CHAPTER-6

EVALUATION OF RISK-LEVEL AND SELECTION OF RISK MANAGEMENT STRATEGIES

In the present dynamic business environment, Indian small manufacturing organisations have to realize the importance of SCRM to make their supply chain robust against disruptions. To implement the SCRM, organisations must examine the risk-level of their supply chain, main SCR variables and their attributes. Assessment of the risk-level is essential to understand the current risk exposure of the organisation's supply chain.. There are several techniques to manage supply chain risks, such as design the new process to manage the identified risk, implement risk mitigating strategies and periodically re-assess the risks, transfer the risks to another party, avoid the risks, etc. (Jüttner. *et al.*, 2003).

Seven SCR variables and forty-two SCR attributes, which have a significant impact on supply chain of small Indian manufacturing firms, were identified in Chapter-4. In the previous chapters, Interpretive Structural Modeling (ISM) was used to understand the interrelationship among these seven SCR variables, and Analytic hierarchy process (AHP) was used to obtain the relative importance of each SCR variable. This chapter comprises of two phases; the risk-level of the supply chain is evaluated in the first phase and the risk management strategies are evaluated in the second phase. A flow chart of these two phases is shown in Figure 6.1. Figure 6.1 shows that a Fuzzy Logic Approach (FLA) was used in the first phase to find the risk-level of the supply chain of case organisation and also to find the SCR attribute which are critical for SCRM while in the second phase, ANP is adopted to identify the risk management strategies. Experts opinion were sought to determine the risk-level of the supply chain. Lin *et al.* (2006a) developed a fuzzy agility index (FAI) of the supply chain of a manufacturing organisation and also asserted that Fuzzy Logic is the most informative and reliable tool for decision making for complex and vague problems. Fuzzy Logic Approach (FLA) due to Lin et *al.* (2006a) was adopted to identify the main obstacles of SCRM.

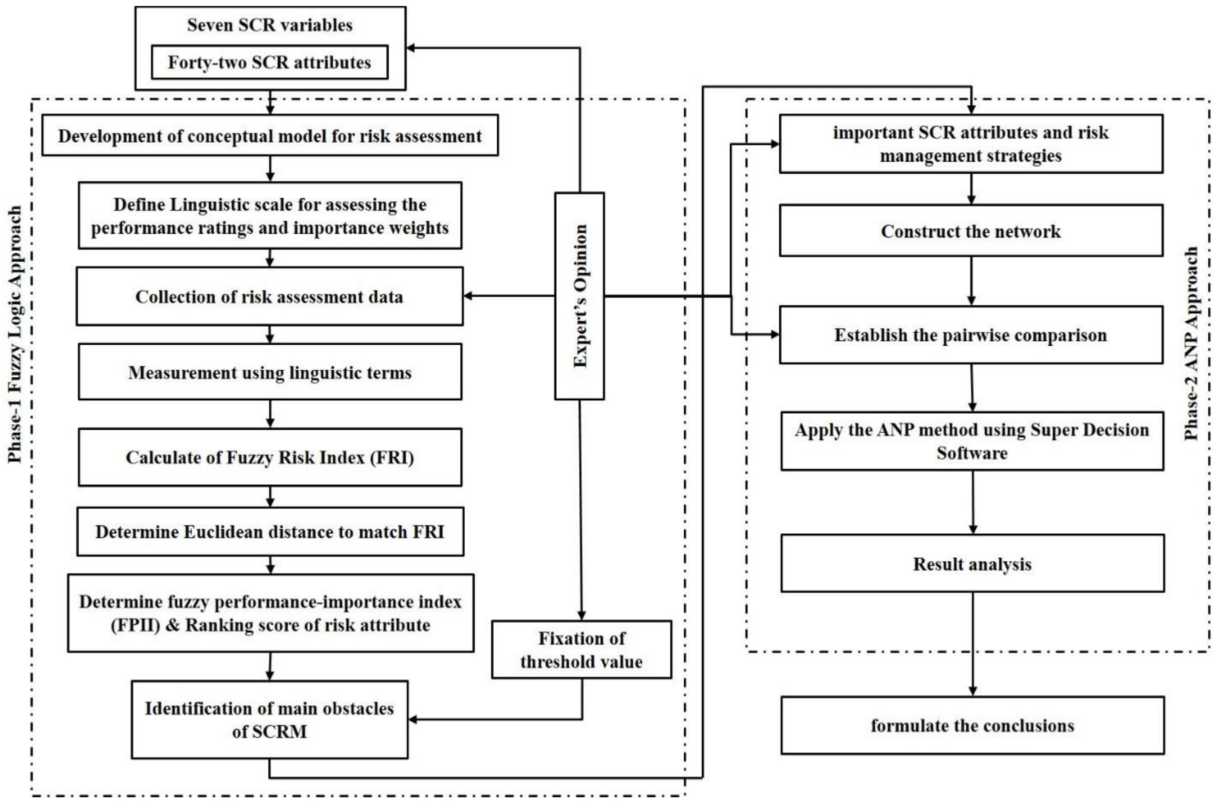


Figure 6.1. Flowchart for evaluation of risk-level and selection of risk management strategies

6.1. PHASE-1: EVALUATION OF RISK-LEVEL USING FUZZY LOGIC APPROACH

Most of the conventional assessment tools are crisp and dichotomous such as ‘True-or-False’, ‘Yes-or-No’, whereas, Fuzzy theory is different from the crisp system. Empirical researches are mainly dependent on the expert’s opinion, which may be ambiguous and imprecise. Vagueness of estimation can be minimised by using the fuzzy logic approach (Lin *et al.*, 2006a; Tseng and Lin, 2011). This theory was introduced in 1965 by Lotfi A. Zadeh. As discussed earlier, FLA due to Lin *et al.* (2006a) is adopted, this phase I introduces the conceptual model first.

6.1.1. Conceptual model for evaluation of the risk-level

With already identified seven SCR variables and their forty-two attributes, a conceptual model is developed with the help of industry experts for evaluation of the risk-level of the supply chain. This conceptual model is shown in Figure 6.2. Figure 6.2 shows the objective first followed by the SCR variables associated with problem. SCR variable divided into SCR attribute and is shown below each such variable. Nomenclature for SCR variable and associated attribute is shown in Table 6.1.

