CHAPTER VII
COMPARATIVE STUDY AND RISKS ASSESSMENT OF DIFFERENT SUPPLY CHAINS

7.1 INTRODUCTION

Risk management is an important part of supply chain. For the success of supply chain risks can’t be ignored. Supply chain risks may result from unexpected variations in capacity constraints or from breakdowns, quality problems, fires or even natural disasters at the supplier end (Blackhurst et al., 2005; Yang and Yang, 2010). A failure of any one element in a supply chain potentially causes disruptions for all partnering companies upstream and downstream (Yang and Yang, 2010). Therefore supply chain risk management (SCRM) is the imperative to devise and develop appropriate performance measures and metrics to evaluate, educate and direct the operational and strategic decisions. Rossi and Pero (2012) have explained timed attributed petri nets both to represent the considered logistic network and to identify the risky events it deals with and simulation techniques and statistical analysis to perform risk evaluation. Alawamleh and Popplewell (2012) have worked towards a comprehensive study of the risk in collaborative network. Collaboration is compulsory in order for enterprises to participate and to operate with speed and flexibility. However, there is some risk due to this relationship. According to Chaudhuri (2013) companies strive to minimize supply chain related risks during new product development as any glitch while developing new products can lead to considerable delay in product launch with severe financial implications. 

Svensson (2000) have discussed that the vulnerability of a supply chain increases with increasing uncertainty and it increases even further if companies, by outsourcing, have become dependent on other organisations. Understanding the propagation of disruptions and gaining insight into the operational performance of a supply chain system under the duress of an unexpected change can lead to a better understanding of supply chain disruptions and how to lessen their effects (Wu and Olson, 2009). According to Vilko et al. (2012) disruptions in supply chains are critical issues for many companies and complexity and disintegration are emerging as one of the major challenges to risk management in this context. For the risk management to work on a
proper level the actors in the supply chain need to collaborate and share information. Although many risks exist in business, some have applicability to the supply chain, namely transportation risks, operations risks, supplier related risks and market related risks. Transportation risks occur due to delay in transportation mode chosen. Diabat et al. (2012) have analyzed that operational risks, affect the firm’s internal ability to produce goods and services, ultimately affecting the profitability of the company and may result from a breakdown in manufacturing or processing capability and/or changes in technology. Chen et al. (2013) have described supplier related risks reside in the course of movement of materials from suppliers to the firm and include the reliability of suppliers, and considerations such as single versus multiple sourcing and centralised versus decentralised sourcing. Market related risks reside in the movement of goods from the firm to the customers, and include the risk of obsolescence, stock-outs, and over-inventory (Samvedi et al., 2013). Shimizu et al. (2013) have investigate the use customer claims to improve the organisational processes in supply chain risk management. Padmapriya and Kaur (2012) have done a simulation study on strategy to mitigate lead time uncertainty risk in the context of information sharing. Information sharing between supply chain members provides opportunities to reduce the inventory levels held to face such uncertainty thereby improving the performance of the supply chain. Sawik (2013) have described decision maker needs to select and protect suppliers against disruptions and to allocate order quantity among the selected suppliers and the inventory among the protected suppliers to minimise total cost of supplier protection, inventory holding, ordering, purchasing and shortage of parts and to mitigate the impact of disruption risks. A significant feature of the rapidly evolving business climate, spurred on by significant technology shifts, innovation, communication technologies and globalisation, is the increasing prevalence of risks in almost every aspect of our lives (Wu and Blackhurst, 2009). Risks occur because of uncertainty. Uncertainty creates a gap between what really happens and what a firm has planned for and consequently causes losses due to the sequence of failures and or causal events (Lewis, 2003). However, as risks have the potential for loss, organisations must assess the potential for such a sequence of failures. A crucial element of the risk management process is the identification and assessment of risks (Samvedi et al., 2013). This process involves understanding the conditions that give rise to potential problems and then assessing the likelihood and negative impact of such problems (Tapiero, 2007). In this chapter, four types of supply chain i.e.
traditional supply chain (TSC), agile supply chains (ASC), lean supply chain (LSC) and green supply chain (GSC) are used as alternatives. In a traditional supply chain, the flow of materials and information is linear and from one end to the other. There may be some focus on end-to-end supply chain costs but due to limitations of information sharing, the costs are far from optimized in most cases.

