputs). Risk unprofitably is defined as risk priority number (i.e. the intensity of the risks) to the weighted sum of related resources (i.e. the costs of risk management). REI attempts to determine which of the venture type is more destructive and most critical to manage. Two types of loss concede equivalent if damage scales be equal. It means more resources execute, less failure occur. A fundamental supposition behind this method is that if a given Failure Vulnerability level, F, is talented for loss occurrence L(F) unit whereas use S(F) resources, then other loss points with the same failure Vulnerability level inference identical. The heart of the analysis lies in finding the "most significant" risky points in a system. If the virtual case is better than the original cases occur in system by either making more loss with the same resources or making the same loss with less input than the original cases are inefficient.

The strength of REI is introduced in the various ways. REI can be a powerful tool when used wisely. REI can handle multiple resources as input and output models. It doesn't require an assumption of a functional form relating inputs to outputs. Inputs and outputs can have very different units.

3.1. REI method

RIE index is a fraction conclude from loss occurs due to potential risks, which divided on resources imply for controlling the potential hazards. At first we attempt to rank various risks and determine the level of failure it made. So, we use FMEA (failure mode and effect analysis) to determine risk priority number. Since, risk occurs in ambiguous areas then we consider Fuzzy FMEA to assess supply chain potential risks. This method structure based on the Technique for order Preference by Similarity to Ideal Solution "TOPSIS", however different solution method implement from TOPSIS. In this method an ideal solution determined for parameters, then, parameters value for each failure compare with ideal solution. Each solution is far from ideal solution is most risky point and must be managed seriously. There are continuous steps to failure causes order preference:

Step 1- failure causes and linguistic variables identification

In this phase, a matrix of linguistic variables is created.by triangular fuzzy number to present failure severity, occurrence and detection. Failure causes depicted as follow:

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \dots \\ x_n \end{pmatrix} = \begin{pmatrix} x_1(S) & x_1(O) & x_1(D) \\ x_2(S) & x_2(O) & x_2(D) \\ x_3(S) & x_3(O) & x_3(D) \\ \dots & \dots & \dots \\ x_n(S) & x_n(O) & x_n(D) \end{pmatrix} \tag{1}$$

$(x_1 \quad x_2 \quad \cdots \quad x_n)^T$ Are failure causes in FMEA and $(x_i(S) \quad x_i(O) \quad x_i(D))$ are linguistic variable related to severity, occurrence and detection for i-th failure causes.

Step 2- utility matrix determination

The goal of risk management is minimize risk parties. So, ideal condition appear when each of problem parameters means severity, occurrence and detection incline to their minimum value. Ideal utility matrix depicted ideal situation of parameters present in follow:

