ANALYSIS AND MANAGEMENT OF RISKS IN GREEN SUPPLY CHAIN

Ph.D. THESIS

by

SACHIN KUMAR

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE – 247667, INDIA

JULY, 2015

ANALYSIS AND MANAGEMENT OF RISKS IN GREEN SUPPLY CHAIN

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

in

MECHANICAL ENGINEERING

by

SACHIN KUMAR

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE – 247667, INDIA

JULY, 2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this thesis entitled **"ANALYSIS AND MANAGEMENT OF RISKS IN GREEN SUPPLY CHAIN"** in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy and submitted in the Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period from July, 2012 to November, 2015 under the supervision of Dr. Pradeep Kumar, Professor, Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, and Dr. Mukesh Kumar Barua, Associate Professor, Department of Management Studies, Indian Institute of Technology Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

(SACHIN KUMAR)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date:

(Mukesh Kumar Barua) (Pradeep Kumar)
(Supervisor) (Supervisor)

The Ph. D. Viva-Voce Examination of **Mr. Sachin Kumar**, Research Scholar, has been held on...

Chairman, SRC **Signature of External Examiner**

This is to certify that the student has made all the corrections in the thesis.

Signature of Supervisor **Head of the Department**

ACKNOWLEDGEMENT

I sincerely express my profound sense of gratitude and heat-felt thanks to my supervisor **Dr. Pradeep Kumar**, Professor, Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee, for his valuable guidance and constant encouragement throughout the course of my research work. I am grateful to him for the love and affection. I proudly acknowledge that working under his guidance has made me wiser and smarter. I feel privilege to have worked under him. I express my indebtedness to him for his guidance, imagination and innovative ideas scholarly advice and sympathetic understanding, which enabled me in the timely completion of this work.

I also wish extend profound gratitude to my co-supervisor **Dr. M. K. Barua**, Associate Professor, Department of Management Studies, Indian Institute of Technology Roorkee. I consider it as a special blessing of the Almighty that I could get the help of such a mastermind to supervise and advise me. His dynamism and foresightedness helped me in a big way in completion of this work and I really feel privileged to have worked under their supervision.

I am thankful to God almighty who bestowed upon me the blessings, enabling me to stand up to the expectations of my ‘Gurus’.

Guru Bramha Guru Vishnu

Guru Devo Maheshwara

Guru Saakshat Para Bramha

Tasmai Sree Guruve Namaha

I am thankful to **Prof. P. K. Jain**, Head of Department, and **Prof. B. K. Mishra**, Chairman, Departmental Research Committee, for their unflinching support at the various junctures of my work. I feel honored and privileged to extend my heartfelt gratitude to **Dr. Rajat Agrawal**, Associate Professor, Department of Management Studies, IIT Roorkee and **Dr. Dinesh Kumar,** Professor, Department of Mechanical Engineering, IIT Roorkee, who are members of my Student Research Committee, for giving their valuable time and suggestions in successful completion of this work. I would like to acknowledge **Mr. Sunil Luthra**, Government Polytechnic, Jhajjar, Haryana, India, for his guidance and suggestions in successful completion of this work.

I am very much thankful to the staff of MIED, IIT Roorkee, especially for their help during the course work and research work. I also thank the Departmental library staff and

Central library staff for providing excellent facilities. I also express my sincere thanks to all the faculty of the department for their constant support and encouragement during my Ph.D. work.

My special thanks to **Mr. Sunil Luthra and Dr. Sanjay**, Department of Mechanical Engineering, International Institute of Technology and Management, Haryana, India who had supported contributed to my work during documentation. I remember you all with great pleasure. I would like to thank my friends and colleagues, Mr. Chandra Prakash, Mr. Yogesh Singla, Mr. Dilbagh, Panchal, Mr. Manoj Saini, Mr. Dinesh Saini, Mr. Saurabh Yadav, Mr. Saurabh Bakshi, Mr. Ambrish Maurya, Mr. Saurabh Chaitaniya, Dr. Rakesh Katiyar, Dr. Mohit Tyagi, Mr. Divesh Kumar, Mr. Sunny Zafar, Mr. Mudimallanna Goud, Mr. Nitin Kumar Lautre, Mr. Radha Raman Misra, Mr. Venkateshwarlu Devuri, Mr. Manjot Singh Cheema, Mr. Kishore Debnath. Dr. Amit Bansal, Dr. Dheeraj, Dr. Vivek, Mr. Khtri, Mr. Krishnakant, Mr. Naveen, Mr. Vinayak Viswakarma, Mr. Amit Agrawal, Mr. Balon, Mr. Mani, Mr. Debnath, Mr. Irfan, and all the fellows who helped me directly or indirectly during the entire period of this work.

My heart full gratitude to the staff of Mechanical and Industrial Engineering and QIP centre at QIP IIT Roorkee. I am thankful to the management of the poly-plastic manufacturing business organizations (all in Northern region of India) for providing the information in the course of research work.

My very special thanks to my life partner **Mrs. Pretty Mangla** for her continuous support, motivation and encouragement.