Agile supply chain is defined business-wide capability that embraces organizational structures, information systems, logistics processes and in particular, mindsets (Power et al., 2001). Agility is being defined as the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety (Christopher, 2000). Lean supply chain means developing a value stream to eliminate all waste, including time and to ensure a level schedule. Green supply chain management define a phenomenon where environmental innovations diffuse from a customer firm to a supplier firm, with environmental innovation defined as being either a product, process, technology or technique developed to reduce environmental impact (Hall, 2000). Risks like transportation risks, operational risks, supplier related risks and market related risks with their sub-criterias are used for the analysis.

In this chapter, ANP and MOORA techniques have been used to find out the best alternatives by analysing the weights of criteria and their sub-criteria. The main objectives of this chapter are as follows:

- To determine supply chain evaluation criteria
- To evaluate and rank the alternatives by using ANP and MOORA.

**7.2 ANALYTICAL NETWORK PROCESS (ANP) METHOD**

In this chapter, first an external environment analysis is performed by an expert team familiar with the supply chain of the organization. In this way, those risks sub-criteria which affect the success of the organizations but cannot be controlled by the organizations are identified. In addition, an internal analysis is performed to determine the sub-criteria which affect the success of the organizations but can be controlled by the organization. Based on these analyses, the strategically important sub-criteria, i.e. the sub-criteria which have very significant effects on the success of the organization, are determined. Using the risks sub-criteria, the risks matrix and alternatives based on these ANP network is developed (Figure 7.1). This chapter aims
of the risks analysis is to determine the priorities of the alternatives and to determine
the best supply chain, illustration of different steps of ANP are discussed below:

**Step 1:** The problem is converted into a network in order to transform the sub-criteria
and alternatives into a state in which they can be measured by the ANP technique.
The schematic structure established is shown in Figure 7.1. The aim of Low risk
rating supply chain is placed in the first level of the ANP model and the risk criteria
(transportation risks, operational risks, supplier related risks, market related risks) are
placed in the second level. The risks sub-criteria in the third level include four sub-
criteria for the transportation risks, operational risks, supplier related risks and market
related risks are considered. Four alternatives considered in this chapter placed in the
last level of the model are traditional supply chain, agile supply chain, lean supply
chain and green supply chain.

**Step 2:** Assuming that there is no dependence among the risks criteria, pairwise
comparison of the risks criteria using a 1–5 scale is made with respect to the goal. The
comparison results are shown in Table 7.1.
The pairwise comparison matrix, given in Table 7.1, analyzes using expert opinion,
and the following eigenvector is obtained. Keeping in view, the consistency ratio
(CR) is less than 0.10.

**Step 3:** Inner dependence among the risks criteria is determined by analysing the
impact of each factor on every other factor using pairwise comparisons. Based on the
inner dependencies, pairwise comparison matrices are formed for the criteria (Tables
7.2–7.5). The following question, ‘‘what is the relative importance of transportation
risks when compared with operational risks?’’ may arise in pairwise comparisons and
lead to a value of 2 (absolute importance) as denoted in Table 7.4. The resulting
eigenvectors are presented in the last column of Tables 7.2–7.5. Using the computed
relative importance weights, the inner dependence matrix of the risks criteria ($W_2$) is
formed.
Figure 7.1: ANP model
Table 7.1: Pairwise comparison of risks ($W_1$)

<table>
<thead>
<tr>
<th>Risks</th>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>MRR</th>
<th>Degree of risk criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>0.46</td>
</tr>
<tr>
<td>OR</td>
<td>0.33</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0.24</td>
</tr>
<tr>
<td>SRR</td>
<td>0.5</td>
<td>0.33</td>
<td>1</td>
<td>2</td>
<td>0.18</td>
</tr>
<tr>
<td>MRR</td>
<td>0.33</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Table 7.2: Inner dependence matrix of transportation risks

<table>
<thead>
<tr>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>MRR</th>
<th>Degree of TR criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>0.62</td>
</tr>
<tr>
<td>SRR</td>
<td>0.25</td>
<td>1</td>
<td>0.5</td>
<td>0.14</td>
</tr>
<tr>
<td>MRR</td>
<td>0.33</td>
<td>2</td>
<td>1</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Table 7.3: Inner dependence matrix of operational risks