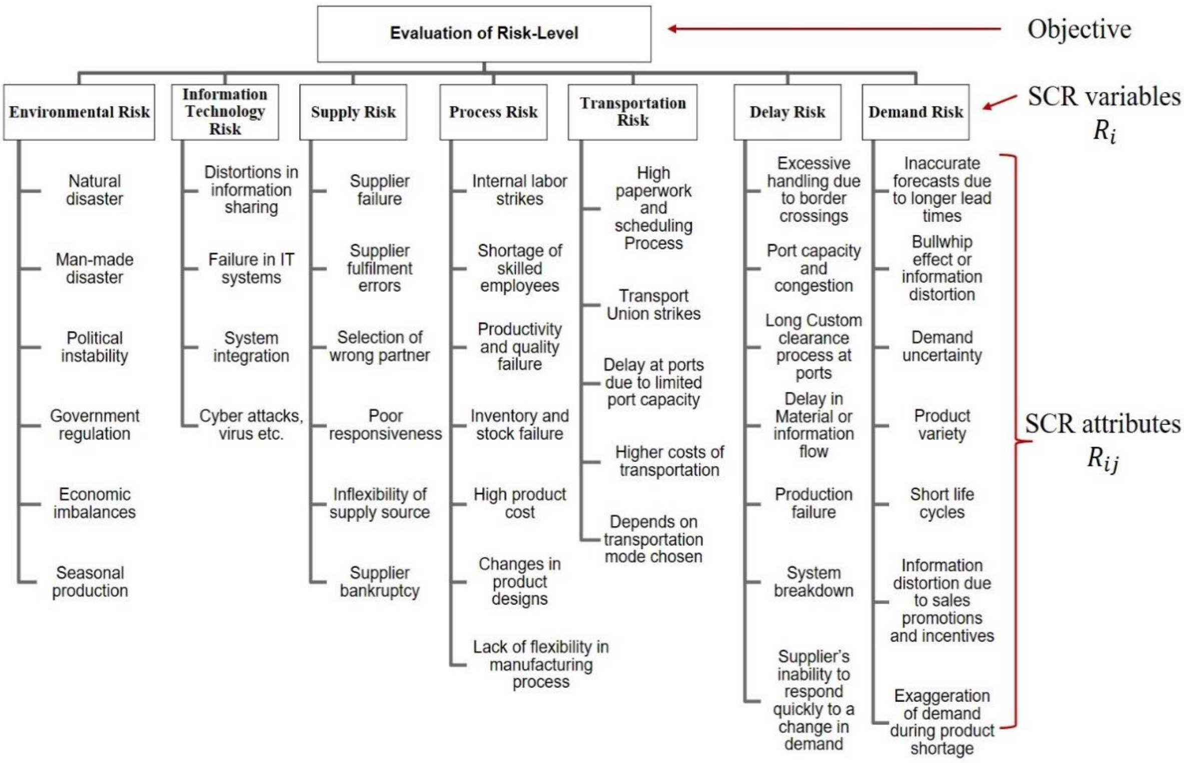


Figure-6.2 Conceptual SCRM model for measuring risk-level

Table 6.1. SCR variables and their attributes for evaluation of risk-level

S.N.	SCR Variables	SCR attributes
1	Environmental Risk (ER)	ER1- Natural disaster ER2- Man-made disaster ER3- Political instability ER4- Change in government regulation ER5- Economic imbalances ER6- Seasonal production
2	Information Technology Risk (IR)	IR1- Distortions in information sharing IR2- Failure in IT systems IR3- System integration IR4- Cyber-attacks, virus etc.

3	Supply Risk (SR)	SR1- Supplier failure SR2- Supplier fulfilment errors SR3- Selection of wrong partner SR4- Poor responsiveness and delivery performance SR5- Inflexibility of supply source SR6- Supplier bankruptcy
4	Process Risk (PR)	PR1- Internal labor strikes PR2- Shortage of skilled employees PR3- Productivity and quality failure PR4- Inventory and stock failure PR5- High product cost PR6- Changes in product designs PR7- Lack of flexibility in manufacturing process
5	Transportation Risk (TR)	TR1- High paperwork and scheduling Process TR2- Transport Union strikes TR3- Delay at ports due to limited port capacity TR4- Higher costs of transportation TR5- Depends on transportation mode chosen
6	Delay Risk (DE)	DE1- Excessive handling due to border crossings DE2- Port capacity and congestion DE3- Long Custom clearance process at ports DE4- Delay in Material or information flow DE5- Production failure DE6- System breakdown DE7- Supplier's inability to respond quickly to a change in demand
7	Demand Risk (DR)	DR1- Inaccurate forecasts due to longer lead times DR2- Bullwhip effect or information distortion DR3- Demand uncertainty DR4- Product variety DR5- Short life cycles DR6- Information distortion due to sales promotions and incentives DR7- Exaggeration of demand during product shortage

For all these SCR variables and their attributes, data were collected from the experts of case organisation only.

6.1.2. Collection of data

The expert's judgements plays a major role for assessment of importance weights and performance ratings of SCR variables and their attributes. For assessment of importance weights and performance ratings, linguistic terms are required to capture the expert's judgements (Lin *et al*., 2006b). Determination of linguistic scale is an important aspect of an empirical research to deal with impreciseness and ambiguity. Linguistic scale deals with conversion of qualitative data into quantitative data. For this purpose, a linguistic scale is obtained from the previous studies (Lin *et al*., 2006b, Tseng and Lin, 2011, Vinodh *et al*. 2011), and is already exhibited in Table 3.3 of Chapter 3. Experts were apprised about this linguistic scale. After determination of linguistic scale, the next step is to collect the data from the experts. In this study, five experts from the case organisation were approached to assess the performance ratings and importance weights of SCR variables and their attributes. The data is collected from the expert's opinion in the form of linguistic variables is shown in Appendix-A. Appendix- A represents the performance rating and importance weights of the all SCR variables and their attributes. Table 6.2 & 6.3 reproduce such data as a sample. Table 6.2 shows the exerts responses in linguistic terms for performance rating of the SCR attribute 'Environmental Risk' (ER). Similarly, Table 6.3 shows for importance weights of the SCR attribute 'Environmental Risk' (ER).. The linguistic data is collected from the experts are shown in Table 6.2, 6.3 and Appendix-A by have the following notations:

W_i = importance weight of SCR variable i

R_{ij} = performance rating of j^{th} SCR attribute of i^{th} variable

W_{ij} = importance weight of j^{th} SCR attribute of i^{th} variable

R_{ijk} = performance rating of j^{th} SCR attribute of i^{th} variable given by expert k

