STUDY OF SELECT ISSUES OF UNCERTAINTY AND RISK MANAGEMENT IN SUPPLY CHAIN

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CANDIDATE'S DECLARATION

I, hereby, declare that this thesis entitled **STUDY OF SELECT ISSUES OF UNCERTAINTY AND RISK MANAGEMENT IN SUPPLY CHAIN** by **Mahesh Chand**, being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in DEPARTMENT OF MECHANICAL ENGINEERING under Faculty of Engineering & Technology of YMCA University of Science & Technology Faridabad, during the academic year 2014-2015, is a bonafide record of my original work carried out under guidance and supervision of **Dr. TILAK RAJ, PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, YMCAUST, FARIDABAD** and **Dr. RAVI SHANKAR, PROFESSOR, DEPARTMENT OF MANAGEMENT STUDIES, IIT, DELHI** and has not been presented elsewhere.

I, further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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We, further declare that to the best of our knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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ABSTRACT

Supply chain management (SCM) come into existence in late 80's. SCM is one of the most important components of an organization supporting its production system. So, there is a need of proper understanding and effective management of supply chain. For an effective control of supply chain, there is an urgent need to understand and handle different issue related to it. Regarding this, uncertainty and risks in supply chain has been an area of high importance.

In this research work, different types of uncertainty and risk issues in supply chains have been enlisted and analyzed. For this purpose, a literature review has been conducted to understand the importance and impact of uncertainty and risks in supply chains. Different issues related to uncertainty and risks with their factors, barriers, success factors and type of supply chains have been identified through literature review. Weighted Interpretive structural modeling (W-ISM) technique has been used to identify the relationship and dependence among the risks in supply chains. Analytical network process (ANP) and multi objectives optimization by ratio analysis (MOORA) techniques has been utilized to find out the best supply chain. Graph theoretic approach (GTA) has been used to find out the important risks and risk measurement index (RMI) of uncertainty and risks in supply chains.

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.
- 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.
- Agile supply chain has been identified as the best SC.

- Risk measurement index (RMI) has been found out to quantity the uncertainty and risks related to supply chain.
- Risk mitigations and their contingency actions in supply chain have been proposed.

Keywords: Supply Chain Management (SCM), Uncertainty and Risks, Weighted Interpretive Structural Modeling (W-ISM) Technique, Analytical Network Process (ANP), Multi Objectives Optimization by Ratio Analysis (MOORA) Techniques, Graph Theoretic Approach (GTA).

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SR. NO	TITLE	ABBREVIATIONS
1.	**Supply Chain Management**	**SCM**
2.	**Supply Chains**	**SCs**
3.	**Supply Chain Risk Management**	**SCRM**
4.	**Weighted Interpretive Structural Modelling Technique**	**W-ISM**
5.	**Effectiveness Index**	**EI**
6.	**Multi Criteria Decision Making Approaches**	**MCDM**
7.	**Analytical Network Process**	**ANP**
8.	**Analytical Hierarchy Process**	**AHP**
9.	**Technique For Order Preference By Similarity of Ideal Solutions**	**TOPSIS**
10.	**Weighted Sum Method**	**WSM**
11.	**Multi-Objective Optimization By Ratio Analysis**	**MOORA**
12.	**Graph Theoretical Approach**	**GTA**
13.	**Traditional Supply Chain**	**TSC**
14.	**Agile supply chain**	**ASC**
15.	**Green Supply Chain**	**GSC**
16.	**Lean Supply Chain**	**LSC**
17.	**Information Technology**	**IT**
18.	**Sustainable Supply Chain Management**	**SSCM**
19.	**Just in Time**	**JIT**
20.	**Council of Supply Chain Management Professionals**	**CSCMP**
21.	**Human Resource**	**HR**
22.	**Supply Chain Planning and Coordination**	**SCPC**
23.	**Master Production Schedule**	**MPS**
24.	**Rough Cut Capacity Planning**	**RCCP**
25.	**Material Requirements Planning**	**MRP-I**
26.	**Capacity Requirements Planning**	**CRP**
27.	**Concept of Collaborative Planning, Forecast and Replenishment**	**CPFR**

28.	**Demand Uncertainty**	**DU**
29.	**Total Quality Management**	**TQM**
30.	**Structural Self-Interaction Matrix**	**SSIM**
31.	**Reachability Matrix**	**RM**
32.	**Interpretive Structural Modeling**	**ISM**
33.	**Disruptions**	**DR**
34.	**Deviation**	**DV**
35.	**Disaster**	**DS**
36.	**Plan and Control Risks**	**PCR**
37.	**Process Risks**	**PR**
38.	**Natural and Social Risks**	**NSR**
39.	**Demand Risks**	**DR**
40.	**IT Planning and Control**	**ITPC**
41.	**Material Planning and Control**	**MPC**
42.	**Production Planning and Control**	**PPC**
43.	**Sales Marketing Plan and Control**	**SMPC**
44.	**Reduced Lead Time**	**RLT**
45.	**Machine Damage**	**MD**
46.	**Human Error**	**HE**
47.	**Capacity Bottleneck**	**CB**
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49.	**Change in Preference**	**CP**
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51.	**Short Life Cycles**	**SLC**
52.	**Natural Disasters**	**ND**
53.	**Political Instability**	**PI**
54.	**Crime Rate**	**CR**
55.	**High Carbon Footprint**	**HCF**
56.	**Supply Chain Planning and Control Overall Risk Weighted Index**	**SCPCORWI**
57.	**Consistency Ratio**	**CR**
58.	**Transportation Risks**	**TR**
59.	**Operational Risks**	**OR**

60.	**Supplier Related Risks**	**SRR**
61.	**Market Related Risks**	**MRR**
62.	**High Cost of Transportation**	**HCT**
63.	**Port Strike**	**PS**
64.	**Poor Schedule**	**ps**
65.	**Transportation Mode Chosen**	**TMC**
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70.	**Delivery Mistakes**	**DM**
71.	**In-Flexibility**	**IF**
72.	**Mix**	**M**
73.	**Product Quality**	**PQ**
74.	**No. of Quantified Suppliers**	**NQS**
75.	**High Degree of Market Saturation**	**HDMS**
76.	**General Increase in Price Fluctuation**	**GIPF**
77.	**Level of Supplier**	**LS**
78.	**Risk Measurement Index**	**RMI**
79.	**Economic Recession**	**ER**
80.	**Fuel Prices**	**FP**
81.	**Financial Market Instability**	**FMS**

CHAPTER I
INTRODUCTION

1.1 INTRODUCTION

Supply chain management (SCM) is the most important part of production system. There has been a growing interest in supply chain management (SCM) since late 80's. SCM has picked up consideration as it spotlights on material, data and money streams from sellers to clients or the other way around. A key element of present day business is the real trick that it is supply chains (SCs) that contend, not organizations (Christopher and Towill, 2001) and the achievement or disappointment of supply chains is at last decided in the commercial center by the end purchaser. Getting the right item, at the perfect time to the purchaser is the linchpin to aggressive accomplishment, as well as the way to survival (Agarwal et al., 2005). SCM takes care of this important objective of the companies for better customer satisfaction and it searches for the joining of a plant with its suppliers and its clients to be overseen right now and the co-appointment of all the info/yield streams (materials, data and funds) so items are created and disseminated at the right amounts, to the right areas, and at the perfect time (Simchi-Levi et al., 2008). Many definitions of SCM have been published in different articles and books; however, these can be explained with three perspectives: activity-based perspective, benefit-based perspective, and component-based perspective. Stadtler (2008) defines SCM as the demonstration of sharing material, information and monetary information inside authoritative units, to satisfy client needs and right now, improve the execution of whole store network included. SCM has turn into a vital center of upper hand for association business on the grounds that the chance of a coordinated administration of SC can decrease the proliferation of surprising/undesirable occasions through the system and can influence definitively the gainfulness of the considerable number of individuals (Guillena et al., 2005). The principle reason of SCM is to give a key weapon to develop and improve practical upper hand by expense lessening without trading off consumer loyalty (Mentzer et al. 2001). Since these SCs involve manufacturers, distributors, retailers, as well as consumers, which are spatially dispersed and hence, they are characterized by heightened risks and uncertainty (Nagurney and Toyasaki, 2005). For the success of supply chains, it is very much important to study and analyze the risks associated with them. To have the capacity to examine the risk of SCs, it is important to audit quickly the meaning of risk. Word references have characterized risk as a probability of misfortunes or unsafe outcomes. This sound judgment definition uncovers the two key segments of risks: misfortunes and vulnerability about their event and sum (Hallikas et al., 2004). Numerous different meanings of risk exist in the writing. Sitkin and Pablo (1992) have characterized risk as the degree to which there is instability about whether possibly critical and disillusioning results of choices will be figured it out. Zsidisin et al. (2004) characterized supply risk as the transpiration of critical and/or frustrating disappointments with inbound merchandise and administrations. Supply chain risk is characterized right now that antagonistically influences supply chain operations and henceforth its fancied execution measures like expense, extensive administration levels and responsiveness (Tummala and Schoenherr, 2011). In short, it can be said that risks of the companies are related to their objectives e.g. profitability, future growth, better position in the market, customer satisfaction, better competitive edge and capability to handle corporate social responsibility etc. However, management of profitability is usually needed to survive and to achieve other possible objectives. Therefore, for achieving good profitability, SCs must respond to the realities of world events, which, in the given age, are characterized by heightened risks and uncertainty. The risks initiate from uncertainty. Hallikas et al. (2004) have emphasised that the main uncertainties for companies come from two sources: customer demand and customer deliveries. The demand of the end customer does not guarantee the business for a supplier. Delivery uncertainties are connected to the ability to manage the costs, time and quality as well as the responsibilities for confidential information. They have further, reported that an additional uncertainty is the future requirements; how the current orientation, knowledge and resources should be maintained and modified to succeed in the future objectives.

Therefore, risk management is the most important part of supply chain and for this purpose, it is very much necessary to identify and classify different types of risks associated with SCs. The literature on supply chains reveals different types of risks and their classifications. Tummala and Schoendherr (2011) have reported some types of risks related to SCs such as demand risks, delay risks, disruption risks, inventory risks, manufacturing (process) breakdown risks, physical plant (capacity) risks, supply (procurement) risks, system risks, sovereign risks and transportation risks. Kleindorfer and Saad (2009) categorized these risks into two groups i.e those arising from coordinating complex systems of supply and demand and those arising from disruptions to normal activities.

For the management of these uncertainty and risks, already some approaches and models are available in the literature. But, these techniques are too complex to be used in real industrial environment. Therefore, for the purpose of avoiding costly mistakes and realizing the objectives and optimal productivity of supply chains, there is a strong and justifiable need for extensive analysis of risks and elaborate design of these SCs before their trouble free implementation. This research is aimed at examining different types of risks and uncertainties associated with SCs and suggesting some proper mitigation techniques for getting fruitful results through SCs.

1.2 NEED AND BENEFITS OF SCM

There are certain objectives to be achieved through SCM. Improving customer satisfaction, service and competitiveness are a number of these objectives. Supply chain management also aims to lower the costs and resources involved in the creation of products as well as improve efficiency and effectiveness. SCM also focuses on reducing inventory levels and respective costs, increasing profits and improving cooperation. Supply chain management has been becoming increasingly important in competitive business.

To compete at the supply chain level, firms must adopt an appropriate supply chain management strategy. Mason-Jones et al. (2000) have suggested that supply chains need to adopt a strategy that suits both their particular product and marketplace. Fisher (1997) have suggested that the first step in developing the supply chain strategy is to consider the nature of the demand for an organization's product, proposing that these are either functional or innovative.

Fawcett et al. (2008) reviewed key benefits of SCM proposed in literature and noted the following in the order of their importance:

- Increased inventory turnover
- Increased revenues
- Cost reduction in SCM
- Product availability
- Decreased order cycle time
- Responsiveness

- Economic value addition
- Proper capital utilization
- Decreased time to market and
- Reduced logistics costs.

No doubt, SCs offer many benefits as listed above, but their proper implementation and maintenance is not hassle free.

1.3 UNCERTAINTY AND RISK MANAGEMENT IN SC

There are numerous meanings of Uncertainty and risk in the field of SCM. Uncertainty is one fundamental normal for the SC arranging issue. This Uncertainty may influence the assumptions about the crude materials supply and/or the business sector conduct (interest, costs, conveyance prerequisites, and so on.), and other inner components (i.e. working parameters like lead times, transport times, and so forth., or the accessibility of generation assets). A risk is breakdown of streams between diverse individuals from the supply chain. This variability can possibly influence the stream of information, materials and/or items, and it may adjust the utilization of human and gear assets.

Risk is characterized presently or baffling aftereffects of actualized choices (Sitkin and Pablo, 1992). Supply chain risk is characterized right now that unfavorably influences supply chain operations and thus its fancied execution measures like expense, extensive administration levels and responsiveness (Tummala and Schoenherr, 2011). Despite the fact that outcomes are normally negative, they can possibly create positive results if proper risk-taking is performed (Ritchie and Brindley, 2007). Sitkin and Pablo (1992) have characterized risks as the degree to which there is instability about whether possibly noteworthy and/or frustrating results of choices will be figured it out. Zsidisin et al. (2000) have characterized supply risks as the transpiration of critical and/or baffling disappointments with inbound products and administrations. Zsidisin et al. (2004) have characterized supply risks as the likelihood of an occurrence connected with inbound supply from an individual supplier disappointment or the supply market happening, in which its results bring about the powerlessness of the buying firm to take care of client demand or reasons dangers to client life and security. On the off chance that risk is excessively solid, then it is no more a risk yet an occasion sure to happen. On the off chance that the likelihood is too low, there is liable to be an unlikely and unwarranted apprehension that supervisors won't look to deal with the circumstance. This conveys to the bleeding edge the need to fittingly survey risk and create procedures to oversee it.

Recently, many manufacturing companies have introduced supply chain management (SCM) strategies for the reduction of time and cost but to increase the benefits. If hazardous events such as fires and earthquakes occur, their effects could propagate quickly through the supply chain because of low inventory and short lead time, and cause enormous losses. Furthermore, recent supply chains entail greater risks due to the advances in globalization. Moreover, the introduction of new technologies also results in new risks such as information and communication technology risks.

To cope with such problems, manufacturing companies should consider supply chain risk management (SCRM), which evaluates the probabilities and magnitudes of losses caused by hazardous events and implements the necessary countermeasures. The importance of SCRM gained recognition in the late 90's owing to the occurrences of supply chain risk events. The issue has been discussed from various researchers such as risk identification and modeling, impact assessments of various types of risks, evaluation of vulnerability of supply chain network, countermeasures to mitigate risks, and the simulation technologies for evaluation of supply chain risk.

The literature on supply chain risks suggests a number of different risk identification and classifications. Tummala and Schoendherr (2011) have cited the as supply chain risks as demand risks, delay risks, disruption risks, inventory risks, manufacturing (process) breakdown risks, physical plant (capacity) risks, supply (procurement) risks, system risks, sovereign risks, and transportation risks. Kleindorfer and Saad (2009) categorized these risks into two groups, those arising from coordinating complex systems of supply and demand and those arising from disruptions to normal activities. Chopra and Sodhi (2004) have identified nine risk categories such as disruptions risk, delays risk, systems risk, forecast risk, intellectual property risk, procurement risk, receivables risk, inventory risk and capacity risk.

Many researchers have attempted to find risk mitigating strategies in SCRM. This has resulted in to several different models, however, a four-step system seems common as a means to manage risk. These four steps are identifying risks, assess risks, implement solutions and control risks. According to Harland et al. (2003), attitude toward risk depends on trade-offs made by organizations; what is deemed as an acceptable level of risk, the size of the benefit and the attitude of the organization concerning risk taking. Some organizations and individuals are highly risk-averse, others are risk-takers. Attitude toward risk is influenced by the nature of the business but also by individual style, behavior and it changes with experience and maturity. An individual, organization or sector accustomed to taking risks may change their attitude after experiencing heavy losses. Harland et al. (2003) describe six steps to manage risk in a logistics network, which are as follows:

Step 1: Design supply chain network

Step 2: Identify risk elements and their location

Step 3: Assess risks occurrence, stage and losses

Step 4: Proper management of risks

Step 5: Shared supply network strategy and

Step 6: Execute shared supply network strategy.

1.4 MOTIVATION OF RESEARCH

The purpose of this research is to investigate the research development in supply chain risk management (SCRM), which has shown an increasing global attention in the past. In today's volatile era with businesses more specifically, supply chains becoming increasingly global, the industrial environment is heavily affected by uncertainty and risk, which can potentially turn into unexpected disruptions. Financial and political turmoil, socio-cultural changes, highly fragmented and demanding behaviour of consumers, rapid development and changeover of products, have seriously modified the economic and industrial environment in which companies act, bringing out new issues related to continuity of the business against potential disruptive events.

Moreover, one of the key factors contributing to disrupting supply chains is the focus on lean supply chains in academia and industry. Zero-inventory and just-in-time movement of goods became the dominant model that increased the sensitivity of supply chains. Little issues quickly become big issues. Outsourcing has also become the dominant model, increasing the forces driving disruptions such as other customers competing for volume and attention, information flow issues, mistrust, win-lose negotiations, financial stress, misalignment of interests and goals. These have increased the likelihood of a disruption exponentially.

As a common term to designate the likelihood of occurrence of such events the word risk is used although the concept of risk is multi-dimensional and not univocally defined, it is generally established the fact that it is linked to uncertainties associated with events.

Amid the most recent events, a few occasions (i.e. seismic tremor in Kobe in 1995, terrorist assault to World Trade Center in (2001) have essentially disturbed supply chains and created significant misfortunes for the organizations included (Tang, 2006). Organizations, for example, Ericcson, Hershey, Apple, Walmart and a large group of other real organizations who depend on convenient conveyance of items and administrations to address client issues have caused significant misfortunes because of supply chain disruptions. Traded on an open market firms encountering supply chain disruptions, for instance, have reported negative stock exchange responses to declarations of such troublesome occasions, with the greatness of the decrease in business promotion being as substantial as 10% (Knight and Pretty, 1996; Hendricks and Singhal, 2005). Ericsson reported a $400 million misfortune on the grounds that it didn't get chip deliveries from the Philips plant in a convenient way (Latour, 2001). Despite the fact that the genuine expenses of any supply chain disruption can be hard to measure correctly, no less than one firm studied by Rice and Caniato (2003) evaluated that the day by day expense effect of a disruption in its supply system to be in the area of $50-$ 100 million. In the view of above, it is clear that management of SC has become sensitive issues because a small disturbance can cause heavy loss to a company. That has motivated to focus the present research in identification of different types of uncertainty and risks associated with SCM and to suggest some effective risk mitigation techniques which are useful for industries.

1.5 GAPS IN LITERATURE

This review has piloted to identify and classify the uncertainty and risk associated with different flows, namely material, cash and information flows. Consequently, some research gaps regarding uncertainty and risk management in supply chain have been identified and there is an urgent need to study the supply chain risk management (SCRM) from industrial aspect. A review of literature brings out the following gaps in the context of uncertainty and risk management in supply chain.

- Low awareness regarding uncertainty and risk in supply chain in Indian manufacturing industries has motivated the researchers to pursue research in exploring and analysing the uncertainty and risk issues in supply chain.
- Quantitative models in the field of uncertainty and risk management are relatively lacking and information flow in risk has received less attention.
- It is also interesting to observe the evolutions and advancements of supply chain risk management (SCRM) discipline. Although various issues related to uncertainty and risk have been 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 Indian manufacturing industries.
- In the literature, the quantitative analysis of uncertainty and risk issues has not been upto the mark.
- In the literature, the uncertainty and risk issues have not been considered for selecting the best SC.
- Not much attention has been paid regarding the issues of disruptions, deviations and disasters affecting the SCs.
- A large number of articles have been presented regarding the uncertainty and risk issues and their management in supply chain. But techniques used by researches for developing the risk mitigation models are too complex to be used in real industrial environment. Therefore, there is an urgent need of some simple techniques which can be easily used by industries for overcoming these uncertain and risky natures of supply chains.

Keeping in view the above identified gaps in SCM, an attempt has been made through this research to analyse the uncertainty and risk associated with SC both qualitatively and quantitatively.

1.6 RESEARCH OBJECTIVES

The main objective of this research is to study and analyse the uncertainty and risk measures in supply chain, thus making a contribution to the state of supply chain risk knowledge. Supply chains are being used by many industries in present scenario but to extract the maximum benefits from the SCs, it is very much essential to minimize the uncertainty and risk associated with them. Keeping in view the above fact in mind the present research work has been taken up. The main objectives of the research work are as follows:

- To identify the important risks associated with SCM through literature survey.
- To understand the research trend both from industrial and academic perspectives
- To identify the possible research gaps and opportunities in supply chain area.
- To identify the uncertainty and risk measures in supply chain and to develope a structural relationship among different risk factors.
- To identify the operational risks and to develope a structural relationship among them.
- To determine the evaluation criteria and ranking of different supply chain alternatives.
- To quantify the major risk factors in supply chain.
- To propose some important mitigation and different contingency actions.

1.7 RESEARCH METHODOLOGY

In achieving the above mention objectives, different methodologies used in the present research are as follows:

1.7.1 Questionnaire Based Survey

After identification of evaluation criteria with the help of expert committee, a questionnaire was designed on a 5-point Likart scale. It contained risks issues regarding the implementation and maintenances in SCs. Risks criteria were selected through literature survey and discussed with experts. The respondents were asked to indicate the level of difficulty in managing these risks criteria in supply chain, on the Likart scale from 1 to 5, in this scale, 1 stand for not much important and 5 stand for very important. The self-contact, e-mail and postal survey methods were used for the administration of survey. Survey was conducted in Indian manufacturing industries. The chief-executives/managing directors/general managers/works managers/senior executives were contacted for getting their response. Some questionnaires were e-mailed to Indian manufacturing industries, along with a covering letter, self-addressed and with a stamped envelope. In total, questionnaires were sent to 430 Indian manufacturing industries.

Out of 430 questionnaires, 87 filled up and complete questionnaires were received. Seven questionnaires were incompletely filled and were discarded for further analysis. This gives a response rate of 20.23% which is not very low for such surveys (Malhotra and Grover, 1998). In most of the cases, the addressee filled the questionnaire on their own but in some cases; some senior executives of the companies also filled the questionnaires on behalf of addressee.

1.7.2 Weighted Interpretive Structural Modelling Technique (W-ISM)

Weighted interpretive structural modelling technique is basically the combination of interpretive structural modelling (ISM) technique and effectiveness index (EI) method. ISM is one of the intelligent administration strategies which help exploration bunches in managing complex issues (Warnfield, 1974; 1987). ISM changes hazy, inadequately explained mental models of a framework into noticeable all around characterized, hierarchal models. It is a no doubt understood strategy for distinguishing and compressing connections among particular elements which characterize an issue or an issue and by which request can be forced on the multifaceted nature of such elements (Mandal and Deshmukh, 1994). Along these lines an arrangement of distinctive and straightforwardly related elements are organized into an exhaustive methodical model. ISM is basically expected presently learning procedure, however people might likewise apply it (Ravi and Shankar, 2005; Faisal et al., 2007; Panahifar et al., 2014). For computing the effectiveness index, the mean score of elements is calculated and rank is decided for each elements. After the rank calculation, inverse rank and weights for each element is to found out. For assigning weights to different elements, the highest and lowest values of five point Likert scale i.e. 5 and 1 are mapped as 100% and 0% respectively. For each of the element of effectiveness a weight is assigned. In this research work, this methodology has been used for qualitatively analysing the operational risks and uncertainty and risk measures in SC.

1.7.3 Analytical Network Process (ANP)

There are numerous multi criteria decision making approaches (MCDM) approaches available in the literature such as Analytical Network Process (ANP), Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity of Ideal Solutions (TOPSIS), Weighted Sum Method (WSM) etc. Among these models the most widely used method is analytical hierarchy process (AHP) (Saaty, 1980). AHP can be used but it is not utilized over because of its limitations. Sarkis and Tulluri (2002) have listed out the various advantages of ANP over AHP. Analytical network process (ANP) has the capability to incorporate the relationships which involve multiple factors and relationship may exist between these factors. One factor may affect the other factors and the degree of such relationship may vary between factors. Interdependencies among the elements may be represented by two-way arrows and four-ways arrows between levels, or if within the same level of analysis (Meade and Sarkis, 1998). The hierarchical relationship is allowed within the AHP network model, but the existence of a feedback relationship among the levels is only found in ANP. The ANP approach is capable of handling interdependence among elements by obtaining weights through the development of a 'supermatrix' (Hamalainen and Seppalainen, 1986).

ANP (Saaty, 1996) is a extensive decision-making technique that captures the outcome of the dependence and feedback within and between the clusters of elements. Analytical hierarchy process (AHP) serves as the initial stage of ANP. The ANP is a combination of two parts, where the first consists of a control hierarchy or network of criteria and sub-criteria that controls the interactions, while the second part is a network of influences among the elements and clusters. In fact, ANP uses a network without a need to specify levels as in a hierarchy.

In this research work, this methodology has been used for selecting the best alternative (supply chain) by analysing the uncertainty and risk measures in supply chains.

1.7.4 Multi-Objective Optimization by Ratio Analysis (MOORA)

Like other multi criteria decision making (MCDM) tools, multi objectives optimization by ratio analysis (MOORA) method, which was first put forward by Brauers (2004) and Brauers and Zavadskas (2006), is used to prioritise the alternatives on the basis of several criteria or objectives. Multi-objectives optimization on the basis of ratio analysis (MOORA) is also known as multi-criteria or multi-attribute optimization. As proposed by Zavadskas et al., (2009) performance of an alternative on an objective is compared with denominator which is representative for all the alternatives concerning that objective. It is defined as the process of simultaneously optimizing two or more conflicting attributes subject to some constraints. In the present work, this methodology has been used for selecting the best alternatives (supply chain) by analysing the uncertainty and risk measures.

1.7.5 Graph Theoretical Approach (GTA)

Graph theoretical approach (GTA) is an efficient system for change of subjective factors to quantitative qualities and scientific displaying gives an edge to the proposed procedure over routine routines like reason impact charts, stream outlines and so on. Chart hypothesis serves very moment model of any framework that incorporates multi relations among its constituent components due to its diagrammatic representations and tasteful angles. Graph hypothesis is a subject of combinatorial science and draws a ton from lattice hypothesis. The network representation of the chart forms the issue to make utilization of PCs for different complex operations. It comprises of the digraph representation, the framework representation and the lasting capacity representation. The digraph is the visual representation of the factors and their reliance which influences the kick the bucket execution. The network changes over the digraph into scientific structure. The perpetual capacity is a numerical model that serves to focus file. Diagram theoretical approach has been utilized by numerous specialists i.e. Gandhi and Agrawal, 1996; Testa et al., (2003); Grover et al., (2006); Raj et al., (2010); Dev et al., (2014). In this research work, this methodology has been used for quantitative analysis of risks in SCs.

1.8 ORGANIZATION OF THE THESIS

The present research work has been planned in 11 chapters. The chapter wise organization of the research has been depicted in Figure 1.1. Summary of each chapter have been discussed as below:

Chapter I: In this chapter**,** the proper understanding of supply chain, their need and benefits, uncertainty and risk in supply chain, motivation, gaps in literature, research objectives and methodologies used in the present research have been discussed.

Chapter II: As the supply chain management is a global issue and supply chains are being used in the leading industries of the world. A lot of research work has been done and reported in the form of research papers and different leading global journals.

Therefore for the best possible contribution in the present research work a lot of research papers related to supply chain management were studies. Through this literature review general definitions of supply chain, their types and different burning issues with supply chain management mainly risk identification and management were identified and have been presented in this chapter. Some critical barriers and important success factors related to supply chain management are also discussed in this chapter. Some important technique such as W-ISM, ANP, MOORA and GTA which are used in this research work for extracting different models and frameworks are also reported in this chapter.

Chapter III: This chapter covers the development of questionnaire for conducting a national wide survey. The survey was conducted in small-large-medium scale industries. Questionnaire consists of the questions related to the uncertainty and risk issues in supply chain i.e. plan and control risks, procurement 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 and supply chains such as agile supply chain, green supply chain, lean supply chain etc. responses from the industries were collected, analyzed and presented through discussion for different issues.

Chapter IV: In this chapter, operational risks in supply chain have been identified and analysed by using W-ISM technique by developing the ISM model, MICMAC analysis and by calculating the effectiveness index.

Chapter V: In this chapter, uncertainty and risk measures in supply chain have been identified and analysed by using W-ISM technique by developing the ISM model, MICMAC analysis and by calculating the effectiveness index.

Chapter VI: In this chapter, the ANP method is used for risk mitigations in supply chain planning and control to select the best alternative among the traditional, agile, and green supply chain by analysing the plan and control risks, process risks, demand risks and natural and social risks with the dimensions such as disruption, deviation and disasters.

Chapter VII: In this chapter, a comparative study and risk assessment of supply chains with different multi criteria decision making approaches have been done to find out the best supply chain among the traditional, agile, lean and green supply chain by analysing the transportation risks, operational risks, supplier related risk and market related risk. And the objective was carried out by using the ANP based model which followed by AHP and MOORA method.

Chapter VIII: In this chapter, GTA based approach is used for the quantification of risks in supply chain. The risks such as supply risks, process risks, natural and social risks, financial risks, transportation risks and demand risks are used for the analysis. And the most important risks among these that need more attention is found out.

Chapter IX: In this chapter, some important risk mitigation techniques have been reported. A step wise procedure has been reported to mitigate the SC risks.

Chapter X: In this chapter, the synthesis of research work as mentioned in the previous chapter has been presented. This chapter presents the overall picture of the research work.

Chapter XI: In this chapter summary, implications and limitations of this research work have been discussed. Final conclusion of this research and scope of future work have also been presented.

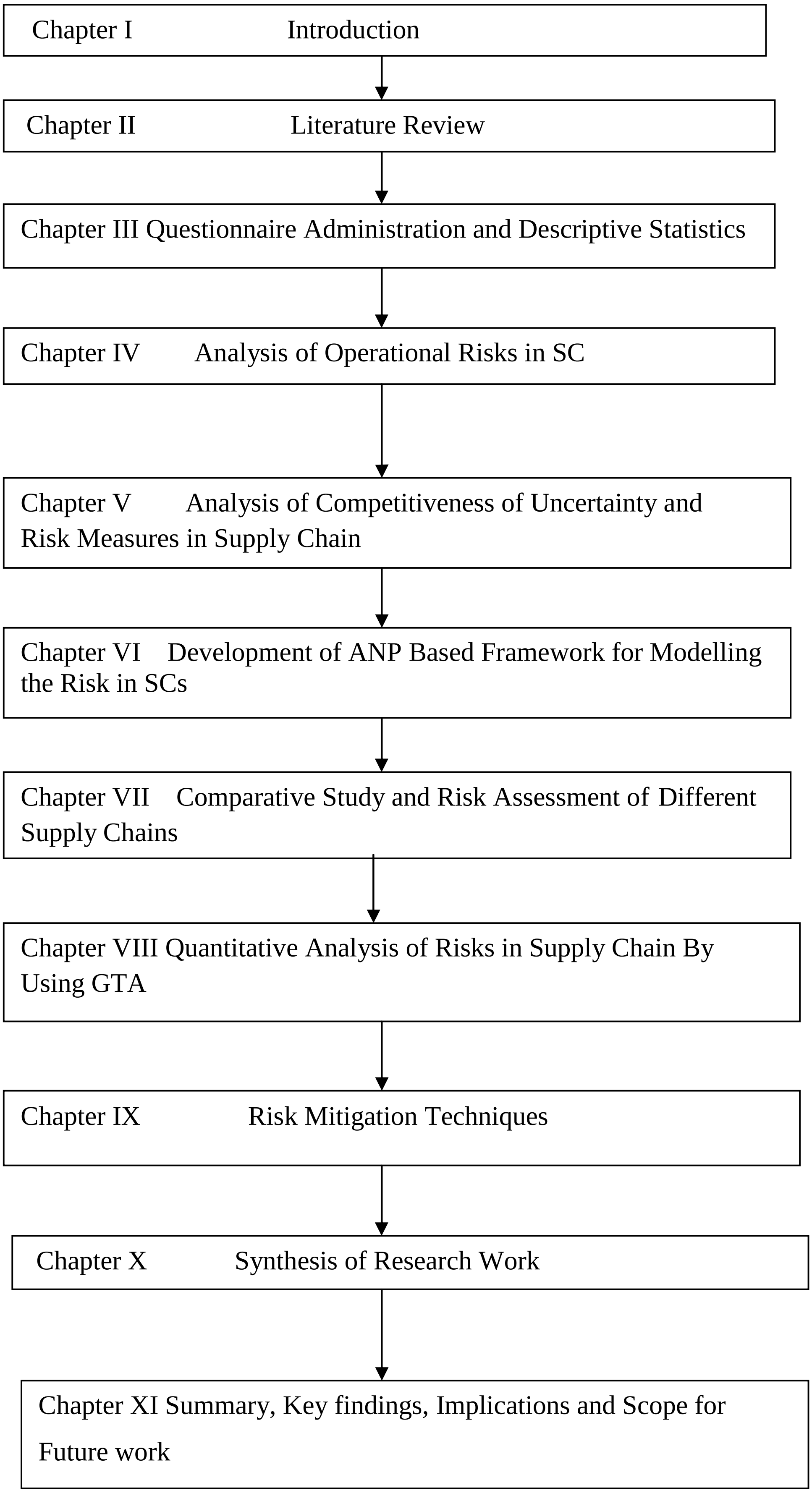


Figure 1.1: Organization of research work

1.9 SUMMARY AND CONCLUSION

The current industries environment of rapidly changing technologies, threats, needs and money have created a need of better understanding the uncertainty and risks in supply chain. The wide range of types of uncertainty and risk associated with supply chain and possible responses to them make cohesive of problem difficult. So there is a need to profile the potential risks associated with the supply chain activity. Also there is a need to mitigate these uncertainty and risks to improve the quality, productivity and to reduce cycle time by identifying the important risk issues. There is a need to develop the hierarchy or network for mitigating the uncertainty and risks. In this chapter, introduction, needs, benefits of SCs, and issues related to uncertainty and risks in supply chain have been discussed. After identifying the gaps in literature regarding uncertainty and risks in SCM, a comprehensive research work was prepared and executed. Different research objectives, methodologies used in the present research work and organization of whole research work has been presented in the chapters.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION TO SUPPLY CHAIN

As of late, the zone of supply chain management (SCM) has ended up extremely prominent. While enthusiasm for SCM is massive, it is pass that learning about SCM lives in decreased useful storehouses among the individuals, for example, purchasing, logistics, IT and promoting. Ganeshan and Harrison (1995) has characterized SCM as a system of offices and appropriation alternatives that performs the elements of acquisition of materials, change of these materials into middle and completed items, and the circulation of these completed items to clients.

For the expression "supply chain management" there has all the earmarks of being little agreement on its definition (Lummus et al., 2001; Mentzer et al., 2001). Kathawala and Abdou (2003) have inferred that SCM has been ineffectively characterized and there is a high level of variability in individuals' brains about supply chain. Mentzer et al. (2001) have endeavored to conquer this situation by proposing a definition that is expansive, not bound to any particular order zone and satisfactorily mirroring the broadness of issues that are typically secured under this term. Supply chain management is characterized as the systemic, vital coordination of the conventional business capacities and the strategies over these business capacities inside a specific organization and crosswise over organizations inside the supply chain, for the reasons of enhancing the long haul execution of the individual organizations and the supply chain all in all (Mentzer et al., 2001).

SCM has been deciphered by numerous specialists. Taking into account the moderately late advancement of the supply chain writing, it is not astounding that there has been much verbal confrontation on diverse sort of supply chains.

2.2 TYPES OF SUPPLY CHAINS

The different type of supply chains enlisted in literature are as follows:

2.2.1 Traditional Supply Chain (TSC)

In a traditional supply chain (TSC), the flow of materials and information is linear and from one part to the part. There is a limited collaboration and visibility in TSC. Each supply chain partner has limited information regarding, for example, the carbon footprint and greenhouse gas emission of the other partners. Hence, each player may be concerned about his own footprint and may try to reduce this, irrespective of the impact on upstream and downstream supply chain. 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.

2.2.2 Agile Supply Chain (ASC)

Agile supply chain (ASC) means speedily move to the market according to the customer requirement. The review of some ASC frameworks was made in order to identify main elements and attributes of agile enterprise. According to Goldman et al. (1995), an agile competitive environment in SC is where the people skills, knowledge and experience are the main differentiators between the companies. Thus, continuous work force education and training are integral to an agile company's operations and represents an investment into future success.

According to Jackson and Johansson (2003), agility is not a goal in itself but the necessary means to maintain the competitiveness in the market characterized by uncertainty and risk. Agility in SC is based on several capabilities found in three main enterprise dimensions: manufacturing, product and market dimensions. Goldman et al. (1995) have proposed strategic dimensions of agility in supply chain such as enriching the customer, cooperating to enhance competitiveness, organizing to master changes and leveraging the impact of people and information.

Jackson and Johansson (2003) have divided agility capabilities into four main dimensions such as product-related change capabilities, change competency within operations, internal and external co-operation and creativity. Yusuf et al. (1999) have identified speed, flexibility, innovation, pro activity, quality, and profitability as the competitive foundation of agility. Sharifi et al. (2001) have identified four main aspects of ASC such as agility drivers, strategic abilities, agility providers and agility capabilities.

Lin et al. (2006) have identified three main agility capabilities such as organizational management agility, product design agility and product manufacturing agility. Arteta and Giachetti (2004) took a perspective that the primary dimension of agility is an ability of the enterprise to respond to a change. Dove (2001) noted the complexity of organization in transition needs to be reduced in order to deal with the transition. The complexity of system hinders the ability of the enterprise to quickly react to change by re-configuration of products, processes, or organization structure. Since, the less complex system is easier to change and more agile, the complexity of the system can be used as the measure of agility.

2.2.3 Green Supply Chain (GSC)

An environmentally conscious supply chain, also called a green supply chain, is a new concept appearing in recent years. Although this environmental issue has been realized very important for business, its introduction to supply chain management has only been developed recently.

Environmentally-responsible consumption and production is seen as an essential part of the strategy to improve environmental quality, reduce poverty and bring about economic growth, with resultant improvements in health, working conditions and sustainability and is today highlighted agenda. In particular, organizations were called upon to exercise leadership in the promotion of environmentally sound goods and services.

Green supply chain management (GSCM) is considered as a process of integrating the environmental concerns, values and thinking into supply chain. It can also be defined as a phenomenon where environmental innovations diffuse from a customer firm to a supplier firm, with environmental innovation defined as being a product, process, technology or technique developed to reduce environmental impact (Hall, 2000).

Adding the ‘green’ component to supply chain management involves addressing the influence and relationship between supply chain management and natural environment (Srivastava, 2007). GSCM, also known as Sustainable Supply Chain Management (SSCM), combines green purchasing, green manufacturing/material management, green distribution/marketing and reverse logistics (Hervani et al., 2005).