$$x_0 = (x_0(S) \quad x_0(O) \quad x_0(D)) \tag{2}$$

Table 1. Utility matrix

SC Potential risk	severity					occurrence				detection		
cost risk	9	8.1	8.3	9.1	9.3	7	6.4	6.8	7.3	7.7	9	8.1
material flow risk	9	8.1	8.3	9.1	9.3	6	5.2	5.8	6.1	6.7	9	8.1
quantity risk	7	6.4	6.8	7.3	7.7	7	6.4	6.8	7.3	7.7	8	7.3
financial risk	7	6.4	6.8	7.3	7.7	7	6.4	6.8	7.3	7.7	8	7.3
investment risk	7	6.4	6.8	7.3	7.7	7	6.4	6.8	7.3	7.7	6	5.2
strategic risk	8	7.3	7.8	8.2	8.7	5	4.4	4.6	5.2	5.4	7	6.4
supply risk	8	7.3	7.8	8.2	8.7	5	4.4	4.6	5.2	5.4	7	6.4
Knowledge leak risk	5	4.4	4.6	5.2	5.4	7	6.4	6.8	7.3	7.7	7	6.4
quality risk	9	8.1	8.3	9.1	9.3	3	2.3	2.5	3.8	4	8	7.3
innovation risk	6	5.2	5.8	6.1	6.7	5	4.4	4.6	5.2	5.4	6	5.2
legal risk	7	6.4	6.8	7.3	7.7	3	2.3	2.5	3.8	4	7	6.4
managerial capability	6	5.2	5.8	6.1	6.7	3	2.3	2.5	3.8	4	8	7.3
demand risk	8	7.3	7.8	8.2	8.7	3	2.3	2.5	3.8	4	6	5.2
competitive risk	5	4.4	4.6	5.2	5.4	7	6.4	6.8	7.3	7.7	4	3.6
time risk	7	6.4	6.8	7.3	7.7	3	2.3	2.5	3.8	4	6	5.2
information flow risk	6	5.2	5.8	6.1	6.7	5	4.4	4.6	5.2	5.4	4	3.6
knowledge flow risk	5	4.4	4.6	5.2	5.4	5	4.4	4.6	5.2	5.4	4	3.6
Relationship asymmetry risk	3	2.3	2.5	3.8	4	6	5.2	5.8	6.1	6.7	4	3.6
Partner Relationship management	4	3.6	3.8	4.6	4.8	3	2.3	2.5	3.8	4	4	3.6
control and coordination flow risk	4	3.6	3.8	4.6	4.8	6	5.2	5.8	6.1	6.7	2	1.4
Disruptive risk	7	6.4	6.8	7.3	7.7	1	0.6	0.8	1.6	1.8	4	3.6
overseas risk	3	2.3	2.5	3.8	4	2	1.4	1.6	2.5	2.7	4	3.6
sovereign risk	3	2.3	2.5	3.8	4	2	1.4	1.6	2.5	2.7	4	3.6

$x_0(S)$ is failure severity ideal value, $x_0(O)$ is failure occurrence probability ideal value and $x_0(D)$ is detection probability ideal value. In crisp area with scale 1 to 9, each variable has least value. Proposed vector show as:

$$x_0 = (x_0(S) \quad x_0(O) \quad x_0(D)) = (0.6 \quad 0.8 \quad 1.6 \quad 1.8 \quad 0.6 \quad 0.8 \quad 1.6 \quad 1.8 \quad 0.6 \quad 0.8 \quad 1.6 \quad 1.8)$$

Step 3- determination distances to ideal solution

TOPSIS implement differences between decision variables and their ideal value to compare each parameter with its ideal solution. Distance matrix design as:

$$D = \begin{pmatrix} \Delta_1(S) & \Delta_1(O) & \Delta_1(D) \\ \Delta_2(S) & \Delta_2(O) & \Delta_2(D) \\ \cdots & \cdots & \cdots \\ \Delta_n(S) & \Delta_n(O) & \Delta_n(D) \end{pmatrix} \tag{3}$$

$$\Delta_i(j) = |x_o(j) - x_i(j)| \tag{4}$$

$\Delta_i(k)$ is difference between i-th failure causes value and ideal value for j-th parameters.

Table 2. Difference between failures causes value and ideal value for severity parameters

SC Potential risk	$\Delta_i(k)$			
cost risk	6.3	6.7	8.3	8.7
material flow risk	6.3	6.7	8.3	8.7
quantity risk	5.5	6.2	7.4	8.1
financial risk	5.5	6.2	7.4	8.1
investment risk	3.4	4.2	5.3	6.1
strategic risk	4.6	5.2	6.5	7.1
supply risk	4.6	5.2	6.5	7.1
Knowledge leak risk	4.6	5.2	6.5	7.1
quality risk	5.5	6.2	7.4	8.1
innovation risk	3.4	4.2	5.3	6.1
legal risk	4.6	5.2	6.5	7.1
managerial capability	5.5	6.2	7.4	8.1
demand risk	3.4	4.2	5.3	6.1
competitive risk	1.8	2.2	3.8	4.2
time risk	3.4	4.2	5.3	6.1
information flow risk	1.8	2.2	3.8	4.2
knowledge flow risk	1.8	2.2	3.8	4.2
Relationship asymmetry risk	1.8	2.2	3.8	4.2
Partner Relationship management	1.8	2.2	3.8	4.2
control and coordination flow risk	0.4	0	1.7	2.1
Disruptive risk	1.8	2.2	3.8	4.2
overseas risk	1.8	2.2	3.8	4.2
sovereign risk	1.8	2.2	3.8	4.2