W_{ijk} = importance weight of j^{th} SCR attribute of i^{th} variable given by expert k

Table 6.2: Performance rating of SCR variable 'Environmental Risk (ER)' in linguistic terms

SCR Variables	SCR Attributes	R_{ij1}	R_{ij2}	R_{ij3}	R_{ij4}	R_{ij5}
ER	ER1	G	G	VG	G	VG
	ER2	VG	VG	G	G	G
	ER3	G	G	G	VG	G
	ER4	VG	G	G	G	G
	ER5	G	G	F	G	G
	ER6	G	F	G	F	F

Table 6.3: Importance weight of SCR variable 'Environmental Risk (ER)' in linguistic terms

SCR Variables	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}	SCR Attributes	W_{ij1}	W_{ij2}	W_{ij3}	W_{ij4}	W_{ij5}
ER	VH	VH	H	VH	H	ER1	H	H	VH	H	VH
						ER2	VH	VH	H	VH	H
						ER3	FH	FH	H	H	H
						ER4	H	H	H	H	FH
						ER5	FH	M	M	FH	FH
						ER6	M	M	FH	FH	M

These linguistic variables are converted into fuzzy numbers. From the Table 3.3 of Chapter 3, the expert's opinion in the form of linguistic terms are converted into fuzzy numbers. Sample data of such converted values are shown in Table 6.4 and 6.5 for Table 6.2 and 6.3 respectively. After completion of conversion, this data is used for determination of average fuzzy importance weights and average performance ratings.

Table 6.4 Performance rating of SCR variable 'Environmental Risk (ER)' in Fuzzy numbers

SCR Variables	SCR Attributes	R_{ij1}	R_{ij2}	R_{ij3}	R_{ij4}	R_{ij5}
ER	ER1	(5, 6.5, 8)	(5, 6.5, 8)	(7, 8, 9)	(5, 6.5, 8)	(7, 8, 9)
	ER2	(7, 8, 9)	(7, 8, 9)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)
	ER3	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)	(7, 8, 9)	(5, 6.5, 8)
	ER4	(7, 8, 9)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)	(5, 6.5, 8)
	ER5	(5, 6.5, 8)	(5, 6.5, 8)	(3, 5, 7)	(5, 6.5, 8)	(5, 6.5, 8)
	ER6	(5, 6.5, 8)	(3, 5, 7)	(5, 6.5, 8)	(3, 5, 7)	(3, 5, 7)

Table 6.5: Importance weight of SCR variable 'Environmental Risk (ER)' in Fuzzy numbers

SCR-V	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}	SCR-A	W_{ij1}	W_{ij2}	W_{ij3}	W_{ij4}	W_{ij5}
ER	(0.85, 0.95, 1.0)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	ER1	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)
						ER2	(0.85, 0.95, 1.0)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)	(0.85, 0.95, 1.0)	(0.7, 0.8, 0.9)
						ER3	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)
						ER4	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.7, 0.8, 0.9)	(0.5, 0.65, 0.8)
						ER5	(0.5, 0.65, 0.8)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)
						ER6	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.65, 0.8)	(0.5, 0.65, 0.8)	(0.3, 0.5, 0.7)

SCR-V: SCR-Variable, SCR-A: SCR-Attribute

6.1.3. Determination of fuzzy importance weights and performance ratings

In this study, the performance ratings and importance weights are collected from the five experts of case organisation. Therefore, aggregation of data is essential step to get the final fuzzy importance weight and performance rating of each SCR variable. As explained in Chapter 3, arithmetic mean method is used in the present research to aggregate the opinion collected from 'n' number of expert's. The computation of average performance ratings (R_{ij}) and average importance weights (W_{ij}) of SCR attributes and average importance weights (W_i) are carried using the following equations (Lin *et al.,* 2006a, Vinodh *et al*. 2013).

$$R_{ij} = \frac{R_{i1}+R_{i2}+\cdots....+R_{in}}{n} \tag{6.1}$$

$$W_{ij} = \frac{W_{i1}+W_{i2}+\cdots....+W_{in}}{n} \tag{6.2}$$

$$W_{i} = \frac{W_{1}+W_{2}+\cdots....+W_{n}}{n} \tag{6.3}$$

Where,

W_i= importance weight of SCR variable *i;*

R_{ij}= Performance rating of j^{th} SCR *attribute of* i^{th} *SCR variable;*

W_{ij}=importance weight of j^{th} SCR *attribute of* i^{th} *SCR variable;*

As a sample calculation, average fuzzy performance rating of the SCR-attribute *'Natural disaster' (ER1)* is calculated as follows:

$$R_{11} = \frac{[G + G + VG + G + VG]}{5}$$

$$R_{11} = \frac{[(5, 6.5, 8)+(5, 6.5, 8)+(7, 8, 9) +(5, 6.5, 8) +(7, 8, 9)]}{5}$$

$$R_{11} = (5.80, 7.10, 8.40)$$

Similarly, average fuzzy importance weight of the SCR-attribute *'Natural disaster' (ER1)* is calculated as follows:

$$W_{11} = \frac{[H + H + VH + H + VH]}{5}$$

$$W_{11} = \frac{[(0.7, 0.8, 0.9)+(0.7, 0.8, 0.9) +(0.85, 0.95, 1.0)+(0.7, 0.8, 0.9)+(0.85,0.95,1.0)\ ]}{5}$$

$$W_{11} = (0.76, 0.86, 0.94)$$

The average importance weights and average performance ratings of of SCR variable 'Environmental Risk' (ER) are shown in Table 6.6. Appendix- B presents the average importance weights and average performance ratings of the all SCR variables and their attributes. The data of Appendix-B is used to calculate Fuzzy Risk Index.