I express my profound regard to my parents, **Sh. Madan Lal** and **Smt. Raj Rani** for their blessings and for being the main source of inspiration to succeed in my endeavors. I also acknowledge my regard to my in-laws parents, **Sh. Parveen Singla** and **Smt. Savita Singla** for their blessings. I am also thankful to my younger sister **Miss Neha Mangla** for his encouragement and love.

I would like to thank everyone who supported me for completing this work successfully and I express my apology that I could not mention everyone individually. Above all, I would like to express my sincere gratitude from the core of my heart to almighty for giving courage, strength and patience to carry out my research out.

(Sachin Kumar)

ABSTRACT

Due to increase in customer environmental awareness, competitiveness and strict governmental policies, the approach of incorporating Green Supply Chain Management (GSCM), to conserve resources and sustainable production, is gradually becoming more imperative for organizations. In the line of getting of the maximum economic-environmental advantages, many organizations have either initiated or about to initiate the green trends in their business activities. However, still, organizations are reluctant in adoption of green initiatives in their supply chain planning. One of its reasons is inadequacy in their knowledge of green and economic benefits obtained from adoption and implementation of GSCM. Another reason is an incomplete understanding of what is responsible for green adoption to fail in the supply chain. It is due to because the initiatives of green at various aspects of business involve several complexities. Due to which, it arises different risks and risk factors in implementing different Green Supply Chain (GSC) initiatives in business, which would certainly affect the overall performance. Therefore, to effectively managing initiation and implementation of GSC initiatives, the background of the risks related to GSC essentially needs to be known, analyzed, and managed.

All India Plastics Manufacturers Association (AIPMA) report estimates that plastics is one of the major contributors to India's GDP and the consumption of plastic will increase to almost 2-3 times a year in 2020 from the existing 8 million tons a year in India. It has been noticed that the global trend and competitions in the plastic industrial sector proposes a great pressure to consider green or ecological influence in the supply chain planning process. However, the managers/business professionals may face several risks in GSCM network design. Under these considerations, to help organizations in this sector to adopt effective green initiatives, it is important to manage and reduce the convolution of risks in GSC. Hence, GSCM example of poly-plastic manufacturing business organizations operational in India has been identified and discussed in this research work.

Twenty five specific risks, associated with the GSC, were identified. The basis of identification of the risks was literature and inputs received from the experts. Further, these identified risks were grouped into six categories of risks, namely, Operational risks (O), Supply risks (S), Product recovery risks (PR), Financial risks (F), Demand risks (D), and Government

and Organizational related risks (GO). These categories of risks were finalized through an interactive discussion with the experts of decision-making team.

After the identification of risks of GSC in the context of Indian plastic business organizations, a qualitative model has been developed to prioritize the selected risks using fuzzy Analytic Hierarchy Process (AHP) approach. It will provide a measure for determining the relative concerns of recognized six categories of risks and twenty five specific risks in GSC. The fuzzy AHP analysis results point out that operational risk is the most prioritized risk with an overall priority value of 0.2507. The used fuzzy AHP approach is also useful in dealing with the human subjectivity and ambiguity involved in the risk analysis. To confirm the fuzzy AHP based ranking, the methodology of Interactive Ranking Process (IRP) was used. This method present interpretive logic for dominance of one risk over the other for each paired comparison developed, and thus, overcome the shortcomings of the AHP - fuzzy AHP method. Six categories of risks (O, S, PR, F, D, and GO) relevant to GSC and four expected performance (Environmental performances (P1), Economic performances (P2), Operational performances (P3), and Competitiveness performance (P4)) measures by implementing efficient GSCM concept were identified. Interpretive ranking model of the derived final ranks of the risks helps to interpret how each risk is influencing various performances. The results obtained from the fuzzy AHP and IRP analysis shows a reasonable consistency in the findings of the present research work. Human judgment input is utilized to calculate the weights for the listed categories of risks and specific risks. Thereby, sensitivity analysis is conducted to test the final ranking by varying the weights of all the categories of risks.

The present work also analyzes the performance of GSC from risks management viewpoint. The risks identified in this work were evaluated to access their effects in terms of Time, Brand image, Economic, Health and Safety, and Quality. The maximum impacts were seen in time based effects and that was measured in terms of time delays and disruptions. In time based dimension, time delay/disturbance is the significant impact of GSC risks. The human based assessment unable to give extreme scenario. Thus, simulation approach was used. Monte Carlo Simulation approach was used to analyze the drivers of risk and their impact on GSC performance. In addition, it also helps to capture the uncertainties in the inputs. A sensitivity analysis test was performed to capture the effects of risks on the delay profile mean. The proposed model will provide analytic means to analyze the risks more efficiently towards effective implementation of GSCM.