The aim of organisations adopting GSCM practices is to enhance their environmental and financial performance, investment recovery and eco-design or design for environmental practices (Zhu and Sarkis, 2004). Also, there is pressure from both business and the public who as customers want products and services that support their efforts to be sustainable (Tuttle and Heap, 2008). Thus, environmental sustainability has emerged as one of the biggest challenges for the global community to confront with. Organizations are conducting business within complex legal structures, while stakeholders' demands are increasing and environmental performance expectations are becoming more demanding. To operate effectively in this environment, organisations are now required to demonstrate proactive management of the environmental impacts of their business activities and adopt environmentally responsible practices, i.e., green business practices into everyday business processes. There is a definite relation between environmental concerns and economic growth. The economic growth is linked to the environment through extraction, production and consumption of natural resources. The excessive economic growth creates not only resource scarcity but also pollutants that might exceed the assimilative capacity of natural environments, thereby degrading essential life-supporting systems. Zhou (2009) have defined green supply chain management as a sort of modern management mode which could comprehensively consider the environmental influence and resource utilization efficiency in the whole supply chain and how to implement the green supply chain management in special industrial operation at present has become into one of hotspot problems. But, this is not an easy task, business managers in manufacturing organizations now required to identify, analyse and manage these barriers in their 'supply chains' such that the business practices can turn out to be effective and efficient in addressing environmental concerns.

2.2.4 Lean Supply Chain (LSC)

The Lean supply chain involved the identification of customer value, firm organisation around customer value streams rather than production functions, elimination of waste to allow production to flow, synchronisation of production with the pull of customer demand, and finally the philosophical culture that there is always room for improvement in any process through the pursuit of perfection (Womack and Jones, 1996). Cox (2004) argues that in recent years this has led to a tendency to think that a lean chain brings together the best practices, but that in fact the wholesale extension of lean to other sectors can be challenged as contingent. Lean approach can only succeed for products which operate in chains characterized by regularity, high volume and standardized demand. One of the most important operations management discipline lean has been extensively tested and implemented in the pork sector but lean has been questioned as contingent on supply circumstances with the agile discipline proposed as more appropriate in certain situations (Naylor et al., 1999; Taylor and Fearne 2006).

2.3 DIFFERENT ISSUES CONCERNED WITH SUPPLY CHAINS

Supply chain management encompasses strategic planning, manufacturing and operations management necessary to bring a product to the market place, from the sourcing of materials to the delivery of the product (Shukla et al., 2011). In literature there are many issues concerned with supply chains. Some of the important issues in supply chains are as follows:

2.3.1 Role of Information Technology (IT) in SC

Information technology among supply chain members is a basic requirement for effective supply chain management (SCM). The range of technologies available to support SCM efforts is vast and ever changing. Unfortunately, there is not a single 'right' information technology (IT) solution to SCM. Organizations need to explore various options to arrive at a solution that provides the functionality required for their specific SCM initiative. SCM initiatives are unlikely to succeed without the appropriate information systems and the technology required to support them. IT-based SCM systems coordinate and integrate the issues involve the flow of materials, money and information from supplier to manufacturer to wholesaler to retailer to the end consumer. Here, IT serves as a key issue of supply chain integration and contributes to firm profits by improving quality and by reducing coordination costs and transaction risks (Vickery et al., 2003).

2.3.2 Performance Measurement in SC

Performance measurement is one of the most important issues in supply chain. Performance measurement is process of quantifying the effectiveness and efficiency of action in supply chain (Neely et al., 1995). Effectiveness is the extent to which a customer's requirements are met and efficiency measures how economically a firm's resources are utilised when providing a pre-specified level of customer satisfaction (Gunasekaran et al.,2004).

The performance measurement system is ultimately responsible for maintaining alignment and coordination. Alignment deals with the maintenance of consistency between the strategic goals and metrics as plans are implemented and restated as they move from the strategic through the tactical and operational stages of the planning process. Alignment attempts to ensure that at every stage that the objectives set at the higher levels are consistent with and supported by the metrics and activities of the lower levels. In contrast, coordination recognizes the presence of interdependency between processes, activities or functions. Coordination strives to reduce potential conflict that can occur when one area focuses on maximizing uptime and another focuses on quality and flexibility. Coordination tries to maintain an equivalence of activities, goals, and purpose across departments, groups, activities and processes. It is observed that in today business environment different problems faced are by operations managers such as never satisfied customers, the need to manage the whole supply chain rather than only internal factors, shortened product life cycles, more data and increasing number of alternatives (McKenna, 1997).

2.3.3 Just in Time (JIT)

JIT is one of the most celebrated modern techniques and its use has helped many firms to become more productive and competitive. JIT is designed to virtually eliminate the need to hold items in inventory. However, the benefits associated with JIT, generally surpass the mere savings in inventory holding costs. Improper management of JIT, result different problems like low quality, cost increase and stop the production. A well implemented JIT system will also result in improved quality, lower manufacturing costs, lower ordering costs, elimination of waste, streamlining of the production process, and elimination of production process bottlenecks. Commonly used JIT practices are such as JIT purchasing, single sourcing/reducing supplier base, close supplier location, long-term buyer-supplier relationships, frequent deliveries of small lot sizes, reduction in order lead-time, quality control measures, reducing inventory, supplier selection and evaluation, supplier certification, long term contract with transportation companies, quality circles, focused factory, total preventive maintenance, group technology, uniform work load, multifunctional employees, kanban, self inspection by operators, elimination of non-value added processes, situating sales and engineering personnel at buyer premises and total quality control. Most JIT companies view JIT purchasing as a significant component of their JIT implementation and as a major factor in their success. In the traditional JIT environment, the supplier of raw materials is dedicated to the manufacturing firm, and is normally located close-by (Singh and Chand, 2010).

Strategies of JIT replenishment often suggest reduction of the supplier base for each item and the building of long term relationships with suppliers. Having fewer suppliers reduces the coordination efforts in order to ensure on-time deliveries and facilitates the provision of high quality supply. The negative side of single sourcing is the involvement of several kinds of risks.

2.3.4 Flexibility in SC

Flexibility is a multifaceted and multidimensional concept, difficult to summarize (Gupta and Buzacott, 1996). Flexibility reflects the ability of a system to properly and rapidly respond to changes, coming from inside as well as outside the system. The SC flexibility involves the components of SC and the relationships among the components, in order to evaluate their impact on the whole supply chain. The SC flexibility is categories in two main aspects such as process flexibility and logistics flexibility. While the process flexibility is the type of manufacturing system flexibility and the logistics flexibility can be referred to the routing flexibility at the shop floor level that is the ability of using alternative routes to move the work-in-process through different resources offering the same processes (Das and Nagendra, 1997; Garavelli, 2001). Logistics flexibility is intended as the possibility of shifting the production of an item to different sites of a given stage of the SC, allowing reducing the negative impact of demand and process variability on SC performance. Improper supply chain flexibility can affect production system, customer demand, quality of product and inventory management. To produce products of global quality and to meet the customer's demand, Indian industries have to adapt flexibility in supply chain management.

2.3.5 Logistics

In today competitive global economy, companies face the challenge of evolving strategies and capabilities to compete effectively. The increasing trend of economic globalisation has made efficient logistics management critical to the success of every business organisation. Logistics, however, is human-centric relying, to a great extent, on the capabilities of the individuals managing the logistics processes. A good logistics system requires a skilled workforce. A major concern of most researchers and practitioners is the nature and role of employee skills on logistics performance (Dadzie, 1998). The Council of Supply Chain Management Professionals (CSCMP) (2007) defines logistics as that part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption to meet customers' requirements. Logistics is critical to the success of every organisation as customers' demand for quality products, quality service and increasing value, has increased the importance of the logistics function (Tompkins, 1997; Sohal and D'Netto, 2004). There are many issues in logistics like improper man machine management, increase lead time, customer satisfaction etc. One major concern of logistics is the determination of the right kind of skills required to function effectively. Logistics is very broad and requires a diverse set of skills; from people to process to information skills. Previous researches have tried to identify the skills required for logistics profession. These skills include team orientation, people, technology, cross-functional and supply chain skills (Cooke, 2000; Gammelgaard and Larson, 2001). Many studies have highlighted the shortage of suitably qualified logistics talents to fill vacant positions (Sarana, 2006).

2.3.6 Uncertainty and Risk

Uncertainty and risks is one of the indispensable parts of any manufacturing or service supply chain. No matter how strong is the supply chain, risk and uncertainty come into the picture by disrupting the operational flow (Mishra and Shekhar, 2012). Uncertainty and risks management is the one of the most important issues in supply chains. Improper management of uncertainty and risk can affect the whole supply chain members like supplier manufacturer, distributer, transportation, whole seller etc. The situation further gets complicated, if the nature of the material the supply chain deals in is perishable requiring conditioned transportation and storage. Tang (2006) have structured the literature on supply chain risk management according to the mitigation approach. Supply management, demand management, product management and information management can all contribute to successful risk mitigation in supply chain. Samvedi et al. (2013) have described risk is inherent in almost every activity of supply chain management. With the ever-increasing push for efficiency, supply chains today are getting more and more risky.

2.4 RISK IDENTIFICATION IN SUPPLY CHAINS

Uncertainty and risk identification is an important part of supply chains. Uncertainty is the deviation from actual demand on other hand risk is the probability of the occurrence. Uncertainty and risk in the supply chain can be classified in three ways deviation, disruption and disaster (Gaonkar and Viswanadham, 2004). A deviation is occurred when one or more parameters, such as cost, quality, delivery, etc., within the supply chain system occurs from their expected or mean value, without any changes to the underlying supply chain structure. Deviation in supply chain is responsible for affecting cost, quality and delivery. A disruption occurs when the structure of the supply chain system is radically transformed, through the non-availability of certain production, warehousing and distribution facilities or transportation options due to unexpected events caused by human or natural factors. Disruptions may be influenced by the distinctive supply related characteristics of each entity, including environment, infrastructure, service delivery, inter organisational linkages and relationships, or a combination of these factors (Peck, 2005). Disaster means a temporary irrecoverable shut-down of the supply chain network due to unforeseen catastrophic system-wide disruptions. Disasters like terrorist attacks, earthquake, heavy rain etc are responsible for the complete shutdown of supply chain (Tang, 2006). Different types of uncertainty and risks associated with supply chains are discussed in the following sections:

2.4.1 Plan and Control Risks

Strategic planning can reduces the plan and control risks in supply chains. This is the one most important risk, which start at the planning stage at supply chain. Improper planning can give the invitation to other type of risks. It involves the issues related to production, material management and information technology etc. Plan and control risks are characterised by different measures such as IT planning and control (ITPC), material planning and control (MPC), production planning and control (PPC), sales marketing plan and control (SMPC) (Moeinzadeh and Hajfathaliha, 2009).

2.4.2 Procurement Risks

A procurement risk is the potential deviations in the inbound supply in terms of time, quality and quantity that may result in uncompleted orders (Kumar et al., 2010). Inconsistency in the suppliers' performance will make their performance unpredictable and thus increase procurement risks. There are many factors that can affect suppliers' performance such as production capacity constraints, lack of quality control, congestion in the production, or even a machine break down (Zsidisin and Ellram, 2003). All these can interrupt supply in terms of supply lead time, quantity and quality.

Due to the practice of outsourcing, the capability of the suppliers to assure supply is critical for the buying companies. Inconsistent supply lead-time makes it unpredictable and thus increases the forecast error (Zsidisin 2003). Problems also occur when suppliers cannot satisfy volume or mix requirements in the order. Since the buying company relies on its suppliers to maintain capable production processes, the inability of suppliers to deliver the required material, components or products will have detrimental effects on the supply chain's ability to serve its customers. Success of an organization depends upon the seamless linkages between different activities within the chain such as inbound logistics and outbound logistics. Supply risk will have detrimental effects on outbound logistics, which will ultimately impact on the performance of the supply chain.

2.4.3 Process Risk

Process risk is the potential deviations from producing the desired quality and quantity at the right time (Kumar et al., 2010). Different variation exists in all production systems. Hopp and Spearman (2000) have summarised two main types of variability in a manufacturing system. First is process variability which is mainly caused by various detractors such as machine downtime, setups or operator unavailability. The other is flow variability which is caused by the way the work is released to the system and the movement between stations. These factors may result in inconsistency in the throughput time, process yield and product quality which makes the performance of the production process unpredictable and induces process risk. The corrupting role of variability in a manufacturing system has long been studied. Inconsistent throughput time, output rate or the quality of the products degrades the efficiency and effectiveness of a production system. Any scrap or rework requires additional capacity and redoing an operation requires additional time (Hopp and Spearman 2000). Longer throughput time will keep the customer waiting and lower the customer satisfaction, which finally damages the effectiveness of supply chain to serve its customers. In a nutshell, process risk undermines the capability of the manufacturer to efficiently fulfil customer orders and ultimately damage the performance of the supply chain.

2.4.4 Demand Risks

Demand risk is the potential deviations of the forecasted demand from the actual demand (Kumar et al., 2010). Large variations reflected in order changes make it more difficult for manufacturers to forecast the demand and infuses high demand risk. Order changes could be insertion, expediting or volume changes. The changes may result from shorter product life cycle or introduction of new products in the market (Manuj and Mentzer, 2009). A fundamental purpose of a supply chain is to match supply with demand however the unexpected changes in the demand decrease the accuracy of forecast and make it more difficult to achieve this goal (Cohen and Kunreuther, 2007). The mismatch between the actual orders and forecast will harm the efficiency and effectiveness of the supply chain. If the forecast is higher than the actual demand, it may result in excess inventory, obsolescence, inefficient capacity utilisation or price-markdown, which results in inefficiency of the supply chain (Sodhi and Lee, 2007). If the forecast is less than the actual demand, it may result in shortages on the shelf and failure to serve the customer, which results in the ineffectiveness of the supply chain. Therefore demand risk is a vital threat for the supply chain to serve its customer.

2.4.5 Natural and Social Risks

Natural and social risks are defined as events driven by external forces such as weather, earthquakes, political, regulatory and market forces (Wagner and Bode, 2006). Recent research has shown an increased attention towards environmental (man-made and natural) disruptions due to several global events in past disrupting SC (Ghadge et al., 2012). Environmental risk sources comprise any uncertainties arising from the SC environment interactions (Juttner et al., 2003). Environmental risk can arise due to physical, social, political, legal or economic environment (Bogataj and Bogataj, 2007). Fires or terrorist attacks have brought forth the importance of not only data backup but have made organizations to seriously think of mirror sites to keep the flow of information uninterrupted in a supply chain. Also the omnipresent internet technology could be leveraged by the terrorists to sieve contents of government web sites and find potential targets, identify or exploit weaknesses, obtain and integrate disparate information (Halchin, 2004).

2.4.6 Transportation Risks

Transportation risks occur due to delay in transportation mode chosen. Due to transportation risk overall production system can be stopped. To outcome this type of risks suitable mode of transportation should be chosen. Diabat et al. (2012) have analysed that transportation 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.

2.4.7 Market-Related Risks

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). Market related risks are related to the excess and less demand of customer or depend on the seasonality. Shimizu et al. (2013) have investigated the customer claims to improve organizational processes in supply chain risk management**.**

2.4.8 Supplier-Related Risks

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 (Chen et al., 2013). 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.

2.4.9 Financial Risks

The financing sources of firms can be categorized into short-term and long-term debts. Short-term debt has naturally more flexibility than long term debts. This means that a large amount of short-term debt is a fundamental source of financial fragility. On the other hand, Rodrik and Velasco (1999) have showed that the ratio of short-term debt to reserves helps predict large reversals of capital cash flow. Although the short-term debt ratio may increase operational risk, it does provide sufficient liquidity for firms. Moreover, economic development has a significant positive effect on the share of short-term debt due to lower costs from rolling over short-debt debt. Diamond and Rajan (2001) have suggested that short-term debt can play a beneficial role in improving an enterprise's operational performance. Detragiache and Spilimbergo (2004) have analysed standard model of optimal borrowing without creditor runs, finding a significantly positive relation between short-term and financial crises.

2.4.10 Operations Risks

The major risk issues which effect the operation of supply chain are product design, processing of products, production capacity, and operational disruption. First, product design problems risk occurs with the inability to cope with changes, particularly during the product development stage and product launch activity (Handfield et al., 1999; Khan et al., 2008)). Production capacity refers to technological, skills and quality capacities (Handfield et al., 1999). Finally, operational disruption often happens due to operational contingencies, natural disasters and political instability (Kleindorfer and Saad, 2005). Operational risks refer to a company's reduced ability to produce and supply products and services as a consequence of a breakdown in a core operating, manufacturing or processing capability (Sadgrove, 2005; Meulbrook, 2000; Simons, 1999). This category also includes operational problems caused by human-resource problems, capacity constraints, logistics challenges and leadership issues (CAS, 2003). Operational risks include the everyday management of the supply chain whereas disruptions risks are associated with unexpected events including natural disasters (Kouvelis et al., 2006).

2.4.11 Performance Measurement Risks

Measuring supply chain risk performance continues to present a challenge to researchers as well as practitioners. Berg et al. (2008) have conducted a case study about how companies assess the performance of their supply chain risk management programs. Risk management activities finally aim at reducing the frequency and impact of supply risks. Consequently, any risk performance evaluation should measure such reductions (Berg et al., 2008; Manuj and Mentzer, 2008). However, a reduction of frequency and impact does not fully capture our proposed risk performance construct. A well identified, assessed and mitigated risk can unfold with only little negative impact on the business. Good risk performance is consequently signaled by well-defined procedures on how to manage supply chain risks as well (Kern et al., 2012). With a systematic process, clear responsibilities and elaborated contingency plans, companies are able to accommodate risks according to their daily routines and without unplanned frequent fire fighting actions (Berg et al., 2008; Kleindorfer and Saad, 2005; Norrman and Jansson, 2004; Matook et al., 2009; Wagner and Bode, 2008; Zsidisin et al., 2004). Even though a supply risk manager may have the lead in mitigating a risk, interdisciplinary teams are usually necessary to adequately solve the situation and mitigate the risk entirely. Thus, a high supply chain risk management level requires the preparedness and risk awareness of many employees within the firm beyond the purchasing and supply management staff (Hallikas et al., 2002; Manuj and Mentzer, 2008b).

2.5 IDENTIFICATION OF OPERATIONAL RISKS IN SUPPLY CHAIN

Operational risks stem from operations, i.e. from activities and resources. Any potential source that generates a negative impact on the information, goods, and finance in different operations is an operational risk. Operational risks refer to a company's reduced ability to produce and supply products and services as a consequence of a breakdown in a core operating, manufacturing, or processing capability (Sadgrove, 2005; Meulbrook, 2000; Simons, 1999). This category also includes operational problems caused by human-resource problems, capacity constraints, logistics challenges, IT problems, and leadership issues (CAS, 2003). Operational risks include the everyday management of the supply chain (Kouvelis et al., 2006). Liu et al. (2010) illustrates how firms implement supply chain strategies to reduce operational risks, especially risk exposure involving catastrophic events. Drawn on risk management and supply chain research, the concepts of operational risk and the underlying demand and supply uncertainties are delineated. Then, based on literature review and numerical demonstrations, the effectiveness of supply chain strategies is evaluated in reducing operational risks. Some of the operational risks identified through literature have been discussed as below:

2.5.1 Poor Quality

Poor quality is defined as non-fitness for purpose such as imperfection of product and unsatisfied customer. Quality failures can stem from the failure of suppliers to maintain capital equipment, lack of supplier training in quality principles and techniques, and damage that occurs in transit (Zsidisin et al., 2000). Poor quality is related to the quality of row material supplied and quality of finished products which affect the market and the customers.

2.5.2 Utility Failure

In operations management, however, the expected profit maximization assumption started coming into question only recently. Some authors, for example, Lim and Ho (2007) and Ho and Zhang (2008) have studied considerable rejections through the lens of the random utility theory. The theory postulates that when faced with several options people do not select the highest utility option with certainty, but instead select it only with some probability, depending on the relative utility of the option and the precision parameter.

2.5.3 Human Resource (HR) Problems

As companies reorganize to gain competitive edge, human resources play a key role in helping companies to deal with a fast-changing competitive environment and the greater demand for quality employees. New approaches are applied to work process design, succession planning, career development and inter-organizational mobility. One major concern of logistics practitioners is the determination of the right kind of skills required to function effectively. Logistics is very broad and requires a diverse set of skills; from people to process to information skills. Many researchers have identified the skills required for logistics profession. These skills include: team orientation, people, technology developement, cross-functional and supply chain skills (Cooke, 2000; Gammelgaard and Larson, 2001). Additional skills identified by other researchers include: functional, managerial and interfacing, customer service, strategic management, communications, leadership, computer, collaborative, problem solving and financial skills (Bowersox et al., 2000; Sohal and D'Netto, 2004).

2.5.4 Information Technology (IT) System Failure

SCM initiatives are unlikely to succeed without the appropriate information systems and the technology required to support them. Van Donk (2008) have discussed the effect and influence of IT both as a motivation for new business and as an enabler of a fast flow of information to support operations and SCM. IT-based SCM systems coordinate and integrate the flow of materials, money, and information from supplier to manufacturer to wholesaler to retailer to the end consumer. Here, IT serves as a key enabler of value chain integration through the capture, organizations and sharing of vital information regarding key business processes, both within and outside a firm's boundaries and contributes to firm profits by improving quality and by reducing coordination costs and transaction risks (Mabert and Venkataramanan, 1998; Frohlich and Westbrook, 2001). Lee et al. (1997) have presented the information distortion as one of the key preserves for bullwhip effect in supply chains.

2.5.5 Loss of Key Equipments, Personnel and Suppliers

For the successful supply chain of a firm, key equipments, personnel and suppliers play an important role. Key equipments are related to the machinery which are helpful in the operation of supply chain.

For business owners, the consequences of the loss of a vital member, known as a key person, in the company through death, disability or critical illness could be significant. There could be significant need out-of-pocket costs in terms of recruiting and training a suitable replacement. For many businesses, the definition of a key person extends beyond the business owner to key sales people, product developers or managers. For a business, it can define a key person as anyone connected to the business whose temporary or permanent absence might cause a significant disruption to the business operations. Nagar and Raj (2013) has also emphasized about the use of human elements and importance of human characterization in advance manufacturing system.

Reliable suppliers are also very important for any company and for checking the reliability of supplier many factors may be used. Weber et al. (1991) have provided a comprehensive view of the criteria that might be helpful in supplier selection. They showed that quality, delivery and price have need of attention. Production facility, geographical location, financial position and capacity generated an intermediate amount of attention. Nydick and Hill (1992) have considered four criteria in supplier selection such as quality, price, delivery and service. Verma and Pullman (1998) have illustrated that how managers trade off among quality, cost, on-time delivery, delivery lead-time and flexibility attributes when choosing a supplier. They indicated that managers perceive quality to be most important supplier attribute, followed by on-time delivery and cost. Karpak et al. (2001) have considered cost, quality and delivery reliability as vendor selection criteria. Supplier performance is a critical component of the entire supply chain governance and integrates with supplier quality and supply chain risk management processes.

2.5.6 Theft of Information

Information risk can be defined as the probability of loss arising because of incorrect, incomplete, or illegal access to information. Information risk management is the management of information risks in supply chain through coordination or collaboration among the supply chain partners so as to ensure profitability and continuity. Risks associated with information have a wide variety of impacts. While the impact of information security/breakdown risks are very evident and immediate on supply chain operations, the impact of risk like intellectual property are not immediate but are critical for overall supply chain viability in the long term. The financial consequences of information failure make it necessary to develop a strong link between risk and cost-benefit analysis (Maguire, 2002). Four basic approaches that a firm could employ to mitigate risks through a combined and synchronized mechanism are supply management, demand management, product management and information management (Tang, 2006).

2.5.7 Logistic Route/Mode Disruption

Logistics is critical to the success of every organisation as customers' demand for quality products, quality service and increasing value, has increased the importance of the logistics function (Sohal and D'Netto, 2004). Transport has traditionally been considered as a marginal activity within supply chains and it has not been explicitly taken into account in those frameworks (Stank and Goldsby, 2000). In the order to minimize the operational risks and disruption in supply chain suitable logistic route should be chosen.

2.5.8 Computer Virus

A computer virus is a program or piece of code that is loaded onto the computer without our prior knowledge or permission and runs against wishes of users. All computer viruses are man-made. A virus is capable of transmitting itself across networks and bypassing security systems. As technology has made web an integral and necessary part of a business operation, hackers are using this technique to find confidential information which they use as backdoor entry into a company's innermost secrets (Ford and Ray, 2004). Viruses, worms and trojans are common menace to information technology systems. Spyware is such a program that is present in computers linked to the internet and surreptitiously collects various types of personnel information so in a supply chain they may pose threat by illegal transfer of proprietary information (Kucera et al., 2006).

2.6 BARRIERS OF SUPPLY CHAIN MANAGEMENT

SCM is not an easy task. Many hurdles or barriers are experienced while implementing SCM in any company. Some of these barriers are discussed below:

2.6.1 Vendor Selection Problems in Supply of High Tech Equipment

Vendor selection is a key element in the industrial buying process and appears to be one of the major activities of the professional industries (Patton, 1997). Selecting an appropriate vendor is often a non-trivial task, and is complicated by the fact that various criteria must be considered in the decision making process (Weber et al., 1991*)*. Vendor selection is a vital strategic issue for evolving an effective supply chain and the right vendors play a significant role in deciding the overall performance (Kumar et al., 2004).

2.6.2 Lack of Supply Chain Planning and Coordination

Supply chain planning and coordination (SCPC) is to coordinate the release of materials and resources in the supply network under consideration such that customer service constraints are met at minimal costs. The SCPC problem thus relates to the integration of the Master Production Schedule (MPS), Rough Cut Capacity Planning (RCCP), Material Requirements Planning (MRP-I) and Capacity Requirements Planning (CRP) functions in the well-known MRP-II framework (Hopp and Spearman, 1996). Information from other parts of the chain is systematically used to planning and control activities. The primary objectives of SCPC are to realize cost reductions by means of lower inventories along the supply chain and efficient use of resources and to improve customer service levels. Recently, the Concept of Collaborative Planning, Forecast and Replenishment (CPFR) has been introduced (Barrat and Oliveira, 2001). Collaborative planning serves for cross-organizational coordination of planning activities of several organizational units (Schiegg et al., 2004). Supply chain inefficiencies, like the bullwhip effect, can be counteracted by collaborative supply chain coordination initiatives (Lee et al., 1997). Within this concept, the focus is on designing and operating a joint decision-making process that coordinates the whole material flow between two supply chain partners (Ireland and Bruce, 2000).

2.6.3 Demand Uncertainties

Demand uncertainty (DU) means variation in demand. Demand uncertainty occurs when it is more or less than the requirement. In this, demand chain management will offer the companies new tools and models to develop their businesses in the global scale without missing the link to the end-customers. Jüttner et al., (2007) have introduced demand chain management as an approach that combines the strengths of marketing and SCM to build and manage global business networks. In developing competitive DU, the focus on marketing and SCM has to be changed to the customer and customer-centered supply chains. Jüttner et al., (2007) have defined three aspects of DU such as managing integration between demand and supply processes, managing the structure between the integrated processes and customer segments and managing the working relationships between the marketing and supply chain management.

2.6.4 Lack of Knowledge

Where there is no knowledge of the risks that may occur there is an increased likelihood that these risks will occur and also have a greater impact. According to Hallikas et al. (2004) where there is a greater understanding of the risks that may occur in an SC there is likely to be improved decision making and lower risk to each enterprise involved as well as to the whole undertaking. It is possible to categorise the many different forms of SC risks in terms of how their occurrence would affect a business and its environment (Harland et al., 2003). It is important for organisations to come collectively to an understanding of the risks they may face (Jüttner, 2005). Risk analysis means to detect risk in a process and this enables a secure environment in which decisions can be taken so that there is a continuous assessment of the possibility of risk; it is possible to decide which are serious and then take appropriate action to deal with them (Sinha et al., 2004).

2.6.5 Inadequate IT Infrastructure Resources

Information Technology (IT) and its use in organizations and across the supply chain has become a determinant of competitive advantage for many corporations. It also highlights the contribution of IT in helping to restructure the entire distribution set up to achieve higher service levels and lower inventory and lower supply chain costs.

Recent development in technologies enables the organization to avail information easily in their premises. These technologies are helpful to coordinates the activities to manage the supply chain. The cost of information is decreased due to the increasing rate of technologies. According to Macleod (1994) supply chain managers increasingly want to automate all of the supply chain, from forecasting to distribution, and to link every element of the chain. More and more companies want an integrated solution to enable them to see the entire supply chain at once. Unfortunately for many midsize companies in these times of economic recession, such clarity in global distribution remains largely restricted to major multinationals with deep pockets and volumes large enough to justify the hefty initial investment in IT that can run into millions of dollars.

2.6.6 Lack of Purchase Management

The performance of any firm is largely determined by the effectiveness and efficiency of its purchasing activities. Consequently, purchasing and supply managers are assuming more strategic roles in their organizations. According to Carr and Pearson (2002) purchasing strategy should be the part of overall corporate strategy. The movement towards global sourcing, rapid changes in technology and increased competition requires purchasing to assume more responsibility in the planning and implementation of strategies to support the overall corporate strategy. Hurdles faced by purchasing organizations are on time delivery, quality problems and transportation etc.

2.6.7 High Costs of Implementation

Cost of implementation is also the one of barrier in SCM. Cost is defined as the total amount of currency charged, incurred, or accrued for an item, part, or material from any organization operating as a supplier of goods or services. Cost is one of the leading criteria on which a supplier is selected. This method typically applies pressure on the supplier to reduce their bid price to match the price bid by a separate supplier. The suppliers are kept at arm‘s length, meaning they are not notified of any information concerning the use or needs of the product they are bidding on. A supplier that has been awarded the sale because they quoted the lowest cost has no reason to make any improvements in the product being supplied. Any defect in the product would likely remain in the design until the item was released for bid next time. So usually the potential supplier with the lowest calculated total cost is the one selected to join the chain of suppliers. Due to increase in the cost of materials supplied, transportation charges etc is directly affect the customers.

2.6.8 Lack of Sharing and Accurate Information

It is crucial for information to be shared where there is decreasing information visibility so that there is less risk including that of catalogue non-availability that includes up to date and standardized profiles of organizations. However, the availability of more information sharing can cause loss of IPR. In order for knowledge sharing to be accepted, a organization must have established values relating to sharing and collaboration as part of their fundamental ethos. Some may feel that they have an advantage because they possess knowledge that others do not and this causes a refusal to share knowledge with others out of a desire to protect their own interests.

Networks must share information because where it is lacking the result may be panic, confused behaviour and increased costs (Childerhouse et al., 2003). It is agreed currently by models for SCM that sharing business information is vital, connecting SC completely together (Zhenxin et al., 2001; Yu et al., 2001). It has been felt that there is a risk involved in sharing with other members such sensitive information as inventory levels and production schedules. Information sharing should be subject to choosing those with whom the information will be shared, what type of information it will be and of what quality. Efficient network coordination depends upon information sharing, with a number of studies finding that it impacts significantly on network performance and, in particular, is able to reduce the bullwhip effect. Information sharing leads to better operational decision making within enterprises which leads to more efficient use of resources and lower costs (Lee et al., 1997; Yu et al., 2001). A bond made between two independent members in supply channels is called a supply chain partnership. It is formed by increasing the levels of information sharing in order to lower the total costs and inventories.

2.6.9 Lack of Time and Decision Making

Decision-making is often said to one part of three levels, the strategic, tactical and operational level. Strategic decisions typically deal with market entry and mobilizing resources needed to meet market requirements over time (Muckstad et al. 2001). On the tactical level, medium-level decisions are made, such as weekly demand forecasting, distribution and transportation planning, and materials requirement planning (Huin et al., 2002). The operational level is concerned with the very short-term decisions made from day-to-day (Huin et al., 2002). Dekker and Goor (2000) have presented a categorisation of logistics decision-making using strategic, tactical and operational levels. Strategic logistics decisions concern major capital commitments and long time horizon (typically several years), including the location choices within a distribution networks or more basic make or buy decisions. Tactical logistics decisions are made on an annual, semi-annual or monthly basis tactical logistics decisions entail choices such as mode of transportation, type of materials handling equipment or layout of warehouses. Operational logistics decision-making relates to day-to-day operations and usually involves low capital investment.

2.7 CRITICAL SUCCESS FACTORS IN SUPPLY CHAIN

The success of supply chain is a joint effort made by every member in supply chain. Some of the critical success factors in supply chains are discussed as below:

2.7.1 Top Management Commitment

Risks are increased where a weak part is played by top level management at particular points in operations where crucial decisions are made (Westphall et al., 2007; Bamford et al., 2004). According to Kanter (1997) there is a risk that low commitment to a partnership will lead to a failure to meet objectives. The role of top management is critical, responsible for all activities at every level of an organization, for the technological infrastructure and for decision making in order that there will be efficient creation of knowledge together with sharing and use (Brand, 1998).

2.7.2 Development of Effective SCM Strategy

Innovation is an interactive and dynamic process and refers to the process of learning and knowledge creation through complex interdependencies among technological, organizational, and external settings, collectively known as the national system of innovation.

The sources of innovation and the implications of a firm being innovative vary according to its stage of technological development argues that different strategies have different objectives and requirements in terms of capabilities, critical knowledge, and sources of knowledge Mytelka (1999). Second, competitive firms can exist even farther inside the technological frontier as long as the firm is constantly innovative. This concept has obvious measurement difficulties in field studies because it is difficult to quantitatively capture the innovative activities of latecomers. Firms involved in strategic technology partnering with outside organizations, particularly in the west, can speed up the process of technology transfer through faster adoption and diffusion of new technologies.

2.7.3 Logistics Synchronization

Supply chain synchronization is the tight co-ordination of a variety of data, transaction and physical process and activity schedules of a number of players in supply chains. As supply chain management advances to extend across the supply chains of multiple companies, it becomes necessary to tightly synchronize supply chain data, methods and scheduling. Supply chain synchronization begins with base product data in electronic catalogues, to standard transactions such as purchase orders, shipment notices and supply chain exceptions.

2.7.4 Use of Modern Technologies

Technological capabilities are directly related to the ability of the organization or members of the organization, to handle or use technology. Technology can also be defined imply as knowledge. Some researchers define technology as any tool or technique, any product or process, any physical equipment or method of doing or making, through which the capability of an individual is extended. According to Christensen and Bower (1996) have defined technology is the processes by which an organization transforms labor, capital, materials, and information into products or service. By this definition, all firms have a technological presence and use technology regardless of how extensive it is.

Organizations have routines that contribute to the development and production of a given technology. This brings forward two important concepts. The first is that technical capabilities are a by-product of past activities. The second is their significance is in the range of future activities they make possible. The capabilities of the organization make the future possible. The stored knowledge of the collective organization makes the actions and desires possible. Porter (1985) states that technological change in one part of the value chain impacts other parts of the chain. The rate of change of technology has increased to the point that no one firm can know it all.

2.7.5 Forecasting of Demand on Point of Sale (POS)

Point of sale means sharing the data based on ordering decisions in supply chain. In particular, POS data helps to reduce the bullwhip effect, the tendency of orders to increase in variability as one move up a supply chain. POS data can lead to a reduction in the bullwhip effect when suppliers have no prior knowledge of the demand distribution. The benefit of sharing POS data in stable industries, where the demand distribution is commonly known, is less clear that sharing POS information *does* help reduce some components of the bullwhip effect in a stable demand setting like order oscillation of upstream members (Croson and Donohue, 2003).

2.7.6 Trust Development in SC Partners

Trust among the SC partners is the important part for the success of SC. Trust is generally seen as a precondition for risk sharing. Supply chain management is built on a foundation of trust (Kumar and Van, 1996). Sahay (2003) have studied how trust fosters greater cooperation, reduces functional conflict and enhances integration and decision-making under conditions of uncertainty and ambiguity. Sinha et al. (2004) stated that lack of trust is one of the major factors that contribute to supply chain risks. Trust is an expectation that partners will not act in an opportunistic manner, even if there are short-term incentives to do so and can contribute significantly to the long-term stability of an organization and its supply chain (Chiles and McMackin, 1996). Londe (2002) have argued that trust and risk issues are very vital in supply chain relationships because of the interdependency between corporations. This dimension of the supply chain allows cooperation and collaboration to take place both within the organization and across partners in the supply chain (Faisal et al., 2007).

The degree of trust that exists between partners relates to how much partners believe in the honesty, generosity and overall competence of the others. Where there is no trust between partners problems arise; for instance they become unwilling to pass on sensitive information, find it difficult to agree about how finances should be managed. Trust and commitment are crucial to collaboration and for cooperation over a period of time together with a preparedness to share risks (Sahay and Maini, 2002). The more the trust between SC partners, the more the commitment (Mistry, 2005). However a lack of trust is one of main contributors to SC risks (Sinha et al., 2004). According to Lengnick-Hall et al. (2013) where trust has grown out of good communication, it leads to resources that themselves can give a competitive edge. Trust assumes that those parties to an agreement will not act opportunistically even when they are tempted by possible short-term advantage to themselves and it can make a marked contribution to the stability of an organisation in the long term and to its network (Speckman and Davis, 2004).

2.7.7 Developing JIT Capabilities in System

JIT is one of the most celebrated modern techniques and its use has helped many firms to become more productive and competitive toward their success. JIT is designed to virtually eliminate the need to hold items in inventory. However, the benefits associated with JIT generally surpass the mere savings in inventory holding costs. A well implemented JIT system will also result in improved quality, lower manufacturing costs, lower ordering costs, elimination of waste, streamlining of the production process, and elimination of production process bottlenecks. Most JIT companies view JIT purchasing as a significant component of their JIT implementation and as a major factor in their success (Singh and Chand, 2010).

2.7.8 Development of Reliable Suppliers

Right selection of supplier is also important for the success of supply chain. Supplier selection is the process in which suppliers are reviewed, evaluated, and chosen in order to eventually become part of the company’s supply chain (Saen, 2007). As a supplier becomes a part of established SC, it will have a lasting effect on the competitiveness of the entire SC and, hence, supplier selection decisions are an important component of production and logistics management for many firms (Chen et al., 2003). Further, selecting appropriate cooperation partners is the first crucial step in SCM and its failure and, as a result, working with the wrong suppliers could be enough to erode the whole SC’s financial and operational position (Araz and Ozkarahan, 2007; Chou and Chang, 2008). Such decisions entail the selection of individual suppliers to employ, and the determination of order quantities to be placed with the selected suppliers (Xia and Wu, 2007). Supplier selection might involve several and different types of criteria and different decision models to be run simultaneously with different individuals and various forms of uncertainty that makes it difficult to deal with and therefore, the most important issue in the process of supplier selection is to develop a suitable method to select the right supplier (Chen et al., 2003).

2.7.9 Higher Flexibility in Production System

Flexibility is the most important part of production system and helpful for the success of SC. Higher flexibility helps the organizations to fulfil the customer need timely. Kogut (1985) writes that MNEs can utilize an international activity network to provide operational flexibility. MNEs need not only operating and product abilities, but also flexibility in order to achieve the maximum profit and minimum risk. Buckley and Casson (1998) have defined flexibility as the ability to reallocate resources quickly and smoothly in response to changes. Flexibility is the response of an organization to uncertainty in the business environment. Flexibility can also be described as the agility of a manufacturing firm. It reflects change and spontaneity. Flexibility is the organizational ability to meet an increasing variety of customer expectations without excessive cost, time, disruption or loss hence increasing the range of products available and improving performance and response.