In this step relationship between failure causes value and its related ideal value determine to consider distances between parameters value and their ideal value. Chen proposed a Relational ratio which implement as a measure of distances between linguistic variables and their ideal solution. We use the space below of the curve of trapezoid numbers to determine maximum and minimum of fuzzy number were calculated:

*"*Area of a trapezoid number *"= S = 0.5 *h* [(d-a) + (b-c)]*

$$\vartheta_i(j) = \frac{\Delta_{min} + 0.5\Delta_{max}}{\Delta_i(k) + 0.5\Delta_{max}} \quad (5)$$

Δ_{min} = minimum area of trapezoid numbers in D matrix, $\Delta_{min}=0.35$
Δ_{max} = maximum area of trapezoid numbers in D matrix, $\Delta_{max}=0.8$

Resulted matrix present in follow:

$$\vartheta = \begin{pmatrix} \vartheta_1(S) & \vartheta_1(O) & \vartheta_1(D) \\ \vartheta_2(S) & \vartheta_2(O) & \vartheta_2(D) \\ \cdots & \cdots & \cdots \\ \vartheta_n(S) & \vartheta_n(O) & \vartheta_n(D) \end{pmatrix} \quad (6)$$

Risk priority number (RPN) for j-th failure causes calculated based on the degree of relational degree of j-th failure causes. Two approaches can implement. In first one, we can use sum of j-th failure causes factor as rational degree means:

$$\gamma(x_i) = \vartheta_i(S) + \vartheta_i(O) + \vartheta_i(D) \quad (7)$$

Table 3. Relationship matrix

SC Potential risk	severity				occurrence				detection			
cost risk	0.112	0.106	0.086	0.082	0.15	0.13	0.11	0.10	0.112	0.106	0.086	0.082
material flow risk	0.112	0.106	0.086	0.082	0.20	0.16	0.13	0.12	0.112	0.106	0.086	0.082
quantity risk	0.150	0.134	0.109	0.100	0.15	0.13	0.11	0.10	0.127	0.114	0.096	0.088
financial risk	0.150	0.134	0.109	0.100	0.15	0.13	0.11	0.10	0.127	0.114	0.096	0.088
investment risk	0.150	0.134	0.109	0.100	0.15	0.13	0.11	0.10	0.197	0.163	0.132	0.115
strategic risk	0.127	0.114	0.096	0.088	0.25	0.22	0.16	0.14	0.150	0.134	0.109	0.100
supply risk	0.127	0.114	0.096	0.088	0.25	0.22	0.16	0.14	0.150	0.134	0.109	0.100
Knowledge leak risk	0.250	0.221	0.156	0.144	0.15	0.13	0.11	0.10	0.150	0.134	0.109	0.100
quality risk	0.112	0.106	0.086	0.082	0.83	0.58	0.22	0.20	0.127	0.114	0.096	0.088
innovation risk	0.197	0.163	0.132	0.115	0.25	0.22	0.16	0.14	0.197	0.163	0.132	0.115
legal risk	0.150	0.134	0.109	0.100	0.83	0.58	0.22	0.20	0.150	0.134	0.109	0.100
managerial capability	0.197	0.163	0.132	0.115	0.83	0.58	0.22	0.20	0.127	0.114	0.096	0.088
demand risk	0.127	0.114	0.096	0.088	0.83	0.58	0.22	0.20	0.197	0.163	0.132	0.115
competitive risk	0.250	0.221	0.156	0.144	0.15	0.13	0.11	0.10	0.341	0.288	0.179	0.163
time risk	0.150	0.134	0.109	0.100	0.83	0.58	0.22	0.20	0.197	0.163	0.132	0.115
information flow risk	0.197	0.163	0.132	0.115	0.25	0.22	0.16	0.14	0.341	0.288	0.179	0.163
knowledge flow risk	0.250	0.221	0.156	0.144	0.25	0.22	0.16	0.14	0.341	0.288	0.179	0.163
Relationship asymmetry risk	0.833	0.577	0.221	0.197	0.20	0.16	0.13	0.12	0.341	0.288	0.179	0.163
Partner Relationship management	0.341	0.288	0.179	0.163	0.83	0.58	0.22	0.20	0.341	0.288	0.179	0.163
Control/coordination flow	0.341	0.288	0.179	0.163	0.20	0.16	0.13	0.12	1.500	1.071	0.375	0.300
Disruptive risk	0.150	0.134	0.109	0.100	1.50	1.07	0.38	0.30	0.341	0.288	0.179	0.163
overseas risk	0.833	0.577	0.221	0.197	1.50	1.07	0.38	0.30	0.341	0.288	0.179	0.163
sovereign risk	0.833	0.577	0.221	0.197	1.50	1.07	0.38	0.30	0.341	0.288	0.179	0.163