After listing the potential risks and their impacts, it is needed to understand how to manage the risks and its consequences. For managing the GSC risks, various mitigation strategies and response measures need to be proposed. Therefore, a model is proposed by using an integrated approach based on the fuzzy AHP and the fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods to prioritize the responses in GSC to manage its risks under the fuzzy environment. In order to manage the risks, seventeen responses were identified. These responses were selected through literature and inputs received from the experts of the decision-making team. The fuzzy AHP is useful in deciding the importance weights of the GSC risks. While, the priority of the responses in a successful accomplishment of GSC business initiatives is determined using the fuzzy TOPSIS. According to the values of closeness coefficient, the priority of concern of the responses of the risks in GSC is given as, R12 - R15 - R10 - R7 - R17 - R16 - R8 - R6 – R14 - R11 - R13 - R5 - R4 - R9 - R3 - R1 - R2. To develop and upgrade on technology being used in the specific sectors for implementation of green (R12) obtains the highest rank. Thus, it needs to focus this response at priority in managing the risks in GSC. The model proposed would offer a scientific decision means to the managers/business professionals/practitioners for systematic implementation of the responses of risks relevant to adoption and effective implementation of GSC initiatives in business. A sensitivity analysis test was also performed to monitor the robustness of the proposed model.

A framework is developed to evaluate the strategies to mitigate risk in GSC, which would be helpful for business organizations in improving the GSC robustness. This framework is developed on the basis of SAP-LAP (Situation Actor Process - Learning Action Performance) and IRP approaches. According to the SAP-LAP approach, the standpoint of the actors including ultimate users, supply chain managers, suppliers, and top management should be considered in building a GSC risk mitigation strategy framework. Managers must make good understanding on both the values and shortcomings of the strategies, as well as their appropriateness for an organization. To capture the interactions among the variables of SAP-LAP based model, i.e., Actors v/s Processes and Actions v/s Performances, an interactive process of decision making is used. The methodology of IRP enables the managers to limit the limitations of the SAP-LAP. According to the findings of IRP approach, the role of top management as an Actor and the commitment of top management as an Action come out be most important in building and implementation of GSC risk mitigation strategies. The developed framework can help in reviewing current risk mitigation strategies in GSC by supply chain experts and managers to plan for further improvements to make them more comprehensive and robust. Furthermore, the developed SAP-LAP and IRP based framework would help organizations to address risk mitigation strategies for GSC with concerns over situation, actors, process, learning, actions and performance aspects, together with to interpret the of role and influence of actors and actions in accordance with process and performance, that will increase the GSC effectiveness.

The findings of this research would be useful for managers in managing the risks and risk factors relevant to a successful implementation of GSC business initiatives, and hence enhancement in ecological-economic gains of the related organizations. The main purpose of this study is to provide a better understanding of developing and managing of GSC in a most effective way. Besides, this work touched on various problematic issues of Indian plastic business organizations that may be helpful in developing strategies and will be useful in improving GSC effectiveness. The present work is useful to both theoretical and practical domains in the field of GSCM. Finally, this research work may help managers and practitioners to manage the GSC efficiently, while achieving sustainability in business.

TABLE OF CONTENTS

CHAPTER 6: PRIORITIZING THE RESPONSES TO MANAGE RISKS

CHAPTER 7: FLEXIBLE DECISION FRAMEWORK FOR PROPOSING RISK MITIGATION STRATEGIES

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AHP	Analytic Hierarchy Process
AIPMA	All India Plastics Manufacturers Association
ANP	Analytical Network Process
B2B	Business-to-Business
B2C	Business-to-Consumer
D	Demand risks
DEA	Data Envelopment Analysis
DEMATEL	Decision Making Trial and Evaluation Laboratory
EFA	Explanatory Factor Analysis
EMS	Environmental Management System
EPA	Environmental Protection Agency
EPI	Environmental Performance Index
EPR	Extended Producer Responsibilities
ERP	Enterprise Resource Planning
EU	European Union
F	Financial risks
FAHP	Fuzzy Analytic Hierarchy Process
FANP	Fuzzy Analytic Network Process
FMEA	Failure Mode & Effect Analysis
FNIS	Fuzzy Negative Ideal Response
FPIS	Fuzzy Positive Ideal Response
FSS	Flexible Supplier Selection
FSS	Flexible Supplier Selection
GDP	Gross Domestic Product
GO	Government and Organizational related risks
GSC	Green Supply Chain
GSCM	Green Supply Chain Management
I	Consequences
IRP	Interpretive Ranking Process
ISM	Interpretive Structural Modeling
ISO	International Organization for Standardization

JIT	Just-In-Time
LSI	Large Scale Industries
MCDM	Multi Criteria Decision Making
MCS	Monte Carlo Simulation
MINLP	Mixed Integer Nonlinear Programming
MINLP	Mixed Integer Nonlinear Programming
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
NIS	Negative Ideal Response
O	Operational risks
P	Probability
PEST	Political, Economic, Social and Technological
PIS	Positive Ideal Response
PR	Product Recovery risks
PVC	Polyvinyl Chloride
QFD	Quality Function Deployment
RFID	Radio-frequency Identification
RL	Reverse Logistics
RoHS	Restrictions of the use of Hazardous Substances
RS	Risk Score
S	Supply risks
SAP-LAP	Situation Actor Process – Learning Action Performance
SARS	Severe Acute Respiratory Syndrome
SC	Supply Chain
SCM	Supply Chain Management
SEM	Structural Equation Modeling
SME	Small Scale Industries
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TFN	Triangular Fuzzy Number
TOPSIS	Technique for Order Performance by Similarity to Ideal Solution
WEEE	Waste Electronics and Electrical Equipment Directives

CHAPTER 1

INTRODUCTION

This chapter gives a background of the present study. It starts with detail introduction of the present research work, motivation and need for this work, and the research objectives and research question, have also been discussed. Lastly, a brief outline of the thesis chapters is provided.