Jack and Raturi (2002) have identified the key issues in the definition of volume flexibility are the effectiveness of the flexible response not just the ability. This demonstrates the fact that flexibility is a capability of an organization. If the purchasing function of an organization can manage supplier capabilities effectively, the result could be an increase in manufacturing flexibility. The volume flexibility capability of potential suppliers is a requirement for the improvement of coordination at each level of the SC, especially with increasing demand.

2.7.10 Focus on Core Strengths

For the success of SC, organizations should focus on their core strength. Core strength varies from organization to organizations. Organizations have their competitive strategy mainly on the four basic competitive priorities of cost, quality, dependability and flexibility. In which cost and quality are the most important priorities for remain competitive in the market. Dependability and flexibility are the source of competitive advantage for firms that fluctuate with seasonal or cyclical changes. Organizations have developed flexibility into a key competitive strategy.

2.7.11 Improvement in Product Quality

In today market, Quality of the product is most important factor for the success of an organization. Quality is defined as the customer satisfaction or fitness for use. In manufacturing or service, the term quality usually means conformance to predefined product requirements. Quality, is the performance of a supplied part or material that meets or exceeds the customer‘s expectation of durability of wear and tear in addition to the survivability in periods of high demand. Quality is considered to be the most important criteria in the selection of a resource.

Manufacturing firms require their suppliers to perform quality checks on the product prior to shipment. Performance of quality check reduces the need for product inspection by the purchasing firm upon arrival. The primary indicators of a manufacturing plant‘s performance are quality and flexibility. Total quality management (TQM) is a manufacturing program aimed at continuously improving and sustaining quality products and processes by capitalizing on the involvement of management, workforce, suppliers, and customers, in order to meet or exceed customer expectations.

2.7.12 Supply Chain Benchmarking

Supply chain operations within an organization should be constantly reviewed to identify where improvements can be made or deficiencies eliminated. One method to perform a series of benchmarking tests on their supply chain processes. Benchmarking or goal setting allows a company to assess the opportunities they may have for improving a number of areas in their supply chain including productivity, inventory accuracy, shipping accuracy, storage density and bin-to-bin time. The benchmarking process can provide a company some estimate of the benefits achieved by the implementation of any improvements. It allows the companies to compare their supply chain process with the successful supply chain process.

2.7.13 Timely Delivery

Delivery performance is defined as the timely transfer or exchange of the manufactured parts meeting the specifications requested from the supplier or its delivery agent to the assembly plant. The prompt arrival of parts and material can assist organizations in maintaining low costs. In the global marketplace of today, there are many organizations that are attempting to gain a competitive edge or maintain a competitive advantage by procuring parts and material from suppliers who offer a reduction in the standard delivery time.

The selection of a supplier based on the speed of delivery is a very important performance evaluation criterion**.** The components that impact timely delivery are supplier lead-time, manufacturing or production time, and delivery time performance. Delivery performance is measured by four distinct variables such as delivery lead-time, throughput time, the percentage late deliveries and the average lateness; with the first two variables measure speed of delivery and the final two measures the reliability of delivery performance.

2.8 METHODOLOGIES USED FOR RISK ANALYSIS

The different techniques, which have been used in this research for the analysis of uncertainty and risk issues in supply chains are as follows:

2.8.1 Weighted Interpretive Structural Modeling Technique (W-ISM)

W-ISM is the combination of interpretive structural modeling (ISM) and effectiveness index (EI). ISM is one of the interactive management methods which assist research groups in dealing with complex issues (Warnfield, 1974; 1987). ISM transforms unclear, poorly articulated mental models of a system into visible well defined, hierarchal models. It is a well known methodology for identifying and summarizing relationships among specific elements, which define an issue or a problem, and provide a means by which order can be imposed on the complexity of such elements (Mandal and Deshmukh, 1994). Thus, a set of different and directly related elements are structured into a comprehensive systematic model. ISM is primarily intended as a group learning process, but individuals may also apply it (Ravi and Shankar, 2005; Faisal et al., 2007). Any methodology for dealing with complex issues, must, therefore, be able to break complexity down into manageable chunks of information so that the human mind can deal with it. ISM tries to do this, by enabling an individual or a group to focus on the interrelations between two elements in an issue at a time, without losing sight of the properties of the whole.

From the risk sources which have been identified earlier and the potential impact of failure to meet delivery time, cost and quality targets or total failure for the collaboration, a questionnaire was developed using ISM methodology to determine underlying relations among these sources. ISM is a process that helps people to structure their collective knowledge and to model interrelationships in a way that enhances our ability to understand.

Various steps involved in ISM methodology are as follows:

- First of all, risk measures which are related to defined problem are identified (through literature review and expert opinion) and enlisted by survey or group problem solving technique.
- Established a contextual relationship among the risk measures with respect to which pairs of risks would be examined.
- On the behalf of contextual relationship a structural self-interaction matrix (SSIM) is developed for risk measures. This matrix indicates the pair-wise relationship among these measures of the system.
- A reachability matrix is developed from the SSIM and this matrix is checked for transitivity. Transitivity of the contextual relation is the basic assumption in ISM which states that if measure X is related to Y and Y is related to Z, then, measure X is automatically related to measure Z.
- The reachability matrix is partitioned into different levels.
- The reachability matrix is converted into its conical form.
- Based on the above analysis, a directed graph (digraph) is drawn and transitivity links are removed and digraph is than converted into an ISM model by replacing nodes of the measures with statements.

ISM is a powerful and widely used technique for such kind of analysis, which has been applied by many researchers in different areas.

Different applications of ISM available in the literature are shown in Table 2.1

Table-2.1: Brief review of ISM applications

S. No.	Author(s)	Remarks
1.	Saxena et al. (1990)	Identified the key variables using direct and indirect interrelationships amongst the variables a case for 'Energy conservation in the Indian cement industry'.
2.	Saxena et al. (1992)	Used this technique to identify the key actors, objectives and activities for energy conservation in the Indian cement industry.
3.	Mandal and Deshmukh (1994)	Shows the inter-relationships of criteria and their different levels in vendor selection
4.	Sharma et al. (1995)	Develop a hierarchy of actions required to achieve the future objectives of waste management in India.
5.	Singh et al. (2003)	Use this technique for the implementation of knowledge management in engineering industries.
6.	Ravi and Shankar (2005)	Analysis of interactions among the barriers of reverse logistics.
7.	Ravi et al. (2005b)	Productivity improvement in supply chain
8.	Jharkharia and Shankar (2005)	IT enablement of supply chains: understanding the barriers
9.	Bolanos et al. (2005)	Use in Strategic decision making
10.	Faisal et al. (2006)	Risk mitigation in supply chain
11.	Singh and Garg (2007)	Improving the SMEs competitiveness.
12.	Raj et al. (2008)	Modelling the enablers of flexible manufacturing system: the case for India.
13.	Singh and Kant (2008)	Analysing the knowledge management barriers

14.	Raj et al. (2009)	Analyse interaction between barriers of transition to Flexible Manufacturing System.
15.	Mudgil et al. (2010)	Modelling the barriers of greening the supply chain practices
16	Pramod and Banwet (2010)	Understanding the Inhibitors of a Telecom Service Supply Chain.
17.	Chidambaranathan et al. (2010)	Analyzing the buyer supplier relationship factors: an integrated modeling approach
18.	Hans et al. (2011)	Modeling of supply chain risks
19.	Singh (2011)	Developing a framework for the coordination in supply chain of SME's
20.	Attri et al. (2012)	Modeling the enablers in the implementation of Total Productive Maintenance (TPM).
21.	Nagar and Raj (2012a)	Risk mitigation in the implementation of AMTs: A guiding framework for future
22	Nagar and Raj (2012b)	Analysis of critical success factors for implementation of humanised flexible manufacturing system in industries
23.	Mishra et al. (2012)	Interrelationship of drivers for agile manufacturing: an Indian experience
24.	Diabat et al. (2012)	Supply chain risk management and its mitigation in a food industry
25.	Panahifar et al. (2014)	Analysis of CPFR implementation barriers

For computing the effectiveness index the mean score with their rank of risk measures is calculated. After this rank, inverse rank and weight for each measure is to be finding out. For assigning weight to different measures of effectiveness index, the highest and lowest values of five point Likert scale i.e. 5 and 1 are mapped 100% and 0% respectively. For each of the issues of competitiveness a weight is assigned. The criteria for weight (Wi) is as under:

Wi = +1 (Strength), when percentage score > 60% (Mean value >3).

= 0 (Neutral), when percentage score is between 40-60% Mean value between 2 and 3).

= -1 (Weakness), when percentage score < 40% (Mean value < 2). This framework was given by Cleveland et al. (1989) is Cj= Sum [Wi Log Ki]. Chand and Singh (2010) have also used this model for study the select issues of supply chain management. Competitiveness analysis of a medium scale organisation in India: a case (Singh et al. 2006).

2.8.2 Analytical Network Process (ANP)

There are numerous MADM approaches available in the literature such as ANP, AHP, ELECTRE, TOPSIS, ECA, MOORA, COPRAS etc. Among these models the most widely used method is AHP (Saaty, 1980). AHP can be applied to this problem also but it is not utilized over because of its limitations. Sarkis and Tulluri (2002) have listed out the various limitations of AHP over ANP. Among all of these models ANP has the capability to incorporate such relationships which involve multiple factors and relationship may exist between these factors, one factor may affect the other factors and the degree of such relationship may vary between factors. Interdependencies among the mitigations may be represented by two-way arrows and four-ways arrows between levels, or if within the same level of analysis (Meade and Sarkis, 1998). The hierarchical relationship is allowed within the AHP network model, but the existence of a feedback relationship among the levels is only found in ANP. The ANP approach is capable of handling interdependence among elements by obtaining weights through the development of a 'supermatrix' (Hamalainen and Seppalainen, 1986).

ANP (Saaty, 1996) is a extensive decision-making technique that captures the outcome of the dependence and feedback within and between the clusters of elements. Analytical hierarchy process (AHP) serves as the initial stage of ANP. The ANP is a combination of two parts, where the first consists of a control hierarchy or network of criteria and sub-criteria that controls the interactions, while the second part is a network of influences among the elements and clusters. In fact, ANP uses a network without a need to specify levels as in a hierarchy. The main reason behind choosing the ANP in our case is for selecting the best alternatives. Some of the fundamental ideas in support of ANP are (Saaty, 1999) as follows:

- ANP is built on the widely used on the basis of AHP technique,
- ANP allows for interdependency among the elements
- ANP technique deals with dependence within a set of elements (inner dependence) and among different sets of elements (outer dependence),

- The ANP networks make possible, the representation of any decision problem without concern for what criteria comes first and what comes next as in a hierarchy.
- The ANP is a non-linear structure that deals with sources, cycles and sinks having a hierarchy of linear form with goals in the top level and the alternatives in the bottom level.
- ANP portrays a real world representation of the problem under consideration by prioritizing not only just the elements but also groups or clusters of elements as is often necessary.
- The ANP utilizes the idea of a control hierarchy or a control network in dealing with different criteria, eventually leading to the analysis of benefits, opportunities, costs and risks.

Different applications of ANP available in the literature are shown in Table 2.2

Table-2.2: Brief review of ANP applications

S. No.	Author(s)	Applications
1.	Meade and Sarkis (1999)	Organisational project alternatives for agile manufacturing process
2.	Chung et al. (2005)	Product mix for efficient manufacturing in a semiconductor fabricator
3.	Ravi et al (2005a)	Analyzing alternatives in reverse logistics for end- of- life computers
4.	Aggarwal et al. (2005)	Modelling the matrices of lean, agile and leagile supply chain
5.	Cheng and Li (2005)	Project selection
6.	Bayazit (2006)	Vendor selection decision
7.	Coulter and Sarkis (2006)	Advertising media budget allocation decision
8.	Wey and Wu (2007)	Resource allocation in transportation
9.	Jharkharia and Shankar (2007)	Selection of logistics service provider

10.	Wu and Lee (2007)	Selecting knowledge management strategies
11.	Aragones-Beltran et al. (2008)	Valuation of urban industrial land
12.	Khan and Faisal (2008)	Municipal solid waste disposal options
13.	Chen et al. (2009)	To identify the committee who intend the pattern of tourism
14.	Saaty (2009)	Real application of ANP in entertainment business
15.	Ayaj and Ozdemir (2009)	An intelligent approach to machine tool selection
16.	Anand and kodali (2009)	Selection of lean manufacturing system
17.	Hemmati and Rabbani (2010)	To determine the appropriate product delivery strategy for different products in manufacturing systems
18.	Alptekin (2010)	To predict the market share in white goods sectors
19.	Subbaiah et al. (2011)	Customer-driven product planning using conjoint analysis
20.	Anand et al. (2011)	Selection of material handling systems in the design of flexible manufacturing systems
21.	Ibrahim and Turkan (2012)	An assessment model for lean enterprise transformation
22.	Shahin et al. (2012)	Selecting optimum maintenance strategy with a case study in the mining industry
23.	Goyal and Grover (2013)	Manufacturing system’s effectiveness measurement
24.	Neumüller et al. (2015)	Integrating three-dimensional sustainability in distribution centre selection

2.8.3 Multi-Objective Optimization by Ratio Analysis (MOORA)

Multi objective optimization (or programming), also known as multi criteria or multi attribute optimization, is the process of simultaneously optimizing two or more conflicting attributes (objectives) subject to certain constraints. The MOORA method, first introduced by Brauers (2004) is such a multi objective optimization technique that can be successfully applied to solve various types of complex decision making problems in the manufacturing. Lootsma (1999) starts with a decision matrix showing the performance of different alternatives with respect to various criteria (objectives). The applications of MOORA method have been used by different researchers (Brauers, et al. 2006, 2008, 2009; Kalibatas, et al. 2008). Various steps involve in MOORA are as follows:

Step 1: The first step is to determine the objective, and to identify the pertinent evaluation criteria.

Step 2: The next step is to represent all the information available for the criterias in the form of a decision matrix. The data given in eq. (1) are represented where A_i represents the alternatives, $i = 1, 2, \ldots, m$; C_j represents jth criterion, $j = 1, 2, \ldots, n$, related to i^{th} alternative. The SC of the j^{th} attribute is denoted by W_j and x_{ij} indicates the performance of each alternative A_i with respect to each criterion C_j. Then a ratio system is developed in which each performance of an alternative on an attribute is compared to a denominator which is a representative for all the alternatives concerning that criterion.

$$
D = \left[X_{ij} \right] = \begin{array}{c} \\ \\ A_1 \\ A_2 \\ \dots \\ \dots \\ A_i \\ \dots \\ \dots \\ A_m \end{array} \begin{array}{ccccccc} C_1 & C_2 & \dots & C_j & & \dots & C_n \\ W_1 & W_2 & \dots & W_j & & \dots & W_n \\ X_{11} & X_{12} & \dots & X_{1j} & & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2j} & & \dots & X_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ X_{i1} & X_{i2} & \dots & X_{ij} & & \dots & X_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ X_{m1} & X_{m2} & \dots & X_{mj} & & \dots & X_{mn} \end{array} \tag{1}
$$

Step 3: Brauers et al. (2008) concluded that for this denominator, the best choice is the square root of the sum of squares of each alternative per criteria. This ratio can be expressed as below:

$$
X^{*}_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{2}
$$

Where x_{ij} is a dimensionless number which belongs to the interval [0, 1] representing thenormalized performance of i^{th}alternative on j^{th}criteria.

Step 4: For multiobjective optimization, these normalized performances are added in case of maximization (for beneficial criteria) and subtracted in case of minimization (for non-beneficial criteria). Then the optimization problem becomes:

$$
y^{*}_{i} = \sum_{j=1}^{g} w_i X^{*}_{ij} - \sum_{j=g+1}^{n} w_i X^{*}_{ij} \tag{3}
$$

Where wj is the weight of jth criteria, which can be determined applying analytic network process (ANP).

Step 5: The yi value can be positive or negative depending of the totals of its maxima (beneficial criteria) and minima (non-beneficial criteria) in the decision matrix. An ordinal ranking of yi shows the final preference. Thus, the best alternative has the highest yi value, while the worst alternative has the lowest yi value. Different applications of MOORA available in the literature are shown in Table 2.3.

Table-2.3: Brief review of MOORA applications

S. No.	Author (s)	Applications
1.	Lootsma (1999)	Decision matrix showing the performance of different alternatives with respect to various criteria (objectives).
2.	Brauers (2004)	Multi objective optimization technique that can be successfully applied to solve various types of complex decision making problems in the manufacturing.
3.	Maniyaand Bhatt (2010)	Selection of material using a novel type decision-making method.
4.	Gadakh (2011)	Parametric optimization of milling process.
5.	Maniya and Bhatt (2011)	Optimal facility layout design selection problems.
6.	Karande and Chakraborty (2012)	Normalization by comparing the performance of an alternative on a criterion to a denominator which is a representative for all the alternatives concerning that criterion.
7.	Das et al. (2012)	Comparative evaluation of Indian technical institutions.
8.	Attri and Grover (2013)	Decision making over the production system life cycle
9.	Gadakh et al. (2013)	For solving multi-criteria (objective) optimization problem in welding.

2.8.4 Graph Theoretical Approach (GTA)

GTA is a powerful technique that can be applied in various fields. Several examples of its use have appeared in the literature (Wani and Gandhi, 1999; Rao and Gandhi, 2002; Grover et al., 2004; Faisal et al., 2006). GTA synthesises the interrelationship among different variables or subsystems and provides a synthetic score for the entire system. It also takes care of the directional relationship and interdependence among variables. However, it is more computationally intensive compared to the other approaches. This methodology consists of the following components:

- Digraph representation
- Matrix representation
- Permanent function representation.

The digraph characterises the visual representation of the barriers and their interdependence. The matrix converts the digraph into mathematical form and the permanent function is a mathematical model that helps determine the Intensity of Risk (IOR). The following features highlight the uniqueness of this approach over other similar approaches (Raj et al. 2010).

- It presents a single numerical index for all barriers
- It is a systematic methodology for the conversion of qualitative factors to quantitative values and mathematic modelling gives an edge to the proposed technique over conventional methods
- It permits the modelling of the interdependence of barriers under consideration
- It allows visual analysis and computer processing
- It leads to the self-analysis and comparison of different organisations.

Different applications of GTA available in the literature are shown in Table 2.4

Table-2.4: Brief review of GTA applications

S. No.	Author (s)	Applications
1.	Agrawal and Rao (1989)	Identification and isomorphism of kinematic chains.
2.	Gandhi and Agrawal (1994)	Failure Mode Effect Analysis
3.	Venkatasamy and Agrawal (1996)	System and structural analysis of the automobile vehicle.
4.	Rao and Gandhi (2002)	Selection, identification, and comparison of metal cutting fluids
5.	Grover et al. (2004)	Quantifying TQM environment
6.	Grover et al. (2006)	Human Factors in TQM
7.	Rao and Padmanabhan (2006)	Selection of industrial robots
8.	Prabhakaran et al. (2006)	Structural modeling and analysis of composite product system.
9.	Faisal et al. (2007)	Mitigation of risk in supply chain environment.
10.	Jangra, et al. (2010)	Performance evaluation of carbide compacting die manufactured by wire EDM
11.	Raj et al. (2010)	To evaluate the intensity of barriers in the implementation of FMSs
12.	Saha and Grover (2011)	Evaluation of critical factors of website performance
13.	Dev et al. (2014)	Combined cycle power plant efficiency analysis

2.8 CONCLUSION

From this chapter it is concluded, there are different types of uncertainty and risks associated with the different types of supply chains i.e. traditional supply chain, lean supply chain, agile supply chain, green supply chain. For a successful supply chain management and to cope with the uncertainty and risks, there is a need of deep understanding of different concerned issues with the supply chain partners. The various issues related to the uncertainty and risks in the context of supply chain have been reviewed. The various directions for risk mitigations and their benefits have been found for a successful supply chain management. From the literature, it is found that the main focused issues which affect the whole supply chain are information technology, performance measurement, just in time, flexibility and logistics. Among these issues some of the important uncertainty and risk measures have been identified so that they can be analyzed for a successful supply chain management. At last it is concluded that industries should focus on the important uncertainty and risk measures, and try to improve these areas by removing the barriers in the way of successful developed supply chain management. So the strategies should be developed to tackle the uncertainty and risk measures, and to identify the key areas by utilizing the different methodologies tools and techniques. The identified uncertainty and risk issues, measures should be further analysed for mitigating the risks in supply chains.

CHAPTER III

QUESTIONNAIRE ADMINISTRATION AND DESCRIPTIVE STATISTICS

3.1 INTRODUCTION

In this chapter, a questionnaire based survey report has been presented with the objective to examine some issues related to the uncertainty and risk measures in supply chain along with some other important issues. Key observations from the survey have been discussed and analyzed. Some other aspects such as questionnaire development, its administration in industry as well as in academics have been discussed.

3.2 QUESTIONNAIRE DEVELOPMENT

The questionnaire based survey was under taken to address various issues related to the uncertainty and risk measures in supply chain with reference to Indian industries. The questionnaire was designed and developed using literature review, experts opinion and academician's opinion in this domain. As the response rate of such survey are not fervent and respondents are generally reluctant to spare time to respond to such questionnaires, therefore the questionnaire was designed in keeping such view. The questionnaire was designed on five point (1 to 5) Linkert's scale. On this scale,1 means not at all, 2 means some what important, 3 means important, 4 stands for quite important, 5 is very important. The questionnaire was divided into three parts. Part-1 dealt with company profile, Part-2 dealt with theme and Part-3 dealt with uncertainty and risk issues related to supply chain management.

3.3 QUESTIONNAIRE ADMINISTRATION

The self-contact, e-mail and postal survey methods were used for the administration of questionnaires. Survey was conducted in Indian manufacturing industries. The chief-executives/managing directors/general managers/works managers/senior executives were contacted in person for getting their response. Questionnaires were e-mailed to some Indian manufacturing industries, along with a covering letter, self-addressed and a stamped envelope. In total, questionnaires were sent to 430 Indian manufacturing industries.

3.4 QUESTIONNAIRE SURVEY RESPONSE AND RESPONDENTS PROFILE

Out of the 430 questionnaires, 87 filled up and complete questionnaires were received. Seven questionnaires were incompletely filled and were discarded for further analysis. This gives a response rate of 20.23% which is not very low for such surveys (Malhotra and Grover, 1998). In most of the cases, the addressee filled the questionnaire on their own but in some cases; some senior executives of the companies also filled the questionnaires on behalf of addressee.

3.5 OBSERVATIONS FROM THE SURVEY

It is highly interesting to note the present trends of uncertainty and risk in supply chain of Indian manufacturing industries. The various important issues related to supply chain were emphasized in this survey such as plan and control risks, supply (procurement) risks, process risk, demand risks, natural and social risks, transportation risks, market-related risks, supplier-related risks, financial risks, operations risks, performance measurement risks, performance measurement of supply chains, barriers for SCM, critical success factors, supplier evaluation, reverse supply chain for the mitigations of uncertainty and risk in supply chains. The survey results have been presented in the following sections.

3.5.1 Related to Plan and Control Risks

In this case, the most important type of plan and control risk as indicated by respondents are material management, production planning etc. From the Table 3.1 it is clear that material management (Mean= 3.92) is the most important type for plan and control risks.

Table 3.1: Response for position of plan and control risks

S.N.	Plan and control risks related to	Mean
1.	Applied methods, concepts and tools	3.24
2.	IT systems	3.41
3.	Material management	3.92
4.	Production planning	3.81
5.	Sales and marketing	3.54
6.	Lack of visibility in supply chain	3.60
7.	Economical risk review	2.01

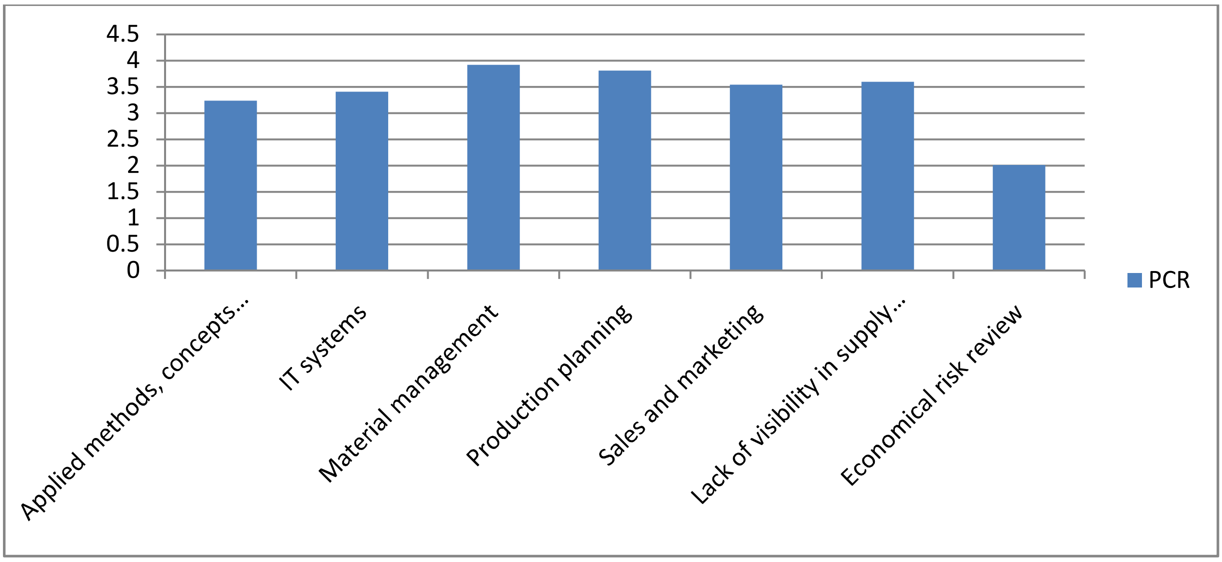


Figure 3.1: Plan and Control Risks

3.5.2 Related To Procurement Risks

The most important type of procurement risks indicated by the respondents are suppliers (Mean=4.12), quality of material (Mean= 3.98), quality of services (Mean=3.96). Similarly other factors score indicated by the respondents are presented in Table 3.2.

Table 3.2: Response for position of procurement risks

S.N.	Procurement risks related to	Mean
1.	Quality of material	3.98
2.	Suppliers (failure, single sourcing, adherence to delivery dates)	4.12
3.	Damage to cargo	3.26
4.	Monopoly situations (single sourcing)	3.36
5.	New strategic alignment of suppliers	3.32
6.	Liquidity problem and insolvency of suppliers	3.68
7.	Quality of service	3.96
8.	Responsiveness and delivery performance	3.76
9.	Supplier fulfilment errors	3.42
10.	Selection of wrong partners	3.54

11.	Inflexibility of supply source	3.81
12.	Quality or process yield at supply source	3.92
13.	Supplier bankruptcy	3.22
14.	Supply disruptions	3.84
15.	Unreliable suppliers	3.16

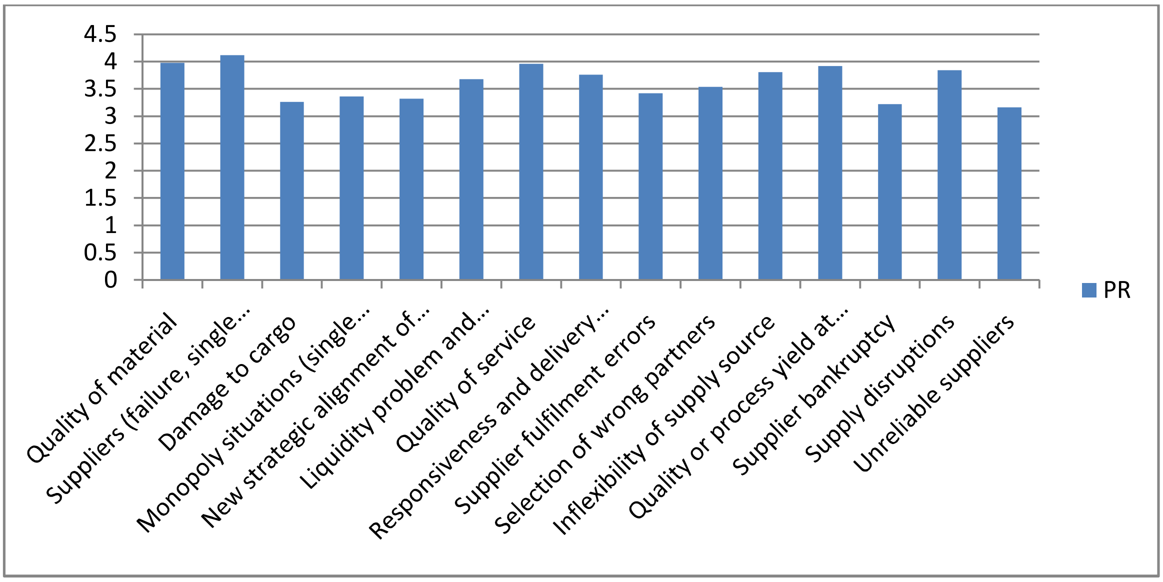


Figure 3.2: Procurement risks

3.5.3 Related to Process Risks

The most important type of process risks in supply chain as indicated by the respondents are related to lead time (Mean= 3.86), machine damage (Mean= 3.72), capacity bottleneck (Mean= 3.66) and others are indicated in the Table 3.3.

Table 3.3: Response for position of process risks

S.N.	Process risk related to	Mean
1.	lead time	3.86
2.	Capacity bottleneck	3.66
3.	Machine damage	3.72
4.	Human error	3.52
5.	Faulty planning	3.44
6.	Trouble with third-party logistics provider	3.36
7.	Inefficient supply teams in the organizations	3.18

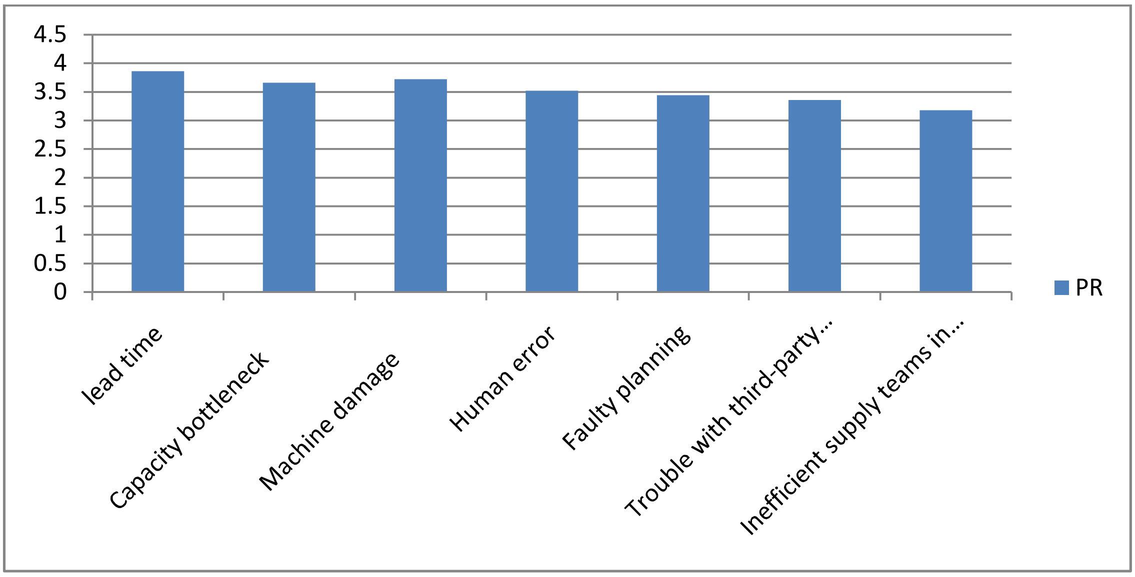


Figure 3.3: Process risks

3.5.4 Related to Demand Risks

The most important type of demand risk in supply chain as indicated by the respondents are lack of supply chain visibility (Mean= 3.76), Planning and communication flaws in sales (Mean= 3.66), Changes in preferences (Mean= 3.58) and others are indicated in the Table 3.4.

Table 3.4: Response for position of demand risks

S.N.	Demand risks related to	Mean
1.	Demand fluctuations	3.44
2.	Changes in preferences	3.58
3.	Cancellation of orders	3.32
4.	Planning and communication flaws in sales	3.66
5.	Order fulfilment errors	3.36
6.	Inaccurate forecasts due to longer lead times	3.16
7.	Seasonality of product	3.22
8.	Short life cycles	2.96
9.	Information distortion due to sales promotions and incentives	3.18
10.	Lack of supply chain visibility	3.76

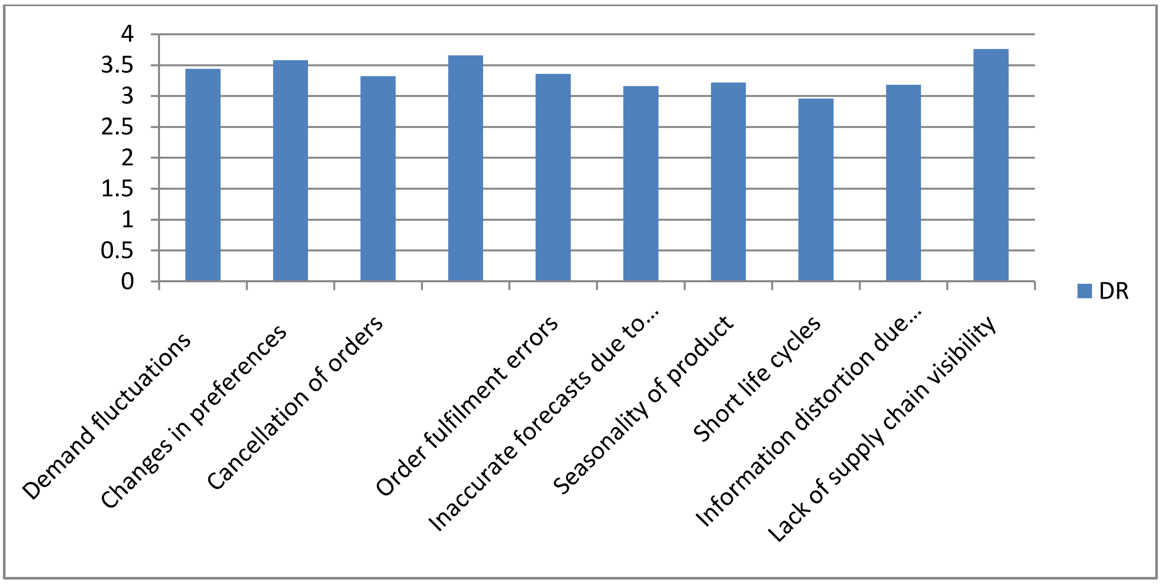


Figure 3.4: Demand risks

3.5.5 Related to Natural and Social Risks

The most important type of natural and social risks in supply chain as indicated by the respondents are natural disasters (Mean= 4.02), crime rate (Mean= 3.90), machine explosion (Mean= 3.88) and others are indicated in the Table 3.5.

Table 3.5: Response for position of natural and social risks

S.N.	Natural and social risks related to	Mean
1.	Natural disasters (fire, earthquake, flood, rock fall, landslide, avalanche, etc.)	4.02
2.	Political instability (strike, taxes, war, terrorist attacks, embargo, political labour conflicts,)	3.66
3.	Social and cultural grievances	2.98
4.	Crime rate	3.90
5.	Price and currency risks/inflation	3.44
6.	Unanticipated resource requirements	3.28
7.	High levels of CO_2 and polluting gas emissions during the global sourcing activity.	3.82
8.	Quota restrictions	2.66
9.	Machine explosion	3.88

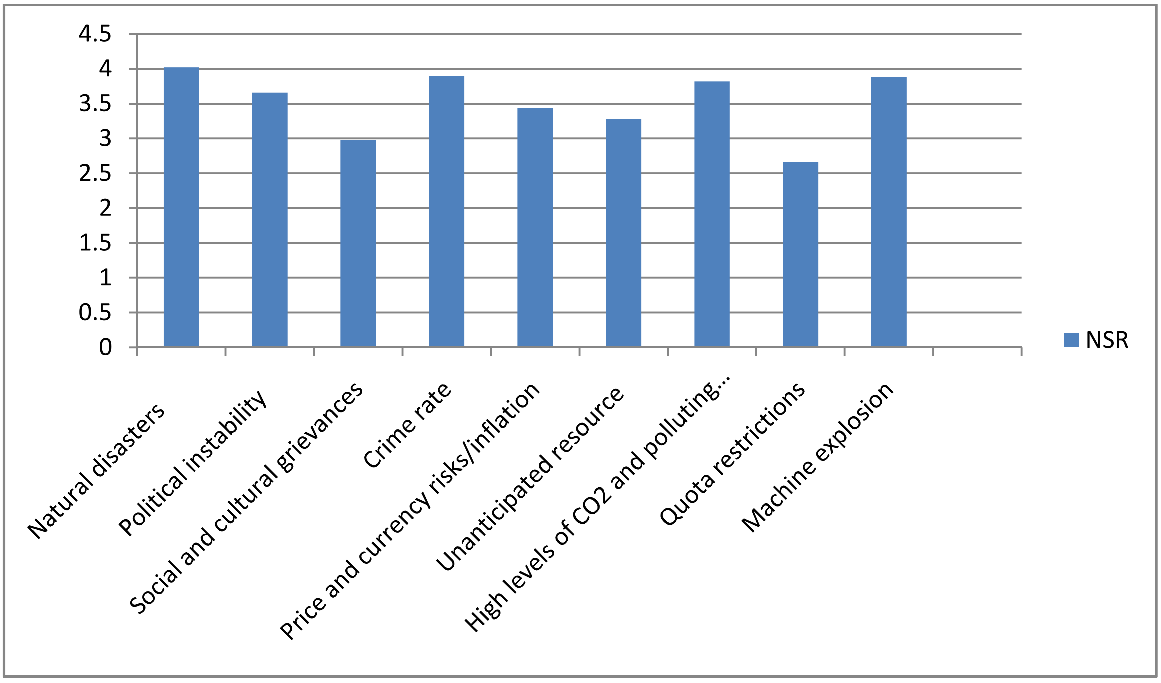


Figure 3.5: Natural and social risks

3.5.6 Related to Transportation Risks

The most important type of transportation risks in supply chain as indicated by the respondents are product deliveries (Mean= 3.88), higher costs of transportation (Mean= 3.64), depends on transportation mode chosen (Mean= 3.48) and others are indicated in the Table 3.6.

