11.1 INTRODUCTION

To fulfill the customer’s need and demand, to face global competition and challenges, industries need to focus on uncertainty and risk issues in their supply chains. Although various issues related to uncertainty and risk are extensively explored during the past decades by researchers but their capabilities are not fully utilized. This is due to the wide gap existing between the theoretical research and practical expectations of manufacturing industries. Low awareness regarding uncertainty and risk in supply chain in Indian manufacturing industries has motivated the researchers to pursue research by exploring and analyzing the uncertainty and risk issues in supply chain.

11.2 SUMMARY OF THE RESEARCH WORK

The present research has developed and justified the uncertainty and risk issues in supply chain. In this section, the summary of research work is presented. The main work undertaken in this research includes the following:

- Exhaustive literature review was conducted to identify some relevant issues in the field of uncertainty and risk measures in supply chain.
- On the basis of literature review and discussion with industrial personnel and academicians, a questionnaire was designed to obtain response from supply chain experts. The responses to the questionnaire based survey helped to understand the impact of each risk in supply chain.
- Different uncertainty and risk issues in supply chain which have been considered in questionnaire includes plan and control risks, supply risks, process risk, demand risks natural and social risks, transportation risks, market-related risks, supplier-related risks, financial risks, operations risks,
performance measurement risks and other issues are performance management, agile supply chain, green supply chain, lean supply chain etc.

- The responses were analysed and some important risk issues were studied based on survey responses. The priority of the industries focus on supply risks, process risks, natural and social risks, transportation risks, financial risk and demand risks etc.
- The W-ISM (ISM models, MICMAC analysis and effectiveness index) methods have been used for operational risks and for uncertainty and risk measures to find out the driving and dependence power of the factors. The developed ISM models also help in understanding the mutual relationship of factors affecting the uncertainty and risk in supply chain.
- ANP and MOORA methods have been used to find out the best supply chain by analysing the different risk issues.
- The GTA based approach has been used to quantify the role of risks in supply chain.
- Risk mitigation techniques have been suggested to improve the supply chain performance.

11.3 MAJOR CONTRIBUTIONS OF THE RESEARCH

The major contributions made through this research are as follows:

- This present research provides a comprehensive review of literature and identifies contemporary issues of uncertainty and risk related to supply chains in Indian manufacturing industries.
- Various obstacles in uncertainty and risk management in supply chain have been identified.
- The present trends and barriers in risk reduction in SCs have been reviewed.
- Inclination of Indian manufacturing industries towards the importance of risks has been found out.
- The issues related to uncertainty and risk measures in supply chain are identified and their drive and dependence power have been found out and most significant uncertainty and risk measures have been extracted.
• The operational risk issues in supply chain are identified and their drive and
dependence power have been analysed and most significant operational risk
measures have been selected.
• Different types of uncertainty and risk issues in different types of supply
chains are analysed. And among all of these supply chains, the best supply
chain is found out which has minimum risk.
• Risk measurement index (RMI) has been found out to quantity the uncertainty
and risk related to supply chain.
• Risk mitigations and their contingency actions in supply chain have been
proposed.

11.4 KEY FINDINGS OF THE RESEARCH

The key findings emerge from this research are as follows

• Most of the Indian manufacturing industries are really wants to mitigate the
uncertainty and risk in supply chain.
• Supply risk and process risk are considered as the most important risk in
supply chain which are followed by natural and social risk, transportation risk
etc.
• Theft of information, logistic route/mode disruption, IT system failure are
treated as the ‘key risk factors’ for affecting the operation in SC.
• Standardization, improper man-machine management, risk of getting the
appropriate quality material, functional development risks, residual
performance risks’ are treated as the root causes of all the uncertainty and risk
measures. These measures may be treated as the ‘key uncertainty and risk
measures’ for affecting the supply chain operation.
• Poor quality, utility failure and loss of key personnells are weak drivers but
strongly depend on one another.
• HR problems’ is a linkage factors. It has strong driving power as well as high
dependencies. This factor can create positive environment dealing with the
operations risk in supply chain.
• In uncertainty and risk measures product performance, process performance, requirement uncertainty and validation of products are weak drivers but strongly depend on one another.

• System development risks’ is a linkage measures. It has strong driving power as well as high dependencies. This measure can create positive environment dealing with the uncertainty and risk measures in supply chain.

• Based on response from questionnaire survey on various risk factors, effectiveness index for the operation risks in supply chain has been evaluated which has been found 5.179 and maximum value can reach up to 6.559. From this index, it has been observed that organizations are doing well in the term of quality, HR, IT, key equipments and key personnel, however there is need for improvement in area of key suppliers, theft of information, logistics route and computer related problems for dealing well with the operation risks.