1.1 Introduction

Today the main concern for any nation is the growing pollution. Steps are been devised to control pollution so that the coming generations can live in a clean atmosphere. There are many sources of pollution; the major shareholder is the industrial pollution resulting from the processes and practices followed by the business organizations. One of the important causes of pollution is the exploitation of natural resources, which is used by the organizations as the source of raw material (Gopalakrishnan et al., 2007). This is done to bring down the gap between demand and supply and to achieve higher profit by providing the customers with a variety of option to satisfy their needs. In the wake of fulfilling above mentioned targets, industries are producing more and more waste, which is not disposed-off properly and is adding up to the environmental pollution. The result of environment exploitation can be seen in the form of climate change and natural calamities across the world.

Due to the major role played by the formal and informal environmental education channels including electronic media, print media, social networking sites, there is an increase in the awareness among the masses regarding the adverse effect of the processes and practices owned by the industries. Taking this into account, pressure is building on the organizations to incorporate eco-friendly steps in their business practices. However, some of the manufacturers mainly in developed nations have adopted some environmental practices to develop an eco-friendly business culture. These environmental practices may include cleaner production, International Organization for Standardization (ISO) 14001 certification, etc. Yet, this subject matter needs to be in complied among the supply chains, which are still proceeding in the conventional ways so that business organizations should not hamper the environment.

The need of the hour is Environmental Sustainability which can only be achieved by incorporating eco-friendly means in the traditional supply chain management (SCM) practices. Government regulations such as the Restrictions of the use of Hazardous Substances (RoHS) directives require organizations to extend their environmental practices to their suppliers and customers. Organizations for a very long time now have been facing the pressure to concentrate on environmental management system (EMS) and indulge it into SCM. Increasing ecological responsiveness of customers and the establishment of more strict regulations have forced business organizations to gradually integrate more environmental (green) practices into their supply chain planning (Zhu and Sarkis, 2006; Zhu et al., 2008a; De Giovanni and Vinzi, 2012; Mangla et al., 2012, 2014a). In addition to this, the concept of sustainable economies has encouraged the nations to adopt green supply chain (GSC) trends in their business activities. GSC initiatives may be of great value to the firms as well as to the external environment (ecological and business both) (Eltayeb et al., 2011). Greening in supply chains and green supply chain management (GSCM) networks can lead organizations to achieve a win-win situation by improving their ecological and economic performances (Srivastava, 2007; Subramanian et al., 2010; Zhu et al., 2011; Gunasekaran and Gallear, 2012). However, the GSC networks are becoming more complex due to the occurrence of different risks. The occurrence of these risks could have severe impacts on the system if managers do not account for the mitigation measures on timely fashion (Mitchell, 1995; Ma et al., 2012). Hence, risk analysis and management in GSC is very important. Accordingly, it is selected as the theme of research in this work. To build a sufficient theoretical background and understanding on the work conducted in this research, it could be very important to know the concepts of traditional supply chain, supply chain management, green supply chain management, and risks in a green supply chain context. The details are provided in the subsequent sections.

1.2 Supply Chain Management

Supply Chain Management (SCM) has gained a remarkable notice from scholars, practitioners, and consultants in the past few years to achieve an objective of enhancement in customer satisfaction and to help firms survive under uninterrupted pressures (Agami et al., 2012; Caniato et al., 2013; Luthra et al., 2014a, 2014b; Ramanathan and Gunasekaran, 2014). The term ‘supply chain’ (SC) was originated somewhere around mid-70’s. Banbury (1975) used supply chain as a term for delivering electricity to the end user. The term ‘supply chain management’ didn’t come into existence until 1980. Keith Oliver, a consultant by profession, used this term in an interview for the Financial Times in 1982. Oliver and Webber (1982) discussed the potential advantages of integrating major internal business functions including purchasing, manufacturing, sales, services and logistics into one cohesive framework. This term gain more importance in 90's when scholars and researchers from education field and industries started to publish books and articles over it. Stevens (1990) defined SCM as the integration of business functions encompassing the flow of materials and information from inbound to outbound ends of the business. An effective sharing of information is important among SC partners and members for an accurate estimation of prduct demand in business (Sunil et al., 2009).

There are various definitions related to SC published by various authors in their research work depending upon their focus area. According to Chopra and Meindl (2007), "SC consists of all business entities involved, directly or indirectly, in achievement of a customer request". The supply chain involves not only the manufacturer and supplier, but also transporters, warehouses, retailers and even customer as shown in Figure 1.1. It starts from collecting the raw material from the source, transforming it into final product by doing various value addition processes and supplying the same to the customers to fulfill their demand and earn profit for themselves. Thus, SCs are actually networks working on a multi-echelon distribution model in which material movies from suppliers and manufacturers through a series of small and large stockholders to reach the customer (Sabri and Beamon, 2000; Tsiakis et al., 2001). To make the concept simpler, Handfield and Nichols (1999) presented the supply chain model divided into three major parts namely: Upstream Suppliers, Internal Functions, and Downstream Distributors. In their study, they mentioned that the SC includes the management of sourcing and procurement, production scheduling, inventory management, order processing, warehousing, customer service and after-market deposition of packaging and materials. The Upstream Suppliers network comprises of all the organizations that are involved in providing inputs, either directly or indirectly to the focal company (Golmohammadi et al., 2009; Pal et al., 2013). The Internal function includes all the processes used in transforming the inputs from the upstream suppliers. In other words, they perform various value addition functions on the material received from the suppliers.