Table 3.6: Response for position of transportation risks

S.N.	**Transportation risks related to**	**Mean**
1.	Extensive paperwork and poor scheduling	3.18
2.	Port strikes	3.32
3.	Delay at ports due to limited port capacity	3.06
4.	Product deliveries	3.88
5.	Higher costs of transportation	3.64
6.	Depends on transportation mode chosen	3.48

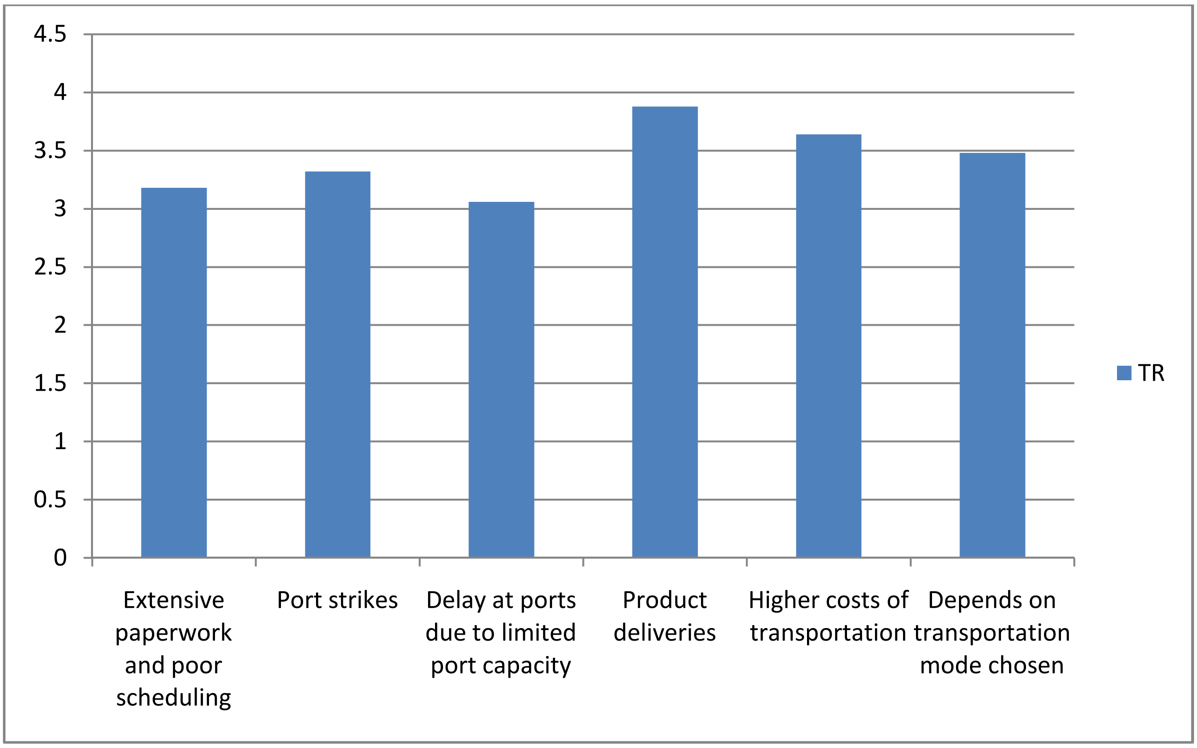


Figure 3.6: Transportation risks

3.5.7 Related to Market-Related Risks

The most important type of market related risks in supply chain as indicated by the respondents are number of qualified suppliers (Mean = 3.66), General increase in price fluctuation (Mean = 3.42), High degree of market saturation (Mean = 3.26) and others are indicated in the Table 3.7.

Table 3.7: Response for position of market-related risks

S.N.	Market-related risks related to	Mean
1.	Number of qualified suppliers	3.66
2.	High degree of market saturation	3.26
3.	General increase in price fluctuation	3.42
4.	High geographical concentration of the suppliers	3.18
5.	Low cost countries suppliers	2.98
6.	Level of supplier certification	2.76

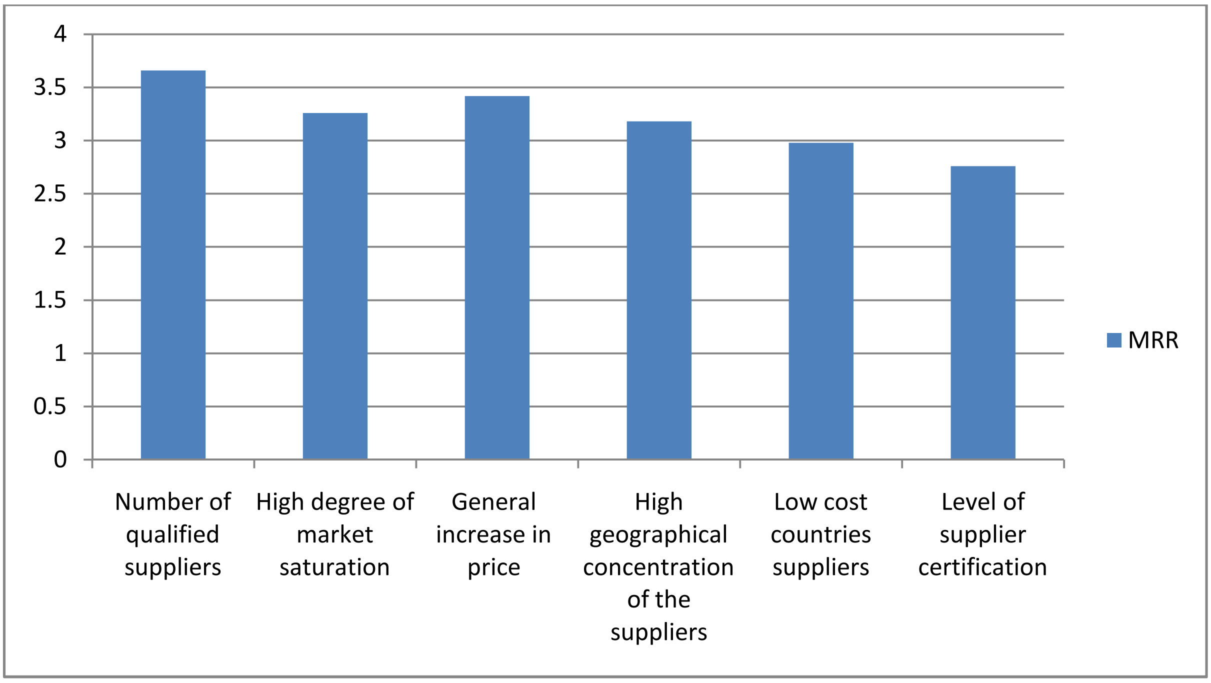


Figure 3.7: Market-related risks

3.5.8 Related to Supplier-Related Risks

The most important type of supplier related risks in supply chain as indicated by the respondents are qualitative problems (Mean= 3.92), delivery mistakes (Mean= 3.78), inability to quickly implement (Mean= 3.72) and others are indicated in the Table 3.8.

Table 3.8: Response for position of supplier-related risks

S.N.	Supplier-related risks related to	Mean
1.	Problems in the product quality	3.42
2.	Delivery mistakes	3.78
3.	Conflictual relationships	3.16
4.	Qualitative problems	3.92
5.	Cost increases	3.62
6.	Difficulties in satisfying the demand	3.26
7.	Technological backwardness	3.52
8.	Discontinuity of supply	3.09
9.	Financial instability	3.59
10.	Information technology	3.02
11.	Inadequate transport	2.97

12.	Inadequate inventory	2.84
13.	Inability to quickly implement	3.72
14.	Mix/Volume	3.36
15.	Inflexibility	2.77

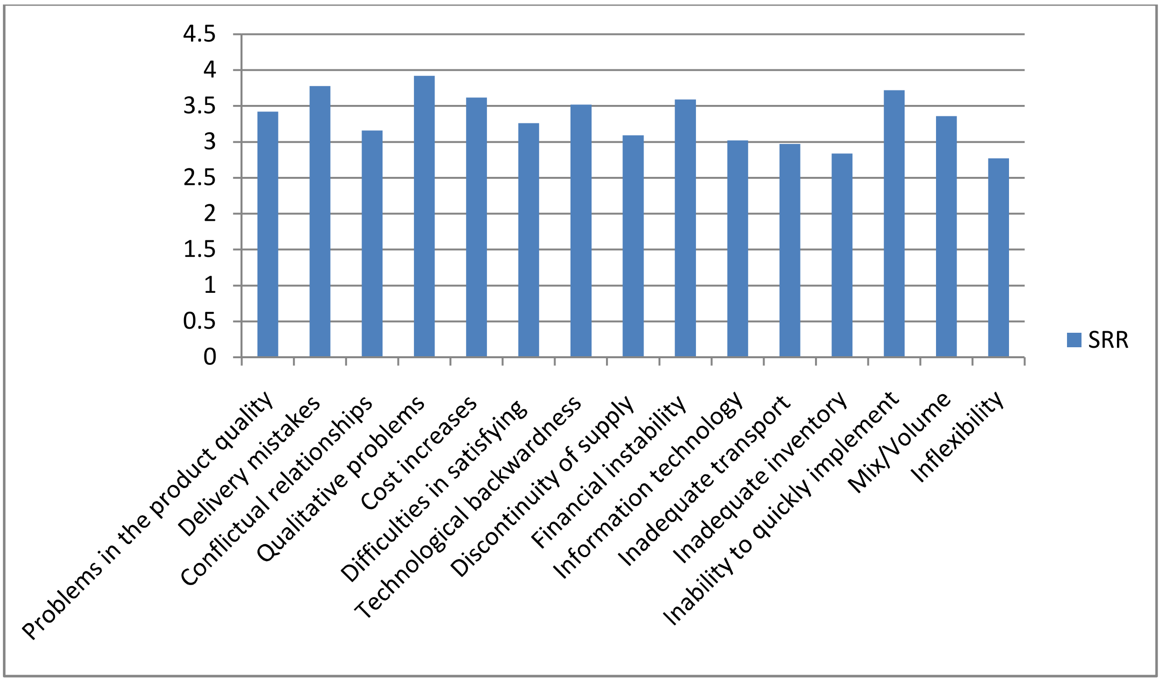


Figure 3.8: Supplier-related risks

3.5.9 Related to Financial Risks

The most important type of financial risks in supply chain as indicated by the respondents are economic recession (Mean= 3.88), fuel prices (Mean= 3.76), currency and foreign exchange rate fluctuations (Mean= 3.64) and others are indicated in the Table 3.9.

Table 3.9: Response for position of financial risks

S.N.	Financial risks related to	Mean
1.	Debt and credit rating	2.90
2.	Liquidity/cash	3.30
3.	Economic recession	3.88
4.	Financial market instability	3.52
5.	Currency and foreign exchange rate fluctuations	3.64
6.	Fuel prices	3.76
7.	Adverse changes in industry regulation	3.46
8.	Credit default	2.84

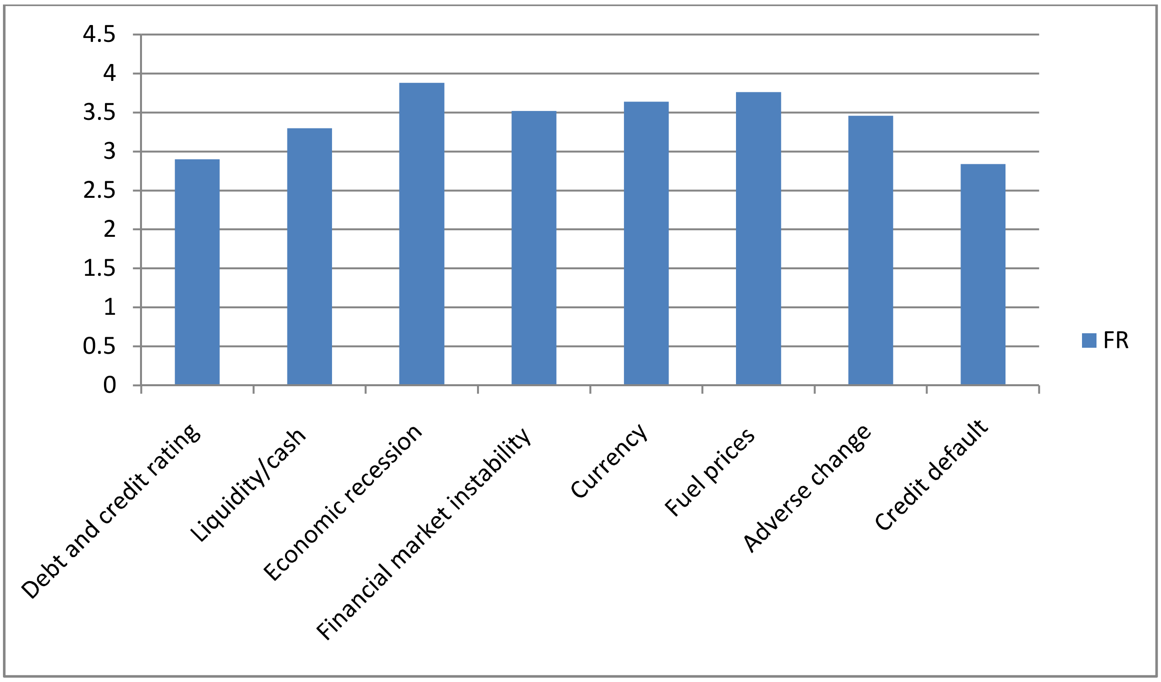


Figure 3.9: Financial risks

3.5.10 Related to Operations Risks

The most important type of operational risks in supply chain as indicated by the respondents are poor-quality (Mean= 3.81), Utilities failures (Mean= 3.67), HR risks (Mean= 3.54) and others are indicated in the Table 3.10.

Table 3.10: Response for position of operations risks

S.N.	Operations risks related to	Mean
1.	Theft of Informations	2.77
2.	Operator errors/accident damage	2.42
3.	Loss of key personnel	3.08
4.	Computer virus	2.47
5.	Poor-quality	3.81
6.	IT systems failures	3.48
7.	HR risks	3.54
8.	Loss of key supplier	2.97
9.	Logistics route or mode disruptions	2.68
10.	Loss of key equipment	3.27
11.	Utilities failures	3.67

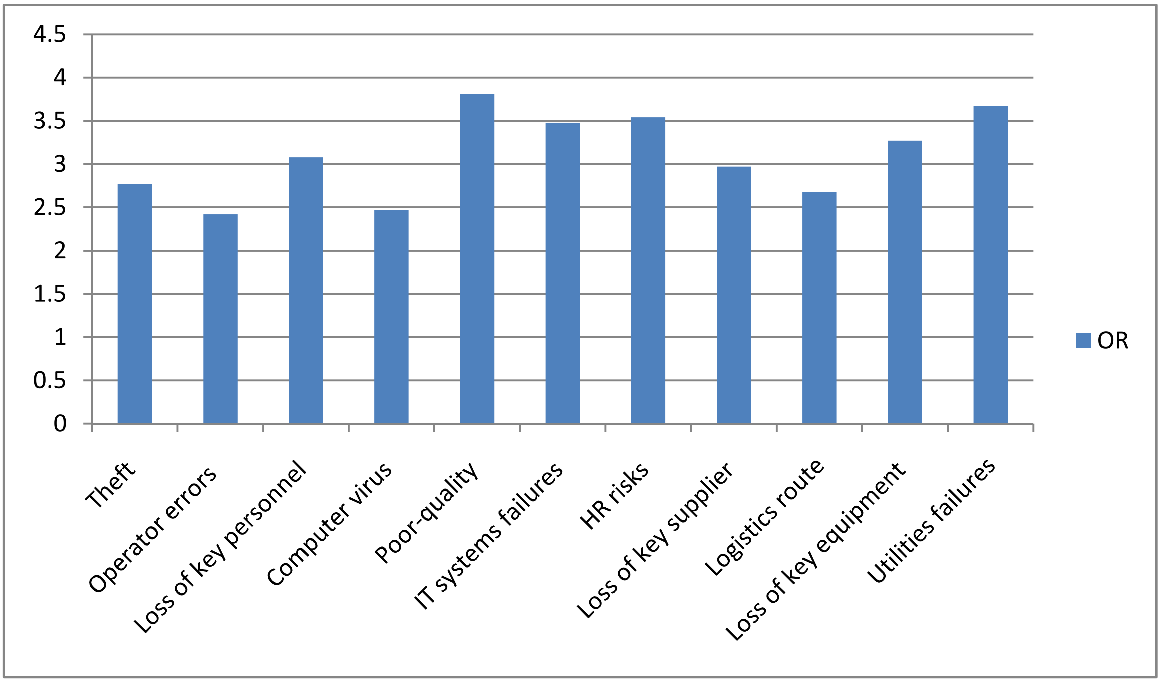


Figure 3.10: Operations risks

3.5.11 Related to Performance Measurement Risks

The most important type of performance measurement risks in supply chain as indicated by the respondents are product performance (Mean= 3.92), system development risk (Mean= 3.84), standardization (Mean= 3.78) and others are indicated in the Table 3.11.

Table 3.11: Response for position of performance measurement risks

S.N.	Performance measurement risks related to	Mean
1.	Requirement Uncertainty	3.42
2.	Residual performance risk	2.68
3.	Functional development risk	2.77
4.	System development risk	3.84
5.	Product performance	3.92
6.	Process performance	3.59
7.	Standardization	3.78
8.	Improper man-machine management	3.26
9.	Validation of product	2.97
10.	Risk of getting the appropriate quality material	3.09

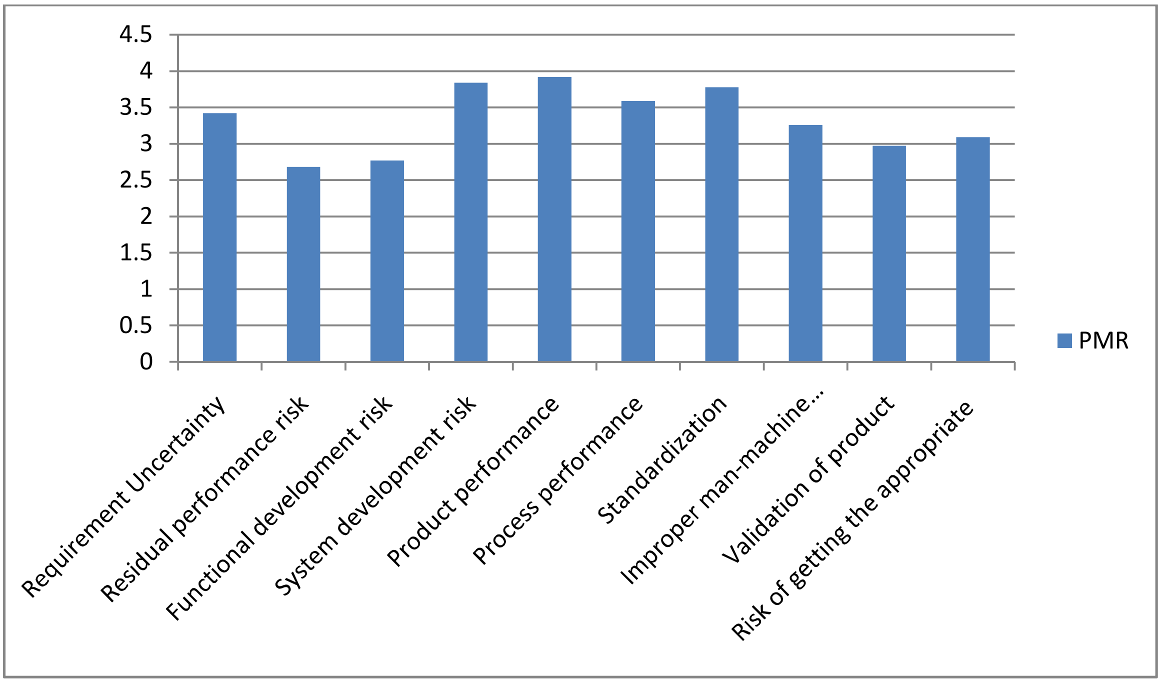


Figure 3.11: Performance measurement risks

3.5.12 Related to Performance Measurement

The most important factor affecting performance in supply chain as indicated by the respondents are customer satisfaction (Mean= 4.22), timely delivery of product (Mean= 4.16) and others are indicated in the Table 3.12.

Table 3.12: Response for position of performance measurement

S.N.	Performance measurement factors	Mean
1.	Manufacturing cost	3.96
2.	Level of inventory	3.72
3.	Timely delivery of product	4.16
4.	Flexibility in production	3.92
5.	Percentage reduction	3.42
6.	Labour productivity	3.66
7.	Capacity utilization	3.64
8.	Employ turnover rate	3.12
9.	Employ satisfaction	3.86
10.	Customer satisfaction	4.22
11.	Supplier satisfaction	3.74
12.	Respond well to customer demand for new features	3.80
13.	Process cycle time	3.84
14.	Market share	3.60
15.	Return on investment	3.48
16.	Net profit	3.54
17.	Total cost reduction	3.66
18.	Conformance with property specifications	3.97

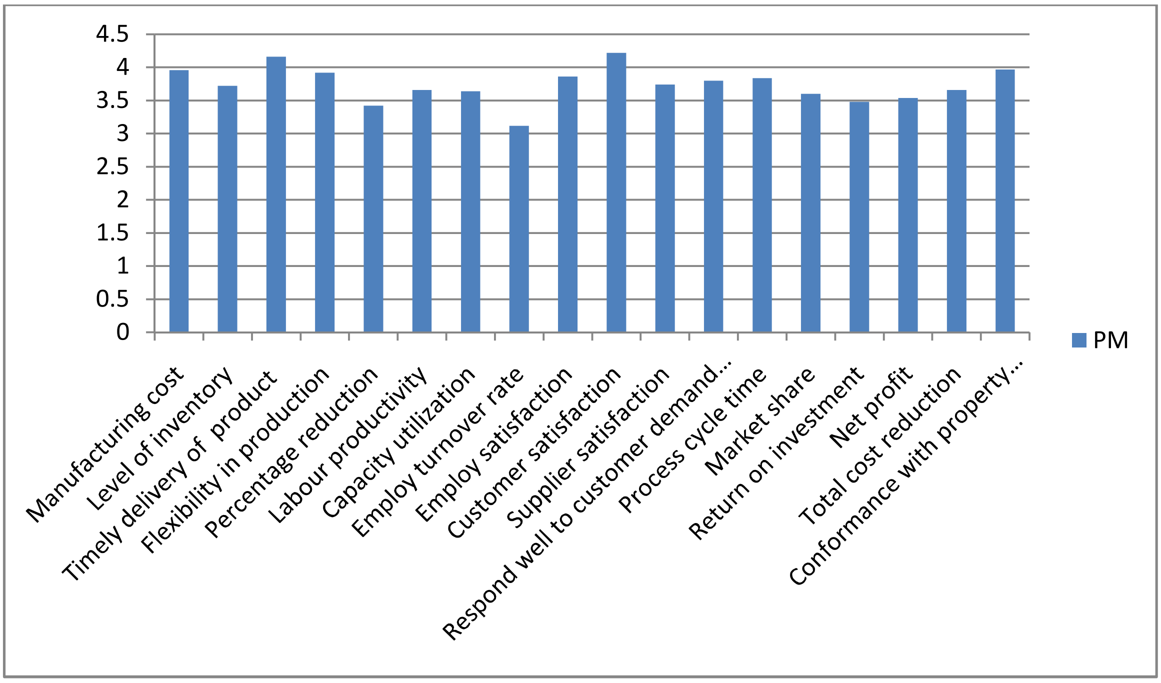


Figure 3.12: Performance measurement

3.5.13 Related to Barriers of Green Supply Chain

The most important barriers of the green supply chain as indicated by the respondents are lack of commitment from top management (Mean= 3.76), lack of integrated information system (Mean= 3.68), lack of Eco-literacy amongst supply chain partners (Mean= 3.66) and others are indicated in the Table 3.13.

Table 3.13: Response for position of green supply chain

S.N.	Green supply chain barriers	Mean
1.	Lack of commitment from top management	3.76
2.	Inadequate adoption of reverse logistic practices	3.22
3.	Lack of eco-literacy amongst supply chain partners	3.66
4.	Lack of corporate social responsibility	3.60
5.	Lack of market demand	3.52
6.	Lack of preparedness on part of suppliers	3.16
7.	Inadequate strategic planning	3.48
8.	Lack of integrated information system	3.68

9.	Lack of appropriate environmental performance metrics	3.40
10.	Lack of support and guidance from regulatory authorities	3.42
11.	Non adoption of cleaner technology	3.11

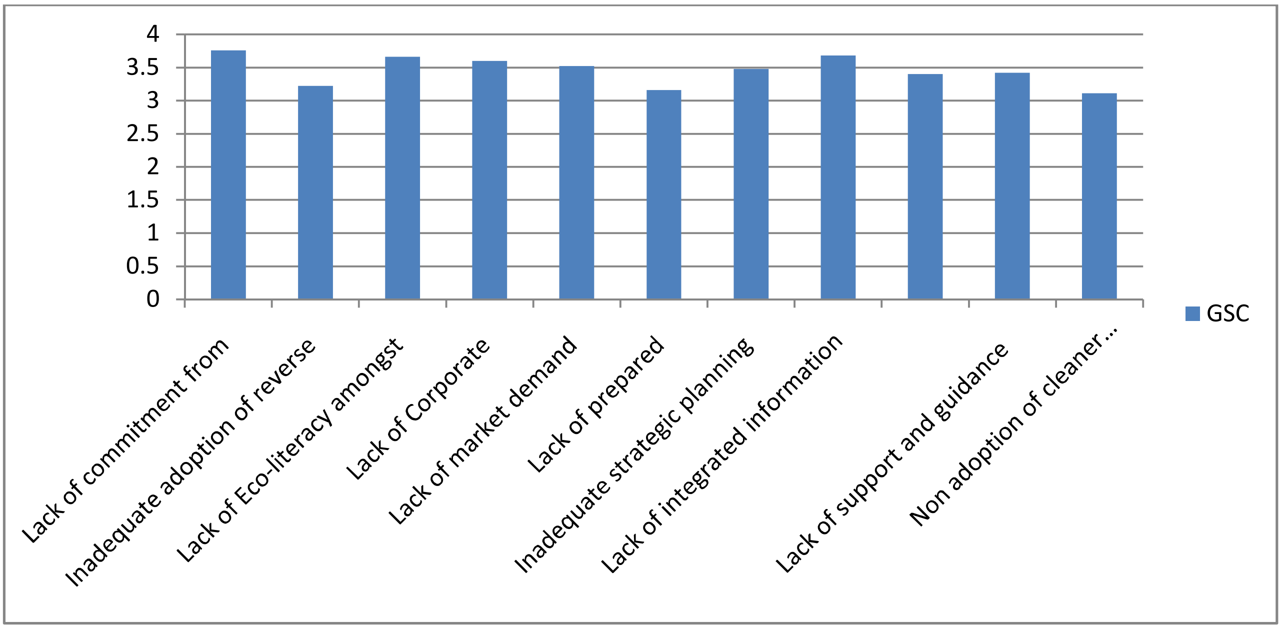


Figure 3.13: Green supply chain

3.5.14 Related to Barriers for SCM

The most important barriers of improving the supply chain as indicated by the respondents are vendor selection problems in the supply of high tech equipment (Mean= 3.76), Lack of supply chain planning and coordination (Mean= 3.69), Lack of knowledge (Mean= 3.56) and others are indicated in the Table 3.14.

Table 3.14: Response for position of barriers for SCM

S.N.	Barriers for SCM	Mean
1.	Vendor selection problems in the supply of high tech equipment	3.76
2.	Big loss of market share during transition period	3.41
3.	Lack of supply chain planning and coordination	3.69
4.	Demand uncertainties	3.21
5.	Lack of knowledge	3.56
6.	Lack of supply chain perception	3.13

7.	Inadequate IT infrastructure resources	2.76
8.	Lack of purchase management	3.46
9.	Fear of supply chain breakdown	2.49
10.	Lack of assets	2.98
11.	Lack of management obligation	3.32
12.	Costs of implementation	3.06
13.	Lack of sharing and accurate information	3.24
14.	Supply chain variance	3.52
15.	lack of awareness	3.22
16.	Increasing production time/financial problems	3.36
17.	Lack of time and management decision	3.27

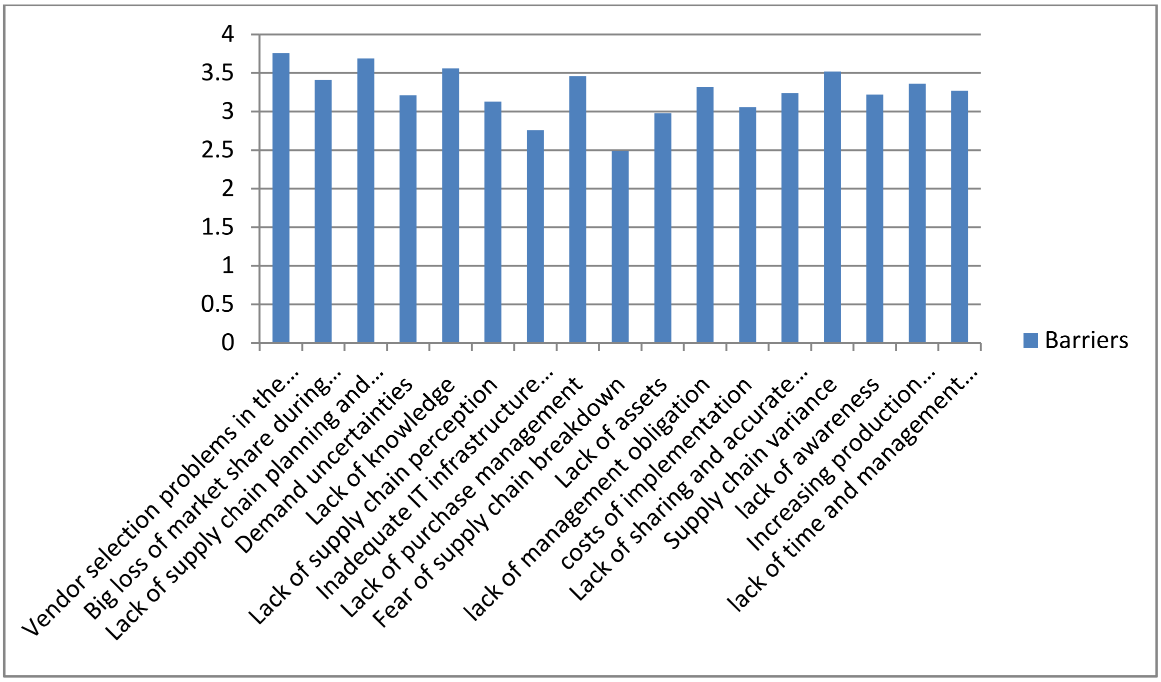


Figure 3.14: Barriers for SCM

3.5.15 Related to Critical Success Factors

The most important critical success factors for supply chain as indicated by the respondents are timely delivery (Mean= 3.98), improvement in product quality (Mean= 3.92), top management commitment (Mean= 3.84), and others are indicated in the Table 3.15.

Table 3.15: Response for position of critical success factors

S.N.	Critical success factors	Mean
1.	Top management commitment	3.84
2.	Development of effective SCM strategy	3.74
3.	Devoted resources for supply chain	2.98
4.	Logistics synchronization	3.10
5.	Use of modern technologies	3.64
6.	Forecasting of demand on Point of sale (POS)	3.44
7.	Trust development in SC partners	3.62
8.	Developing JIT capabilities in system	3.52
9.	Development of reliable suppliers	3.12
10.	Higher Flexibility in production system	3.70
11.	Focus on core strengths	3.48
12.	Improvement in Product quality	3.92
13.	Supply chain benchmarking	3.22
14.	Timely delivery	3.98
15.	Human resources development	3.42
16.	Reduction in product cost	3.78

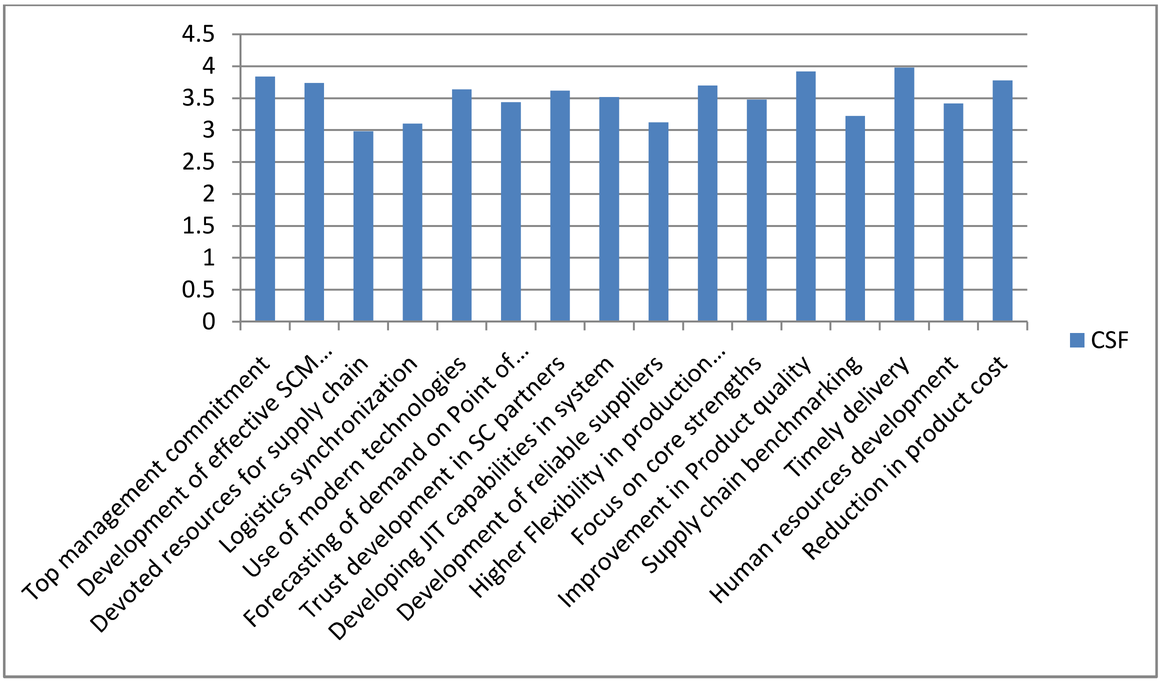


Figure 3.15: Critical success factors

3.5.16 Related to Agile Supply Chain Enablers

The most important enablers for improving the agile supply chain as indicated by the respondents are quality over product life (Mean= 3.64), employee satisfaction (Mean= 3.62), short development cycle time (Mean= 3.54), and others are indicated in the Table 3.16.

Table 3.16: Response for position of agile supply chain

S.N.	Agile supply chain management	Mean
1.	Enterprise integration	3.18
2.	Multi- venturing capabilities	3.24
3.	Team building	3.32
4.	Technology awareness	3.28
5.	Quality over product life	3.64
6.	Continuous improvement	3.50
7.	Trust based relationship with customers/ suppliers	3.12
8.	Response to changing market requirements	3.46

9.	Multi-skilled and flexible people	3.42
10.	Employee satisfaction	3.62
11.	Customer driven innovations	3.40
12.	Short development cycle time	3.54
13.	Culture of change	3.22

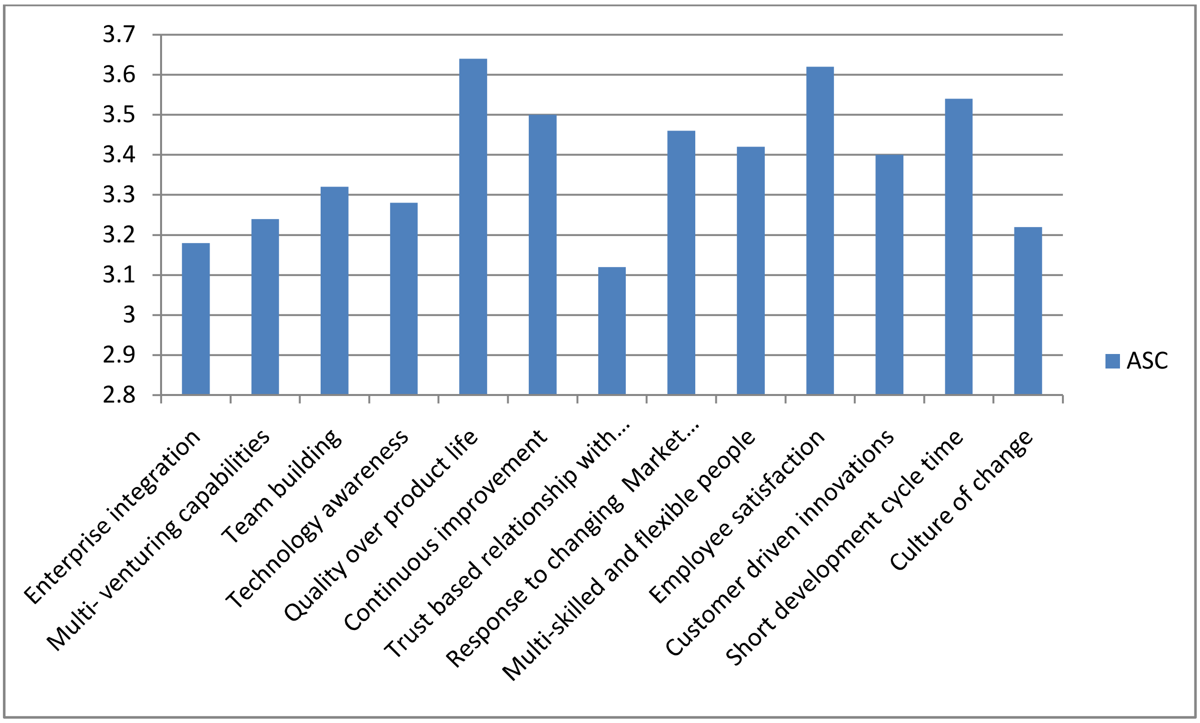


Figure 3.16: Agile supply chain

3.5.17 Related to Supplier Evaluation Factors

The most important factors for supplier evaluation as indicated by the respondents are commitment to quality (Mean= 4.12), on time delivery capability (Mean= 4.06), Cost effectiveness (Mean= 4.02), and others are indicated in the Table 3.17.