• Based on response from questionnaire survey on various uncertainty and risk measures, effectiveness index for the uncertainty and risks in supply chain has been evaluated which has been found to be 4.85 and maximum value can reach up to 6.52. From this index, it has been observed that organizations are doing quite well in terms of product performance, standardization, process performance, requirement uncertainty, improper man-machine management, risk of getting the appropriate quality material, however there is need for improvement in area of validation of products, system development risks, functional development risks, residual performance risks for dealing well with the uncertainty and risk measures in supply chains.

• Agile supply chain has been found best supply chain through ANP analysis.

• A risk measurement index (RMI) has been proposed through GTA based framework. By evaluating RMI value for different organizations, their fitness for transitions towards risks can be compared.

• Other most important findings of this research are to suggest the risk mitigation techniques.
11.5 IMPLICATIONS OF THE RESEARCH

The present research implications are useful for industries, academicians and for managers. In this research different type of tool and techniques are suggested, to deal with the different types of uncertainty and risk measures which can improve the supply chain performance. The questionnaire presented in this research can be used as instruments to carry out further research in the domain of risk measurement in supply chain. The developed ISM, GTA and ANP models help to impose order and direction on the complexity and relationship in different risk factors. The index calculations may direct the academicians and managers to develop the similar indices for different risks. Managers can develop some insights from this present research. The risk mitigation techniques and their managements are highly desirable and managers can fetch the maximum benefit from this research to improve the supply chain performance. The framework presented in this research can direct the managers to take the necessary actions in their firms for addressing the highly influence risk factors. Firm managers can adopt the best supply chain by analysing the different risk issues.

11.6 LIMITATIONS AND SCOPE FOR FUTURE WORK

This research has provided some sustainable insights into the issues of uncertainty and risk management in supply chains. Though a lot of efforts have been put in this research work to analyze the impact of different risks and uncertainty in SCM yet this research is not free from limitations. The one of the major limitation is that all issues related to uncertainty and risk management were not considered in the present research, only some selected issues of uncertainty and risk management in supply chains were identified for analysis. Expert opinions required to develop the contextual relationships for ISM model and for inner dependence matrix in ANP may be biased. While this research was conducted specifically for Indian manufacturing industries, the research outcomes may differ slightly in industries in other countries depending upon their geographical locations. However, some more work can be done in future and the present research can be extended to following directions:

- The ISM based models developed in this research work can be validated by using structural equation modelling (SEM) which has the capability to validate such ISM based models.
• More number of uncertainty and risk issues which affect the supply chains can be identified to develop W-ISM, ANP, MOORA and GTA based models.

• The ANP method presented in this research is based upon getting the inputs for ANP matrices. This can be improved by plugging in a module to compute the probability based on collected historical data.

• While using graph theory and matrix method, the interactions among the sources can be analysed and they can even be transformed into mathematical equations.

• Some other issues related human resource and flexibility can be analysed in different type of supply chains.

• Some other type of supply chains like sustainable supply chain, low carbon supply chain, ethical supply chain, responsible supply chain etc. can be considered for the analysis.

• Weighted interpretive structural modelling (W-ISM) techniques can be further extended to fuzzy weighted interpretive structural modelling (F-WISM) and total interpretive structural modelling (T-ISM) techniques.

• Present work can be further compared by using some other techniques like genetic algorithm (GA), simple additive weighting (SAW) method, weighted product method (WPM) etc.

• Case study regarding different issues in supply chain for a specific industry can be done.

11.7 CONCLUSION

The present research was started with the objectives to study and analyze the uncertainty and risk issues in supply chains and develop some related frameworks. In this research work, issues related to uncertainty and risk in different supply chains have been addressed. Questionnaire has been developed and survey of Indian manufacturing industries has been done to understand the importance of uncertainty and risks in supply chains. Regarding this, framework based on W-ISM techniques of operational risks and uncertainty and risks in supply chains has been developed. In which theft of information, logistic route/mode disruption, IT system failure, standardization, improper man-machine management, risk of getting the appropriate
quality material, functional development risks and residual performance risks have strong driving power. These risk factors may be treated as the root causes of all the factors for affecting the supply chain operations. And on the basis of effectiveness index it has been observed that there is need of improvement in the terms of key suppliers, logistics route, computer related problems, validation of products, system development risks, functional development risks and residual performance risks.

In next, an ANP based framework has been developed to find the best supply chain by analyzing the process risks, demand risks, plan and control risks and natural and social risks and further an ANP and MOORA based framework has been developed to find the best supply chain by analyzing the transportation risks, operational risks, market related risks, supplier related risks in which agile supply chain is found to be the best among traditional, agile, lean and green supply chains. A GTA based framework has been developed for the quantification of uncertainty and risks in supply chain and risk measurement index has been calculated. In this, GTA based analysis supply risk is found to be the most important risk in supply chains which are being followed by process risk, transportation risk, natural and social risk, demand risk and financial risk. By using risk measurement index, firms can compare their supply chains. Some of the risks mitigation techniques have been suggested for mitigating the effect of uncertainty and risk in supply chains. These proposed risks mitigation techniques will helps academicians and industries to deal with different types of uncertainty and risks issues in supply chains.