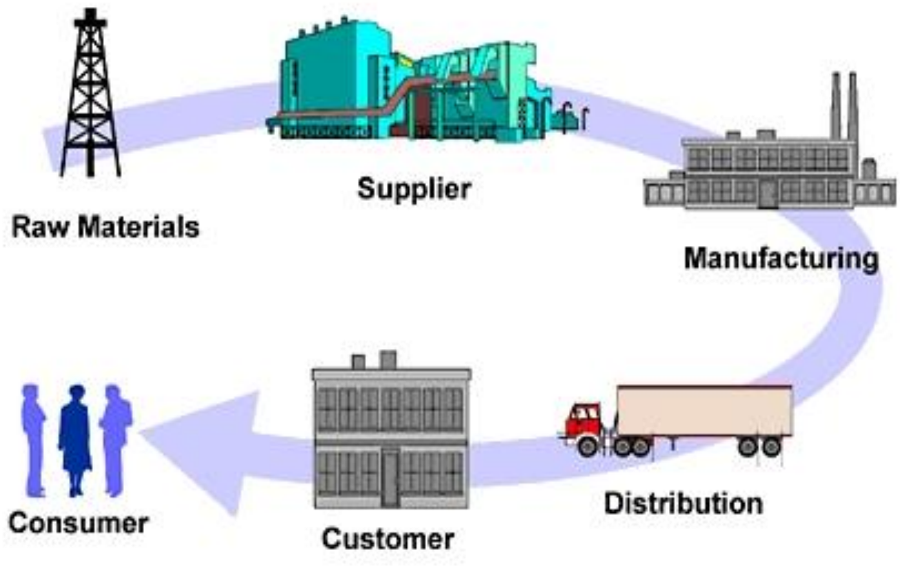


Figure 1.1 Supply Chain Overview (Chopra and Meindl, 2007)

In the wake of 90's, one of the most important reasons, which took SCM to apex, is the globalization, forcing organizations to be more integrative among other organizations to condense the vulnerability of the supply chain. Mentzer, et al. (2001, p.18) stressed that SCM involves the systematic strategic coordination of the conventional business functions and its related tactics across within a particular firm and across businesses within the SC, for the rationale of improving long-term performance of the individual firms and SC as a whole. Coordinating the supply chain is one of the most significant aspects from the point of view of business organizations (Arshinder et al., 2008; Tejpal et al., 2013a,b). Also, understanding the key players that affects the SCM in organizations is important to increase the overall performance. Mohanty and Deshmukh (2005) defined SCM as a loop that starts with the customer and ends with the customer, and includes materials, finished goods, information, and transactions. SCM may also consist of dissimilarities in supply chain practices among different sectors of business. It would be useful for the practicing managers to understand these disimilarities in developing strategies for their supply chains (Jharkharia and Shankar, 2006).

Supply chain management forms the backbone of any organization. To increase the system or organizational performance, various measures in supply chains/production systems/flexible manufacturing systems are given – flexibility, reliability, and producibility (Nagarur, 1992). SCM includes all major functions like from Logistics, Inventory Management, Operations Management, Information Management, etc. The complete course of action includes extraction and exploitation of natural resources. Curbing the ill-effects caused by the business organizations by their traditional SCM practices is one of the major objectives of all the nations and environmental regulatory bodies. One of the most effective ways to achieve this objective is by integrating the traditional supply chain practices with environmental friendly practices, which results in a new concept named Green Supply Chain Management (GSCM).

1.3 Green Supply Chain Management

With the advancement of 20th century, the need came into existence to make the SC more efficient. Henry Ford revolutionized the traditional SCM practices by bringing in the concepts like Lean and Just-In-Time (JIT) in the automobile industry. These strategies were developed with a goal to check the excess inventory in SC (Yadav et al., 2010). It is also stated that small and medium enterprises should practice lean manufacturing practices to improve their overall business performance (Creese, 2001). Based on the lead time and service level constraints, a two-echelon SC inventory model has also been developed to improve the system effectiveness and overall performance (Jha and Shanker, 2009). With further advancements, quality initiatives, product life cycle cost, and revenue models were also need to be addressed to improve the system performance (Perera et al., 1999; Creese and Nandeshwar, 2003; Prakash and Shanker, 2008). However, most of the innovations of 20th century aimed at reducing economic wastes and not much consideration was given to the environmental factors. It was not before 21st century the term “Green” came into the picture and clubbed with supply chain to make it more eco-friendly with regard to protecting the environment. Consequently, this term gain a world-wide recognition.