Table 3.17: Response for position of supplier evaluation

S.N.	Supplier evaluation factors	Mean
1.	Investment in plants and machines	3.84
2.	Willingness to share information	3.66
3.	Use of modern technology	3.62
4.	Capability to change product mix	3.98
5.	Transportation Facilities	3.80
6.	Proximity to plan	3.54
7.	Internal lean practices	3.22
8.	Capability of product design and development	3.92
9.	Commitment to quality	4.12
10.	On time delivery capability	4.06
11.	Cost effectiveness	4.02
12.	Interdependence	3.46
13.	Efficient in problem solving	3.70
14.	Warranty	3.88
15.	Long-Range Perspective	3.74

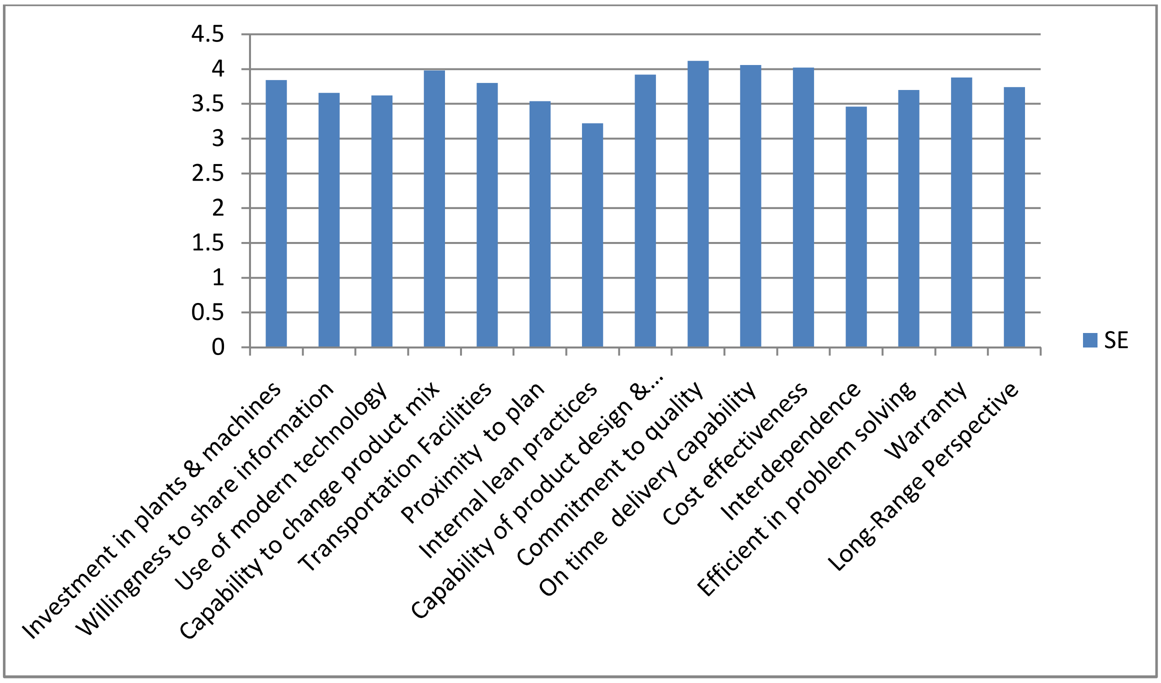


Figure 3.17: Supplier evaluation

3.5.18 Related to Reverse Supply Chain Factors

The most important factors of improving the reverse supply chain as indicated by the respondents are top management commitment (Mean= 3.98), cost benefits (Mean= 3.92), productivity and performance (Mean= 3.88) and others are indicated in the Table 3.18.

Table 3.18: Response for position of reverse supply chain

S.N.	Reverse supply chain factors	Mean
1.	Green purchasing	3.56
2.	Rules and regulations	3.52
3.	Environmental concerns	3.76
4.	State-of-art technologies	3.32
5.	Top management commitment	3.98
6.	Vertical co-ordination among supply chain partners	3.46
7.	Recapturing value from used products	3.44
8.	Resource reduction	3.72

9.	Competitiveness	3.62
10.	Proper disposal of end-of-life products	3.36
11.	Customer benefits	3.84
12.	Environmental benefits	3.74
13.	Cost benefits	3.92
14.	Green products	3.64
15.	Productivity and performance	3.88

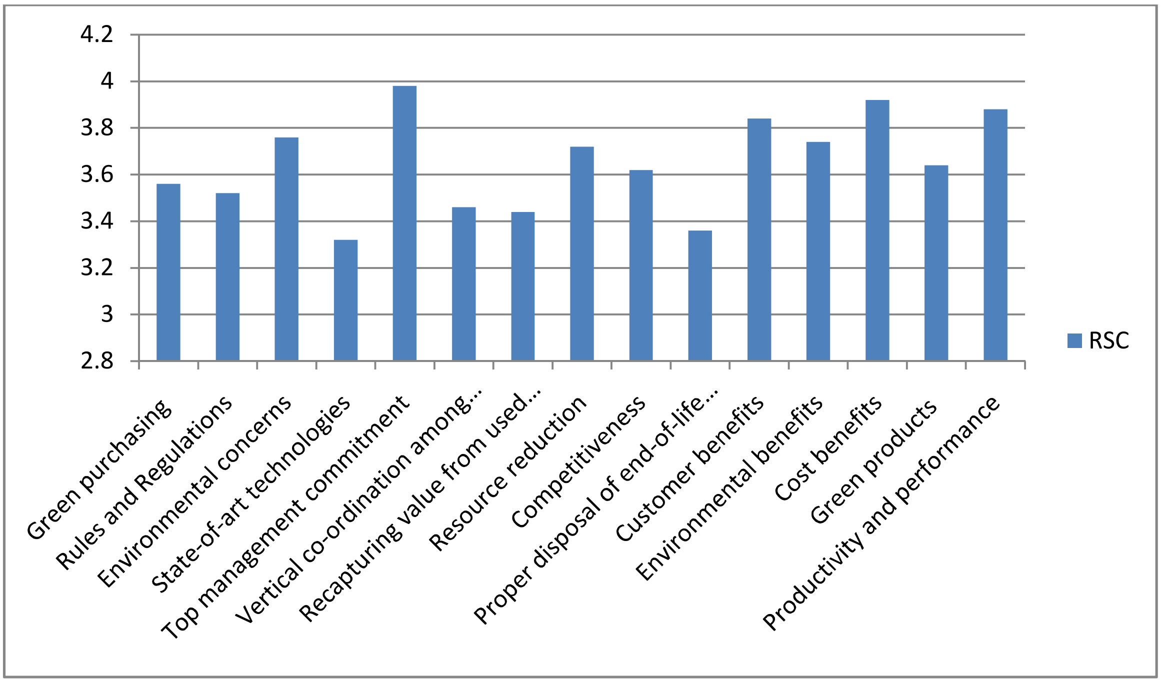


Figure 3.18: Reverse supply chain

3.6 DISCUSSION AND CONCLUSION

Different issues related to uncertainty and risk in supply chain, barriers, critical success factors and different types of supply chain in Indian manufacturing industries have been examined through the questionnaire based survey. The main objective of this survey was to find the present scenario of uncertainty and risk measurement in supply chain in Indian manufacturing industries. From the results of the survey, it is found that there are many factors which are helpful for uncertainty and risk management in supply chains. There are many barriers for risk reduction and for the successful supply chain management. This research empirically examines the response of Indian manufacturing industries towards uncertainty and risks. It is observed from the survey results that many types of risks are associated with supply chains. Therefore, for the successful management of supply chains, an effective and meaningful risk mitigation techniques or procedure is required to be developed.

CHAPTER IV

ANALYSIS OF OPERATIONAL RISKS IN SUPPLY CHAIN

4.1 INTRODUCTION

Supply chain management (SCM) is a set of approaches utilized to effectively integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide cost while satisfying service level requirements (Simchi- Levi et al., 2008). According to Venkatesan and Kumanan (2012) supply chain is a network of facilities designed to procure, produce and distribute goods to customers at right quantities, to the right locations and at the right time. Supply chain studies are focused for improving the operational efficiency through cost reduction. Supply chain involves the flows in the term of material, financial and information. It defines material flow as physical movement of products from suppliers to customers. Letters of credit, timely payment of bills, bankruptcy, payment schedules, credit terms and suppliers' contract fall under the category of financial flows. Finally, the information flow is used to keep all supply chain elements updated and hence provides resources for decision making. Risk management skills which includes, awareness of risk signals, developing risk management plans, and improving end to end information visibility are essential requirements for the successof supply chain (Giunipero and Pearcy, 2000; Christopher and Lee, 2004). Yu and Ramanathan (2011) have suggested that the strongest business environmental factors that influence the degree of emphasis placed on operations strategy choices is environmental dynamism. When faced with the same environmental stimuli, firms with different firm characteristics (such as firm size, firm age, and firm nationality) choose to emphasise different operations strategies.

Few areas of management interest have risen to prominence in recent years as rapidly as supply chain risk management (SCRM), both from the practitioners' perspective and as a research area. The randomness of the business environment, variable consumer demands, actions by competitors, along with market dynamics and continuous improvement initiatives within organisations imply that the supply chain never actually reaches a stable steady state condition (Braithwaite and Wilding, 2005;

Christopher, 1998; Haywood and Peck, 2004). These parameters of uncertainty and risk can promulgate through an effective supply chain design (Christopher, 1998; Vorst and Beulens, 2002).

According to Christopher and Lee (2004) managing risks in the modern environment is becoming increasingly challenging, because of uncertainties in supply and demand, global outsourcing and short product life cycles. Risk in this context can be defined as the potential for unwanted negative consequences that arise from an event or activity (Rowe, 1980). Risk management is becoming an integral part of a holistic SCM design (Christopher and Lee, 2004). There is diverse classification of SC risks found in the literature. Risk itself can be termed as deviation, disruption, vulnerability, uncertainty, disaster, peril and hazard. Vorst and Beulens (2002) have defined uncertainty as a situation for the SC where the decision maker lacks information about the SC network and the environment and hence is unable to predict the impact of the event on SC behaviour. According to Knight (1921) although risk and uncertainty are interchangeably used in SC literature, uncertainty is immeasurable as it lacks complete certainty and has more than one possibility. On the other hand, risk is measurable as it is an outcome of uncertainty with some of possibilities involving loss or other undesirable outcomes (Hubbard, 2007; Hubbard, 2009). According to Williams et al. (2008) SC security is a subcomponent of overall risk management strategy within the organization.

The major risk issues which affect the operation of supply chain are product and process design risk, production capacity risk, and operational disruption. First, product and process design risk occurs with the inability to cope with changes, in particular associated with new product development stage and product launch activity (Handfield et al., 1999; Khan et al., 2008). Production capacity risk refers to technological, skills and quality capacities (Handfield et al., 1999). Finally, operational disruption often happens due to operational contingencies, natural disasters and political instability including terrorism (Kleindorfer and Saad, 2005). Min and Kim (2011) have described indiscreet strategy of sourcing from low cost countries can backfire, since a multitude of invisible supply chain risks may incur hidden costs and subsequently offset cost saving opportunities.

Other risk issues are demand volatility/seasonality, balance of unmet demand and excess inventory. These issues are all affected by the forecasting difficulties due to seasonality, volatility of fads, new product adoptions and short product life (Johnson, 2001;Wong and Hvolby, 2007). In addition, due to rapid technology evolvement and variation in customer demand, excess inventory may expose the obsolete risk (Narayanan and Raman, 2004). Steffen et al. (2008) have highlighted the risk issues pertaining to the sourcing or purchasing decisions in the supply chain. This decision in the production process might give rise to poor quality, higher transportation costs, lower reliability, supply disruptions, logistical failures, natural disasters and increased communication difficulties etc. they have cited. In the recent years supply chain has become increasing vulnerable to risks resulting in poor financial performance and customer service (Venkatesan and Kumanan, 2012). According to Smith (2011) the implementation process is the single most important process to determine if a company will take advantage and achieve all of the possible operational benefits. However, there is some risk due to this relationship. In order that the challenges can be met successfully, it is important that enterprises should be helped to both recognise the risks and then surmount them.

In this chapter, some of the operational risk factors have been identified through the literature review and expert opinion in this domain. An interpretive structural modelling (ISM) approach and a method of effectiveness index is used to analyse these factors. The main objectives of this chapter are as follows:

- To identify and rank the operational risk factors in a supply chain
- To establish the relationship among these factors.
- To find out the effectiveness index of these factors.

Table 4.1: Operational risks in supply chain

S.NO.	Operational Risks	Mean Score	Rank	Sources
1.	Poor quality	3.81	1	Treleven and Schweikhart (1988); Zsidisin et al. (2000); Svensson (2004)
2.	Utility failure	3.67	2	Sounderpandian et al. (2008); Cavinato (2004)
3.	HR problems	3.54	3	Speckman and Davis (2004); Peck (2005)
4.	IT system failure	3.48	4	Banker and Khosla (1983); Glasserman and Wang (1998)
5.	Loss of key equipment	3.27	5	Krause et al. (1998); Chen et al. (2000, 2003)
6.	Loss of key personnel	3.08	6	Griffiths and Margetts (2000); Kolisch (2000)
7.	Loss of key suppliers	2.97	7	Hegedus and Hopp (2001); Childerhouse et al. (2002)
8.	Theft of information	2.77	8	Muffato and Payaro (2002), Song and Yao (2002)
9.	Logistic disruption	2.68	9	Medori and Steeple (2000); Neely (1998); Faisal et al. (2007)
10.	Computer virus	2.47	10	Iyer et al. (2003), Wagner et al. (2003); Biswas and Narahari (2004);

4.2 ANALYSING THE OPERATIONAL RISKS USING WEIGHTED INTERPRETIVE STRUCTURAL MODELING (W-ISM)

For analysing the operational risk and developing the framework a W-ISM methodology have been used. Framework has been developed by using the ISM is further used to evaluate the effective index of operational risks in supply chain. The various steps, which lead to the development of ISM model, are illustrated below.

Step 1: Establishing the contextual relationship between factors

For developing a contextual relationship of factors, an 'affect to' type of relation is chosen for completing this purpose. Which means that one risk factor affect to another chosen risk factor. Based on this concept, a contextual relationship among risk factors is developed. Six experts in this domain, three from industry and three from academia, were consulted in developing the contextual relationship among these factors. Keeping in mind the contextual relationship for each factor, the existence of a relation between any two factors (i and j) and the associated direction of this relation has been decided. The following symbols (V, A, X, O) have been used to denote the direction of the relationship between two risk factors (i and j):

- V - Risk factors i will affect j.
- A - Risk factors j will affect i.
- X - Risk factors i and j will affect to each other.
- O - No relation between two risk factors.

For example: if risk factor 4 affects 9 than indicate the symbol V in concerned cell and if there is no relation between risk factors 7 and 8 then indicate the symbol O in the concerned cell. These notations (V, A, X, O) are used in Table 4.2 for developing the structural self-interaction matrix **(**SSIM) matrix.

Step 2: Development of Reachability Matrix (RM)

The RM is obtained from SSIM. The RM indicates the relationship between operational risks in the binary form. The various relationships between risks depicted by symbols V, A, X and O used in SSIM are replaced by binary digits in the form of 0 and 1. The following rules are used to substitute V, A, X and O of SSIM to get reachability matrix:

- If the cell (i, j) in SSIM is assigned with symbol V, then, this cell (i, j) entry becomes 1 and (j, i) entry becomes 0 in the RM.

- If the cell (i, j) in SSIM is assigned with symbol A, then, this cell (i, j) entry becomes 0 and (j, i) entry becomes 1 in the RM
- If the cell (i, j) in SSIM is assigned with symbol X, then, this cell (i, j) entry becomes 1 and (j, i) entry becomes 1 in the RM
- If the cell (i, j) in SSIM is assigned with symbol, then, this cell (i, j) entry becomes 0 and (j, i) entry also becomes 0 in the initial RM.

Thus RM developed is known as initial RM which is depicted in Table 4.3. The final RM is obtained by incorporating the transitivity. Transitivity is defined as a relation between three elements such that if relationship holds between the first and second - second and third, then relationship must necessarily holds between the first and third. After incorporating the necessary changes final RM is shown in Table 4.4, where transitivity is marked as 1*.

Table 4.2: Structural Self-Interaction Matrix (SSIM)

Risk factors	10	9	8	7	6	5	4	3	2
1	O	O	A	A	A	A	A	A	V
2	A	O	O	A	O	A	A	A	
3	V	V	V	O	A	O	A		
4	A	V	O	O	O	O			
5	O	A	A	O	V				
6	O	A	A	A					
7	O	O	O						
8	V	V							
9	O								

Table 4.3: Initial reachability matrix

Risk factors	1	2	3	4	5	6	7	8	9	10
1	1	1	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0
3	1	1	1	1	0	0	0	1	1	1
4	1	1	0	1	0	0	0	0	1	0
5	1	1	0	0	1	1	0	0	0	0
6	1	0	1	0	0	1	0	0	0	0
7	1	1	0	0	0	1	1	0	0	0
8	1	0	0	0	1	1	0	1	1	1
9	0	0	0	0	1	1	0	0	1	0
10	0	1	0	1	0	0	0	0	0	1

Step 3: Partitioning the reachability matrix

According to Warfield (1974; 1987) and Farris and Sage (1975), the reachability set and antecedent set of risk factors are extracted from final RM. After finding the reachability set and antecedent set, the intersection of all of these sets are derived for these factors. Those factors for which the reachability set and antecedent set have same value are places at the top level in ISM hierarchy.

Once the top level factor is identified, it is extracted from consideration and other top level factors of the remaining sub graph are found. This procedure is continued till all levels of the structure are identified. These identified levels help in the development of digraph and the final model. Top level factor is positioned at the top of digraph and so on. From ISM utility failure is found at the top level I and positioned at the top of hierarchy.

Table 4.4: Final reachability matrix

Risk factors	1	2	3	4	5	6	7	8	9	10
1	1	1	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0
3	1	1	1	1	1*	1*	0	1	1	1
4	1	1	0	1	1*	1*	0	0	1	0
5	1	1	1*	0	1	1	0	0	0	0
6	1	1*	1	0	0	1	0	0	0	0
7	1	1	1*	0	0	1	1	0	0	0
8	1	1*	1*	1*	1	1	0	1	1	1
9	1*	1*	1*	0	1	1	0	0	1	0
10	1*	1	0	1	0	0	0	0	1*	1

In the present case, the risk factors, along with their reachability set, antecedent set, Intersection set and levels are presented in Tables 4.5 - 4.12.

Step 4: Development of conical matrix

A conical matrix is developed by clubbing together all of the risk factors in the same level, across rows and columns of the final RM, as shown in Table 4.13. The drive power and dependence power of all of the risk factor is calculated by summing up the number of ones in rows and the columns respectively.

Step 5: Development of digraph and ISM model

Based on the conical matrix, a digraph including transitivity links is obtained. This is generated by nodes and lines of edges. After removing the indirect links, a final digraph is developed. In this development, the top level factor is positioned at the top of the digraph and second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. Then digraph obtained is converted into the ISM model by converting the node into risk factors as shown in Figure 5.1.

Table 4.5: Iteration 1

Risk factors	Reachability set	Antecedent set	Intersection set	Level
1	1,2	1,3,4,5,6,7,8,9,10	1	
2	2	1,2,3,4,5,6,7,8,9,10	2	**I**
3	1,2,3,4,5,6,8,9,10	3,5,6,7,8,9	3,5,6,8,9	
4	1,2,4,6,7,9	3,4,8,10	4	
5	1,2,3,5,6	3,4,5,8,9	3,5	
6	1,2,3,6	3,4,5,6,7,8,9	3,6	
7	1,2,3,6,7	7	7	
8	1,2,3,4,5,6,8,9,10	3,8	3,8	
9	1,2,3,5,6,9	3,4,8,9,10	3,9	
10	1,2,4,9,10	3,8,10	10	

Table 4.6: Iteration 2

Risk factors	Reachability set	Antecedent set	Intersection set	Level
1	1	1,3,4,5,6,7,8,9,10	1	**II**
3	1,3,4,5,6,8,9,10	3,5,6,7,8,9	3,5,6,8,9	
4	1,4,6,7,9	3,4,8,10	4	
5	1,3,5,6	3,4,5,8,9	3,5	
6	1,3,6	3,4,5,6,7,8,9	3,6	

7	1,3,6,7	7	7	
8	1,3,4,5,6,8,9,10	3,8	3,8	
9	1,3,5,6,9	3,4,8,9,10	3,9	
10	1,4,9,10	3,8,10	10	

Table 4.7: Iteration 3

Risk factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
3	3,4,5,6,8,9,10	3,5,6,7,8,9	3,5,6,8,9	
4	4,6,7,9	3,4,8,10	4	
5	3,5,6	3,4,5,8,9	3,5	
6	3,6	3,4,5,6,7,8,9	3,6	**III**
7	3,6,7	7	7	
8	3,4,5,6,8,9,10	3,8	3,8	
9	3,5,6,9	3,4,8,9,10	3,9	
10	4,9,10	3,8,10	10	

Table 4.8: Iteration 4

Risk factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
3	4,5,8,9,10	5,7,8,9	5,8,9	
4	4,7,9	4,8,10	4	
5	5	4,5,8,9	5	**IV**
7	7	7	7	**IV**
8	4,5,8,9,10	3,8	8	
9	5,9	4,8,9,10	9	
10	4,9,10	8,10	10	

Table 4.9: Iteration 5

Risk factors	**Reachability set**	**Antecedent set**	**Intersection set**	**Level**
3	4,8,9,10	8,9	8,9	
4	4,9	4,8,10	4	
8	4,8,9,10	8	8	
9	9	4,8,9,10	9	**V**
10	4,9,10	8,10	10	

Table-4.10: Iteration 6

Risk factors	Reachability set	Antecedent set	Intersection set	Level
3	4,8,10	8	8	
4	4	4,8,10	4	**VI**
8	4,8,10	8	8	
10	4,10	8,10	10	

Table 4.11: Iteration 7

Risk factors	Reachability set	Antecedent set	Intersection set	Level
3	8,10	8	8	
8	8,10	8	8	
10	10	8,10	10	VII

Table 4.12: Iteration 8

Risk factors	Reachability set	Antecedent set	Intersection set	Level
3	8	8	8	**VIII**
8	8	8	8	**VIII**

Table 4.13: Conical matrix

Risk factors	2	1	6	5	7	9	4	10	3	8	Drive Power
2	0	1	0	0	0	0	0	0	0	0	1
1	1	1	0	0	0	0	0	0	0	0	2
6	1	1	1	0	0	0	0	0	1	0	4
5	1	1	1	1	0	0	0	0	1	0	5
7	1	1	1	0	1	0	0	0	1	0	5
9	1	1	1	1	0	1	0	0	1	0	6
4	1	1	1	1	0	1	1	0	0	0	6
10	1	1	0	0	0	1	1	1	0	0	5
3	1	1	1	1	0	1	1	1	1	1	9
8	1	1	1	1	0	1	1	1	1	1	9
Dependence Power	9	10	7	5	1	5	4	3	6	2	

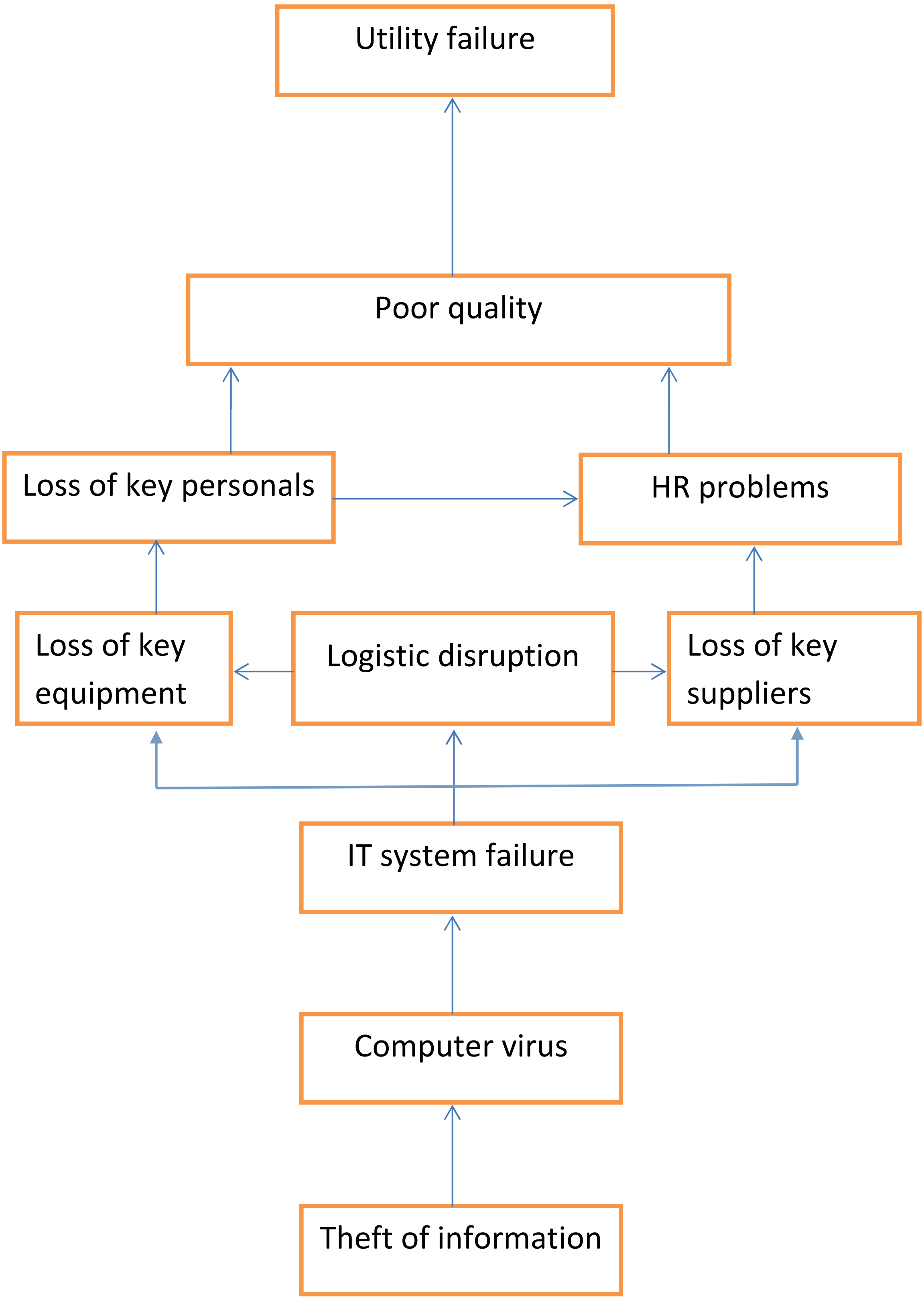


Figure 4.1: ISM model showing the levels of operational risks

4.3 CLASSIFICATION OF OPERATIONAL RISKS ON THE BASIS OF MICMAC ANALYSIS

Matriced'Impactscroises-multipication appliqué anclassment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The main purpose of MICMAC analysis is to analyse the drive power and dependence power of factors. Risk factors are classified into four clusters. First cluster consists of 'autonomous factors' which have weak drive power and weak dependence.

Table 4.14: Clusters of factors affecting the operational risks

10										
9		**8**	**IV**			**3**		**III**		
8										
7										
6				**4**	**9**					
5	**7**		**10**		**5**					
4							**6**			
3			**I**					**II**		
2									**1**	
1										**2**
Driving Power/ ↑ Dependence Power →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

They are relatively disconnected from the system, with which they have few links, which may be very strong. The second cluster consists of 'dependent factors' which have weak drive power but strong dependence power. Third cluster includes ‘linkage factors’ which have strong drive power as well as strong dependence. These are unstable. Any action on these will affect others and also a feedback effect on themselves. Fourth cluster has the ‘independent factors’ having strong drive power but weak dependence power.

The drive power and dependence power of all factors is shown in Table 4.13. Thereafter, the drive power and dependence power diagram is drawn as shown in Table 4.14. In this illustration, it is observed from Table 4.14 that factor 8 has driven power 9 and dependence power 2, hence it is positioned at a place which corresponds to drive power 9 and dependence 2, i.e. in the fourth cluster. Now, its position in the fourth cluster shows that it is independent factors. Similarly, all the factors are positioned at places corresponding to their driving power and dependence.

4.4 EVALUATION OF EFFECTIVENESS INDEX

For computing the effectiveness index the mean score with their rank of operational risks has been calculated on the basis of Table 4.1. After this rank, inverse rank and weight for each factor has been calculated. For assigning weight to different factors of effectiveness index, the highest and lowest values of five point Likert scale i.e. 5 and 1 are mapped 100% and 0% respectively. For each of the issues of effectiveness a weight is assigned. The criteria for weight (Wi) is as under:

Wi= +1 (Strength), when percentage score > 60% (Mean value>3).

= 0 (Neutral), when percentage score is between 40-60% (Mean value between 2 and 3).

= -1 (Weakness), when percentage score < 40% (Mean value <2). This framework was given by Cleveland et al. 1989 is Cj= Sum [Wi X Log Ki]. Chand and Singh (2010) have also used this model for study the select issues of supply chain management.

Sum of entries of last column (Wi X Log Ki), will give effectiveness index i.e. 5.1792. Theoretically, effectiveness index value may range between -6.5593 to +6.5593. Computation of effectiveness index for this study is illustrated with the help of a worksheet as shown in Table 4.15.

Table 4.15: Measurement of effectiveness index

S. No.	Risk factors	Mean	Rank	Inverse Rank(Ki)	Log Ki	Weight (Wi)	Wi X Log Ki
1	Poor quality	3.81	1	10	1	+1	1
2	Utility failure	3.67	2	9	0.9542	+1	0.9542
3	HR problems	3.54	3	8	0.9030	+1	0.9030
4	IT system failure	3.48	4	7	0.8450	+1	0.8450
5	Loss of key equipment	3.27	5	6	0.7781	+1	0.7781
6	Loss of key personnels	3.08	6	5	0.6989	+1	0.6989
7	Loss of key suppliers	2.97	7	4	0.6020	0	0
8	Theft of information	2.77	8	3	0.4771	0	0
9	Logistic route/mode disruption	2.68	9	2	0.3010	0	0
10	Computer virus	2.47	10	1	0.0000	0	0

4.5 RESULTS AND DISCUSSION

This chapter identifies the risk factors which significantly affect the operation of SC in an industry so that management may effectively deal with such type of factors. In this chapter, an ISM-based model has been developed to analyse the interactions among different operational risk factors. It identifies the hierarchy of actions to be taken for handling different factors which affect the operation of SC. The managers can get an insight of these factors and understand their relative importance and interdependencies. The driver power dependence matrix (Table 4.14) gives some valuable insights about the relative importance and interdependence among the operational risk factors. This study has some other implications for the practicing managers not only to deal with operational risks but also the other type of risks occurs in SC. The identified factors need to be overcome by the management of the firms. The driver power dependence diagram gives some valuable insights about the relative importance and interdependencies of the factors. The managerial implications as emerging from this chapter are as follows:

- The driver power dependence (Table 4.14) indicates that there are three autonomous factors, i.e. Loss of key equipment, Loss of key suppliers, computer virus affecting the operation of SC. These factors are weak drivers and weak dependents and do not have much influence on the system.
- Dependent factors are ‘poor quality, utility failure, loss of key personnels’. These factors are weak drivers but strongly depend on one another.
- Factor 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 operation risk in supply chain.
- It is further observed that factors ‘Theft of information, Logistic route/mode disruption, IT system failure are independent factors, i.e. they have strong driving power and less dependent on other factors. Therefore, these are strong drivers and may be treated as the root causes of all the factors. These factors may be treated as the ‘key risk factors’ for affecting the operation in SC.

Based on response from questionnaire survey on various risk factors, effectiveness index for the operation risks in supply chain has been evaluated (Table 4.15). Effectiveness index has been found to be 5.179. Maximum value can reach up to 6.559. Presently effectiveness index of this study among these factors is quite high. This approach can be utilized by the organization to benchmark its performance with national and international standards. It can also help in SWOT analysis of the organizations. It has been observed that organizations are doing quite well in terms of quality, HR, IT, key equipments and key personnels, 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 considered in this chapter.

4.6 CONCLUSION

This chapter presents arguments on operational risks. There is a need to understand the importance and interrelationship between the risk factors. However the research in the area of supply chain and operation management is yet to formalize the risk associated with the operation in supply chain. This will help the authors to identify and develop the nomenclature of operational risks that impact on supply chain. The present study will help the decision-makers to estimate the impact risks and develop the suitable strategies to manage them. The combine approach of interpretive structural modeling (ISM) and effectiveness index (EI) used in this study offers a precise and accurate analysis by integrating the different factors.

CHAPTER V

ANALYSIS OF COMPETITIVENESS OF UNCERTAINTY AND RISK MEASURES IN SUPPLY CHAIN

5.1 INTRODUCTION

Supply chain management (SCM) plays a vital role in operations strategy for achieving organizational competitiveness. Companies are bidding to find different ways to improve their flexibility and responsiveness in the term of competitiveness by changing their operations strategy, methods and technologies (Gunasekaran and Nagi, 2004). Supply chain risk 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; Diabat et al. 2012). A failure of any one element in supply chain potentially causes disruptions for all partnering companies at upstream and downstream level (Yang and Yang, 2010).

Independent firms constituting a supply chain frequently consider conflicting goals, which extend across pricing, purchasing, inventory, transportation, production, service, and other such functions (Kogan andTapiero, 2007). Supply chain risk identification is based on the development of taxonomies of risks, associated sources and manifestations. Supply chain risks are classified according to the material, information and economic flows. Delays or poor quality of suppliers, production disruptions, inadequate inventory levels and lack of capacity are some of the most frequently identified risks which are related to the flow of materials (Cagliano et al., 2012). Kern et al. (2012) have developed a model for upstream supply chain risk management linking risk identification, risk assessment and risk mitigation to risk performance and validate the model empirically. Although investing in accurate forecasting and market research methods diminish the uncertainty, forecast errors which cannot be omitted from the SCs decision making (Chopra and Meindl, 2004). Uncertainty in demand is responsible for uncertainty in profits of all firms through supply chain. The risk attitude of a firm determines the sensitivity towards profit or demand uncertainty. Christopher and Lee (2004) have recognized that increasing risks among the supply chain members may be manage through new responses. The vulnerability of a supply chain increases with increasing uncertainty and it increases even further if companies, by outsourcing, have become dependent on other organizations (Svensson 2000). Colicchia and Strozzi (2012) have discussed that supply chain risks can be manage by considering uncertainty in the design of supply chains, by understanding the impact of risks arising from network collaboration and interactions between supply chain partners and by developing proactive mitigation capabilities to hedge the increasing level of risk. Wakolbinger and Cruz (2011) have defined two types of risk in supply chain namely operational risk and disruption risk. Operational risks are more related to supply and demand related issues while disruption risk may be caused by man-made or natural disasters such as terrorist attacks, strikes, earthquakes etc. (Byrne 2007; Lockamy and McCormack, 2010).

Uncertainty and risk in supply chain can affect the whole range of supply chain and operations performance indicators such as product quality, operational cost and cost of assets, delivery reliability and delivery lead time, and flexibility affect production system (Schonsleben, 2007; Ziegenbein, 2007). Although many risks exist in business, some of them affect the competitiveness of uncertainty and risk management are product performance, standardization, process performance, requirement uncertainty, improper man-machine management, risk of getting the appropriate quality material, validation of products, system development risks, functional development risks and residual performance risks. The result of this process will be information regarding uncertainty and risks upon which strategic decisions can be made.

The development of effective strategies for managing risk hinges on first understanding the sources of risk and their relationships. In this chapter ten uncertainty and risk measures have been identified through the literature review and expert opinion in this domain. A weighted interpretive structure modelling (W-ISM) technique combination of interpretive structure modelling (ISM) approach and a method of effectiveness index (EI) is used to analyse these measures. The main objectives of this chapter are as follows:

- To identify and rank the uncertainty and risk measures in supply chain
- To establish the relationship among uncertainty and risk measures.
- To find out the effectiveness index of uncertainty and risk measures.

Table 5.1: Uncertainty and risk measures

S. No.	Uncertainty and Risk measures	Mean	Rank	Sources
1.	Product performance	3.92	1	Harland et al., (2003); Hallikas et al., (2004)
2.	Standardization	3.78	2	Nagar and Raj, (2012)
3.	Process performance	3.59	3	Hua et al., (2005); Yurdakul (2003)
4.	Requirement uncertainty	3.42	4	Rose, (2012); Stank et al. (1999);
5.	Improper man-machine management	3.26	5	Doddrell, (1996); Lakhe and Mohanty (1995)
6.	Risk of getting the appropriate quality material	3.09	6	Stavrulaki and Davis (2010)
7.	Validation of products	2.97	7	Oehmen et al. (2009)
8.	System development risks	2.84	8	Tang (2006)
9.	Functional development risks	2.77	9	Ziegenbein (2007)
10.	Residual performance risks	2.68	10	Na et al. (2007); Smith, (2012)

5.2 ANALYSING THE UNCERTAINTY AND RISK MEASURES USING W-ISM

For analysing the uncertainty and risk measures and developing the framework a W-ISM technique is used. Framework is developed by using the ISM and it is further used to evaluate the effectiveness index (EI) of uncertainty and risk measures in supply chain. The various steps, which lead to the development of ISM model, are illustrated below.

Step 1: Establishing the contextual relationship between measures

For developing a contextual relationship of measures an ‘affect to’ type of relation is chosen for this purpose. Which means that one measure affect to another chosen measure. Based on this concept, a contextual relationship among uncertainty and risk measures is developed. Seven experts in this domain, three from industry and three from academia, were consulted in developing the contextual relationship among these measures. Keeping in mind the contextual relationship for each measure, the existence of a relation between any two measures (i and j) and the associated direction of this relation has been decided. The following symbols (V, A, X, O) have been used to denote the direction of the relationship between two uncertainty and risk measures (i and j):

- V - Uncertainty and risk measure i will affect j.
- A - Uncertainty and risk measure j will affect i.
- X - Uncertainty and risk measures i and j will affect to each other.
- O - No relation between two uncertainty and risk measures.

For example: if risk measure 5 affects 9 indicate the symbol V in the concerned cell and if there is no relation between measures 3 and 8 then indicates the symbol O in concerned cell. These notations (V, A, X, O) are used in Table 5.2 for developing the structural self-interaction matrix **(**SSIM) matrix. Based on the above suggestions or notations, a SSIM among all risk measures is developed and shown in Table 5.2.

Step 2: Development of the reachability matrix (RM)

The reachability matrix is obtained from SSIM. The RM indicates the relationship between uncertainty and risk measures in the binary form. The various relationships between measures depicted by symbols V, A, X and O used in SSIM are replaced by binary digits in the form of 0 and 1. The following rules are used to substitute V, A, X and O of SSIM to get reachability set:

- If the cell (i, j) in SSIM is assigned with symbol V, then, this cell (i, j) entry becomes 1 and (j, i) entry becomes 0 in the RM.
- If the cell (i, j) in SSIM is assigned with symbol A, then, this cell (i, j) entry becomes 0 and (j, i) entry becomes 1 in the RM.
- If the cell (i, j) in SSIM is assigned with symbol X, then, this cell (i, j) entry becomes 1 and (j, i) entry becomes 1 in the RM.
- If the cell (i, j) in SSIM is assigned with symbol, then, this cell (i, j) entry becomes 0 and (j, i) entry also becomes 0 in the initial RM.

Table 5.2: Structural Self-Interaction Matrix (SSIM)

Uncertainty and risk measures	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	**A**	**A**	**O**	**V**	**A**	**A**	**V**	**O**	**O**
2	**O**	**O**	**O**	**O**	**V**	**V**	**O**	**O**	
3	**O**	**A**	**O**	**V**	**A**	**A**	**V**		
4	**A**	**O**	**A**	**O**	**O**	**A**			
5	**O**	**V**	**V**	**V**	**O**				
6	**A**	**A**	**V**	**O**					
7	**A**	**O**	**O**						
8	**V**	**O**							
9	**O**								

Thus RM developed is known as initial RM which is depicted in Table 5.3. The final RM is obtained by incorporating the transitivity. Transitivity is defined as a relation between three measures such that if relationship holds between the first and second - second and third, then relationship must necessarily holds between the first and third. After incorporating the necessary change final RM is shown in Table 5.4 where transitivity is marked as 1*.