Table 6.6: Average fuzzy weights and fuzzy ratings of SCR variable 'Environmental Risk' (ER)

SCR Variables	Average fuzzy weight	SCR Attributes	Average fuzzy weight	Average fuzzy rating
ER	(0.79, 0.89, 0.96)	ER1	(0.76, 0.86, 0.94)	(5.80, 7.10, 8.40)
		ER2	(0.79, 0.89, 0.96)	(5.80, 7.10, 8.40)
		ER3	(0.60, 0.74, 0.86)	(5.40, 6.80, 8.20)
		ER4	(0.66, 0.77, 0.88)	(5.40, 6.80, 8.20)
		ER5	(0.42, 0.59, 0.76)	(4.60, 6.20, 7.80)
		ER6	(0.38, 0.56, 0.74)	(3.80, 5.60, 7.40)

6.1.4. Calculation of Fuzzy Risk Index(FRI)

The Fuzzy Risk Index(FRI) of the organisation is calculated by considering SCR attributes then SCR variables. It consolidates the fuzzy weights and fuzzy ratings for all the SCR variables and SCR attributes. In order to compute *FRI*, the risk index (*RI*) of each SCR variable (Lin *et al.*, 2006a, Vinodh *et al.*, 2013) is calculated at as follows.

$$RI_i = \frac{\sum_{j=1}^{n}(W_{ij} \times R_{ij})}{\sum_{j=1}^{n} W_{ij}} \quad (6.4)$$

where,

RI_i= Risk index of i^{th} SCR variable; W_i= importance weight of i^{th} SCRvariable*;*

R_{ij}= Performance rating of j^{th} SCR attribute of i^{th} SCR variable;

W_{ij}=Importance weight of j^{th} SCR attribute of i^{th} SCR variable;

$$FRI = \frac{\sum_{i=1}^{n}(W_i \times RI_i)}{\sum_{j=1}^{n} W_i} \tag{6.5}$$

Using the equation 6.4, Calculation of Risk Index of SCR variable 'Environmental Risk' (ER) is as follows;

$$R_{i1} = \begin{bmatrix} (0.76,0.86,0.94) \times (5.80,7.10,8.40) + \\ (0.79,0.89,0.96) \times (5.80,7.10,8.40) + \\ (0.62,0.74,0.86) \times (5.40,6.80,8.20) + \\ (0.66,0.77,0.88) \times (5.40,6.80,8.20) + \\ (0.42,0.59,0.76) \times (4.60,6.20,7.80) + \\ (0.42,0.59,0.76) \times (3.80,5.60,7.40) \end{bmatrix} / \begin{bmatrix} (5.80,7.10,8.40) + \\ (5.80,7.10,8.40) + \\ (5.40,6.80,8.20) + \\ (5.40,6.80,8.20) + \\ (4.60,6.20,7.80) + \\ (3.80,5.60,7.40) \end{bmatrix}$$

$R_{i1} = (5.31,\ 6.69,\ 8.10)$

Similarly, Risk index for other SCR variables are calculated, and shown in Table 6.7.

Table 6.7 Risk index for each SCR Variable

SCR Variable	**Importance weight (W_i)**	**Performance rating (RI_i)**
Environmental Risk (ER)	(0.79, 0.89, 0.96)	(5.31,6.69,8.10)
Information Technology Risk (IR)	(0.76, 0.86, 0.94)	(5.23,6.66,8.08)
Supply Risk (SR)	(0.72, 0.86, 0.92)	(6.30,7.51,8.65)
Process Risk (PR)	(0.73, 0.83, 0.92)	(6.06,7.31,8.52)
Transportation Risk (TR)	(0.69, 0.80, 0.90)	(5.29,6.68,8.10)
Delay Risk (DE)	(0.58, 0.71, 0.84)	(4.71,6.25,7.82)
Demand Risk (DR)	(0.72, 0.83, 0.92)	(5.94,7.21,8.46)

Using the equation 6.5, calculation of Fuzzy Risk Index (FRI) is as follows:

$$FRI = \begin{bmatrix} (0.79,0.89,0.96) \times (5.31,6.69,8.10) + \\ (0.76,0.86,0.94) \times (5.23,6.66,8.08) + \\ (0.72,0.86,0.92) \times (6.30,7.51,8.65) + \\ (0.73,0.83,0.92) \times (6.06,7.31,8.52) + \\ (0.69,0.80,0.90) \times (5.29,6.68,8.10) + \\ (0.58,0.71,0.84) \times (4.71,6.25,7.82) + \\ (0.72,0.83,0.92) \times (5.94,7.21,8.46) \end{bmatrix} / \begin{bmatrix} (5.31,6.69,8.10) + \\ (5.23,6.66,8.08) + \\ (6.30,7.51,8.65) + \\ (6.06,7.31,8.52) + \\ (5.29,6.68,8.10) + \\ (4.71,6.25,7.82) + \\ (5.94,7.21,8.46) \end{bmatrix}$$

$FRI = (5.57,\ 6.92,\ 8.25)$

This *FRI* is now matched with the appropriate linguistic level.

6.1.5. Matching Fuzzy Risk Index (FRI) with an approximate linguistic level

After obtaining the FRI, it is matched with the natural linguistic risk level(RL_i) by identifying the closest membership function of fuzzy risk index. In the literature, several methods are available to match the fuzzy index with linguistic terms such as successive approximation and Euclidean distance. Euclidean distance method is recognized as most intuitive method for perceiving proximity (Lin *et al.,* 2006a), hence the same method is used in the present research. The Euclidean distance $D(FRI,\ RL_i)$ from the fuzzy risk index to linguistic risk level is calculated by using equation 6.6 (Tseng and Lin, 2011 and Vinodh *et al*. 2013).

$$D(FRI,\ RL_i) = \left\{\sum_{x\in p}(U_{FRI}(x)) - U_{FLi}(x))^2\right\}^{1/2} \tag{6.6}$$

Where, $U_{FLi}(x)$ represent the membership functions of the *FRI*

$U_{FRI}(x)$ represent the membership functions of linguistic risk level

Sample calculation of Euclidean distance using the formula 6.6 for the linguistic term 'High risk level' shown as (5.5, 7.0, 8.5)is calculated as follows:

$$D(FRI,\ High) = \{(5.57 - 5.5)^2 + (6.92 - 7.0)^2 + (8.25 - 8.5)^2\}^{1/2}$$

$D(FRI,\ High)$ = 0.27

The linguistic variable and their Euclidean distance to FRI for each linguistic variable for the case organisation are calculated and shown in Table 6.8.

Table 6.8 Natural Linguistic terms and fuzzy numbers for risk level

Linguistic variable	Fuzzy Number	Euclidean distance
Very High (VH)	(7.0, 8.5, 10)	D (FRI, VH) =2.76
High (H)	(5.5, 7, 8.5)	D (FRI, H) = 0.27
Moderate (M)	(3.5, 5, 6.5)	D (FRI, M) = 3.32
Low (L)	(1.5, 3, 4.5)	D (FRI, L) = 6.78
Very Low (VL)	(0, 1.5, 3)	D (FRI, VL) = 9.38

After matching the *FRI* to the linguistic level, the risk-level of supply chain of the case organisation is analysed. Table 6.8 shows that minimum Euclidean distance is 0.27 i.e. FRI (5.57, 6.92, 8.25) is closely matching with the linguistic variable 'High' (5.5, 7, 8.5). This has been graphically shown in Figure 6.3.