The space below of the curve of trapezoid numbers is calculated to determine maximum and minimum of fuzzy number:

"Area of a trapezoid number "= S = 0.5 *h* [(d-a) + (b-c)] (8)

In last approach, is considered risk measurement factors, severity and occurrence and detection, have not equal value in RPN calculation. So, we use expert opinions to measure importance degree of each factor. Weighted sum of rational degrees consider as RPN.

$$\gamma(x_i) = \alpha_1\vartheta_i(S) + \alpha_2\vartheta_i(O) + \alpha_3\vartheta_i(D)\ ,\ a_1 + \alpha_2 + \alpha_3 = 1 \qquad (9)$$

α_j is weighting ratio of factor j-th.

$\gamma(x_i)$ as the rational degree is the risk priority number use for ranking failure causes. The more RPN, the least loss occurs in system. If rational degree for a specific case higher than others, then effect of this cause is lower because parameters have lower distance from ideal solution.

In this approaches we emphasis on resources use to handle various risks such as labor, information, material and etc. supply chain risk management is cost wasting. Then amount of resources impalement to manage potential risks faced supply chain network has a critical role in risk importance. Ranking potential risks help us, to plan mitigate huge cost of supply chain risks, adequately. Suppose, various source of human, machine, material, information, knowledge, energy, marketing expense, money and etc. apply to manage source of specified supply chain risk. First, we should change these resource values to money. For each potential risk a specified weighting implement to calculate a part of our fraction. The least sources use to manage hazards, the more utility occur. Or in the other words, the greater hazard managed with the least resources is more desirable. In follow resources use to manage separate potential risks in our case study presented. As mentioned, the resource costs are presented in scale 0 to 1. The resulted REI is shown in table 6.

Table 4. Risk priority number/ S

SC Potential risk	Risk priority number (RPN)				S
cost risk	0.37	0.04	0.35	0.28	0.26
material flow risk	0.42	0.07	0.37	0.30	0.28
quantity risk	0.43	0.07	0.38	0.31	0.29
financial risk	0.43	0.07	0.38	0.31	0.29
investment risk	0.50	0.09	0.43	0.35	0.32
strategic risk	0.53	0.09	0.47	0.36	0.33
supply risk	0.53	0.09	0.47	0.36	0.33
Knowledge leak risk	0.55	0.10	0.49	0.37	0.34
quality risk	1.07	0.13	0.80	0.40	0.37
innovation risk	0.64	0.14	0.55	0.42	0.38
legal risk	1.13	0.15	0.84	0.44	0.40
managerial capability	1.16	0.16	0.85	0.45	0.40
demand risk	1.16	0.31	0.85	0.45	0.40
competitive risk	0.74	0.33	0.64	0.44	0.41
time risk	1.18	0.35	0.87	0.46	0.41
information flow risk	0.79	0.35	0.67	0.47	0.42
knowledge flow risk	0.84	0.35	0.73	0.49	0.45
Relationship asymmetry risk	1.37	0.40	1.03	0.53	0.48
Partner Relationship management	1.52	0.42	1.15	0.58	0.52
control and coordination flow risk	2.04	0.60	1.52	0.69	0.58
Disruptive risk	1.99	0.62	1.49	0.66	0.56
overseas risk	2.67	0.85	1.94	0.77	0.66
sovereign risk	2.67	0.85	1.94	0.77	0.66

The fraction of failure to resource is a superior scale for critical risk point identification in supply chain network. Firm can design its supply chain strategies based on risk decline and efficiently resource usage. We apply fuzzy AHP to our case study data and assess potential risks according to expert's opinions.