<table>
<thead>
<tr>
<th>OR</th>
<th>TR</th>
<th>SRR</th>
<th>MRR</th>
<th>Degree of TR Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>1</td>
<td>0.25</td>
<td>0.5</td>
<td>0.16</td>
</tr>
<tr>
<td>SRR</td>
<td>4</td>
<td>1</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>MRR</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Table 7.4: Inner dependence matrix of market related risks

<table>
<thead>
<tr>
<th>MRR</th>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>Degree of MRR criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>1</td>
<td>2</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>OR</td>
<td>0.5</td>
<td>1</td>
<td>0.5</td>
<td>0.19</td>
</tr>
<tr>
<td>SRR</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Table 7.5: Inner dependence matrix of supplier related risks

<table>
<thead>
<tr>
<th></th>
<th>TR</th>
<th>OR</th>
<th>MRR</th>
<th>Degree of SRR criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0.57</td>
</tr>
<tr>
<td>OR</td>
<td>0.25</td>
<td>1</td>
<td>2</td>
<td>0.24</td>
</tr>
<tr>
<td>MRR</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Then

\[
\begin{pmatrix} TR & OR & SRR & MRR \\
TR & 1 & 0.16 & 0.57 & 0.24 \\
OR & 0.62 & 1 & 0.24 & 0.19 \\
SRR & 0.14 & 0.33 & 1 & 0.57 \\
MRR & 0.24 & 0.51 & 0.19 & 1 \\
\end{pmatrix}
\]

\[W_2 = \begin{pmatrix} TR & OR & SRR & MRR \\
TR & 0.170 & OR & 0.351 & SRR & 0.212 & MRR & 0.267 \\
\end{pmatrix}\]

**Step 4:** In this step, the interdependent priorities of the risks criteria are calculated as follows:

(W criteria = \(W_2 \times W_1\)) significant differences are observed in the results obtained for the criteria priorities (\(W_1\), Table 7.1) when the interdependent priorities of the risks criteria (\(w\) criteria) and dependencies are ignored. The results change from 0.46 to 0.17, 0.24 to 0.351, 0.18 to 0.212, and 0.12 to 0.267 for the priority values of criteria TR, OR, SRR and MRR, respectively.
Step 5: In this step, local priorities of the risk sub-criteria are calculated using the pairwise comparison matrix. In the same way the local priorities of $W_{sub-criteria}$ risks criteria are

\[
\begin{align*}
W_{sub-Criteria (TR)} &= PS 0.301 \\
&= HCT 0.311 \\ 
W_{sub-Criteria (OR)} &= PQ 0.336 \\
&= OR 0.137 \\
W_{sub-Criteria (SRR)} &= IF 0.072 \\
&= HDMS 0.273 \\
&= GOPF 0.347 \\
W_{sub-Criteria (MRR)} &= M 0.542 \\
&= PQ 0.212 \\
&= LS 0.136 \\
W_{sub-Criteria (LKP)} &= LKP 0.426 \\
&= HRR 0.101
\end{align*}
\]

Step 6: In this step, the overall priorities of the risks sub-criteria are calculated by multiplying the interdependent priorities of risks criteria found in Step 4 with the local priorities of risks sub-criteria obtained in step 5. The computations are provided in Table 7.6. The $W_{sub-criteria}$ (global) vector, obtained by using the overall priority values of the sub-criteria in the last column of table 7.6.

**Table 7.6: overall priorities of risks criteria**

<table>
<thead>
<tr>
<th>Risks criteria</th>
<th>Priorities of risks criteria</th>
<th>Risks sub-criteria</th>
<th>Priorities of sub-risks criteria</th>
<th>Overall priorities of sub-risks criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation risks (TR)</td>
<td>0.170</td>
<td>HCT</td>
<td>0.311</td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PS</td>
<td>0.301</td>
<td>0.051</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ps</td>
<td>0.108</td>
<td>0.018</td>
</tr>
</tbody>
</table>
### Operational risks (OR)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Importance</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMC</td>
<td>0.351</td>
<td>0.180</td>
</tr>
<tr>
<td>LKP</td>
<td>0.426</td>
<td>0.149</td>
</tr>
<tr>
<td>PQ</td>
<td>0.336</td>
<td>0.117</td>
</tr>
<tr>
<td>OE</td>
<td>0.137</td>
<td>0.048</td>
</tr>
<tr>
<td>HRR</td>
<td>0.101</td>
<td>0.035</td>
</tr>
</tbody>
</table>