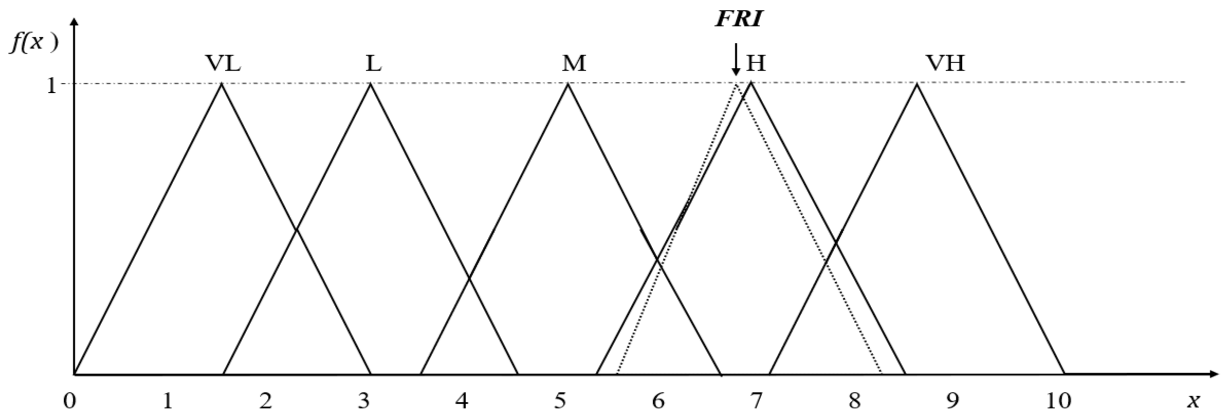


Figure 6.3. Matching the Fuzzy Risk Index (*FRI)* with the standard linguistic level

Knowing the risk level as 'High' for the case organisation, an effort has been made to identify the important SCR attributes contributing to this risk-level by calculating FPII.

6.1.6. Determine Fuzzy Performance-Importance Index (FPII)

The risk-level of the supply chain of case organisation is found to be "High", which is very far away from risk-level 'Low'. Some SCR attributes have a high impact while determining the risk level. These SCR attributes can be treated as the main obstacles and the same can be identified by using the fuzzy performance importance index (FPII). FPII can be calculated by using the following equations (Lin *et al*., 2006a; Vinodh *et al*., 2013)

$$FPII = W'_{ij} \times R_{ij} \tag{6.7}$$

$$W'_{ij} = \left[(1,1,1) - W_{ij}\right] \tag{6.8}$$

Where,

R_{ij} = Performance rating of j^{th} SCR attribute of i^{th} SCR variable;

W_{ij} = Importance weight of j^{th} SCR attribute of i^{th} SCR variable;

Using above equations, Calculation of FPII of SCR attribute '*Natural disaster'* (ER1) is as follows;

$$FPII_{ER1} = \{(1,1,1) - W_{ij}\} \times R_{ij}$$

$$FPII_{ER1} = \{(1,1,1) - (0.76, 0.86, 0.94)\} \times (5.80, 7.10, 8.40)$$

$$FPII_{ER1} = (0.24, 0.14, 0.06) \times (5.80, 7.10, 8.40)$$

$$FPII_{ER1} = (1.39, 0.99, 0.50)$$

Accordingly, FPII for all forty-two SCR attributes are calculated, are shown in Appendix-C. In the literature, several methods are available to rank the FPIIs. In the past researches, centroid method is widely used for ranking, hence the same method is used in this research. The ranking score of each risk-attribute is calculated based on centroid method for membership function (a, b, c) as given in Eq. 6.9, where a, b and c are the lower, middle and upper values of triangular fuzzy number (Vinodh *et al.*, 2013). For example , a= 1.39 , b= 0.99, c= 0.50 for $FPII_{ER1}$.

$$\text{Ranking Score} = \frac{a + 4b + c}{6} \tag{6.9}$$

Using above equation, calculation of Ranking Score of SCR attribute ''*Natural disaster'* (ER1) is as follows;

$$\text{Ranking Score} = \frac{1.39 + 4 \times 0.99 + 0.50}{6}$$

$$= 0.98$$

Similarly, the ranking score of each risk-attribute is calculated. Appendix-C shows ranking score of each SCR attributes. Now these scores are compared with the threshold value. A threshold value is required to identify the obstacles of SCRM. With the help of experts, the threshold value is determined to 1.40 for this case organisation. SCR attributes having ranking score less than determined threshold value are identified as main obstacles to

SCRM. A Scatter plot of the FPII of all SCR-attributes is plotted and shown in Figure 6.4. Based on threshold value and ranking score of SCR attribute, 20 SCR attributes are identified as main obstacles of SCRM. Table 6.9 shows the ranking score of these SCR attributes. The supply chain manager should primarily focus on these risk attributes to make supply chain more robust.