Table 5.3: Initial reachability matrix

Uncertainty and risk measures	1	2	3	4	5	6	7	8	9	10
1	1	0	0	1	0	0	1	0	0	0
2	0	1	0	0	1	1	0	0	0	0

3	0	0	1	1	0	0	1	0	0	0
4	0	0	0	1	0	0	0	0	0	0
5	1	0	1	1	1	0	1	1	1	0
6	1	0	1	0	0	1	0	1	0	0
7	0	0	0	0	0	0	1	0	0	0
8	0	0	0	1	0	0	0	1	0	1
9	1	0	1	0	0	1	0	0	1	0
10	1	0	0	1	0	1	1	0	0	1

Table 5.4: Final reachability matrix

Uncertainty and risk measures	1	2	3	4	5	6	7	8	9	10
1	1	0	0	1	0	0	1	0	0	0
2	1*	1	1*	1*	1	1	1*	1*	1*	0
3	0	0	1	1	0	0	1	0	0	0
4	0	0	0	1	0	0	0	0	0	0
5	1	0	1	1	1	0	1	1	1	1*
6	1	0	1	1*	0	1	1*	1	0	1*
7	0	0	0	0	0	0	1	0	0	0
8	1*	0	0	1	0	1*	1*	1	0	1
9	1	0	1	1*	0	1	1*	1*	1	0
10	1	0	1*	1	0	1	1	1*	0	1

Step 3: Partitioning the RM

According to Warfield (1974; 1987) and Sage (1977), from the final RM, the reachability set and antecedent set consist of uncertainty and risk measures are carried out. After finding the reachability set and antecedent set, the intersection of all of these sets are derived for the measures. These measures for which the reachability set (RS) and antecedent set (AS) having same value is places at the top level in ISM hierarchy.

Once the top level measure is identified, it is extracted from consideration and other top level measures of the remaining sub graph are found. This procedure is continued till all levels of the structure are identified. These identified levels help in the development of digraph and the final model. Top level measure is positioned at the top of digraph and so on. From Table-5.5 requirement uncertainty and validation of product is found at the top level I, these are positioned at the top of hierarchy.

In the present case, the uncertainty and risk measures, along with their reachability set (RS), antecedent set (AS), intersection set (IS) and levels are presented in Tables 5.5-5.10.

Table 5.5: Iteration 1

Uncertainty and risk measures	**RS**	**AS**	**IS**	**Level**
1	1,4,7	1,2,5,6,8,9,10	1	
2	1,2,3,4,5,6,7,8,9	2	2	
3	3,4,7	2,3,5,6,9,10	3	
4	4	1,2,3,4,5,6,8,9,10	4	**I**
5	1,3,4,6,7,8,10	2,5	5	
6	1,3,4,6,7,8,10	2,6,8,9,10	6,8,10	
7	7	1,2,3,5,6,7,8,9,10	7	**I**
8	1,4,6,7,8,10	2,5,6,8,9,10	6,8,10	
9	1,3,4,6,7,8,9	2,5,9	9	
10	1,3,4,6,7,8,10	5,6,8,10	6,8,10	

Table 5.6: Iteration 2

Uncertainty and risk measures	RS	AS	IS	Level
1	1	1,2,5,6,8,9,10	1	**II**
2	1,2,3,5,6,8,9	2	2	
3	3	2,3,5,6,9,10	3	**II**
5	1,3,5,8,9,10	1,2,5	5	
6	1,3,6,8,10	2,6,8,9,10	6,8,10	
8	1,6,8,10	2,5,6,8,9,10	6,8,10	
9	1,3,6,8,9	2,5,9	9	
10	1,3,6,8,10	5,6,8,10	6,8,10	

Table 5.7: Iteration 3

Uncertainty and risk measures	RS	AS	IS	Level
2	2,5,6,8,9	2	2	
5	5,8,9,10	2,5	5	
6	6,8,10	2,6,8,9,10	6,8,10	**III**
8	6,8,10	2,5,6,8,9,10	6,8,10	**III**
9	6,8,10	2,5,9	9	
10	6,8,10	5,6,8,10	6,8,10	**III**

Table 5.8: Iteration 4

Uncertainty and risk measures	RS	AS	IS	Level
2	2,5,9	2	2	
5	5,9	2,5	5	
9	9	2,5,9	9	**IV**

Table 5.9: Iteration 5

Uncertainty and risk measures	RS	AS	IS	Level
2	2,5	2	2	
5	5	2,5	5	**V**

Table 5.10: Iteration 6

Uncertainty and risk measures	RS	AS	IS	Level
2	2	2	2	**VI**

Step 4: Development of conical matrix

A conical matrix is developed by clubbing together all of the uncertainty and risk measures in the same level, across rows and columns of the final RM, as shown in Table 5.11. The drive power and dependence power of all of the risk measure is calculated by summing up the number of ones in the columns and rows respectively.

Step 5: Development of digraph and ISM model

Based on the conical matrix, a digraph including transitivity links is obtained. This is generated by nodes and lines of edges. After removing the indirect links, a final digraph is developed. In this development, the top level measure is positioned at the top of the digraph and second level measure is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. Then digraph obtained is converted into the ISM model by converting the node into uncertainty and risk measures as shown in Figure 5.1.

Table 5.11: Conical Matrix

Uncertainty and risk measures	**4**	**7**	**1**	**3**	**6**	**8**	**10**	**9**	**2**	**5**	**Driving Power**
4	1	0	0	0	0	0	0	0	0	0	1
7	0	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	0	3
3	1	1	0	1	0	0	0	0	0	0	3
6	1	1	1	1	1	1	1	0	0	0	7
8	1	1	1	0	1	1	1	0	0	0	6
10	1	1	1	1	1	1	1	0	0	0	7
9	1	1	1	1	1	1	1	0	0	0	7
2	1	1	1	1	1	1	0	1	1	1	9
5	1	1	1	1	1	1	1	1	0	1	8
Dependence Power	9	9	7	6	6	6	5	2	1	2	

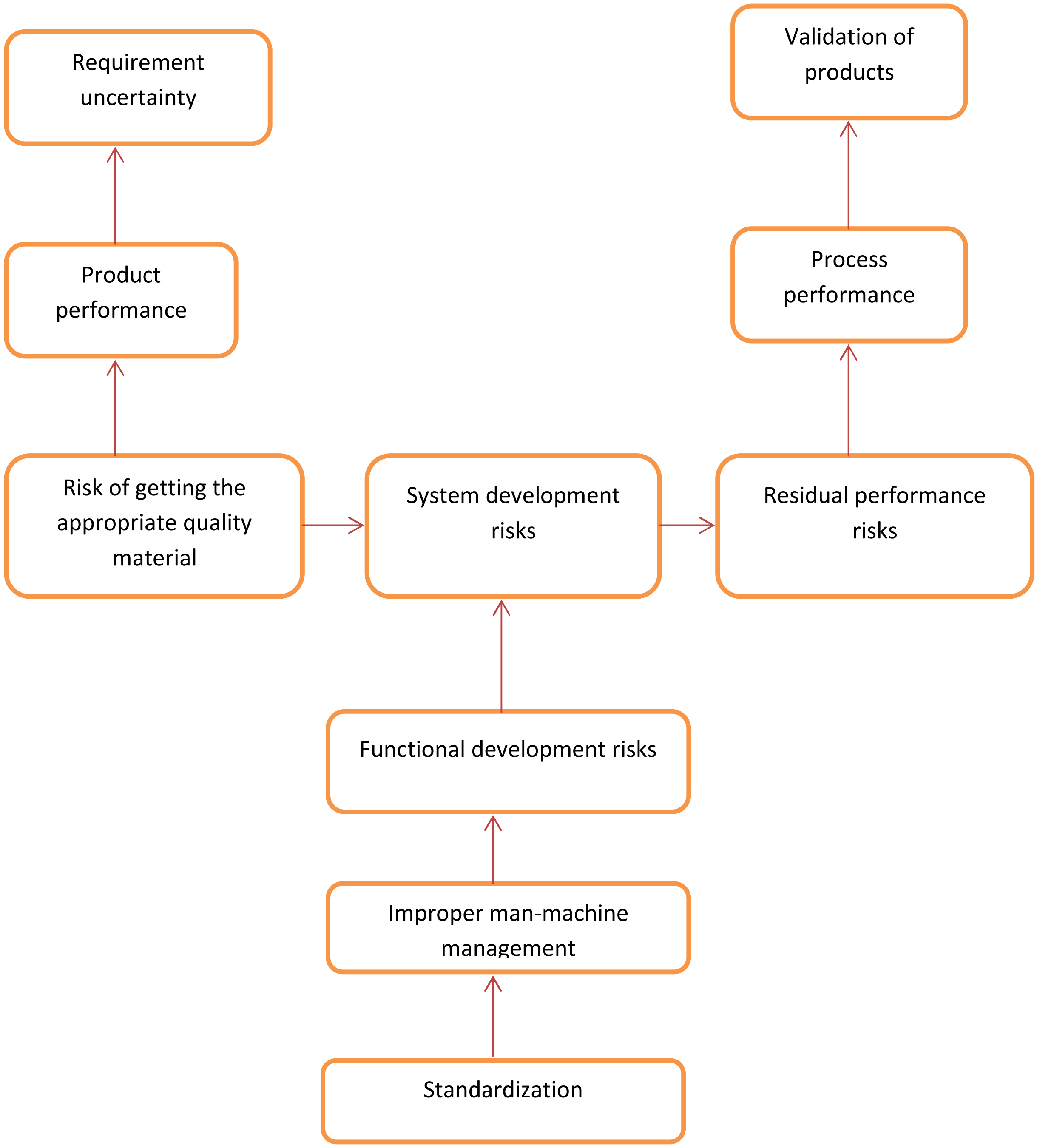


Figure 5.1: ISM based model showing the level of Uncertainty and risk measures

5.3 CLASSIFICATION OF UNCERTAINTY AND RISK MEASURES ON THE BASIS OF MICMAC ANALYSIS

Matriced'Impacts croises-multipication appliqué anclassment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The main purpose of MICMAC analysis is to analyse the drive power and dependence power of measures. Uncertainty and risk measures are classified into four clusters. In this, the first cluster consists of 'autonomous measures' which have weak drive power and weak dependence.

Table 5.12: Clusters of measures

10										
9	**2**		**IV**					**III**		
8		**5**								
7		**9**			**6,10**					
6						**8**				
5										
4										
3			**I**			**3**	**1**	**II**		
2										
1									**4,7**	
Driving Power ↑ / Dependence Power →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

They are relatively disconnected from the system, with which they have few links, which may be very strong. The second cluster consists of 'dependent measures' which have weak drive power but strong dependence power. Third cluster includes 'linkage measures' which have strong drive power as well as strong dependence. These are unstable. Any action on these will have an effect on others and also a feedback effect on themselves. Fourth cluster has the 'independent measures' having strong drive power but weak dependence power.

The drive power and dependence power of all measures is shown in Table 5.12. Thereafter, the drive power and dependence power diagram is drawn as shown in Table 5.11. In this illustration, it is observed from Table 5.12 that measure 5 has driven power 8 and dependence power 2 hence it is positioned at a place which corresponds to drive power 8 and dependence 2, i.e. in the fourth cluster. Now, its position in the fourth cluster shows that it is independent measures. Similarly, all the measures are positioned at places corresponding to their driving and dependence power.

5.4 EVALUATION OF EFFECTIVENESS INDEX (EI)

For computing the effectiveness index, the mean score with their rank of uncertainty and risk measures has been calculated on the basis of Table 5.1. After this rank, inverse rank and weight for each measure has been calculated. For assigning weight to different measures of competitiveness index, the highest and lowest values of five point Likert scale i.e. 5 and 1 are mapped 100% and 0% respectively. For each of the issues of effectiveness a weight is assigned. The criteria for weight (Wi) is as under:

Wi = +1 (Strength), when percentage score > 60% (Mean value > 3).

= 0 (Neutral), when percentage score is between 40-60% Mean value between 2 and 3).

= -1 (Weakness), when percentage score < 40% (Mean value < 2). This framework was given by Cleveland et al. (1989) is Cj= Sum [Wi X Log Ki]. Sum of entries of last column (Wi X Log Ki), will give effectiveness index i.e. 4.85. Theoretically, effectiveness index value may range between - 6.52 to +6.52. Computation of effectiveness index for this study is illustrated with the help of a worksheet as shown in Table 5.13.

Table 5.13: Measurement of effectiveness index

S. No.	Uncertainty and risk measures	Mean	Rank	Inverse Rank(Ki)	Log Ki	Weight (Wi)	Wi X Log Ki
1.	Product performance	3.92	1	10	1	+1	1.00
2.	Standardization	3.78	2	9	0.95	+1	0.95
3.	Process performance	3.59	3	8	0.90	+1	0.90
4.	Requirement uncertainty	3.42	4	7	0.84	+1	0.84
5.	Improper man-machine management	3.26	5	6	0.77	+1	0.77
6.	Risk of getting the appropriate quality material	3.09	6	5	0.69	+1	0.69
7.	Validation of products	2.97	7	4	0.60	0	0.00
8.	System development risks	2.84	8	3	0.47	0	0.00
9.	Functional development risks	2.77	9	2	0.30	-1	-0.30
10.	Residual performance risks	2.68	10	1	0.00	-1	0.00

5.5 RESULTS AND DISCUSSION

This chapter identifies the uncertainty and risk measures that significantly affect the operation of supply chain in an industry so that management may effectively deal with such type of measures. In this chapter, an ISM-based model has been developed to analyse the interactions among different uncertainty and risk measures. It identifies the hierarchy of actions to be taken for handling different measures which affect the operations of supply chain. The driver power dependence matrix (Table 5.12) gives some valuable insights about the relative importance and interdependence among the uncertainty and risk measures. The driver power dependence diagram gives some valuable insights about the relative importance and interdependencies of the measures. The managerial implications as emerging from this chapter are as follows:

- The driver power dependence (Table 5.12) indicates that there are no autonomous measures which affect the operation of SC. Means no measures have weak drivers and weak dependents and do not any influence on the system.
- Dependent measures are ‘product performance, process performance, requirement uncertainty, validation of products’. These measures are weak drivers but strongly depend on one another.
- Measure ‘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 operation risk in supply chain.
- It is further observed that measures standardization, improper man-machine management, risk of getting the appropriate quality material, functional development risks, residual performance risks’ are independent measures i.e. they have strong driving power and less dependent on other measures. Therefore, these are strong drivers and may be treated as the root causes of all the measures. These measures may be treated as the ‘key uncertainty and risk measures’ for affecting the supply chain operation.

Based on response from questionnaire survey on various uncertainty and risk measures, effectiveness index for uncertainty and risk measures in supply chain has been evaluated (Table 5.13). Effectiveness index has been found to be 4.85. Maximum value can reach up to 6.52. Presently effectiveness index of this study among uncertainty and risk measures is quite high. This approach can be utilized by the organization to benchmark its performance with national and international standards. 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 considered in this chapter.

5.6 CONCLUSION

This chapter presents arguments on uncertainty and risk measures. There is a need to understand the importance and interrelationship among these measures. However the research in the area of uncertainty and risk measures supply chain management is yet to formalize the risk associated with in supply chain. This will help the authors to identify and develop the nomenclature of uncertainty and risk measures that impact on supply chain. The present study will help the decision-makers to estimate the impact risks and develop the suitable strategies to manage them. The combine approach of interpretive structural modeling (ISM) and effectiveness index (EI) used in this chapter offers a precise and accurate analysis by integrating the different measures.

CHAPTER VI

DEVELOPEMENT OF ANP BASED FRAMEWORK FOR MODELING THE RISKS IN SCs

6.1 INTRODUCTION

Supply chain risk management (SCRM) is an emerging field that generally lacks integrative approaches across different disciplines (Bandaly et al., 2013). Supply chain risk management is a rapidly emerging area boosted both by the prevalent external conditions of uncertainty and increased push for an efficient chain (Samvedi and Jain, 2013). Risk management is an emerging and important contributor to the most of the fields of management and decision control. The challenge to business organizations is to mitigate that risk through creating more resilient supply chains. The motives behind use of risk management approaches are the global competition, changes in technology and the continuous contention for competitive advantage (Brindley, 2004). Organizations generally concentrate on the type of disruption and not its source in order to know how to get it prepared against risk. Once the risk events are being identified effective methods for managing the risks must be developed. There are wide instances in the literature regarding risks management and complex supply chains. The advancement of globalization in industries has increased uncertainties and risks in both demand and supply and the likelihood of supply chain disruption, deviation and disasters. Effective risk management requires quantifying risk in order to place them in their proper context and to weigh the costs of risk and benefits of making particular decisions. Supply chain risk management offers improved focus on risk and therefore, more effective risk mitigations. In recent years performance of a supply chain among their members is examined based on a framework that identifies the activity categories critical for the effective management of the supply chain (Parkan and Wang, 2007). Complexity and dynamics of supply chains are not always proportional to their reliability and supply chain risk management becomes a very important tool in minimizing risk and uncertainties caused by, logistics-related activities or resources in the supply chain (Radivojević and Gajović, 2013)

Therefore it is essential that companies plan for disruptions (DR), deviation (DV) and disaster (DS) to develop contingency plans as they design or redesign their supply chains. Risk management action plans can be developed to preferably avoid the identified risks, or if not possible, at least mitigate, contain and control them. As such, this chapter makes an important contribution to the area of supply chain risk management, and highlights analytical network process (ANP) approach to manage risks in supply chain planning and control. In this chapter three types of supply chains (Traditional, agile and green) have been included to analyse the risks in supply chain planning and control.

In traditional supply chain, the flow of materials and information is linear and from one end to the other. There is a limited collaboration and visibility. Each supply chain partner has limited information regarding i.e. high carbon footprint and natural disasters of the other partners. Agile supply chain 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). Agile is the fundamental characteristic of a supply chain needed for survival in turbulent markets, where environmental forces create additional uncertainty resulting in higher risk in the supply chain management (Ghatri et al. 2013). In contrast, green supply chains consider the environmental effects of all processes of supply chain from the extraction of raw materials to the final disposal of goods. The aim of organisations adopting green supply chain management (GSCM) practices is to enhance their environmental and financial performance, investment recovery and eco-design or design for environmental practices (Zhu and Sarkis, 2004). Green supply chain will strive to achieve what any individual organization on its own could not possibly achieve i.e. minimized waste, minimized environmental impact while assuring maximized consumer satisfaction and healthy profits.

This chapter presents a framework for modelling risks in traditional, agile and green supply chains on the basis of interdependent variables. Here the risks in SC planning and control are important to fulfil the need of the customer and organization. This framework provide an add to decision makers in analyzing the variables affecting the dimensions such as plan and control risk (PCR), process risk (PR), demand risk (DR), natural and social risk (NSR) in traditional, green and agile supply chains for the improvement of risks in SC planning and control for the study of a manufacturing organizations. In this chapter, analytical network process (ANP) is presented to develop framework for modeling the risks in SC and to select the best SC.

6.2 ANP MODEL FOR RISKS IN SUPPLY CHAIN PLANNING AND CONTROL

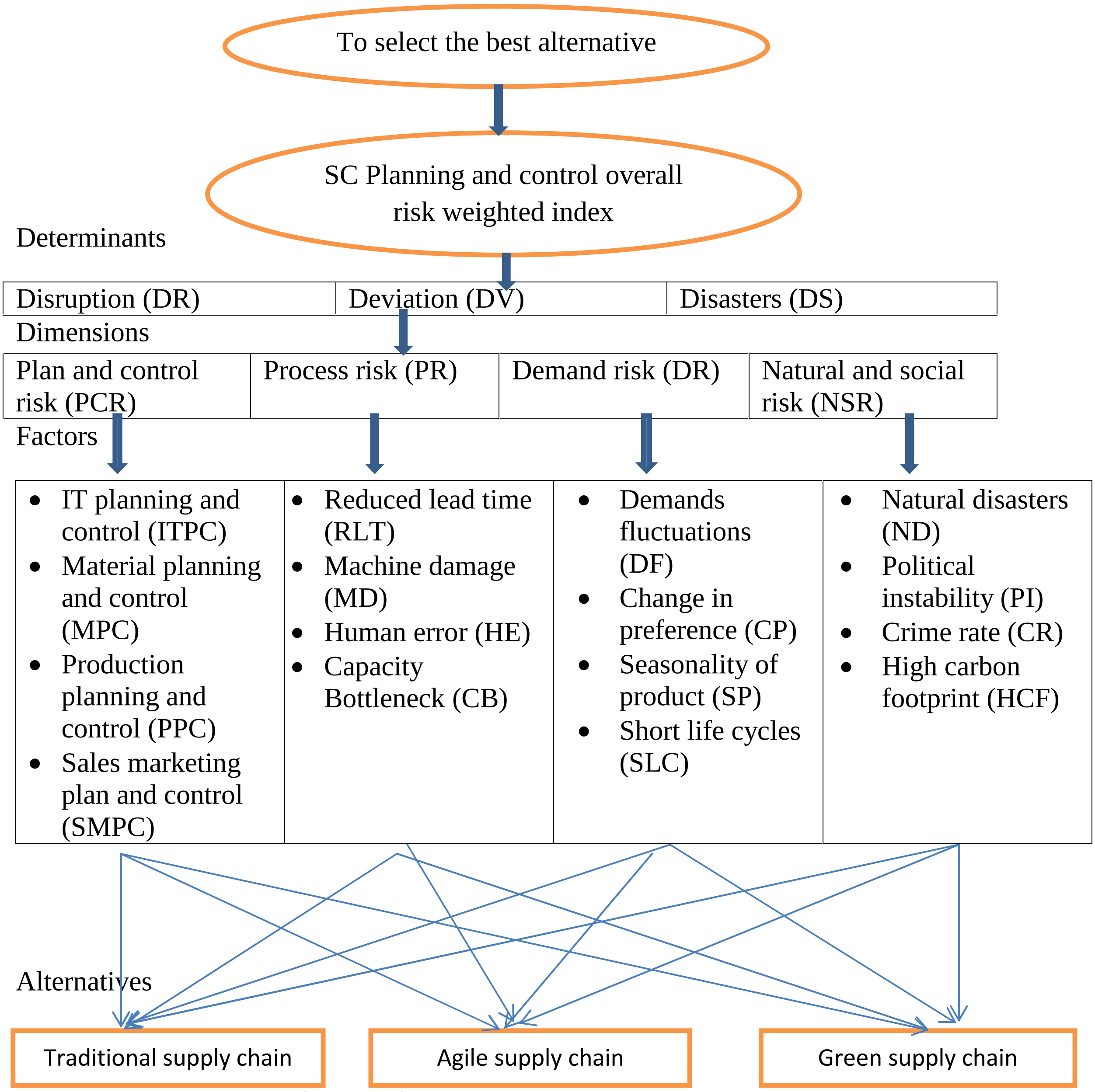


Figure 6.1: ANP model for risk factors strategy in supply chain planning and control

The network representation of the ANP model and its decision environment is shown in Figure 6.1. It can be seen that the overall objective is to analyses the risks in supply chain planning and control. The determinants have dominance over the dimensions of the risks in supply chain planning and control. The supply chain planning and control risk factors are those which assist in achieving the dimension of risk in supply chain planning and control. Thus, these are dependent on the dimensions. Also, there are some interdependencies among the risk factors, hence the arrow showing the relationship among the risk factors in the network (Figure 6.1). For example, PPC (Production planning and control) and SMPC (Sales marketing plan and control) are interdependent to one another at instant. In order to achieve production, company should focus on sales and planning also.

The alternatives considered in this study are traditional supply chain (TSC), agile supply chain (ASC), green supply chain (GSC) for analysing the risks in supply chain planning and control. The main objective of this model is to select the best alternative by analyzing the risk in supply chain planning and control.

6.3 APPLICATION OF ANP FOR RISKS IN SUPPLY CHAIN PLANNING AND CONTROL

The ANP model presented in this research has been evaluated in Indian manufacturing industries, who were interested in reducing the risk in supply chain planning and control.

Industries are interested to adopt a systematic way to determine the best possible option for analysing the risk. This case experience helps to understand in a better way of ANP methodology how to deal with risks. The analysis and the implementation of the ANP methodology are presented as below:

Step 1: Model development and formulation

In this step, the decision problem is structured into its important components. The relevant criteria and alternatives are structured in the form of a control hierarchy where the criteria at the top level in the model have the highest strategic value. The top-level criteria in this model are disruption, deviation and disasters. These three criteria are termed as the determinants. In the second level of hierarchy, four sub-criteria termed as dimensions of the model is placed which supports all the four determinants at the top level of hierarchy. These are plan and control risk, process risk, demand risk, natural and social risk). For example, plan and control risk helps in reducing the three determinants such as disruptions (DR), deviation (DV) and disaster (DS). Similar relationships are applicable for PR, DR and NSR. In this ANP model, each of the four dimensions has some mitigation, which helps achieve that particular dimension. For example, the dimension DR is supported by the risk factors DF, CP, SP and SLC.

These risk factors also have some interdependency to each other. The strength of the ANP model is that the feedback and the network structure of the ANP makes possible the representation of the decision problem without much concern for what comes first and what comes next in a hierarchy. The opinion of the supply chain manager of the company was brought in the comparisons of the relative importance of the criteria and the formation of pair-wise comparison matrices to be used in analysing the risk in supply chain planning and control model. In this chapter, mainly for the purpose of brevity, the results only of the deviation determinant have been presented. The results of all the three determinants would be included in the calculation of supply chain planning and control overall risk weighted index (SCPCORWI), which indicates the score assigned to risk in supply chain planning and control.

Step 2: Pair-wise comparison of determinants

In this step, the decision maker is asked to respond to a series of pair-wise comparisons where two components at a time are compared with respect to an upper level 'control' criterion. These comparisons are made so as to establish the relative importance of determinants in achieving the case company's objectives. In such comparisons, a scale of 1–5 is used to compare two options (Saaty, 1980). In this score of 1 indicates that the two options under comparison have equal importance, while a score of 5 indicates the overwhelming dominance of the component under consideration (row component) over the comparison component (column component) in a pair-wise comparison matrix. In case, a component has weaker impact than its comparison component, the range of the scores will be from 1 to 1/5, where 1 indicates indifference and 1/5 represents an overwhelming dominance by a column element over the row element. For the reverse comparison between the components already compared, a reciprocal value is automatically assigned within the matrix, so that in a matrix $a_{ij}a_{ji}=1$. The matrix showing pair-wise comparison of determinants along with the e-vectors of these determinants is shown in Table 6.1. In which consistency ratio is less than 0.10 for all the comparisons.

The e-vectors are the weighted priorities of the determinants and shown in the last column of the matrix. In this chapter, a two-stage algorithm (Saaty, 1980) is used for computing e-vector. These e-vectors would be used in Table 6.9 for the calculation of supply chain planning and control overall risk weighted index (SCPCORWI) for alternatives.

Table 6.1: Pair-wise comparison of determinants

Determinants	DR	DV	DS	e-vectors
DR	1	1/5	3	0 .2584
DV	5	1	2	0.5703
DS	1/3	1/2	1	0 .1713

Step 3: Pair-wise comparison of dimensions

In this step, a pair-wise comparison matrix is prepared for determining the relative importance of each of the dimensions of risk in SC planning and controls (PCR, PR, DR and NSR) on the determinant of SC planning and control. In the model, four such matrices would be formed one for each of the determinant. One such matrix for the deviation determinant is shown in Table 6.2. From this table, the results of the comparison (e-vectors) of the dimensions for the legislation determinant are carried as Pja (relative importance weight of dimension of risk in supply chain planning and control) in Table 6.8.

Step 4: Pair-wise comparison matrices between risk factors

In this step, the decision maker is asked to respond to a series of pair-wise comparisons where two components would be compared at a time with respect to an upper level control criterion. For a determinant, pair-wise comparison is done between the applicable risk factors within a given dimension cluster. The pair-wise comparison matrix for the dimension PR under the DV determinant is shown in Table 6.3. For the pair-wise comparison, the question asked to the decision maker is, ‘what is the relative impact on process risk by factor X when compared to factor Y, in improving the deviation? In Table 6.3, the relative importance of human error (HE) when compared to reduced lead time (RLT) with respect to process risks (PR), in achieving the deviation is five. From Table 6.3 it is also observed that for the case study, the factor HE has

Table 6.2: Pair-wise comparison matrices between dimensions

Deviation	PCR	PR	DR	NSR	e- vectors
PCR	1	1/5	3	2	0 .2000
PR	5	1	5	1/4	0.3819
DR	1/3	1/5	1	3	0.1667
NSR	1/2	4	1/3	1	0.2514

Table 6.3: Pair-wise comparison matrices between risk factors

Process risk (PR)	RLT	MD	HE	CB	e- vectors
RLT	1	1/4	1/5	1/4	0.0533
MD	4	1	1/5	5	0.2356
HE	5	5	1	4	0.5079
CB	4	1/5	1/4	1	0.2032

the maximum influence (0.5079) on PR in improving the deviation. Similarly, RLT has the minimum influence (0.0533) on PR in improving the deviation. The e-vectors obtained from these matrices are imported as AD kja in Table 6.8.

Step 5: Pair-wise comparison matrices of interdependencies

Pair-wise comparisons are done to consider the interdependencies among the risk factors i. e. one such comparison is presented in Table 6.4, which shows the result of DV-PR cluster with RLT as the control factors over other risk factors. The question asked to the decision maker for evaluating the interdependencies is 'when considering RLT with regards to improve the deviation, what is the relative impact of risk factor a when compared to mitigation Y?' For example, 'when considering RLT, with regards to improve the deviation, what is the relative impact of MD when compared to HE?' From Table 6.4, it is observed that MD (0.5801) has the maximum impact on DV-PR cluster with RLT as the control risk factor over others. It is also observed that the impact of CB on RLT in DV-PR cluster has minimum (0.1100). Therefore, CB is not a problem for the user company and it will have little impact reducing lead time in DV-PR cluster. For each determinant, there will be 16 such matrices at this level of relationship. The e-vectors from these matrices are used in the formation of super matrices. As there are three determinants, 48 such matrices will be formed. The e-vectors from matrix in Table 6.4 have been used in sixth column of the super matrix in Table 6.6.

Step 6: Evaluation of alternatives

The final set of pair-wise comparisons is made for the relative impact of each of the alternatives on the risk factors in influencing the determinants. The number of such pair-wise

Table 6.4: Pair-wise comparison matrices of interdependencies

Reduced lead time (RLT)	MD	HE	CB	e- vectors
MD	1	5	3	0.5801
HE	1/5	1	5	0.3099
CB	1/3	1/5	1	0.1100

Table 6.5: Pair-wise comparison matrices of alternatives

Reduced lead time (RLT)	TSC	ASC	GSC	e- vectors
TSC	1	1/5	1/3	0.1095
ASC	5	1	2	0.5812
GSC	3	1/2	1	0.3091

comparison matrices is dependent on the number of risk factors that are included in each of the determinants. In our present case, there are 16 risk factors for each of the determinants, which lead to 48 such pair-wise matrices. One such pair-wise comparison matrix is shown in Table 6, where the impacts of three alternatives are evaluated on the factor RLT in influencing the determinant DV. The e-vectors from Table 6.5 are used in columns 6, 7and 8 of compatibility desirability indices matrix in Table 6.8. The columns 6, 7and 8 in Table 6.8 correspond to TSC, ASC and GSC, respectively.

Step 7: Super matrix formation and illustration

The super matrix allows for a resolution of the interdependencies that exist among the elements of a system. It is a partitioned matrix where each sub-matrix is composed of a set of relationships between and within the levels as represented by the decision maker's model. In this model, there are four super matrixes for each of the three determinants of supply chain planning and control hierarchy network, which need to be evaluated. One such super matrix M, shown in Table 6.6, presents the results of the relative importance measures for each of the risk factors for the deviation determinant of risk in supply chain planning and control.

The values of the elements of the super matrix M have been imported from the pair-wise comparison matrices of interdependencies (for example, Table 6.4). As there are 16 such pair-wise comparison matrices, one for each of the interdependent risk factors in the deviation, there will be 16 non-zero columns in this super matrix. Each of the non-zero values in the column is the relative importance weight associated with the interdependent pair-wise comparison matrices.

In the next stage, the super matrix M is made to converge to obtain a long-term stable set of weights. For convergence, super matrix needs to be column stochastic, i.e. the sum total of each of the columns of the super matrix needs to be one. Raising the super matrix M to the power 2^{K+1}, where k is an arbitrarily large number, allows for the convergence of the interdependent relationships (Meade and Sarkis, 1999). In this case, convergence is reached at $M^{31.}$ The converged super matrix is shown in Table 6.7. (Convergence is done with the help of Matrix laboratory software).

Step 8. Selection of the best alternative for determinant

The selection of the best alternative depends on the outcome of the 'desirability index'. The desirability index, Dia, for the alternative i and the determinant X is defined as (Meade and Sarkis, 1999)

Dia= $\sum_{j=1}^{J} \sum_{k=1}^{k}$ Pja A^D kja A^I kja Sikja; (1)

Table-6.6: Super matrix M for deviation before convergence

Risks	ITPC	MPC	PPC	SMPC	RLT	MD	HE	CB	DF	CP	SP	SLC	ND	PI	CR	HCF
ITPC	0	.2740	.1933	.3177												
MPC	.2882	0	.2896	.0895												
PPC	.5154	.5475	0	.5928												
SMPC	.1964	.1785	.5171	0												
RLT					0	.2383	.2835	.2844								
MD					.5801	0	.4488	.5147								
HE					.3099	.4957	0	.2009								
CB					.1100	.2660	.2677	0								
DF									0	.2351	.4051	.2603				
CP									.4157	0	.5163	.4434				
SP									.5258	.4778	0	.2963				
SLC									.0585	.2871	.0786	0				
ND													0	.6510	.2111	.6242
PI													.1216	0	.1423	.3333
CR													.6212	.1237	0	.0425
HCF													.2572	.2253	.6466	0

Table-6.7: Super matrix M^{31} for deviation after convergence

Risks	ITPC	MPC	PPC	SMPC	RLT	MD	HE	CB	DF	CP	SP	SLC	ND	PI	CR	HCF
ITPC	.2013	.2013	.2013	.2013												
MPC	.1844	.1844	.1844	.1844												
PPC	.3571	.3571	.3571	.3571												
SMPC	.2571	.2571	.2571	.2571												
RLT					.2091	.2091	.2091	.2091								
MD					.3371	.3371	.3371	.3371								
HE					.2690	.2690	.2690	.2690								
CB					.1847	.1847	.1847	.1847								
DF									.2664	.2664	.2664	.2664				
CP									.3186	.3186	.3186	.3186				
SP									.3150	.3150	.3150	.3150				
SLC									.1300	.1300	.1300	.1300				
ND													.3272	.3272	.3272	.3272
PI													.1643	.1643	.1643	.1643
CR													.2352	.2352	.2352	.2352
HCF													.2733	.2733	.2733	.2733

Where Pja is the relative importance weight of dimension of risk in supply chain planning and control, j on the determinant of risk in supply chain planning and control a, A^D kja is the relative importance weight for risk in supply chain planning and control attribute factor k of dimension of risk in supply chain planning and control j in the determinant of risk in supply chain planning and control hierarchy network a for the dependency (D) relationships between component levels, A^I kja is the stabilized relative importance weight (carried out by the super matrix) for risk in supply chain planning and control attribute factor k of dimension of risk in supply chain planning and control, j in the determinant of risk in supply chain planning and control hierarchy network a for interdependency (I) relationships within the risk in supply chain planning and control attribute risk factors' component level, Sikja is the relative impact of risk in supply chain planning and control implementation alternative i on reverse logistics attribute Mitigation k of dimension of risk in supply chain planning and control, j of risk in supply chain planning and control hierarchy network a, Kja is the index set of risk in supply chain planning and control attribute risk factors for dimension of risks in supply chain planning and control.

j in for risk in supply chain planning and control determinant control hierarchy a, and J is the index set for the dimensions of risk in supply chain planning and control.(same process for all control hierarchies).

Table 6.8 shows the desirability indices for the compatibility determinant (Di Deviation).

It is based on the deviation hierarchy using the relative weights obtained from the pair-wise comparison of alternatives, dimensions and weights of risk factors from the converged super matrix. These weights are used to calculate a score for the determinants of supply chain planning and control overall risk weighted index (SCPCORWI) for each of the alternative being considered. In Table 6.8, the values of second column are imported from Table 6.2, which are obtained by comparing the relative impact of the dimensions on the deviation determinant. For example, in improving the deviation, the role of process risk is found to be most important (0.3819), which is followed by NSR (0.2514), PCR (0.2000), and DR (.1667).

Table-6.8: Desirability indices for compatibility determinant

Dimensions	P_{ja}	Risk factors	A^D_{kja}	A^1_{kja}	S_{1kja}	S_{2kja}	S_{3kja}	TSC	ASC	GSC
PCR	.2000	ITPC	.4514	.2013	.1643	.1376	.6981	.0029	.0025	.0128
PCR	.2000	MPC	.2110	.1844	.1114	.3366	.4520	.0028	.0026	.0035
PCR	.2000	PPC	.2040	.3571	.1792	.3557	.4651	.0026	.0051	.0067
PCR	.2000	SMPC	.1336	.2571	.3680	.3053	.3267	.0025	.0020	.0022
PR	.3819	RLT	.0533	.2091	.1095	.5812	.3091	.0004	.0024	.0013
PR	.3819	MD	.2356	.3371	.5801	.3099	.1100	.0175	.0093	.0033
PR	.3819	HE	.5079	.2690	.3256	.2411	.4333	.0170	.0125	.0227
PR	.3819	CB	.2032	.1847	.2570	.5684	.1746	.0036	.0081	.0025
DR	.1667	DF	.3124	.2664	.4903	.3122	.1975	.0068	.0043	.0027
DR	.1667	CP	.8232	.3164	.0630	.5975	.3395	.0027	.0259	.0147
DR	.1667	SP	.2031	.3150	.1863	.3432	.4705	.0019	.0036	.0050
DR	.1667	SLC	.4013	.1300	.3333	.3667	.3000	.0028	.0031	.0026
NSR	.2514	ND	.4214	.3272	.5473	.2411	.2111	.0189	.0083	.0076
NSR	.2514	PI	.3021	.1643	.1553	.2375	.6072	.0019	.0029	.0075
NSR	.2514	CR	.2562	.2352	.1266	.5662	.3072	.0019	.0085	.0046
NSR	.2514	HCF	.0203	.2733	.3432	.2217	.4351	.0004	.0003	.0006

The values in the fifth column of Table 6.8 are the stable independent weights of risk factors obtained through converged super matrix (Table 6.7). The next three columns are from the pair-wise comparison matrices giving the relative impact of each of the alternatives on the risk factors. The final three columns represent the weighted values of the alternatives are calculated by using Equation 1. The summations of these results, for the deviation of each of these alternatives, are presented in the final row of Table 6.8. These results indicate that the ASC with a value of 0.1014 has maximum influence on the deviation. It is followed by GSC (0.0998) and TSC (0.0846). Till this step, the analysis has been conducted only for the deviation determinant.

Similar analysis is carried out for other two determinants. In the next step, an index would be calculated to capture the achievement of overall goal of selecting an alternative.

Step 9: Output analysis of risks in supply chain planning and control overall risks weighted index (SCPCORWI)

The SCPCORWI for an alternative i (SCPCORWIi) is the summation of the products of the desirability indices (Dia) and the relative importance weights of the determinants (Ca) of the overall risks weighted index. It is represented as:

$$SCPCORWI_i = \sum DiaCa \quad (2)$$

Results shown in Table 6.9 are found by using Equation 2 in ANP. From Table 6.9 it is observed that ASC is best alternative in this study and GSC and TSC follow this alternative. These results should be seen in the light of the characteristics of the case study and the inputs provided by its SCM manager in the pair-wise comparison.