4. FUZZY ANALYTICAL HIERARCHY PROCESS

T.L.Saaty introduced the analytical hierarchy process (AHP) as one of the most well-known methodologies for handling multi-criteria problems. He began using Fuzzy AHP to make AHP more realistic and to obtain more precise results. The analytical hierarchal process (AHP) approach's core premise is to build a pairwise ranking of the boxes at any given level compared to the boxes at the next highest level to which they are connected. These pairwise rankings are then merged to establish an overall priority for each plan of action under consideration. The most important line of action is then determined.

Uncertainty in priority assignment and the use of semantic variables in priority assignment naturally lead to the incorporation of fuzzy logic into the structure of the AHP paradigm.

First, locate the pairwise matrix (A) type that decision makers prefer: aij= (aij, bij, cij, dij)

The 23*23 matrix presented in Appendix A is entirely filled up by 5 experts in such a way that they compared parameters two by two with each other and answered with fuzzy trapezoid numbers in this matrix. The average of expert's ideas is also shown in the table.

Table 5. REI index

SC Potential risk	REI
cost risk	0.077704
material flow risk	0.083734
quantity risk	0.301534
financial risk	0.086274
strategic risk	0.099387
supply risk	0.28537
Knowledge leak risk	0.25815
investment risk	0.290668
competitive risk	0.1031
innovation risk	0.33673
knowledge flow risk	0.34973
information flow risk	0.38152
quality risk	0.26435
legal risk	0.39509
managerial capability	0.35178
demand risk	0.34957
time risk	0.40167
Relationship asymmetry risk	0.46023
Partner Relationship management	0.42739
Disruptive risk	0.43957
control and coordination flow risk	0.44912
overseas risk	0.44681
sovereign risk	0.44756

Table 6. SC potential risk

Number	Supply Chain Potential Risk
1	strategic risk
2	material flow risk
3	legal risk
4	managerial capability
5	quantity risk
6	competitive risk
7	quantity risk
8	Partner Relationship management
9	knowledge leak risk
10	investment risk
11	Demand risk
12	competitive risk
13	innovation risk
14	disruptive risk
15	time risk
16	cost risk
17	information flow risk
18	sovereign risk
19	knowledge flow risk
20	overseas risk
21	financial risk
22	control and coordination flow risk
23	Relationship asymmetry risk

Step 2: Calculate wi weight (geometrical average from each row of the A) like this:

Zi= {ai1(0) ai2(0)…(0)ain}1/n : ∀i then wi = zi(:)(z1 (+)z2(+)….(+) zn)

Details of the wi calculation are as below:

Right & left of fuzzy aij (in the crisp line L) were defined in this formula:

fi (α) = [∏ n j=1 (bij- aij) α + aij]1/n ; α € [0, 1]

gi (α) = [∏ n j=1 (dij- cij) α + cij]1/n ; α € [0, 1]

Also:

ai = {∏ n j=1 aij1/n} ; a = ∑ mi=1 ai , bi = {∏ n j=1 bij1/n} ; b = ∑ mi=1 bi

ci = {∏ n j=1 cij1/n} ; c = ∑ mi=1 ci , di = {∏ n j=1 dij1/n} ; d = ∑ mi=1 di

Calculation of is presented in table 7.

Table 7. The calculation of ai bi ci di (first part)

Potential risk	a_i	b_i	c_i	d_i
strategic risk	1572.49	6672.00	39582.48	109347.01
material flow risk	1572.49	6672.00	39582.48	109347.01
legal risk	8.16	14.15	70.83	113.97
managerial capability	9.44	18.32	131.81	233.45
quantity risk	9.44	18.32	131.81	233.45
competitive risk	178.45	1287.50	10906.39	51905.32
quantity risk	178.45	1287.50	10906.39	51905.32
Partner Relationship management	0.00	0.01	0.07	0.15
knowledge leak risk	1572.49	6672.00	32614.96	91163.31
investment risk	0.03	0.68	3.15	8.10
Demand risk	9.44	18.32	131.81	233.45
competitive risk	0.03	0.68	3.15	8.10
innovation risk	178.45	1287.50	10906.39	51905.32
disruptive risk	0.00	0.01	0.07	0.15
time risk	9.44	18.32	131.81	233.45
cost risk	0.02	0.49	4.13	10.41
information flow risk	0.00	0.01	0.07	0.15
sovereign risk	0.00	0.00	0.00	0.00
knowledge flow risk	0.00	0.00	0.00	0.00
overseas risk	0.00	0.00	0.00	0.00
financial risk	0.02	18.32	131.81	233.45
control and coordination flow risk	0.00	0.00	0.00	0.00
Relationship asymmetry risk	0.00	0.00	0.00	0.00