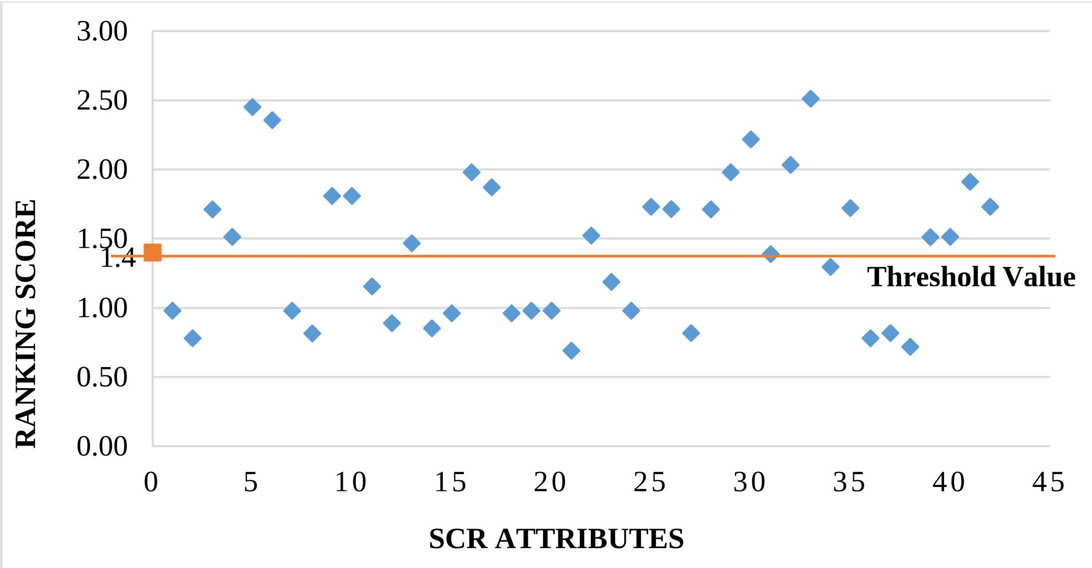


Figure 6.4: Scatter chart of the FPII of all SCR-attributes

Table 6.9: Main obstacles of SCRM

SCR Attributes	Ranking Score
ER1 Natural disaster	0.98
ER2 Man-made disaster	0.78
IR1 Distortions in information sharing	0.98
IR2 Failure in IT systems	0.81
SR1 Supplier failure	1.15
SR2 Supplier fulfilment errors	0.89
SR4 Poor responsiveness and delivery performance	0.85
SR5 Inflexibility of supply source	0.96
PR2 Shortage of skilled employees	0.96
PR3 Productivity and quality failure	0.98
PR4 Inventory and stock failure	0.98
PR5 High product cost	0.69
PR7 Lack of flexibility in manufacturing process	1.19
TR1 High paperwork and scheduling Process	0.98
TR4 Higher costs of transportation	0.82
DR1 Inaccurate forecasts due to longer lead times	0.78
DR2 Bullwhip effect or information distortion	0.82

DR3	Demand uncertainty	0.72
DE3	Long Custom clearance process at ports	1.39
DE6	System breakdown	1.29

In phase I, twenty SCR attributes of seven SCR variables are identified as main obstacles of SCRM. These SCR attributes are taken as input for Phase II. Phase II involves evaluation and selection of suitable risk management strategies for each identified SCR attribute.

6.2. PHASE II: EVALUATION OF RISK MANAGEMENT STRATEGIES BY USING ANP APPROACH

In the literature, many strategies for the risk management are available (Miller, 1992; Jüttner *et al.*, 2003; Chopra and Sodhi 2004; Tomlin 2006; Thun and Hoenig 2011; Lavastre *et al.* 2012) in relations to many types companies and/or industries. In relation to the case organisation, these strategies were evaluated with the help of experts of the case - organisation and four generic strategies were identified, namely: (1) Risk avoidance strategy, (2) Risk mitigation strategy, (3) Risk sharing strategy, (4) Risk retention strategy, which are explained in Chapter 1. ANP approach due to Saaty (1996) is adopted to evaluate these risk management strategies with respect to twenty SCR attributes identified for the case-organisation. ANP is more preferable in the case as this approach can establish multi-directional relationships among multiple elements. Super Decisions Software Version 3.2 (Saaty, 1996) is used for development of ANP model.

ANP approach is initiated with the development of conceptual model with SCR variables, their attributes and identified risk management strategies.

6.2.1. Development of ANP Model

Super Decisions Software Version 3.2 uses, clusters, arrow and nodes for the development of conceptual model. The model development starts with creation of clusters. After creation of clusters, the next step is to create the nodes of each cluster. Clusters and nodes of the proposed model are showed in Table 6.10. The interdependencies among the nodes and clusters are represented with the help of arrows. For example, A→B represent that the decision element B depends upon the decision element A. There are two types of dependencies among the nodes; dependencies between nodes of different clusters is known as 'outer dependence' which is represented by an arrow between clusters, and dependencies between nodes of same cluster is known as 'inner dependence' which is represented by an arrow to connect the cluster itself (Singh and Sharma, 2014). Thus, after connecting the clusters and nodes with the help of arrows, conceptual ANP network model is structured. The model of this case is represented in Figure 6.5.

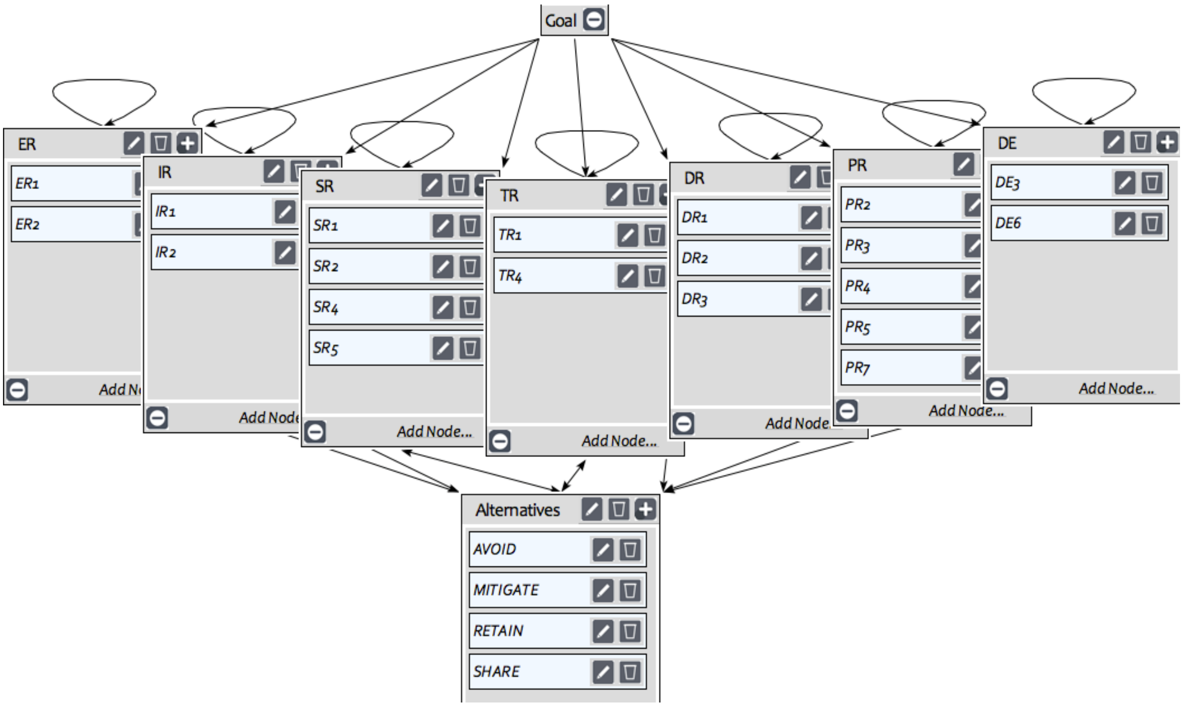


Figure 6.5. ANP model for evaluation of risk management strategies

Table 6.10. Description of clusters and nodes.