### Supplier related risks (SRR)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Importance</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>0.0212</td>
<td>0.174</td>
</tr>
<tr>
<td>IF</td>
<td>0.072</td>
<td>0.015</td>
</tr>
<tr>
<td>M</td>
<td>0.542</td>
<td>0.114</td>
</tr>
<tr>
<td>PQ</td>
<td>0.212</td>
<td>0.044</td>
</tr>
</tbody>
</table>

### Market related risks (MRR)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Importance</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>NQS</td>
<td>0.267</td>
<td>0.244</td>
</tr>
<tr>
<td>HDMS</td>
<td>0.273</td>
<td>0.072</td>
</tr>
<tr>
<td>GIPF</td>
<td>0.347</td>
<td>0.092</td>
</tr>
<tr>
<td>LS</td>
<td>0.136</td>
<td>0.036</td>
</tr>
</tbody>
</table>

**Step 7:** In this step, the importance degrees of the alternative strategies with respect to each risks sub-criteria is calculated. Using Expert opinion, the eigenvectors are computed by analysing these matrices and $W_4$ matrix importance degrees of alternatives are:

Step 8: Finally, the overall priorities of the alternative strategies, reflecting the interrelationships within the risks criteria, are calculated as follows:

\[
\begin{align*}
W_{\text{sub-criteria (Global)}} &= \\
&= 0.052 \\
&= 0.051 \\
&= 0.018 \\
&= 0.030 \\
&= 0.149 \\
&= 0.117 \\
&= 0.048 \\
&= 0.035 \\
&= 0.036 \\
&= 0.015 \\
&= 0.114 \\
&= 0.044 \\
&= 0.065 \\
&= 0.072 \\
&= 0.092 \\
&= 0.036
\end{align*}
\]

This ANP analysis results indicate that ASC is the best supply chain with an overall priority value of 0.426.
7.3 MULTI-OBJECTIVES OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS (MOORA) METHOD

The applicability, accuracy and potentiality of the Multi-objectives optimization on the basis of ratio analysis (MOORA) method in decision making for analysing the risks in supply chain are illustrated as below:

This problem deals with the risks assessment in supply chain of ranking the most appropriate alternative. This risks assessment in supply chain consists of four alternatives and four performances criteria i.e. TR, OR, SRR, MRR as shown in Figure 7.1. Among these all of four criteria are beneficial criteria. The decision matrix for the risk assessment is shown in Table 7.7. The normalized decision matrix and \( W_{\text{criteria}} \) weights as \( W_{\text{TR}} = 0.170, W_{\text{OR}} = 0.351, W_{\text{SRR}} = 0.212 \) and \( W_{\text{MRR}} = 0.267 \) are obtain by using the ANP methodology. In this MOORA method same weights are used here for subsequent analysis. After this, normalized assessment values (\( y_i \)) of all the considered alternatives are computed using Equation (3), pp.53 as shown in Table 7.10.

Table 7.7: Normalization decision matrix found by ANP

<table>
<thead>
<tr>
<th>Alternatives/Risks</th>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSC</td>
<td>0.311</td>
<td>0.426</td>
<td>0.174</td>
<td>0.244</td>
</tr>
<tr>
<td>ASC</td>
<td>0.301</td>
<td>0.336</td>
<td>0.072</td>
<td>0.273</td>
</tr>
<tr>
<td>LSC</td>
<td>0.108</td>
<td>0.137</td>
<td>0.542</td>
<td>0.347</td>
</tr>
<tr>
<td>GSC</td>
<td>0.180</td>
<td>0.101</td>
<td>0.212</td>
<td>0.136</td>
</tr>
</tbody>
</table>