GSCM is an emerging field of the traditional supply chain perspective. There were many revolutions witnessed by industries from time-to-time, “quality revolution in the late 1980’s and the supply chain revolution in the early 1990’s” have initiated the need for business organizations to become environmentally conscious. GSCM achieved its popularity among the academics and practitioners because of its aim of preserving the quality of product-life and the resources and reducing the waste generated. Kelle and Silver were the first to write an article on GSC in 1989. They established an optimal forecasting system for organizations, which could be used to forecast products that can potentially be reused. However, the "green supply chain" term was suggested for the first time by the manufacturing research consortium of Michigan University in 1996 to study the environmental impacts and resource optimization of manufacturing supply chain (Hanfield et al., 2005). In the literature, the definition of GSC varies according to the researcher perception; it varies from green purchasing to integrated supply chain. GSCM is the extension of the traditional SCM to include activities that aims at minimizing environmental impacts of a product throughout its entire life cycle such as green design, resource saving, harmful material reduction and product recycle or reuse (Beamon, 1999). In line with this, Hervani et al. (2005) presented GSCM a mean to include ecological concern at each stage of supply chain planning for instance, green procurement, green manufacturing, green distribution, green packaging and transportation, and reverse logistics for closing the supply chain loop. An overview of green supply chain management is shown in Figure 1.2. According to Srivastava (2007), the scope of the GSCM ranges from reactive monitoring of the general environment management programs to more proactive practices implemented through various Re's (Reduce, Reuse, Refurbish, Rework, Remanufacturing, Reclaim, Recycle, Reverse Logistics, etc.). Green operations in terms of reverse logistics and waste management are the two most important concepts came out of the GSCM concept. As a result, a methodical approach, GSCM, which incorporates environmental concerns into SCM, has been increasingly accepted and practiced by business organizations (Beamon, 1999; Zhu and Sarkis, 2004; Jung, 2011; Muduli and Barve, 2013; Mangla et al., 2014a; Luthra et al. 2014a). With the passage of time, green perspective in SCM becomes more important due to increasing environmental protection, governmental legislations and customer awareness about green (Sarkis, 2003; Srivastava, 2007) as well as behaviour of generating economic benefits. Economic benefits with environmental practices are gaining attractiveness in SCs since it improves green image (Zhu et al., 2012). So, many organizations have revised their operations and methods of production to implement green in their SCs. Electronic industries in Japan, Taiwan and Korea, for instances Sony, Toshiba, Panasonic, IBM, HP, Dell, and Motorola applies GSCM for protecting environment (Zhu and Sarkis, 2006). Manufacturing industries for example in Bristol- Myers Squibb, IBM, Xerox, Ford, GM and Toyota have enforced green practices in supplier related issues. Initiatives of retail giants such as McDonald's and Wal-Mart are worth expressing since they too are now preferring eco-friendly materials.

Figure 1.2 Green Supply Chain Management Overview (Hervani et al., 2005)

From an industrial perspective, GSCM is becoming a useful mean to have high ecological - economic performances, high competitive advantage, integrate the green practices into corporate strategies, conserve resources and ensure sustainability in business activities. The driving force behind the growing importance of GSCM is the deterioration of environment at much faster pace like depreciating of the natural resources, over production of waste, increased pollution level, etc. GSC initiatives may help manufacturers as well as investors to facilitate environmental compliance. Many studies has emphasized the important role being played by the GSCM to minimize the impact on the organizational SC on environment by means of reducing wastes, controlling carbon emission, checking the packaging ways, training their suppliers and developing other eco-friendly means (Subramanian et al., 2010; Zhu et al., 2011).

On the one hand, concept of green in SC is developing; while, on the other hand, complexity in GSC network has also increased due to the occurrence of different risks and risk driving factors. GSCs can be influenced by several factors, such as product returning inconsistency in closing the loop, complex international networks of industrial partners, level of green awareness among workers, knowledge of green methods and procedures, variation in demand of products, reprocessing capacity and inventory related decisions, governmental interference, market pressures, information and communication technology, etc. (Hervani et al., 2005; Sarkis, 2006; Vachon and Klassen, 2008). Any inadequacy in the understanding and implementation of these factors can lead GSCs towards the culture of disturbances, uncertainties and unexpected happenings (Yang and Li, 2012). It could result in reduction of organization's overall performance. Therefore, the issue of understanding of risk, identification of risk and risk driving factors, and their analysis and management/mitigation is important. It may help business organizations to concentrate on understanding and devolving of some appropriate and concrete strategies helpful in effective adoption and implementation of GSCM.

1.4 Risks in GSC

Risk occurs, as it is difficult to predict exactly what will happen in the future (Miller, 1992). It is useful to the best forecasts and does all probable analysis; however, still uncertainty incurred to the future. This uncertainty further leads to risks (Chopra and Sodhi, 2004). Dating back to the 19th century, risk was simply linked to unexpected/unplanned events. It is not a new term and is derived from the Italian word "risicare". Bernstein (1996) defined risk as a means to dare. The concept of risk has also been interpreted as an individual opinion towards the occurrence of a particular event (Frosdick, 1997). Furthermore, Snider (1991) described it with its consequences and has drawn attention to business in the mid nineties. Later, the concept of risk along with its management becomes richer in literature (Miller, 1992). Examination of models and theories of risks in supply chain management practices started to develop in recent years (e.g. Christopher and Peck, 2004; Chopra and Sodhi, 2004; Kleindorfer and Saad, 2005; Faisal et al., 2007a,b; Manuj and Mentzer, 2008). Risk in supply chains is a vital concern for organizations, as incapability in managing risks would lead to a decline in efficiency and overall performance (Faisal et al., 2007b; Gurnani et al., 2012).