Table 6.9: Result of alternatives

Alternative Weights	**0.2584 (DR)**	**0.5703 (DV)**	**0.1713 (DS)**	**SCPC overall risk weighted index**	**Normalized value of SCPCORWI using ANP**	**Normalized value of SCPCORWI using AHP**
TSC	0.0253	0.0846	0.0132	0.0570	0.1916	0.2415
ASC	0.1672	0.1014	0.1707	0.1302	0.4377	0.3948
GSC	0.1425	0 .0998	0 .0972	0.1103	0.3707	0.3637

6.4 COMPARISON OF RESULTS BETWEEN ANP and AHP

By using the ANP methodology, results shows that alternatives are ordered as ASC > GSC > TSC. In this ASC is placed at the 1st alternatives and TSC is placed at the last alternatives for the risk in SC planning and control. The same model is illustrated with the help of analytical hierarchical process given in Fig. 1 by assuming there is no dependence among the criteria. The overall priorities computed for the alternatives are presented in Figure 6.2. The same pairwise comparison matrices are used to compute the AHP priority values. In the AHP analysis, ASC is also found to be the best alternative, with an overall priority value of 0.3948. The priority order of the alternatives in AHP are same (ASC > GSC > TSC) as in ANP, only with the different priority values. When dependence among criteria is taken into account both the priorities values of the alternatives changes from 0.4377 to 0.3948, 0.3707 to 0.3637 and 0.1916 to 0.2415 in ASC, GSC and TSC. The results obtained from ANP and AHP methodology are comparatively listed in Figure 6.2.

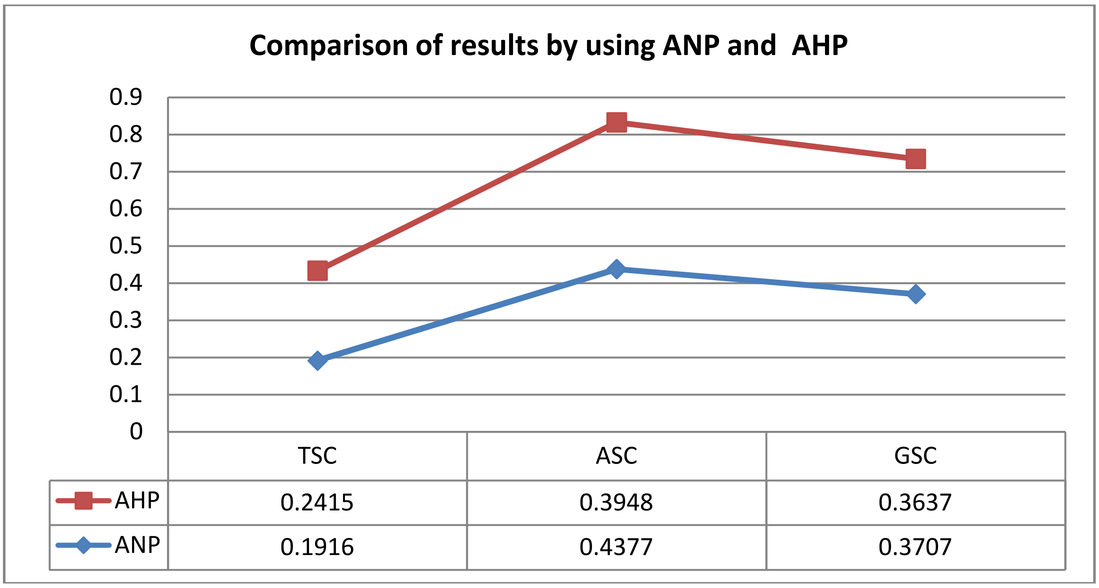


Figure 6.2 Comparison of results using ANP and AHP

6.5 CONCLUSION

The ANP model presented in this chapter structured the problem to present the risks in supply chain planning and control in a hierarchical form and linked the determinants, dimensions, risk factors and the alternatives available to the decision maker for different types of supply chains. Even after making strategies and prioritizing the risk factors in supply chain in context to Indian manufacturing organizations, all risks cannot be invalidated. Risk mitigation planning provides an organization with a more mature decision making process in facing unexpected losses being caused by unexpected events. Existence of supply chain can be seen in both service industries as well as in manufacturing industries and the complexity variation occurs from industries to industries and from firm to firm. This study provides a partial support to managers for managing the risk issues in context of supply chain. This supply chain planning and control overall risk weighted index (SCPCORWI) would help supply chain managers to identify, assess and plan for risk. It is expected that the outcome of the results from this research study will be beneficial to the industries. If the risks are being controlled effectively the efficiencies of supply chain would maintain a balance between financial management and the customer requirements.

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.

Agilie 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.

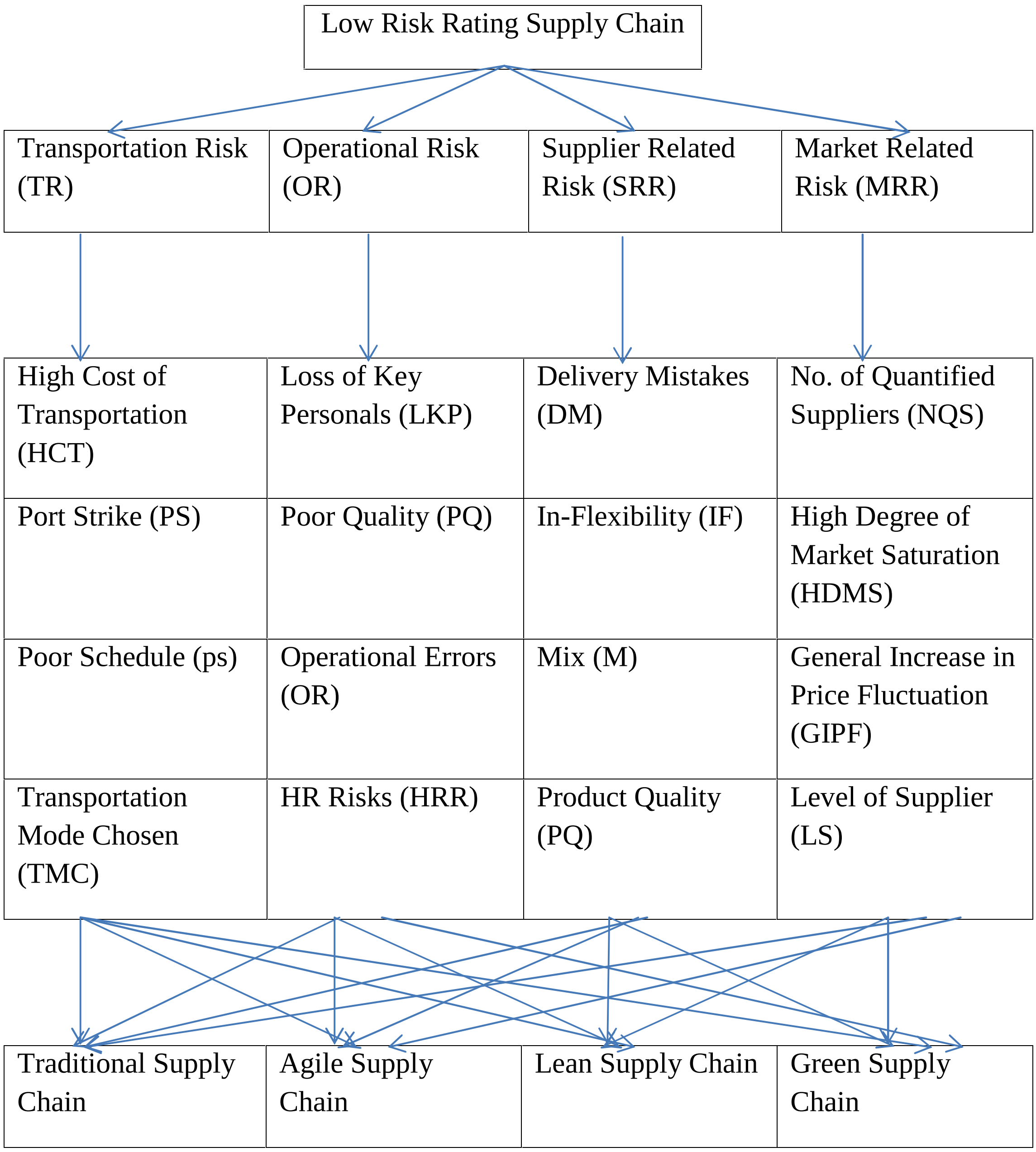


Figure 7.1: ANP model

Table 7.1: Pairwise comparison of risks (W_1)

Risks	TR	OR	SRR	MRR	Degree of risk criteria
TR	1	3	2	3	0.46
OR	0.33	1	3	2	0.24
SRR	0.5	0.33	1	2	0.18
MRR	0.33	0.5	0.5	1	0.12

Table 7.2: Inner dependence matrix of transportation risks

TR	OR	SRR	MRR	Degree of TR criteria
OR	1	4	3	0.62
SRR	0.25	1	0.5	0.14
MRR	0.33	2	1	0.24

Table 7.3: Inner dependence matrix of operational risks

OR	TR	SRR	MRR	Degree of TR Criteria
TR	1	0.25	0.5	0.16
SRR	4	1	0.33	0.33
MRR	2	3	1	0.51

Table 7.4: Inner dependence matrix of market related risks

MRR	TR	OR	SRR	Degree of MRR criteria
TR	1	2	0.25	0.24
OR	0.5	1	0.5	0.19
SRR	4	2	1	0.57

Table 7.5: Inner dependence matrix of supplier related risks

SRR	TR	OR	MRR	Degree of SRR criteria
TR	1	4	2	0.57
OR	0.25	1	2	0.24
MRR	0.5	0.5	1	0.19

Then

$$W_2 = \begin{array}{c} \\ TR \\ OR \\ SRR \\ MRR \end{array} \begin{array}{cccc} TR & OR & SRR & MRR \\ \hline 1 & 0.16 & 0.57 & 0.24 \\ 0.62 & 1 & 0.24 & 0.19 \\ 0.14 & 0.33 & 1 & 0.57 \\ 0.24 & 0.51 & 0.19 & 1 \end{array}$$

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 0.170, 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.

$$W_{Criteria} = W_2 \times W_1 = \begin{array}{c} TR \\ OR \\ SRR \\ MRR \end{array} \begin{pmatrix} 0.170 \\ 0.351 \\ 0.212 \\ 0.267 \end{pmatrix}$$

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 $W_{sub\text{-}criteria}$ risks criteria are

$$W_{sub\text{-}Criteria}(TR) = \begin{matrix} HCT \\ PS \\ Ps \\ TMC \end{matrix} \begin{pmatrix} 0.311 \\ 0.301 \\ 0.108 \\ 0.180 \end{pmatrix} \qquad W_{sub\text{-}Criteria}(OR) = \begin{matrix} LKP \\ PQ \\ OR \\ HRR \end{matrix} \begin{pmatrix} 0.426 \\ 0.336 \\ 0.137 \\ 0.101 \end{pmatrix}$$

$$W_{sub\text{-}Criteria}(SRR) = \begin{matrix} DM \\ IF \\ M \\ PQ \end{matrix} \begin{pmatrix} 0.174 \\ 0.072 \\ 0.542 \\ 0.212 \end{pmatrix} \qquad W_{sub\text{-}Criteria}(MRR) = \begin{matrix} NQS \\ HDMS \\ GOPF \\ LS \end{matrix} \begin{pmatrix} 0.244 \\ 0.273 \\ 0.347 \\ 0.136 \end{pmatrix}$$

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

Risks criteria	**priorities of risks criteria**	**Risks sub-criteria**	**Priorities of sub-risks criteria**	**Overall priorities of sub-risks criteria**
Transportation risks (TR)	0.170	HCT	0.311	0.052
		PS	0.301	0.051
		Ps	0.108	0.018

		TMC	0.180	0.030
Operational risks (OR)	0.351	LKP	0.426	0.149
		PQ	0.336	0.117
		OE	0.137	0.048
		HRR	0.101	0.035
Supplier related risks (SRR)	.0212	DM	0.174	0.036
		IF	0.072	0.015
		M	0.542	0.114
		PQ	0.212	0.044
Market related risks (MRR)	0.267	NQS	0.244	0.065
		HDMS	0.273	0.072
		GIPF	0.347	0.092
		LS	0.136	0.036

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

$$W_4 = \begin{pmatrix} .111 & .374 & .313 & .193 & .113 & .080 & .280 & .152 & .193 & .298 & .094 & .248 & .462 & .067 & .083 & .164 \\ .367 & .211 & .523 & .442 & .575 & .425 & .312 & .233 & .355 & .376 & .351 & .572 & .349 & .435 & .535 & .233 \\ .454 & .345 & .051 & .083 & .253 & .213 & .280 & .452 & .295 & .262 & .508 & .128 & .131 & .345 & .338 & .342 \\ .068 & .070 & .113 & .282 & .059 & .283 & .127 & .163 & .157 & .064 & .047 & .052 & .058 & .153 & .044 & .261 \end{pmatrix}$$

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

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

$$W_{\text{alternatives}} = W_4 \text{ X } W_{\text{sub-criteria (Global)}} = \begin{matrix} \text{TSC} \\ \text{ASC} \\ \text{LSC} \\ \text{GSC} \end{matrix} \begin{pmatrix} 0.162 \\ 0.426 \\ 0.299 \\ 0.113 \end{pmatrix}$$

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 $W_{criteria}$ weights as W_{TR} = 0.170, W_{OR} = 0.351,W_{SRR} = 0.212 and W_{MRR} = .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 (yi) 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

Alternatives/Risks	TR	OR	SRR	MRR
TSC	0.311	0.426	0.174	0.244
ASC	0.301	0.336	0.072	0.273
LSC	0.108	0.137	0.542	0.347
GSC	0.180	0.101	0.212	0.136

Table 7.8: Weight of criteria

W_{ij}	0.170	0.351	0.212	0.267
Alternatives/Risks	**TR**	**OR**	**SRR**	**MRR**
TSC	0.311	0.426	0.174	0.244
ASC	0.301	0.336	0.072	0.273
LSC	0.108	0.137	0.542	0.347
GSC	0.180	0.101	0.212	0.136

Table 7.9: Risk criteria

Alternatives/Risks	TR	OR	SRR	MRR
TSC	0.052	0.149	0.036	0.065
ASC	0.051	0.118	0.152	0.072
LSC	0.018	0.048	0.114	0.092
GSC	0.030	0.035	0.044	0.036

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

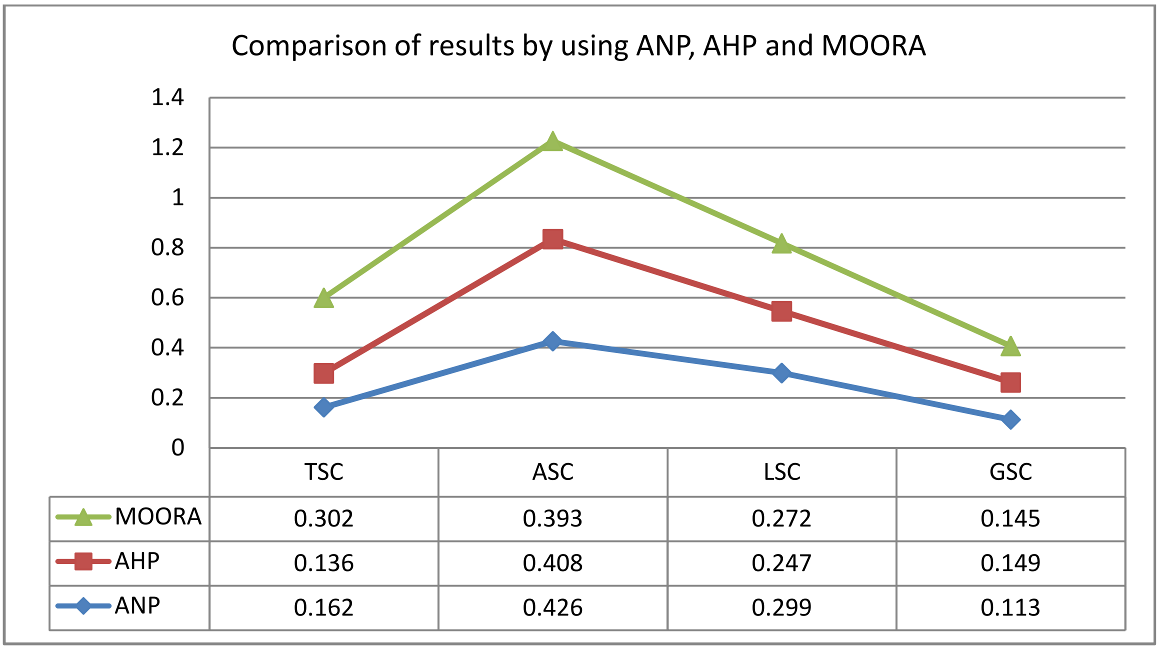
Alternatives	y_i	Ranking
TSC	0.302	2
ASC	0.393	1
LSC	0.272	3
GSC	0.145	4

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

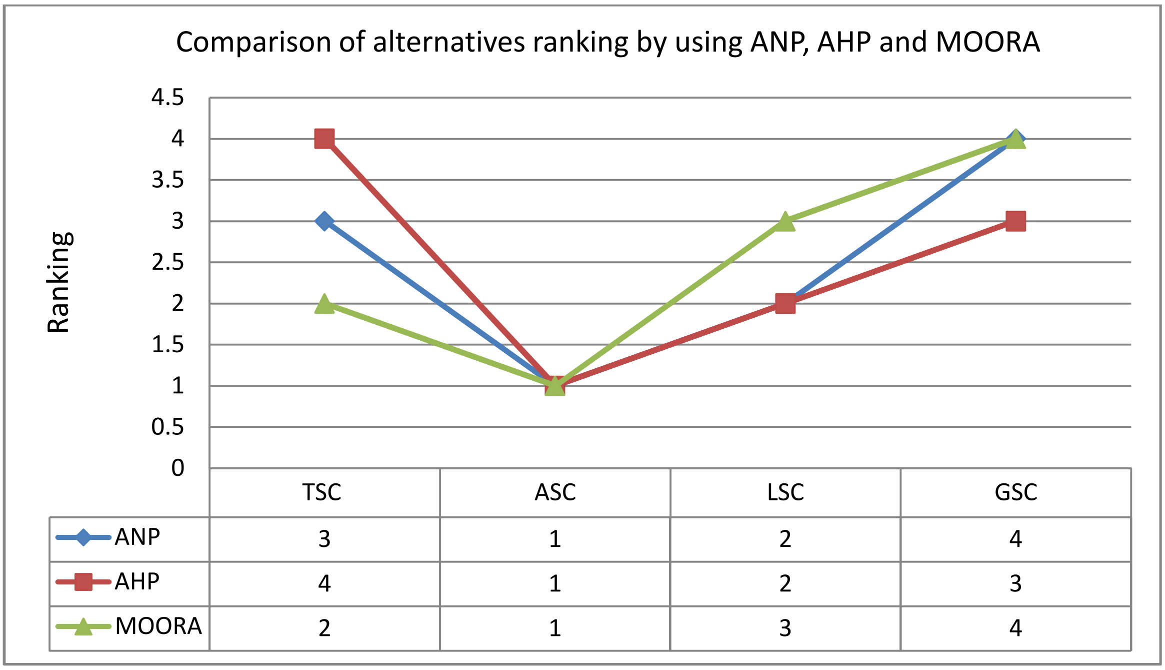
In ANP analysis, alternatives are ordered as ASC > LSC > TSC > GSC. The same example is analysed with the hierarchical model given in Figure 7.1 by assuming there is no dependence among the criteria. The overall priorities computed for the alternatives are presented in Figure 7.3. The same pairwise comparison 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.



	TSC	ASC	LSC	GSC
MOORA	0.302	0.393	0.272	0.145
AHP	0.136	0.408	0.247	0.149
ANP	0.162	0.426	0.299	0.113

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



	TSC	ASC	LSC	GSC
ANP	3	1	2	4
AHP	4	1	2	3
MOORA	2	1	3	4

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.

CHAPTER VIII

QUANTITATIVE ANALYSIS OF RISKS IN SUPPLY CHAIN BY USING GRAPH THEORETIC APPROACH

8.1 INTRODUCTION

Risk management in supply chain is the important part for performance measurement. There are different type of risks which occurs in supply chain. The main objective of an organization is to achieve more profit and satisfying the customer need, to withstand with the market competitors. To achieve this goal it is necessary to select a proper supply chain management system by managing the uncertainty and risk. Supply chain risks may result from unexpected variations in capacity constraints, or from breakdowns, quality problems, natural disasters, political instability, recession, demand fluctuations etc. at the supplier end (Blackhurst et al. 2005; Diabat et al., 2012). A failure in any part of supply chain may causes disruptions in the whole supply chain at upstream and downstream levels (Yang and Yang 2010). The vulnerability of a supply chain increases with increasing uncertainty, and it further increases if companies, by outsourcing are further dependent on other companies. The more uncertainties occur due to mismatch in demand and supply, demand and supply risks are the most important risk in supply chain due to which many other types of uncertainty and risk occurs. Although many risks exist in business, in this chapter six have applicability to the supply chain, namely supply risks, process risks, natural and social risk, transportation risk, financial risks and demand risks. Supply risks are related to the inbound supply chain in the term of cost, time, quality and quantity which may result in incomplete orders, the factors of supply risks are supplier, quality of service, quality of material, in-flexibility at supplier source, supply disruption, responsiveness and delivery performance. Process risk are related to the desired quality and quantity in right time, the factors of process risks are machine damage, capacity bottleneck, reduced lead time, human error, logistic provider. Natural and social risk are related to external forces such as weather, earthquake, political, the factors of natural and social risks are natural disasters, crime rate, machine explosion, political instability. Transportation risk are related to the mode of transportation choosen, the factors of transportation risks are high cost of transportation, product deliveries, port strike, poor scheduling. Financial risks are related to financial stability, the factors of financial risks are economic recession, fuel prices, and financial market in stability. Demand risks are related to the mismatch between the actual orders and forecast. The factors of demand risks are lack of SC visibility, change in preference, cancellation of orders, demand fluctuations. Table 8.1 shows the different risks and their factors with their sources.

Table 8.1: Risk and risk factors

S. No.	**Risk**	**Risk factors**	**References**
1.	Supply Risks (R_1^*)	Supplier (R_{11})	Kumar et al. (2010); Tummala and Schoendherr (2011); Kleindorfer and Saad (2005); Tang (2006); Knemeyer et al. (2009); Wakolbinger and Cruz (2011)
		Quality of service (R_{12})	
		Quality of Material (R_{13})	
		In-Flexibility at Supplier Source (R_{14})	
		Supply Disruption (R_{15})	
		Responsiveness and Delivery Performance (R_{16})	Ho et al. (2005); Manuj and Mentzer (2008)
2.	Process Risks (R_2^*)	Machine Damage (R_{21})	Melnyk et al. (1992); Hopp and Spearman (2000); Tang (2006); Ravi et al. (2005)
		Capacity bottleneck (R_{22})	
		Reduced Lead Time (R_{23})	
		Human Error (R_{24})	
		Logistic Provider (R_{25})	
3.	Natural and Social Risks	Natural Disasters (R_{31})	Samvedi et al. (2013); Diabat et al. (2012); Tummala and Schoendherr
		Crime Rate (R_{32})	

	(R_3^*)	Machine Explosion (R_{33})	(2011)
		Political Instability (R_{34})	
4.	Transportation Risks (R_4^*)	High Cost of Transportation (R_{41})	Chopra and Sodhi (2004); Tang, (2006); Zsidisin, (2003); Peck, (2006)
		Product Deliveries (R_{42})	
		Port Strike (R_{43})	
		Poor Scheduling (R_{44})	
5.	Financial Risks (R_5^*)	Economic Recession (R_{51})	Zhao et al. (2014); Gunasekaran and Ngai (2004); Vaart and Donk (2004); Bhattacharyya et al. (2010)
		Fuel Prices (R_{52})	
		Financial Market In stability (R_{53})	
6.	Demand Risks (R_6^*)	Lack of SC Visibility (R_{61})	Lockamy and McCormack (2010); Bhattacharyya et al. (2010); Lockamy and McCormack (2010); Lee et al. (1997); Croxton et al. (2002); Sharafali *et al.* (2004); Taylor (2006)
		Change In Preference(R_{62})	
		Cancellation of Orders (R_{63})	
		Demand Fluctuations (R_{64})	

To predict and compare the uncertainty and risk in supply chain it is necessary to analyse these above mentioned factors. A mathematical model is required to correlate these factors, sub-factors to evaluate and compare the risk in supply chain. For this many techniques like AHP, ANP, TOPSIS, SAW, MOORA, GTA, SEM etc. are available in the literature. But the present work undertakes the application of graph theoretic approach (GTA) for the quantification of risk in supply chain due to its advantage as compared to other techniques (Grover et al., 2004; Raj et al., 2009; Dev et al., 2015). In this chapter, various risks that can have an impact on the supply chain are included. The main objectives of this chapter are as follows:

- To identify the important risks involved in supply chains
- To establish a relationship among risk and their factors
- To evaluate the impact of risk in supply chain by calculating the risk measurement index (RMI).

8.2 METHODOLOGY USED

GTA is a systematic methodology for conversion of qualitative factors to quantitative values and mathematical modeling gives an edge to the proposed technique over conventional methods like cause-effect diagrams, flow charts etc. Graph theory serves as a mathematical model of any system that includes multi relations among its constituent elements because of its diagrammatic representations and aesthetic aspects. Graph theory is a subject of combinatorial mathematics and draws a lot from matrix theory. The matrix representation of the graph moulds the problem to make use of computers for various complex operations. GTA consists of the digraph representation, the matrix representation and the permanent function representation. The digraph is the visual representation of the factors and their interdependence which affects the die performance. The matrix converts the digraph into mathematical form. The permanent function is a mathematical model that helps to determine index.

8.2.1 Diagraph Representation of Risk Factors

A digraph is used to represent the factors and their interdependencies in terms of nodes and edges. Risk evaluation digraph models the factors, sub-factors and their interrelationship, which affects the supply chain. This digraph consists of a set of nodes P = $\{p_i\}$ with i=1, 2....,p and a set of directed edges R= $\{r_{ij}\}$. A node p_i represents the i^{th} factor affecting the risk and edges represent the relative importance among the factors. Number of nodes P, considered is equal to the number of risk factors affecting the supply chain. If a node 'i' is having the relative importance over another factor 'j' in the analysis of risk measurement, then a directed edge or arrow is drawn from nodes i to j (i.e. r_{ij}) or vice versa. In this chapter, six important factors namely supply risks (R_1^*), process risks (R_2^*), natural and social risks (R_3^*), transportation risks (R_4^*), financial risks (R_5^*) and demand risks (R_6^*) are selected which affect the supply chain performance. Supply risks (R_1^*) affect the process risks, transportation risks and demand risks. Hence there are directed edges from R_1^* to R_2^*,

R_4^* and R_6^*. Process risks (R_2^*) affects the supply risks, transportation risks and demand risks. This is shown by directed edges from R_2^* to R_1^*, R_4^* and R_6^*. Similarly other directed edges from R_3^*, R_4^*, R_5^* and R_6^* to all other factors (Ri) are drawn as shown in Figure 8.1. The diagraphs from Figure 8.2 to 8.7 have been drawn on the basis of relation between various risk factors.

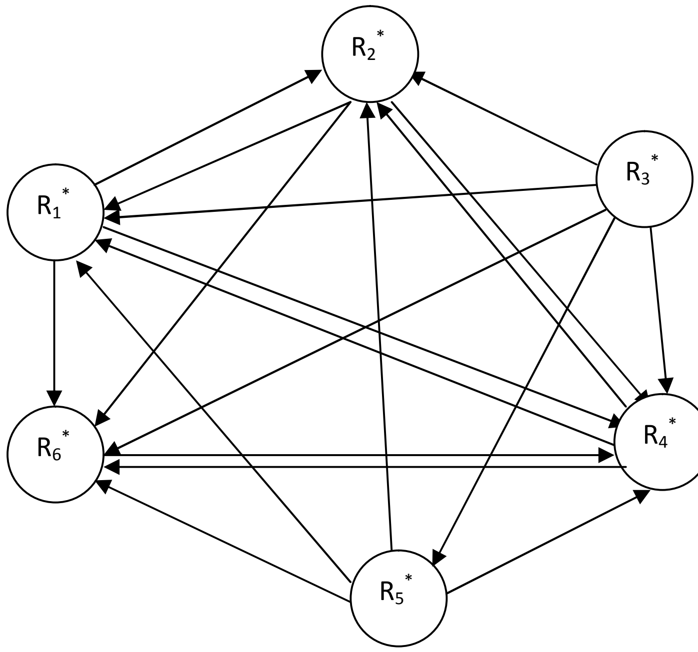


Figure 8.1: Diagraph showing the relationship among the risks

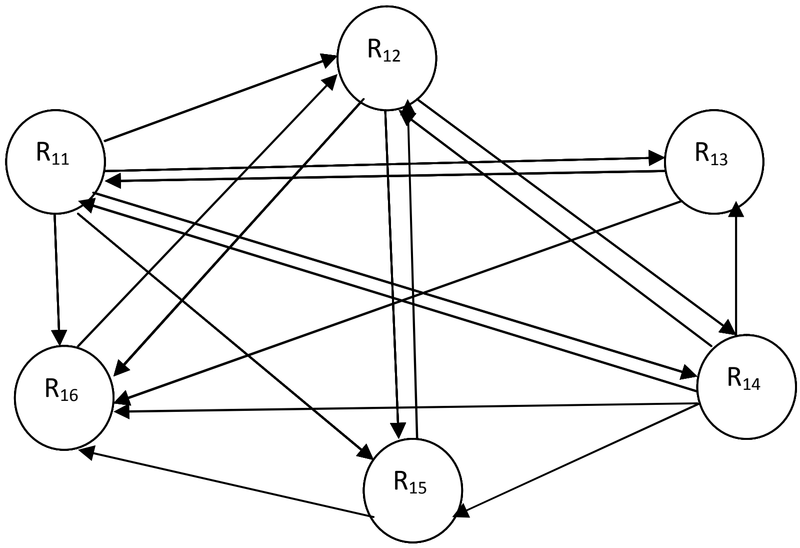


Figure 8.2: Diagraph showing the relationship among the supply risk factors (R_1^*)

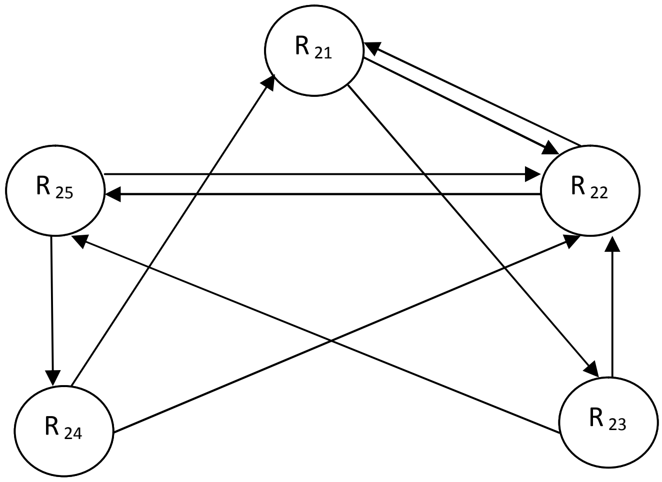


Figure 8.3: Diagraph showing the relationship among the process risk factors (R_2^*)

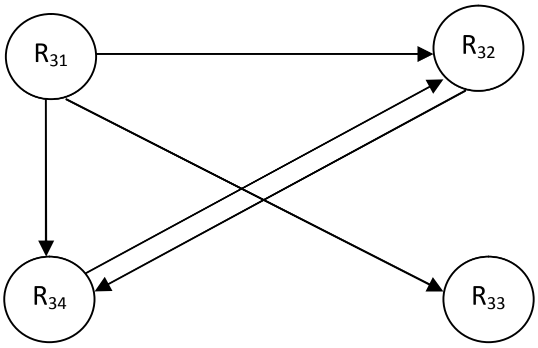


Figure 8.4: Diagraph showing the relationship among the Natural and Social Risks (R_3^*)

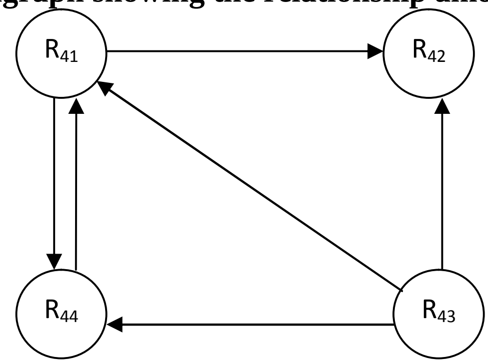


Figure 8.5: Diagraph showing the relationship among the Transportation Risks (R_4^*)

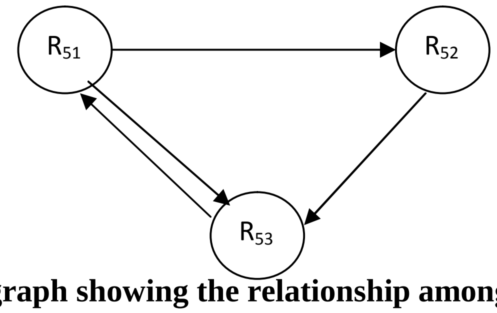


Figure 8.6: Diagraph showing the relationship among the Financial Risks (R_5^*)

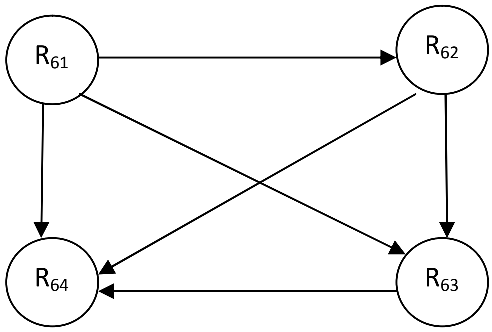


Figure 8.7: Diagraph showing the relationship among the Demand Risks (R_6^*)

8.2.2 Matrix Representation of Risk Factors Diagraph

A digraph is a visual representation so it helps in analysis to a limited extent only. For the establishment of the expression for factors affecting the risk in supply chain, the digraph is represented in matrix form. Matrix representation of the digraph for risk factors gives one to one representation. This matrix is called risk evaluation matrix or variable permanent matrix for risk management (VPMRM). The matrix corresponding to risk factors evaluation digraph is given as:

The diagonal elements R_1^*, R_2^*, R_3^*, R_4^*, R_5^* and R_6^* represent the effect of the six important factors which affects the risk in supply chain and off-diagonal elements represent interdependencies of each factor in the matrix.

$$\mathbf{R_1^*} = \begin{array}{c} \\ R_{11} \\ R_{12} \\ R_{13} \\ R_{14} \\ R_{15} \\ R_{16} \end{array} \begin{array}{c} \begin{array}{cccccc} R_{11} & R_{12} & R_{13} & R_{14} & R_{15} & R_{16} \end{array} \\ \begin{pmatrix} 7 & 3 & 2 & 4 & 3 & 2 \\ 0 & 6 & 0 & 4 & 4 & 3 \\ 3 & 0 & 8 & 0 & 0 & 4 \\ 3 & 2 & 4 & 7 & 3 & 4 \\ 0 & 4 & 0 & 0 & 6 & 5 \\ 0 & 3 & 0 & 0 & 0 & 5 \end{pmatrix} \end{array}$$

Matrix for R_1^* risk factors

$$\mathbf{R_2^*} = \begin{array}{c} \\ R_{21} \\ R_{22} \\ R_{23} \\ R_{24} \\ R_{25} \end{array} \begin{array}{c} \begin{array}{ccccc} R_{21} & R_{22} & R_{23} & R_{24} & R_{25} \end{array} \\ \begin{pmatrix} 8 & 3 & 2 & 0 & 0 \\ 4 & 9 & 0 & 0 & 3 \\ 0 & 4 & 7 & 0 & 4 \\ 4 & 3 & 0 & 8 & 0 \\ 0 & 4 & 0 & 3 & 8 \end{pmatrix} \end{array}$$

Matrix for R_2^* risk factors

$$R_3^* = \begin{array}{c} \\ R_{31} \\ R_{32} \\ R_{33} \\ R_{34} \end{array} \begin{array}{c} \begin{array}{cccc} R_{31} & R_{32} & R_{33} & R_{34} \end{array} \\ \begin{pmatrix} 7 & 4 & 3 & 4 \\ 0 & 8 & 0 & 4 \\ 0 & 0 & 7 & 0 \\ 0 & 4 & 0 & 6 \end{pmatrix} \end{array}$$

Matrix for R_3^* risk factors

$$R_4^* = \begin{array}{c} \\ R_{41} \\ R_{42} \\ R_{43} \\ R_{44} \end{array} \begin{array}{c} \begin{array}{cccc} R_{41} & R_{42} & R_{43} & R_{44} \end{array} \\ \begin{pmatrix} 7 & 4 & 0 & 4 \\ 0 & 7 & 0 & 0 \\ 4 & 4 & 8 & 3 \\ 3 & 0 & 0 & 6 \end{pmatrix} \end{array}$$

Matrix for R_4^* risk factors

$$R_5^* = \begin{array}{c} \\ R_{51} \\ R_{52} \\ R_{53} \end{array} \begin{array}{c} \begin{array}{ccc} R_{51} & R_{52} & R_{53} \end{array} \\ \begin{pmatrix} 8 & 3 & 4 \\ 0 & 7 & 5 \\ 4 & 0 & 8 \end{pmatrix} \end{array}$$

Matrix for R_5^* risk factors

$$R_6^* = \begin{array}{c} \\ R_{61} \\ R_{62} \\ R_{63} \\ R_{64} \end{array} \begin{array}{c} \begin{array}{cccc} R_{61} & R_{62} & R_{63} & R_{64} \end{array} \\ \begin{pmatrix} 6 & 2 & 1 & 3 \\ 0 & 5 & 3 & 2 \\ 0 & 0 & 6 & 3 \\ 0 & 0 & 0 & 5 \end{pmatrix} \end{array}$$

Matrix for R_6^* risk factors

$$\textbf{RMI} = \textbf{Per } \mathbf{R^*} = \begin{array}{c} \\ R_1^* \\ R_2^* \\ R_3^* \\ R_4^* \\ R_5^* \\ R_6^* \end{array} \begin{array}{c} \begin{array}{cccccc} R_1^* & R_2^* & R_3^* & R_4^* & R_5^* & R_6^* \end{array} \\ \begin{pmatrix} 305056 & 4 & 2 & 3 & 0 & 3 \\ 3 & 18592 & 0 & 3 & 0 & 4 \\ 3 & 2 & 784 & 2 & 3 & 3 \\ 2 & 4 & 0 & 2232 & 0 & 3 \\ 3 & 3 & 0 & 2 & 412 & 4 \\ 0 & 0 & 0 & 0 & 0 & 540 \end{pmatrix} \end{array}$$

Matrix for risks (R)

8.2.3 Permanent Function Representation of Risk Factors

The permanent function is basically the standard form of the matrix. Application of permanent function concept will lead to a better appreciation for the risk factors in supply chain. Moreover there is no negative sign will appear in the expression and no chance of losing any data. The permanent function is the determinant of a matrix but considering all the determinant terms as positive terms.

$$\prod_{i=1}^{n} R_i + \sum_{i,j} (r_i r_j) R_k R_l R_m R_n + \sum_{i,j,k,l,m,n} (r_i\ r_j\ r_k\ + r_i\ r_k\ r_j) R_l R_m R_n$$

$$+\left(\sum_{i,j,k,l,m,n} (r_i\ r_j)(R_m R_n) + \sum_{i,j,k,l,m,n} (r_i\ r_j\ r_k\ r_l + r_i r_l\ r_k\ r_j) R_m R_n\right)$$

$$\{\sum_{i,j,k,l,m,n} (r_i\ r_j) + (r_k\ r_l\ r_m\ + r_k\ r_m\ r_l) D_n + \sum_{i,j,k,l,m,n} (r_i\ r_j\ r_k\ r_l\ r_m\ + r_l\ r_m\ r_k\ r_j) R_n\} + [\sum_{i,j,k,l,m,n} (r_i\ r_j)(r_k\ r_l\ r_m\ r_n\ + r_k\ r_n\ r_m\ r_l) + \sum_{i,j,k,l,m,n} (r_i\ r_j\ r_k)(r_l\ r_m\ r_n) + \sum_{i,j,k,l,m,n} (r_i\ r_j)(r_k\ r_l)(r_m\ r_n) + \sum_{i,j,k,l,m,n} (r_i\ r_j\ r_k\ r_l\ r_m\ r_n\ + r_l\ r_n\ r_{ml} r_l\ r_k\ r_j)]$$

The VPF_R is a mathematical expression in symbolic form and it estimates the risk in supply chain. This is a complete expression for risks as it is considered for all of the risk factors and their interdependencies.