Table 7.8: Weight of criteria

<table>
<thead>
<tr>
<th>( W_{ji} )</th>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSC</td>
<td>0.311</td>
<td>0.426</td>
<td>0.174</td>
<td>0.244</td>
</tr>
<tr>
<td>ASC</td>
<td>0.301</td>
<td>0.336</td>
<td>0.072</td>
<td>0.273</td>
</tr>
<tr>
<td>LSC</td>
<td>0.108</td>
<td>0.137</td>
<td>0.542</td>
<td>0.347</td>
</tr>
<tr>
<td>GSC</td>
<td>0.180</td>
<td>0.101</td>
<td>0.212</td>
<td>0.136</td>
</tr>
</tbody>
</table>
### Table 7.9: Risk criteria

<table>
<thead>
<tr>
<th>Alternatives/Risks</th>
<th>TR</th>
<th>OR</th>
<th>SRR</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSC</td>
<td>0.052</td>
<td>0.149</td>
<td>0.036</td>
<td>0.065</td>
</tr>
<tr>
<td>ASC</td>
<td>0.051</td>
<td>0.118</td>
<td>0.152</td>
<td>0.072</td>
</tr>
<tr>
<td>LSC</td>
<td>0.018</td>
<td>0.048</td>
<td>0.114</td>
<td>0.092</td>
</tr>
<tr>
<td>GSC</td>
<td>0.030</td>
<td>0.035</td>
<td>0.044</td>
<td>0.036</td>
</tr>
</tbody>
</table>

All of the criteria are beneficial for risk reduction than $y_i$ is calculated by using Table 7.9.

### Table 7.10: Ranking of alternatives

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>$y_i$</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSC</td>
<td>0.302</td>
<td>2</td>
</tr>
<tr>
<td>ASC</td>
<td>0.393</td>
<td>1</td>
</tr>
<tr>
<td>LSC</td>
<td>0.272</td>
<td>3</td>
</tr>
<tr>
<td>GSC</td>
<td>0.145</td>
<td>4</td>
</tr>
</tbody>
</table>

This MOORA method based analysis gives a comparative ranking of 2–1–3–4 when arranged according to the descending order of their assessment values (ASC > TSC > LSC > GSC). For this problem, agile supply chain is the best choice among the considered alternatives and the worst choice is green supply chain.

### 7.4 Comparing Results with ANP, AHP and MOORA Methods

In ANP analysis, alternatives are ordered as ASC > LSC > TSC > GSC. The same example is analysed with the hierarchical model given in Figure 7.1 by assuming there is no dependence among the criteria. The overall priorities computed for the alternatives are presented in Figure 7.3. The same pairwise comparison matrices are used to compute the AHP priority values. In the AHP analysis, ASC is found to be the best alternative, with an overall priority value of 0.408. However, the priority ordering of the alternatives changed to ASC > LSC > GSC > TSC. When dependence among criteria is taken into account both the priorities and ranking order of the alternatives changes. According to MOORA methodology the ranking of alternatives are ASC >
TSC > LSC > GSC. In overall results, it is found that agile supply chain is the best supply chain by using different methodologies. The results obtained from the ANP, AHP and MOORA analyses are comparatively listed in Figure 7.2 and ranking of alternatives by using ANP, AHP and MOORA are listed in Figure 7.3.

**Figure 7.2: Comparison of results by using ANP, AHP and MOORA**

**Figure 7.3: Comparison of alternatives ranking by using ANP, AHP and MOORA**
7.5 CONCLUSION

In this chapter, alternatives are selected through the light of transportation risks, operations risks, supplier related risks and market related risks. Decision makers for the risks assessment in supply chain involve the complex evaluation process due to imprecise information. The complexity further increase as the number of alternatives and their selection criteria increases. In this regards, multi criteria decision making (MCDM) approaches are recommended for risk assessment in supply chain for the selection of best alternative from a number of alternatives. In this regards same problem is illustrated and compared by three methods ie ANP, AHP and MOORA. In which the ranking of agile supply chain is found to be the best alternative by all three methods and green supply chain is found to be the worst alternative by using ANP and MOORA but in AHP traditional supply chain is the worst one. Overall ranking of alternatives are compared shown in Figure 7.3. The some disparities among the ranking of alternatives may be due to the diverse opinion given by the decision makers. And the weights of risks criteria differ according to the methods due to the dependency or independency of risks criteria. Besides a large number of calculations these methods are very simple and easily comprehensible which can handle a large number of selection criteria. The results obtain from this chapter can help in making strategic and tactical decisions for a firm to tackle the risks in SCM.