Nonetheless, traditional SCs can be understood as the network of various members and all linked together and if any member incurs a risk, it would be automatically transferred to all other members (Samvedi and Jain, 2013). For example, instability in behaviour of any one-supplier, not only affects its immediate customers, but also affects each member of the supply chain. For example, how the past epidemics of Severe Acute Respiratory Syndrome (SARS), or bird flu in 2003 affects the world SC network, likewise, the occurrence of hurricanes Katrina and Rita in the Gulf of Mexico in 2005, have raised the threats of the deficit of fuel and oil around the world and hence increase in price. Considering the case of an organizational SC, it is important to manage these risks and risk driving factors. Otherwise, its consequences could be a reduction in an organization's overall performance and efficiency (Mitchell, 1995). The thought of risk in the organizational GSC can be expressed in terms of disturbances or disruptions incurred in its various activities of network design (Ma et al., 2012). A few of them may include supplier failures, raw material supply disruptions, scarcity of skilled labor, management policy failures, information irregularity, technology risks, market risks, etc. (Ma et al., 2012; Wang et al., 2012). However, many of the above listed risks are observed in a typical forward SC, but still, readers should not be confused as environment is not a major area of concern in traditional SCM. In that way, GSC risks will be different from the traditional SC in terms of organizational environmental performance and ecological-economic benefits (Ma et al., 2012).Therefore, it is important to manage and reduce the convolution of risks in GSC so that business organizations would become more capable in managing GSC risks.

1.5 Motivation and Need for This Research Work

According to the 2012 Living Planet Report, inhabitants are exceeding in the Earth's resources consumption by 50 percent - a per person resource consumption of one and half Earth's has been reported annually. In other words, it takes the earth 1.5 years to restore what person consumes through in a year; by 2050, the consumption of natural resources (virgin raw materials, minerals, etc.), is expected to rise exponentially (Pappas, 2012). A significant scope of use of resources is recognized in manufacturing industry sector as well (Shen et al., 2013). One way to limit the utilization of the natural resources and environmental degradations is to consume less, as a result of which, a less quantity of resources will be needed from industrial viewpoints. Other way could be to use the resources in an efficient way (Shen et al., 2013). To achieve this, it needs to implement GSC initiatives and its related procedures and methods in terms of either using some proficient and competent resource conservation practices, or using them in a responsible manner - emphasizing on more and more on recycling (Muduli and Barve, 2013; Muduli et al., 2013). However, still, organizations are reluctant in adoption of green initiatives in their supply chain planning (Mathiyazhagan et al., 2013; Govindan et al., 2014). One of its reasons is inadequacy in their knowledge of green and economic benefits obtained from adoption and implementation of GSCM (Luthra et al., 2011). Another reason is an incomplete understanding of what is responsible for green adoption to fail in the supply chain. It is due to because the initiatives of green at various aspects of business involve several complexities (Ma et al., 2012; Wang et al., 2012). It involves different risks and risk driving factors in implementing different GSC initiatives in business, which would certainly affect the overall performance (Dan-Li et al., 2011). Therefore, for effectively managing the different business processes and activities linked to GSC, the risks associated with the green supply chain necessarily need to be understood (Ma et al., 2012).

Based on the gaps identified from the literature review (refer Chapter 2), it is obvious that there is enough scope of work for research in this field.

- The number of papers on GSC has been increased in the recent years. There are many journals covering the research on this field of interest.
- There is relatively scarce literature related to risks in GSC, and very few publications have presented identification, understanding, analysis and mitigation of risks in GSC. This research work efforts to fill this gap in GSC.
- The risks in GSC context can be recognized through literature resource and from the expert's inputs. Moreover, various industries may have a different viewpoint about adoption and implementation of GSC business practices (Zhu and Sarkis, 2006). In this manner, various industries may face different GSC risks and problems for greening their respective supply chain. The same risk may not equally be important to the individual industry. To deal with this, identification of the most common GSC risks is essential.
- During literature review, a gap was identified, which is related to the analysis of GSC risks to prioritize them for determining their relative concern. However, it is not easy to conduct this analysis as there may be vagueness and subjectivity in process, which, needs to be resolved. In addition, the ranking obtained for the identified risks should be tested for confirmation. Furthermore, according to the literature, there as such no study is conducted to understand the interpretive logic for dominance of one risk over the other for each pair wise comparison for better understanding the GSC risk analysis. To fill this gap, fuzzy Analytic Hierarchy Process (AHP) and Interactive Ranking Process (IRP) methodologies have been used to prioritize the risks and to understand the interpretive logic of one risk over the other in GSC.
- The one most important gap which was recognized after in-depth literature is that none of the studies has conducted to assess the impacts of risks with regard to the GSC. Therefore, simulation (Monte Carlo Simulation) approach is used to assess the risks and consequences to emerge in GSC.
- Managing the risks is one of the prime responsibilities of business organizations. Literature demands some studies on proposing appropriate response measures to improve the performance of adoption and implementation of green in SC. Thus, an

integrated model based on the fuzzy AHP and fuzzy fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods is suggested to prioritize the responses to manage the risks in GSC.