8.2.4 Evaluating the Risk Measurement Index (RMI)

To find out a single numerical index, the permanent of the matrix, called as variable permanent function. The permanent function is obtained in a similar manner as its determinant but with keeping all signs positive. This expression is represents the rating of risk in supply chain. The value of off-diagonal elements and diagonal elements can be determined by using Table 8.2. To determine the value of factors R_1*, R_2*, R_3*, R_4*, R_5* and R_6* it is proposed to find out the permanent function of the matrix using Equation 1.

The numerical value of risks matrix is named as RMI (Risk Measurement Index). RMI= per R*= Permanent function of risk factors matrix. The values of RMI are as follows: R_1^* = 305056, R_2^*= 18592, R_3^*= 784, R_4^*= 2232, R_5^*= 412, R_6^*= 540. The value for each factor RMI has been used to calculate the overall system index of fitness as states in the last matrix and it is found to be RMI = 1.63559 e^{+19}. Along with this the minimum and maximum values for RMI have been found for each factor. The minimum and maximum values for each factor and overall system have been shown in Table 8.3.

Table 8.2 Quantification of diagonal and off-diagonal elements

S. No.	Qualitative measures of factors(Bi's)	Value assign	Qualitative measures of interdependencies/off diagonal values (Bij's)	Value assign
1.	Exceptionally low	1	Not at all	1
2.	Very low	2	Some whatimportant	2
3.	Low	3	Important	3
4.	Below average	4	Quiet important	4
5.	Average	5	Very important	5
6.	Above below	6		
7.	High	7		
8.	Very high	8		
9.	Exceptionally high	9		

Table 8.3: Values for minimum and maximum of risk factors

Risks	Minimum Value	Current Value	Maximum Value
R_1^*	20717	305056	728421
R_2^*	1244	18592	25116
R_3*	16	784	1296
R_4*	63	2232	3591
R_5*	65	412	561
R_6*	03	540	2187
RMI	6.7555 e^{+12}	1.63559 e^{+19}	1.9106 e^{+20}

8.3 DISCUSSION

Keeping in view, the RMI of different risk factors, good decision may be taken by the managers and academicians for the risk management in supply chain such as:

- From this analysis, it has been observed that supply risks have the maximum value of RMI. Supply risks play an important role for the management of supply chain. To mitigate supply risks management should focus on these factors.
- The next major risk is process risks which comprise the machine damage, capacity bottleneck, reduced lead time, human error, logistic provider and the process involve in production system.
- The next important risk is transportation risk which can't be ignored. This is one of the important risks which can affect the whole supply chain, without focusing on this risk supply chain can't be completed.
- Table 8.3 also reveals an important observation. RMI for the current situation is 1.63559 e^{+19} which is nearer to maximum value (1.9106 e^{+20}). Therefore the current value of RMI indicates that the management of firms is much good for identified risks.

8.4 CONCLUSION

In this chapter, GTA based frame work has been developed to quantify the impact of risks in supply chain and it is concluded that firms should evaluate their risk measurement index toward risks by calculating RMI for them. If the risks are found more in the firms, it should take necessary steps to strengthen these risks in supply chain so that risk measurement index can be improved. Firms should focus on natural and social risks, demand risks and financial risks by caring the disasters, politics and financial stabilities. This procedure also helps to compare the different industries situation by calculating the risk measurement index. It is also concluded that the industries should evaluate the RMI value as proposed and make the suitable strategies for dealing with the different types of risks associated with the supply chains.

CHAPTER IX

RISK MITIGATION TECHNIQUES

9.1. INTRODUCTION

The risk mitigation process in supply chain forms a closed loop in the framework for risk management. With the help of risk modeling results, firms can decide their strategies for the set of risk attributes instead of dealing with each risk independently. This modeling provide a unique ‘management system’ for unpredictable risk events for effective risk management and mitigation. The system can be also used during risk recovery by reactively providing the understanding of most influential risk attribute and their inter-relationship in cascading the risk. This information is crucial for risk mitigation process in order to quickly recover from uncertainty and disruption. For risk mitigation, agility, leanless, flexibility, quickly response and proper forecast are the broad strategies (Ponomarov and Holcomb, 2009). Based on the fundamental understanding of risk nature, firms can defined on agility or flexibility etc. to develop their mitigation strategies. The main objectives of this chapter are as follows:

- To developed a model of risk factors and mitigations
- To suggest some risk mitigation techniques

9.2. RISK MITIGATION TECHNIQUES

Some of the risk mitigations techniques are as follows:

9.2.1 Identify Regional ‘Risk’ Elements

Firm ought to concentrate on the identification regional risks where expansive quantities of operations are sump in a solitary area. To do this firm may attempt to deal with every one of the exercises included in inventory network from the sources to the end client to catch the danger connected with every part. Firms may attempt to redesign the suppliers, sellers and stock administration methods where area or association expands instability and hazard because of single sources. Point layout the actions and attempts to alleviate them.

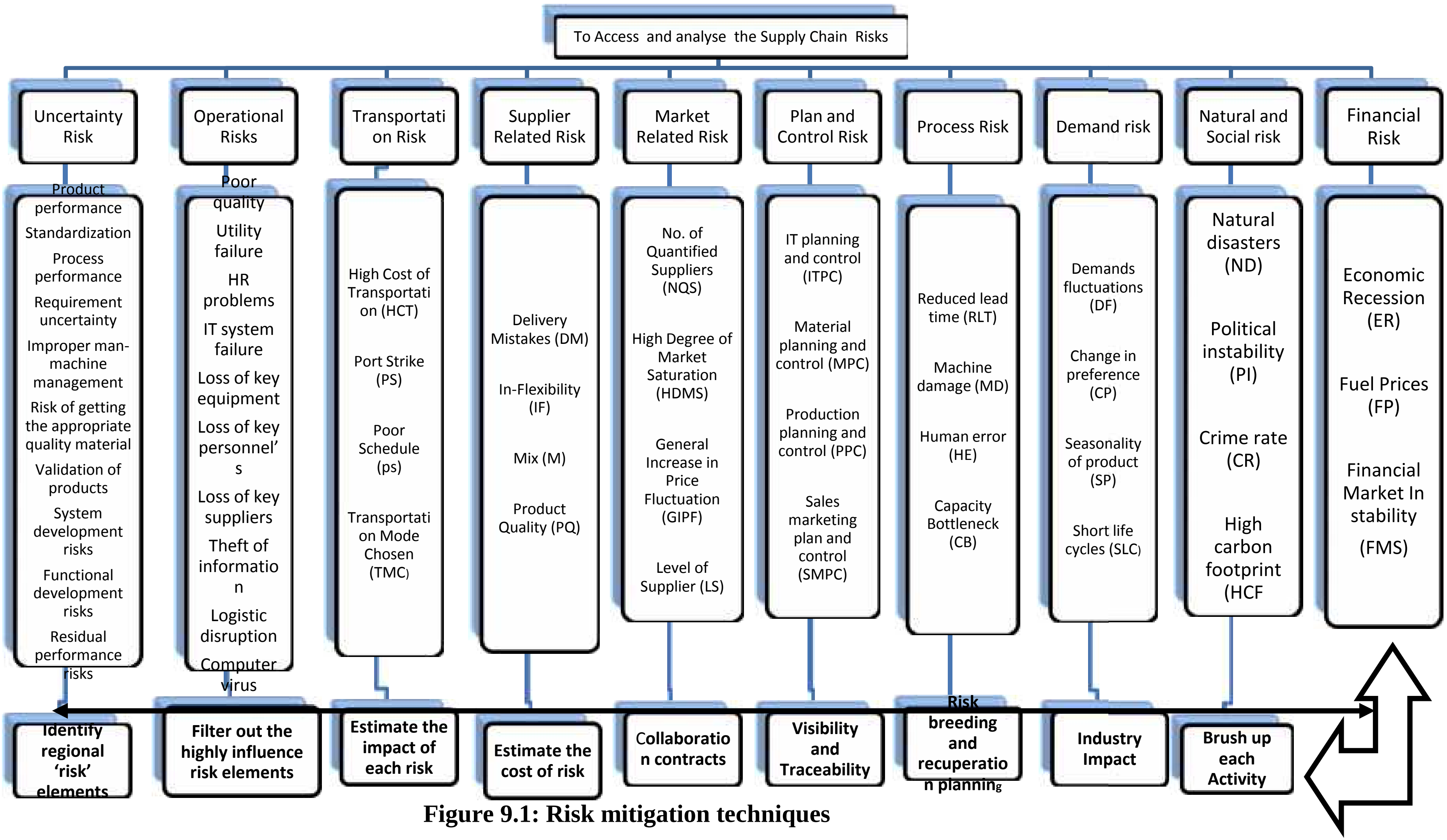


Figure 9.1: Risk mitigation techniques

9.2.2 Filter Out the Highly Influence Risk Elements

Filter out the high influence risks elements/areas. Instead of focusing on the small risks, (which do not highly effect the system) focus on the highly influence risk element (which highly effect the system) (Ghadge et al., 2012).

9.2.3 Estimate the Impact of Each Risk

Firm ought to appraise the effect of risks what one exists for a little period or long stretch of spam. Initially firm ought to concentrate on the risks which happen for the little period after that the risks which happen for the long stretch can be controlled effectively. When a firm knows the danger likelihood, it needs to characterize the effect connected with it. Case in point if, a firm concentrate on its one and only plant than the expense of regular catastrophe can be more than any expense, because of this the whole creation of the plant can be ceased. Be that as it may, for an item created with different offices the danger would be equivalent to incremental possibility, the expense of additional time work to move generation to different plants. While the expense and benefit expansion will specifically influence the poor execution which causes the danger.

9.2.4 Estimate the Cost of Risk

Risk lessening enhances the execution of the framework and it is not important to alleviate each risk. At times, the expense of spreading the risk can be more noteworthy than the effect itself. Eventually spreading the risk over different offices is more exorbitant than shutdown at one plant. By displaying and investigating the risk factors, firm can figure out the aggregate expense of including areas, stock, distribution centers or individuals that lessen risks. Frequently a high cost methodology can build the risk and ease system can lessens the risk administration disturbance and future expense spikes.

9.2.5 Collaboration Contracts

Collaboration and outsourcing by presenting risk sharing and/or contracts amongst production network individuals can help to enhance the system effectiveness (Urciuoli, 2010). Improvement of supplier associations and key organizations together are getting to be key components for long haul productivity and additionally hearty risk moderation systems. Possibility/recuperation arranging methods should be industry or inventory network particular (Juttner et al, 2003). Risk sharing contracts have potential for taking care of risks in supply chains for system coordination later on.

9.2.6 Visibility and Traceability

Information technology among the supply chain partners can improve the risk mitigation due to the timely and accurate information. It is expected that information technology/sharing make a big impact in the term of visibility and traceability in supply chain. Visibility and traceability do not feature within the core of the research on supply chain risk management (SCRM). Hence, this will have a great impact on supply chain.

9.2.7 Risk Breeding and Recuperation Planning

Research in interruption rearing, looking at impacts and recovery of the supply chain risks is inadequate in the writing (Natarajarathinam et al., 2009; Ghadhe et al., 2012). Hazard administration and demonstrating of danger reproducing regarding primary traits i.e. expense, time, administration will give more prominent perceivability to viable danger administration. Understanding the danger potential and how hazard can scatter. Comprehension danger reproducing can likewise prompt better proactive danger administration framework. There is a discriminating requirement for recovery wanting to moderate against the impact of debacles (Bryson, 2002). A few methodologies ought to be accessible to recuperate rapidly after the vulnerability has happens. Making the fitting danger recuperation model needs proper arranging, data and human inclusion.

9.2.8. Industry Impact

Despite the fact that, this study is identified with scholarly chip away at danger management in supply chain, it is basic to place it in the setting of the effect that the work makes inside of industry. Albeit there may be a level headed discussion on which strategy is the most proper and for the benefit of literature survey and questionnaire based survey a percentage of the key territories can be distinguished for the enhancement in danger management. A percentage of the systems like AHP, ANP, W-ISM, MOORA, GTA and so on can be utilized for distinguishing the key components which are useful for danger alleviation and firm can concentrate on these key regions.

9.2.9 Brush Up Each Activity

For risk mitigations there is a need to catch up on all the action, existing issues and to further uncertainty. A coordinated methodology need to consolidate the risk issues. Redeal with the risks management methodologies. All the risk measurements, effect streams, mitigations options, risk management procedure should be look over in entirety.

9.3 CONCLUSION

The risks involved in supply chain of the firm under study were identified and strategies for mitigating these risks have been proposed. In this chapter, risk mitigation techniques which are helpful in mitigating the various uncertainty and risks have been proposed. These techniques are the one of the most important techniques for risk management in supply chains. This type of categorization is the key to identify the relevant mitigation technique to be adopted. Based on this analysis, management can take steps to mitigate the identified risks.

CHAPTER X

SYNTHESIS OF RESEARCH WORK

10.1 INTRODUCTION

Risk can't be eliminated completely but they can be reduced. So risk management for the firms are necessary for successful supply chain management to increase the productivity and cost reduction. For this purpose, different type of uncertainty and risk measures are analyzed. In this chapter, the synthesis of research work mention in the previous chapters has been presented. The main objectives of this chapter are as follows:

- To present the overall picture of the research work
- To illustrate the different studies done in previous chapters
- To establish a link among all the studies carried out in this research.

10.2 SYNTHESIS OF RESEARCH WORK

Research reported in this thesis concerns the investigation of some select issues of uncertainty and risk management in supply chain in the context of Indian manufacturing industries. The research was carried out with objectives specified in chapter I. The achieved objectives are as follows:

- The literature existing on uncertainty and risk in supply chain has been studied and some other different burning issues with supply chain management mainly risk identification and management were identified. Some critical barriers and important success factors related to supply chain management are also discussed.
- The present trends on uncertainty and risk in supply chain in Indian manufacturing industries have been analysed through questionnaire based survey.
- Operational risk factors in supply chain have been identified and W-ISM based model have been prepared for understanding the key risk factors.
- Dominant risk factors related to uncertainty and risk measures in supply chain have been analysed. For this, another W-ISM based model has been prepared for understanding the key risk measures

- Different type of risks have been analysed to find out the best supply chain.
- An analytical study has been developed to evaluate the quantitative impact of risks in supply chain.
- Different risk mitigation techniques have been proposed.

In achieving these objectives, the methodologies used in the present research are presented in Table and Figure 10.1.

Table 10.1: Methodologies used in the research

Objectives	**Methodology Used**	**Study No.**
To identify the select issues of uncertainty and risk measures in supply chain	Literature review and expert opinion	1
To understand the importance of uncertainty and risk measures of Indian manufacturing industries in supply chains	Questionnaire based survey	2
Analysis of operational risk in supply chain	Weighted Interpretive structural modelling technique	3
Analysis of competitiveness of uncertainty and risk measures in supply chain	Weighted Interpretive structural modelling technique	4
Development of ANP based framework for modelling the risk in SCs	Analytical Network Process	5
Comparative study and risk assessment of different supply chains	Analytical Network Process, Multi objective optimization using rational analysis	6
Quantitative analysis of risk in supply chain	Graph theoretic approach	7

The studies conducted in this research have been explained below:

A extensive literature review have been conducted and studies regarding the different issues related to uncertainty and risks, critical success factors, barriers and different type supply chains reported in Chapter II. In Chapter III, observation of Indian manufacturing industries towards the uncertainty and risks in supply chains have been presented. On the basis of results of survey, uncertainty and risk issues were segregated and ranked which provided the base for the development of models by Weighted Interpretive structural modeling technique (W-ISM). Chapters IV and V present the development of W-ISM based frameworks. These frameworks have been developed on the basis of operational risks and uncertainty and risk measures in supply chains, identified through literature review and questionnaire based survey. These models show the interrelationship and respective levels of operational risks and uncertainty and risk measures. The operations risks and uncertainty and risks measure have been categorized according to their driving and dependence powers. Effectiveness indexes also have been calculated to find out the influence of risk factors. After applying the W-ISM, ANP based frameworks have been developed in Chapter VI and VII. In Chapter VI three types of supply chains have been employed for the analysis of uncertainty and risks in supply chains, in which agile supply chain has been found the best one among traditional, agile and green supply chains. In Chapter VII, ANP based model have been prepared for the comparative study and risk assessment in different supply chains to find out the best supply chain. In this chapter again agile supply chain is found best one among traditional, agile, lean and green supply chain. This analysis has been carried out with the comparison of ANP, AHP and MOORA techniques. After this analysis it was felt that there is a need of quantitative analysis of uncertainty and risks in supply chains. Therefore for the quantitative analysis, a GTA based framework has been developed which is presented in Chapter VIII. Graph theoretic approach correlated six categories of risks and encapsulates their quantification based on their sub factors and interdependence. This study proposed a numeric value known as risk measurement index, which can be utilized by industrial managers to quantify the uncertainty and risks associated in their supply chains.

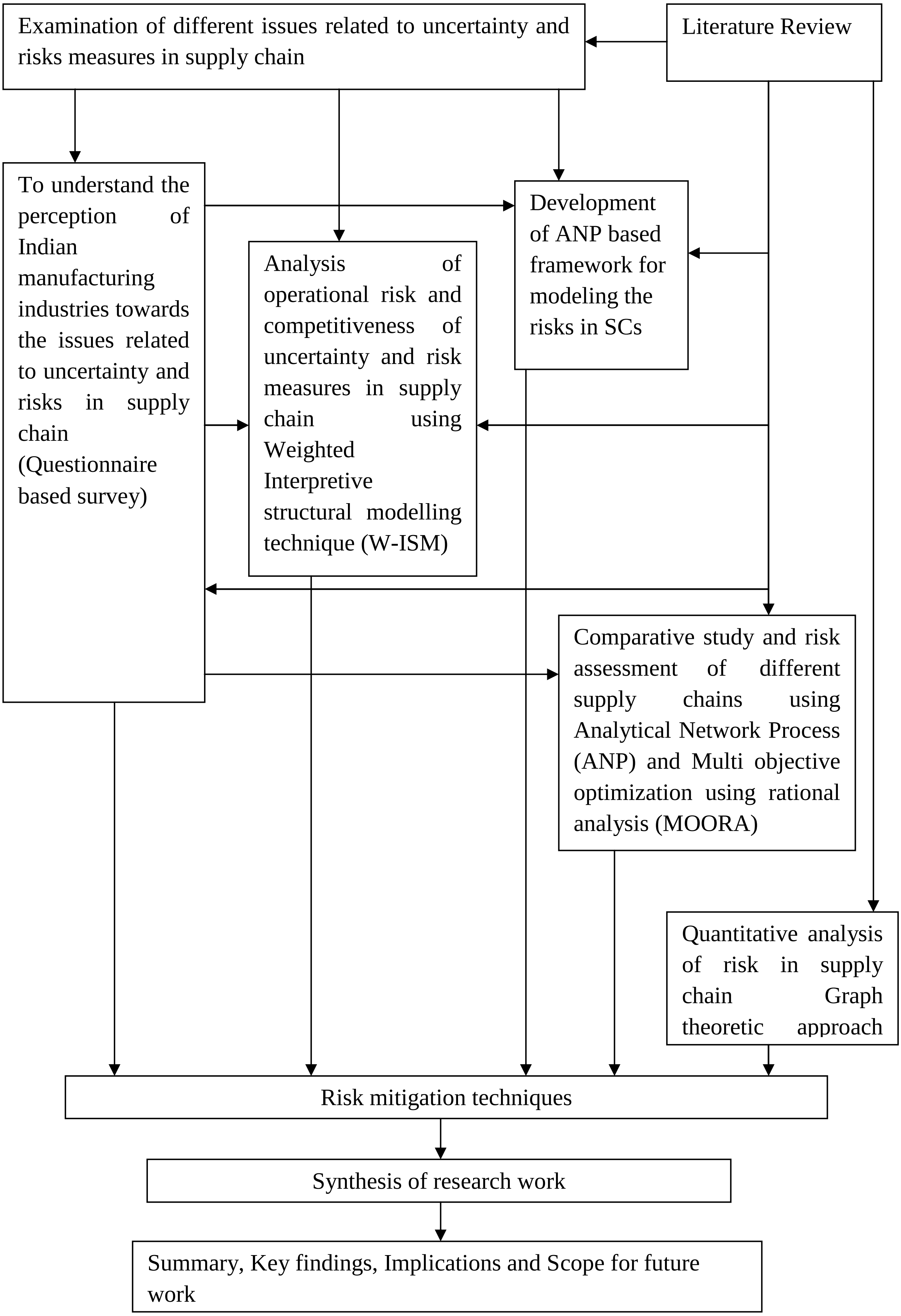


Figure 10.1: Integration of methodologies used in the research

10.3 CONCLUSION

This chapter presents the synthesis of research work presented in this thesis. Linkages between different approaches are reported in this chapter. A diagram is presented to illustrate the integration of different methodologies used in this research. Further, summary, conclusion, key findings, implications and scope for future work have been presented in the next chapter.

CHAPTER XI

SUMMARY, KEY FINDINGS, IMPLICATIONS AND SCOPE FOR FUTURE WORK

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 personnels 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 personnels 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 personnels, 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.

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APPENDIX A1
QUESTIONNAIRE

Research Supervisors 1) Dr.Tilak Raj, YMCA UST, Faridabad.

2) Dr. Ravi Shankar, IIT, Delhi.

Sub: - A research project on "Study of select issues of uncertainty and risk management in supply chain"

Dear Sir/Madam,

Supply chain management is a set of approaches to efficiently integrate suppliers, manufacturers, distributer, warehouses and logistics providers, so that merchandise can be procured, produced and distributed in right quantities, at the right location, and at the right time. Keeping in view the important role of SCM in Indian economy, a research work entitled **"Study of select issues of uncertainty and risk management in supply chain"** is being undertaken for Ph. D thesis at the Mechanical Engineering Department of YMCA University of Science & Technology, Faridabad.

In this regard a questionnaire covering different issues related to supply chain management is being sent to your reputed organization. As the answers to these questions provided by you, will be of utmost value towards achieving the objective. I earnestly request you kindly spare some of your valuable time for giving answers to various questions as observed in your organization. The purpose of the survey is purely academic. Therefore, all responses will be kept strictly confidential and will be used only for this academic work.

I will be highly obliged for your kind cooperation. Further i want to inform you that it is a time bound work, so please try to return it within seven days.

Thanks with warm regards

Yours Sincerely,

Mahesh Chand

(Research Scholar)

Encl-
- Questionnaire
- Self-addressed envelope

Part 1 – Company Profile

1. Name of Company ______________________________

2. Address ______________________________

3. Country ______________________________

4. Tel ____________________ 5. Fax ____________________ 6. Website ____________________

7. E-mail:____

8. No of employees: [______]

9. Sector Types: ☐Manufacturing ☐ Service ☐ Both

10. Industry: ☐Food ☐ Automotive Other (define) ____________________

11. Turnover 2010 : [__________________]

Part 2 – Theme

12. How successful do you think is your company in managing its supply chain in general.

Not successful	Somewhat successful	Successful	Very successful
☐ 1	☐ 2	☐ 3	☐ 4

13. Which of the following you think that your company needs to do in order to manage its supply chain better. Please put a tick mark (√) at appropriate box.

	Improve	Start Implementing	Satisfied already	Not appropriate
Close partnership with suppliers				
Close partnership with customers				

JIT(Just in time) supply				
e-procurement				
EDI**(**Electronic data interchange)				
Outsourcing				
Subcontracting				
3PL(Party logistics)				
Plan strategically				
Supply Chain Benchmarking				
Vertical integration				
Few suppliers				
Many suppliers				
Holding safety stock				
Use of external consultants				
Other (*specify)*				

14. Does your company have a separate SCM department? ☐YES ☐NO

15. Does your company have a clear supply chain strategic plan? ☐YES ☐NO

Part 3- Risk issues related to Supply Chain Management

16. Please mark (√) level of following plan and control risksof your organization feel while working in supply chain. (1-Not at all, 2-somewhatimportant, 3- important, 4- quite important, 5-very important).

S.N.	**Plan and control risks**	1	2	3	4	5
1	Applied methods, concepts and tools					
2	IT systems					
3	Material management					
4	Production planning					
5	Sales and marketing					
6	Lack of visibility in supply chain					
7	Economical risk review					

17. Please mark (√) level of following supply (procurement) risksof your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Supply (Procurement) risks**	**1**	**2**	**3**	**4**	**5**
1	Quality of material					
2	Suppliers (failure, single sourcing, adherence to delivery dates)					
3	Damage to cargo					
4	Monopoly situations (single sourcing)					
5	New strategic alignment of suppliers					
6	Liquidity problem and insolvency of suppliers					
7	Quality of service					
8	Responsiveness and delivery performance					
9	Supplier fulfilment errors					
10	Selection of wrong partners					
11	Inflexibility of supply source					
12	quality or process yield at supply source					
13	Supplier bankruptcy					
14	Supply disruptions					
15	Unreliable suppliers					

18. Please mark (√) level of following Process risks of your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Process risk**	**1**	**2**	**3**	**4**	**5**
1	Reduced lead time					
2	Capacity bottleneck					
3	Machine damage					
4	Human error					
5	Faulty planning					
6	Trouble with third-party logistics provider					
7	Inefficient supply teams in the organisations					

19. Please mark (√) level of following Demand risksof your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	Demand risks	1	2	3	4	5
1	Demand fluctuations					
2	Changes in preferences					
3	Cancellation of orders					
4	Planning and communication flaws in sales					
5	Order fulfilment errors					
6	Inaccurate forecasts due to longer lead times					
7	Seasonality of product					
8	Short life cycles					
9	Information distortion due to sales promotions and incentives					
10	Lack of supply chain visibility					

20. Please mark (√) level of following Natural and Social risks of your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	Natural and social risks	1	2	3	4	5
1	Natural disasters (fire, earthquake, flood, rock fall, landslide, avalanche, etc.)					
2	Political instability (strike, taxes, war, terrorist attacks, embargo, political labour conflicts,)					
3	Social and cultural grievances					
4	Crime rate					
5	Price and currency risks/inflation					
6	Unanticipated resource requirements					
7	High levels of CO2and polluting gas emissions during the global sourcing activity.					
8	Quota restrictions					
9	Machine explosion					

21. Please mark (√) level of following Transportation Risksof your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	Transportation risks	1	2	3	4	5
1	Extensive paperwork and poor scheduling					
2	Port strikes					
3	Delay at ports due to limited port capacity					
4	Product deliveries					
5	Higher costs of transportation					
6	Depends on transportation mode chosen					

22. Please mark (√) level of following market-related risksof your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	Market-related risks	1	2	3	4	5
1	Number of qualified suppliers					
2	High degree of market saturation					
3	General increase in price fluctuation					
4	High geographical concentration of the suppliers					
5	Low cost countries suppliers					
6	Level of supplier certification					

23. Please mark (√) level of following Supplier-related Risks of your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	Supplier-related risks	1	2	3	4	5
1	Problems in the product quality					
2	Delivery mistakes					
3	Conflictual relationships					
4	Qualitative problems					
5	Cost increases					
6	Difficulties in satisfying the demand					
7	Technological backwardness					
8	Discontinuity of supply					
9	Financial instability					
10	Information technology					
11	Inadequate transport					
12	Inadequate inventory					
13	Inability to quickly implement					
14	Mix/Volume					
15	Inflexibility					

24. Please mark (√) level of following Financial Risks of your organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Financial risks**	**1**	**2**	**3**	**4**	**5**
1	Debt and credit rating					
2	Liquidity/cash					
3	Economic recession					
4	Financial market instability					
5	Currency and foreign exchange rate fluctuations					
6	Fuel prices					
7	Adverse changes in industry regulation					
8	Credit default					

25. Please mark (√) level of following operations riskyour organization feel while working in supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Operations risks**	**1**	**2**	**3**	**4**	**5**
1	Theft					
2	Operator errors/accident damage					
3	Loss of key personnel					
4	Computer virus					
5	Poor-quality					
6	IT systems failures					
7	HR risks					
8	Loss of key supplier					
9	Logistics route or mode disruptions					
10	Loss of key equipment					
11	Utilities failures					

26. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Performance measurement risks. (1-Not at all, 2-somewhat important, 3-important, 4-quite important, 5-very important).

S.N.	Performance measurement risks	1	2	3	4	5
1	Requirement Uncertainty					
2	Residual performance risk					
3	Functional development risk					
4	System development risk					
5	Product performance					
6	Process performance					
7	Standardization					

Part 4- Other issues related to Supply Chain Management

27. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Performance measurement. (1-Not at all, 2-somewhat important, 3-important, 4-quite important, 5-very important).

S.N.	Performance measurement	1	2	3	4	5
1	Manufacturing cost					
2	Level of inventory					
3	Timely delivery of product					
4	Flexibility in production					
5	Percentage reduction					
6	Labour productivity					
7	Capacity utilization					
8	Employ turnover rate					
9	Employ satisfaction					
10	Customer satisfaction					
11	Supplier satisfaction					
12	Respond well to customer demand for new features					
13	Process cycle time					
14	Market share					
15	Return on investment					
16	Net profit					
17	Total cost reduction					
18	Conformance with property specifications					

28. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Green supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Green supply chain**	**1**	**2**	**3**	**4**	**5**
1	Lack of commitment from top management					
2	Inadequate adoption of reverse logistic practices					
3	Lack of Eco-literacy amongst supply chain partners					
4	Lack of Corporate Social Responsibility					
5	Lack of market demand					
6	Lack of preparedness on part of suppliers					
7	Inadequate strategic planning					
8	Lack of integrated information system					
9	Lack of appropriate environmental performance metrics					
10	Lack of support and guidance from regulatory authorities					
11	Non adoption of cleaner technology					

29. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Barriers for SCM. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Barriers for SCM**	**1**	**2**	**3**	**4**	**5**
1	Vendor selection problems in the supply of high tech equipment					
2	Big loss of market share during transition period					
3	Lack of supply chain planning and coordination					
4	Demand uncertainties					
5	Lack of knowledge					
6	Lack of supply chain perception					
7	Inadequate IT infrastructure resources					
8	Lack of purchase management					
9	Fear of supply chain breakdown					
10	Lack of assets					
11	lack of management obligation					
12	costs of implementation					
13	Lack of sharing and accurate information					
14	Supply chain variance					
15	lack of awareness					
16	Increasing production time/financial problems					
17	lack of time and management decision					

30. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Critical success factors. (1-Not at all, 2-somewhat important, 3-important, 4-quite important, 5-very important).

S.N.	**Critical success factors**	**1**	**2**	**3**	**4**	**5**
1	Top management commitment					
2	Development of effective SCM strategy					
3	Devoted resources for supply chain					
4	Logistics synchronization					
5	Use of modern technologies					
6	Forecasting of demand on Point of sale (POS)					
7	Trust development in SC partners					
8	Developing JIT capabilities in system					
9	Development of reliable suppliers					
10	Higher Flexibility in production system					
11	Focus on core strengths					
12	Improvement in Product quality					
13	Supply chain benchmarking					
14	Timely delivery					
15	Human resources development					
16	Reduction in product cost					

31. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of agile supply chain management. (1-Not at all, 2-somewhat important, 3-important, 4-quite important, 5-very important).

S.N.	**Agile supply chain management**	**1**	**2**	**3**	**4**	**5**
1	Enterprise integration					
2	Multi- venturing capabilities					
3	Team building					
4	Technology awareness					
5	Quality over product life					
6	Continuous improvement					
7	Trust based relationship with customers/ suppliers					
8	Response to changing Market requirements					
9	Multi-skilled and flexible people					
10	Employee satisfaction					
11	Customer driven innovations					
12	Short development cycle time					
13	Culture of change					

32. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Supplier evaluation. (1-Not at all, 2-somewhat important, 3- important, 4- quite important, 5-very important).

S.N.	**Supplier evaluation**	**1**	**2**	**3**	**4**	**5**
1	Investment in plants & machines					
2	Willingness to share information					
3	Use of modern technology					
4	Capability to change product mix					
5	Transportation Facilities					
6	Proximity to plan					
7	Internal lean practices					
8	Capability of product design & development					
9	Commitment to quality					
10	On time delivery capability					
11	Cost effectiveness					
12	Interdependence					
13	Efficient in problem solving					
14	Warranty					
15	Long-Range Perspective					

33. Please mark (√) the effect of SCM initiatives taken by your organization on following parameters of Reverse supply chain. (1-Not at all, 2-somewhat important, 3- important, 4-quite important, 5-very important).

S.N.	**Reverse supply chain**	**1**	**2**	**3**	**4**	**5**
1	Green purchasing					
2	Rules and Regulations					
3	Environmental concerns					
4	State-of-art technologies					
5	Top management commitment					
6	Vertical co-ordination among supply chain partners					
7	Recapturing value from used products					
8	Resource reduction					
9	Competitiveness					
10	Proper disposal of end-of-life products					
11	Customer benefits					
12	Environmental benefits					
13	Cost benefits					
14	Green products					
15	Productivity and performance					

Respondent Profile

1. Name with signature (If you please):

2. Designation:
(a) CEO [] (b) Sr. Manager [] (c) Manager [] (d) Supervisor [] (e) Junior staff []

3. Your functional area:
(a) Production [] (b) Marketing [] (c) Maintenance [] (d) Quality Control []
(e) Any other [] please specify

4. Your association in years with current organization:
(a) Less than 5 [] (b) 5-7 [] (c) 8-10 [] (d) More than 10 []

5. Would you like to share the findings of the survey (a) Yes [] (b) No []

Thanking you sir for sparing your highly valuable time. Kindly send this back to following address:

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C/o Dr. Tilak Raj
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APPENDIX A2

BRIEF PROFILE OF THE RESEARCH SCHOLAR

Mahesh Chand is working as an Assistant Professor in the Mechanical Engineering Department at the YMCA University of Science and Technology, Faridabad, Haryana India. He has passed his BE in Mechanical Engineering from BSAITM, Faridabad in 2007, ME in Production Engineering from the Delhi College of Engineering, Delhi in 2009 and pursuing his PhD from YMCA University of Science and Technology, Faridabad, India. He is working in the field of supply chain management, operation management, manufacturing technology. He has published over 25 research papers in various international journals and conferences. Some of reputed journals including International Journal Services and Operations Management, International Journal of Logistics Systems and Management, International Journal of Business Information System, International Journal of Advanced Manufacturing Systems etc. and international conferences included IIM Ahmadabad, IIT Roorkee, NIT Jalandhar etc.

APPENDIX A3

LIST OF PUBLICATIONS OUT OF THESIS

List of Published Papers in International Journals

Sr. No	Title of Paper	Name of Journal	Vol. & Issue No.	Year of Publication	Page No.
1.	Weighted-ISM technique for analysing the competitiveness of uncertainty and risk measures in supply chain.	International Journal of Logistics Systems and Management (impact factor-0.47) (Inderscience)	Vol. 21, No. 2.	2015	181-198.
2.	A comparative study of multi criteria decision making approaches for risks assessment in supply chain.	International Journal of Business Information System (Inderscience)	Vol. 18, No. 1	2015	67-84.
3	Risk mitigations strategy in supply chain planning and control: An ANP approach.	International Journal of Productivity and Quality Management (Inderscience)	Vol. 16, No.1	2015	92 – 113
4.	Analysing the operational risks in supply chain by using weighted interpretive structural modelling (W-ISM) technique	International Journal of Services and Operations Management (Inderscience)	Vol. 18, No. 4	2014	378-403.
5.	Analytical Network Process (ANP) Based Modeling For Analysing The Risks In Traditional, Agile, And Lean Supply Chain.	Journal of Statistical Science and Applicat ion (David publishing House, USA)	Vol. 1, ISSN 2328-224X.	2013	1-12

List of Papers Accepted in International Journals

Sr. No	Title of Paper	Name of Journal	Present Status	Vol. & Issue	Year of Publication
6.	Select the best supply chain by risk analysis for Indian industries environment using MCDM approaches	Benchmarking: An International Journal (Emerald	Accepted for Publication	Not Assign	2016
7.	Quantitative analysis of risks in supply chain by using graph theoretic approach	International Journal of system assurance engineering and management (Springer)	(Under Review)		

List of Papers in International Conferences

Sr. No.	Title of Paper	Name of Conference	Year of conference	Place of conference
8.	An approach towards risk mitigations in supply chain by using ANP-MOORA method	International Conference on Research and Sustainable Business	March 8-9, 2014	IIT Roorkee, Uttarakhand
9.	Multi-Objective Optimization (MOORA) Method for Analyzing the Risks in Supply Chain,	7th doctoral colloquium	Dec. 9-10, 2013	Indian Institute of Management, (IIM) Ahmedabad, Gujarat.
10.	Analytical Network Process (ANP) Based	International Conference on	April 13-14, 2013	Indian Institute of

	Modeling For Analysing The Risks In Traditional, Agile, And Lean Supply Chain	Advanced Data Analysis, Business Analytics and Intelligence, (ICADABAI)		Management, (IIM) Ahmedabad, Gujarat.
11.	A Critical Analysis of Select Risks issues in Supply Chain Management. International	International Conference on Production and industrial Engineering, (CPIE)	March 29-31, 2013	NIT Jalandhar, Punjab
12.	Identification of Selected Risk Issues in Supply Chain management: A Literature review	International Conference on Resent Advances in Mechanical Engineering	April 19-20, 2012	Dr. MGR University, Chennai, Tamil Nadu