Clusters	Nodes
C_1: Environmental Risk (ER)	$N_{1.1}$: Natural disaster (ER1) $N_{1.2}$: Man-made disaster (ER2)
C_2: Information Technology Risk (IR)	$N_{2.1}$: Distortions in information sharing (IR1) $N_{2.2}$: Failure in IT systems (IR2)
C_3: Supply Risk (SR)	$N_{3.1}$: Supplier failure (SR1) $N_{3.2}$: Supplier fulfilment errors (SR2) $N_{3.4}$: Poor responsiveness and delivery performance (SR4) $N_{3.5}$: Inflexibility of supply source (SR5)
C_4: Process Risk (PR)	$N_{4.1}$: Shortage of skilled employees (PR2) $N_{4.2}$: Productivity and quality failure (PR3) $N_{4.3}$: Inventory and stock failure (PR4)

	$N_{4.4}$: High product cost (PR5) $N_{4.5}$: Lack of flexibility in manufacturing process (PR7)
C_5: Transportation Risk (TR)	$N_{5.1}$: High paperwork and scheduling Process (TR1) $N_{5.2}$: Higher costs of transportation (TR4)
C_6: Delay Risk (DE)	$N_{6.1}$: Long Custom clearance process at ports (DE3) $N_{6.2}$: System breakdown (DE6)
C_7: Demand Risk (DR)	$N_{7.1}$: Inaccurate forecasts due to longer lead times (DR1) $N_{7.2}$: Bullwhip effect or information distortion (DR2) $N_{7.3}$: Demand uncertainty (DR3)
C_8: Alternatives (Risk Management strategies)	$N_{8.1}$: Risk Avoidance strategy: (RM1) $N_{8.2}$: Risk Mitigation strategy: (RM2) $N_{8.3}$: Risk Sharing strategy (RM3) $N_{8.4}$: Risk Retention strategy: (RM4)

6.2.2. Collection the data

After development of ANP model on Super Decisions Software, all pairwise comparisons are done on the basis of the connections established among the clusters and nodes. As suggested by Saaty (1980), a nine-point scale of Table 3.1 was used to collect pair-wise comparison data. A group discussion process has been preferred over individual preferences by experts to collect the pairwise comparison data. Three experts from the case-organisation has participated in the group discussion session.. For example, a pairwise comparison of node 'Natural disaster (ER1)' is exhibited in Figure 6.6.

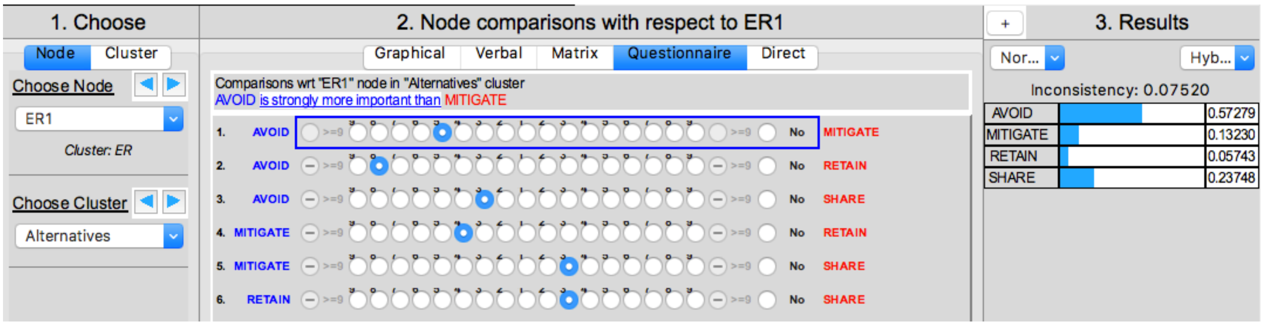


Figure 6.6. Pairwise comparison of node 'Natural disaster (ER1)'

6.2.3. Determining the ranking of each RM Strategy with respect to each SCR attribute

After obtaining the all pair-wise comparison data from the experts, next step is to evaluate and determine the relative weight and ranking of each RM Strategy with respect to each SCR attribute. ANP Solution module of Super Decisions software has been used to analyse the collected data. Table 6.11 shows the relative weights of each RM Strategy with respect to each SCR attribute.

Table 6.11 Relative weight of each RM Strategy with respect to each SCR attribute