Table 8 demonstrated how to find out of from the23*23 matrix based upon the table 8 and also upside formula. In part two of this table shows that all the numbers in first part of table 9 should have 23th square (or power in 1/23) because the matrix was 23*23 so 23 elements in each rows and columns.

Table 8. The calculation of (second part)

	a_i	b_i	c_i	d_i
1	1.3723	1.4603	1.5765	1.6469
2	1.3723	1.4603	1.5765	1.6469
3	1.0944	1.1207	1.2010	1.2259
4	1.1014	1.1332	1.2336	1.2642
5	1.1014	1.1332	1.2336	1.2642
6	1.2497	1.3606	1.4915	1.5950
7	1.2497	1.3606	1.4915	1.5950
8	0.7835	0.8101	0.8916	0.9211
9	1.3723	1.4603	1.5634	1.6341
10	0.8539	0.9838	1.0505	1.0941
11	1.1014	1.1332	1.2336	1.2642
12	0.8539	0.9838	1.0505	1.0941
13	1.2497	1.3606	1.4915	1.5950
14	0.7835	0.8101	0.8916	0.9211
15	1.1014	1.1332	1.2336	1.2642
16	0.8402	0.9698	1.0629	1.1060
17	0.7835	0.8101	0.8916	0.9211
18	0.4382	0.4698	0.5551	0.5846
19	0.6260	0.6477	0.7138	0.7385
20	0.6260	0.6477	0.7138	0.7385
21	0.8364	1.1332	1.2336	1.2642
22	0.4382	0.4698	0.5551	0.5846
23	0.4382	0.4698	0.5551	0.5846
sum	21.6674	23.3217	25.4917	26.5482

a=∑ai = 21.66737007835460 , b=∑bi 23.32172165024620 ,

c=∑ci = 25.49165198653830 , d=∑di = 26.54820511201740

Therefore: weight of wi is like this: wi= (ai/d , bi/c , ci/b , di/a) ;

Table 9. Weighting

	a_i	b_i	c_i	d_i
1	0.0527	0.0598	0.0705	0.0794
2	0.0527	0.0598	0.0705	0.0794
3	0.0421	0.0459	0.0537	0.0591
4	0.0423	0.0464	0.0552	0.0610
5	0.0423	0.0464	0.0552	0.0610
6	0.0480	0.0557	0.0667	0.0769
7	0.0480	0.0557	0.0667	0.0769
8	0.0301	0.0332	0.0399	0.0444
9	0.0527	0.0598	0.0699	0.0788
10	0.0328	0.0403	0.0470	0.0528
11	0.0423	0.0464	0.0552	0.0610
12	0.0328	0.0403	0.0470	0.0528
13	0.0480	0.0557	0.0667	0.0769
14	0.0301	0.0332	0.0399	0.0444
15	0.0423	0.0464	0.0552	0.0610
16	0.0323	0.0397	0.0476	0.0533
17	0.0301	0.0332	0.0399	0.0444
18	0.0168	0.0192	0.0248	0.0282
19	0.0241	0.0265	0.0319	0.0356
20	0.0241	0.0265	0.0319	0.0356
21	0.0321	0.0464	0.0552	0.0610
22	0.0168	0.0192	0.0248	0.0282
23	0.0168	0.0192	0.0248	0.0282

Then μ wi (x) defined as:

Table 10. The μ wi (x) for wi (weight)

x	*μ wi (x)*
≤(ai/d)	***0***
≥(di/a)	***0***
[bi/c , ci/b]	***1***
[ai/d , bi/c]	***α € [0, 1]***
[ci/b , di/a]	***α € [0, 1]***

If x € [ai/d, bi/c] therefore x = fi (α) / gi (α) so f (α) = ∑ mi=1 fi (α)

If x € [ci/b, di/a] therefore x = gi (α) / fi (α) so g (α) = ∑ mi=1 gi (α)

In the last part of the calculation the area under the curve will be calculated in order to find the weight of the eight parameters.