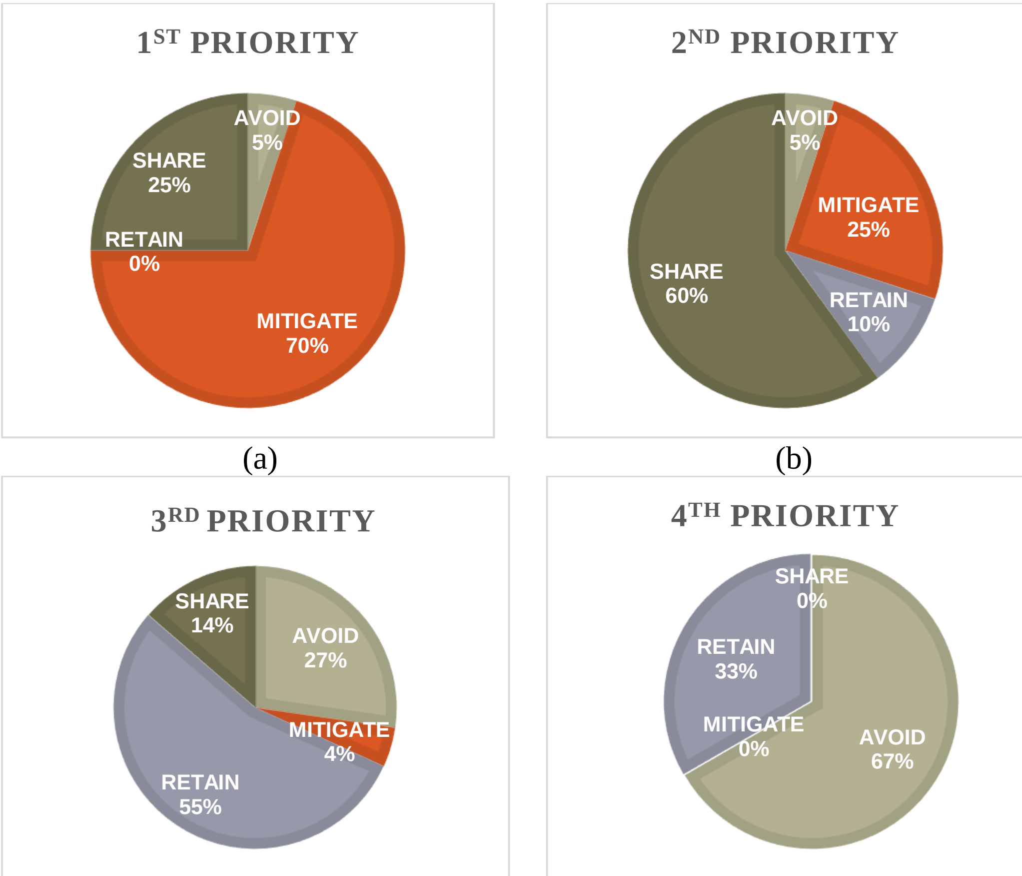
RM Strategy / SCR Attribute	AVOID	MITIGATE	RETAIN	SHARE
DE3	0.0433	0.2772	0.0608	0.1187
DE6	0.0709	0.5974	0.076	0.2557
DR1	0.038	0.3043	0.0534	0.1043
DR2	0.0589	0.2856	0.0482	0.1073
DR3	0.0468	0.2871	0.0502	0.1159
ER1	0.5728	0.1323	0.0574	0.2375
ER2	0.1295	0.2533	0.0475	0.0698
IR1	0.0415	0.2679	0.0724	0.1182
IR2	0.0353	0.244	0.1362	0.0845
PR2	0.0317	0.1429	0.0493	0.2762
PR3	0.0669	0.2922	0.0337	0.1072
PR4	0.0375	0.1364	0.0686	0.2575
PR5	0.0386	0.1436	0.0595	0.2583
PR7	0.0412	0.1394	0.0457	0.2737
SR1	0.0525	0.1507	0.0475	0.2493
SR2	0.0752	0.2062	0.0602	0.1584
SR4	0.0485	0.2718	0.0519	0.1278
SR5	0.0734	0.274	0.0791	0.0734
TR1	0.0526	0.2639	0.0526	0.1309
TR4	0.0392	0.2926	0.0553	0.1129

These relative weights help to prioritize the RM strategy. Rankings of RM strategies are shown in Table 6.12.

Table 6.12 Ranking of RM strategies with respect to each SCR attribute

Ranking of RM Strategies with respect to each risk attributes																				
	DE3	**DE6**	**DR1**	**DR2**	**DR3**	**ER1**	**ER2**	**IR1**	**IR2**	**PR2**	**PR3**	**PR4**	**PR5**	**PR7**	**SR1**	**SR2**	**SR4**	**SR5**	**TR1**	**TR4**
AVOID	4	4	4	3	4	1	2	4	4	4	3	4	4	4	3	3	4	3	3	4
MITIGATE	1	1	1	1	1	3	1	1	1	2	1	2	2	2	2	1	1	1	1	1
RETAIN	3	3	3	4	3	4	4	3	2	3	4	3	3	3	4	4	3	2	3	3
SHARE	2	2	2	2	2	2	3	2	3	1	2	1	1	1	1	2	2	3	2	2

From the above tables, results indicate that mitigation strategy is the most preferential strategy for managing the risks. The prioritization of risk management strategies is represented through pie chart in Figure 6.7.



(a) (b) (c) (d)

Figure 6.7. Ranking of RM Strategies

Figure 6.7(a) shows share of SCR attribute with the rank to use mitigate strategies. It is clear that in 70% cases of SCR attributes are ranked as first priority highlighting the importance of risk mitigation strategy. Figure 6.7 (b, c, d) shows the percentage of each strategy ad so ranking over the SCR attributes for their selection preference.

6.3. CONCLUSION

Modern supply chain operates under a dynamic business environment and faced several types of risks associated with its supply chain network. These supply chain risks can not be completely neutralized, but their impact can be reduced by proactively evaluating the risk-level of the supply chain and thereby developing the risk management plan to control their impact. Risk-level would provide the information about risk-exposure of the supply chain and major SCR variables and their attributes, to enable the SC managers for selection of better risk management strategy to anticipate them.

In this chapter, a Fuzzy-logic approach is used to assess the risk-level for identified SCR variables and SCR attributes, which have significant impact on supply chain of the case-organisation. Risk Index(RI) of each SCR attribute and each SCR variable are identified. With the help of these risk indexes, fuzzy risk index(FRI) is calculated representing the risk-level of the supply chain of the case organisation. *FRI* is matched to the linguistic level and the risk-level of supply chain of the case organisation is found to be "High". For better risk management and to bring down the risk-level of the supply chain, SC managers must know the main obstacles of SCRM. FPII is calculated for each SCR attribute to identify the main obstacles of supply chain. SCR attributes having ranking score are compared with a threshold value to identify the main obstacles to SCRM. Experts' opinion was used to set the threshold value as 1.40. Based on threshold value and ranking score of SCR attribute, twenty SCR attributes are identified as main obstacles of SCRM. The supply chain manager should primarily focus on these twenty SCR attributes to achieve the risk-level from 'High' to 'Low' or 'Very low'.

In the second phase of this chapter, ANP methodology is used for evaluation of four generic risk mitigation strategies to anticipate the identified twenty main obstacles/SCR attributes. ANP model is developed by using Super Decisions Software Version 3.2. Findings of this study shows that mitigation strategy is the most preferential strategy for SCRM followed by sharing strategy, retention strategy and avoidance strategy.

The findings of this study not only provide the insights of main SCR variables and attributes of SCRM, but also provide the insight to assess the risk-level and to identify the main obstacles of SCRM. It also provides an insight to prioritise the risk management strategies using ANP methodology. These findings also help to SC managers for allocation of resources while implementation of the risk management strategies to anticipate the major SCR attributes. This Fuzzy-ANP model would be helpful for SC managers as it is like a measuring instrument from which the risk-level of supply chain is assessed. SC manager can apply these models for regularly monitoring of the performance of their supply chain and can achieve the desired risk-level by anticipating the vulnerability of the supply chain. Findings of this study will also be helpful to enable the SC managers for proactive decision making while dealing with SCRM.