Table 11. Ranking of risk priority

SC risks	Effectiveness
strategic risk	0.01593
material flow risk	0.01593
legal risk	0.00920
managerial capability	0.00984
quantity risk	0.00984
competitive risk	0.01785
quantity risk	0.01785
Partner Relationship management	0.00758
knowledge leak risk	0.01589
investment risk	0.01322
DEMAND RISK	0.00984
competitive risk	0.01322
innovation risk	0.01785
disruptive risk	0.00758
time risk	0.00984
cost risk	0.01319
information flow risk	0.00758
sovereign risk	0.00575
knowledge flow risk	0.00613
overseas risk	0.00613
financial risk	0.02002
control and coordination flow risk	0.00575
Relationship asymmetry risk	0.00575

As it is shown in table 13, the amount of "S" or the area under the curve of trapezoid numbers are calculated in the left column and in the right they arranged based on the rank.

Table 12. Supply chain risk FAHP ranking

SC risks	priority
cost risk	0.04298
material flow risk	0.02130
financial risk	0.02002
competitive risk	0.01785
quantity risk	0.01785
strategic risk	0.01593
material flow risk	0.01593
knowledge leak risk	0.01589
investment risk	0.01322
competitive risk	0.01322
managerial capability	0.00984
quantity risk	0.00984
Demand risk	0.00984
time risk	0.00984
legal risk	0.00920
Partner Relationship management	0.00758
disruptive risk	0.00758
information flow risk	0.00758
knowledge flow risk	0.00613
overseas risk	0.00613
sovereign risk	0.00074
control and coordination flow risk	0.00074
Relationship asymmetry risk	0.00074

5. CONCLUSION

Efficient management of risks occur in supply chain can lead to the most beneficial supply chain networks and loss mitigation. This paper proposes a novel classification of various kinds of potential risks in supply chain network. Seven different classes perform as Managerial risk, Operational risk, Supply chain partner risk, Public infrastructure risk, financial risk, Disruption risk and Transportation risk. Various kinds of supply chain network risks seek different company recourses and then different management manner. Supply chain risk essence is counterpart with uncertainty. Then, we studied supply chain risks in fuzzy environment with trapezoidal fuzzy numbers. A novel method present to measure SC risk importance based on fuzzy FMEA and used resources to mitigate SC risks as Risk Efficiency Index. REI implement to rank SC risks for a real company in alloyed steel industry. Afterward we use fuzzy AHP for SC risk ranking and found the ranking results from REI method show the superiority and novelty of purposed method. Future research can focus on extending the REI method and identification of new ways to measure resources related to SC risks which lead to more efficient model.

REFERENCES

[1] Zsidisin, G. A., Ellram, L. M., Carter, J. R., & Cavinato, J. L. (2004). An analysis of supply risk assessment techniques. International Journal of Physical Distribution & Logistics Management. doi:10.1108/09600030410545445

[2] Tang, C. S. (2006). Perspectives in supply chain risk management. International journal of production economics, 103(2), 451-488. doi:10.1016/j.ijpe.2005.12.006

[3] Bogataj, D., & Bogataj, M. (2007). Measuring the supply chain risk and vulnerability in frequency space. International Journal of Production Economics, 108(1-2), 291-301. doi:10.1016/j.ijpe.2006.12.017

[4] Chopra, S., & Sodhi, M. S. (2004). Supply-chain breakdown. MIT Sloan management review, 46(1), 53-61.

[5] Brindley, C., & Ritchie, B. (2004). Chapter 1: introduction. Ed., Supply Chain Risk, Ashgate Publishing Ltd., Aldershot, Hampshire, UK.