- Literature shows unavailability of any reliable model to manage/mitigate the risks in GSC. Therefore, a model to fulfill this gap in an effective manner is desired. In this sense, SAP-LAP (Situation Actor Process - Learning Action Performance) and Interactive Ranking Process (IRP) based decision framework is developed to propose the risks mitigation strategies in GSC.

1.6 Research Objectives and Research Questions

The aim of this research is to develop a framework to analyze and manage the risks in GSC. Based on the research gaps highlighted above, this work aims in achieving the two objectives, as follows:

Objective I: Identifying, understanding, and analyzing risks in green supply chain from industrial perspective.

To achieve this objective, and for managing the risks in GSC, first of all, it needs to identify the risks to the GSC. It requires a thorough investigation of GSC under study, as well as defining the separate activities and their relationships, and methodically studying these to find loopholes and risks. It will be helpful in listing the possible risks and risk driving factors related to GSC as the initial phase of work. It is not necessary that all recognized risks are disruptive. Thus, in the later phase of this work, it needs to estimate and evaluate the possible impact caused by an individual risk with regard to the individual SC operation's network design and definition.

After listing the potential risks and their impacts, it is needed to understand how to manage the recognized risks and its consequences. In order to manage these risks, various mitigation strategies and response measures need to be proposed. To achieve the stated objective I, four research questions are raised i.e. RQ1, RQ2, RQ3, and RQ4:-

RQ1: What are the risks and risk driving factors, which need to be considered in a GSC?

RQ2: How the identified risks are evaluated, prioritized, and confirmed for effective adoption and implementation of GSCM?

RQ3: In what way, the interpretive logic for dominance of one risk over the others is interpreted?

RQ4: How the probable consequences of risks in GSC are accessed?

Objective II: Effective management of green supply chain risks

The second objective of this research work seeks to explore how GSC risk can be effectively managed. To accomplish the stated objective, an analysis is required in accordance with the responses and mitigation strategies/policies to manage the GSC risks. A thorough investigation is needed to suggest the suitable responses, strategies and to check their robustness and competency from industrial viewpoints. To achieve this objective, three research questions are raised (i.e. RQ5, RQ6 and RQ7) as follows:-

RQ5: What responses need to be proposed and prioritized not only to diminish the effect of identified risks but also to prevent from happening in managing the GSC efficiently?

RQ6: What strategies need to be proposed to develop a risk mitigation decision framework in a GSC?

RQ7: In what way, the variables (actors and actions in relation to process and performance) involved in the GSC risk mitigation are analyzed?

1.7 Organization of the Thesis

The organization of the present research work has been covered in eight chapters illustrated in Figure 1.3. However, a brief outline of each chapter is given as below:

Chapter 1

It presents an introduction of the work and gave a brief introduction to the supply chain management, green supply chain management, and risks in the green supply chain. It also covers a description on the need of the present research work, problem definition, research objectives and research questions.

Chapter 2

It deals with an extensive and in-depth literature analysis in the field of green supply chain and green supply chain management. This chapter covers the meaning of risk management in green supply chain and explores the various risks in the context of GSC. It also identifies the research gap for the present study.

Chapter 3

This chapter proposes a conceptual framework for analyzing and mitigating the risks in GSC. It also covers methodology adopted for this work. Besides, it extends the details for the proposed and used research methods. The data collection methods and procedures, sample design, target populations, data analysis and interpreting of the information have also been discussed.

Chapter 4

This chapter provides details about the understanding, identification, prioritization, and confirmation of the risks related to GSC. It proposes a flexible structural operational model for risks analysis in GSC using fuzzy AHP and IRP methodologies.

Chapter 5

This chapter context focuses the identified GSC risk evaluation and management by capturing of the uncertainty and evaluating the risks by means of simulation to demonstrate the delay and disturbance impacts of the risk. The uncertainties are identified and assessed, and a Monte Carlo Simulation (MCS) risk evaluation procedure is followed to assess the delay and disturbance impacts of the risk in GSC.

Chapter 6

This chapter proposes the details and suggests a structural model to identify and prioritize the responses of risks in GSC. For this, an integrated approach based on the fuzzy AHP and fuzzy TOPSIS methods has been developed.

Chapter 7

This chapter effort to develop a managerial framework consists of mitigation strategies to facilitate planners to successfully manage risks in GSC. Thus, a SAP-LAP based approach is used for building a risk mitigation decision framework in GSC. Further, to interpret interactions between the variables involved in SAP-LAP based decision model, the methodology of IRP is proposed and applied.

Chapter 8

This chapter provides a comprehensive overview of the research work conducted and the major findings along with the contribution of the present study in the existing set of literature. Besides, this chapter also provides the managerial implications of the present study. The last section of this chapter provides the limitation of the study. This chapter concludes by highlighting the suggestions related to scope of future work.

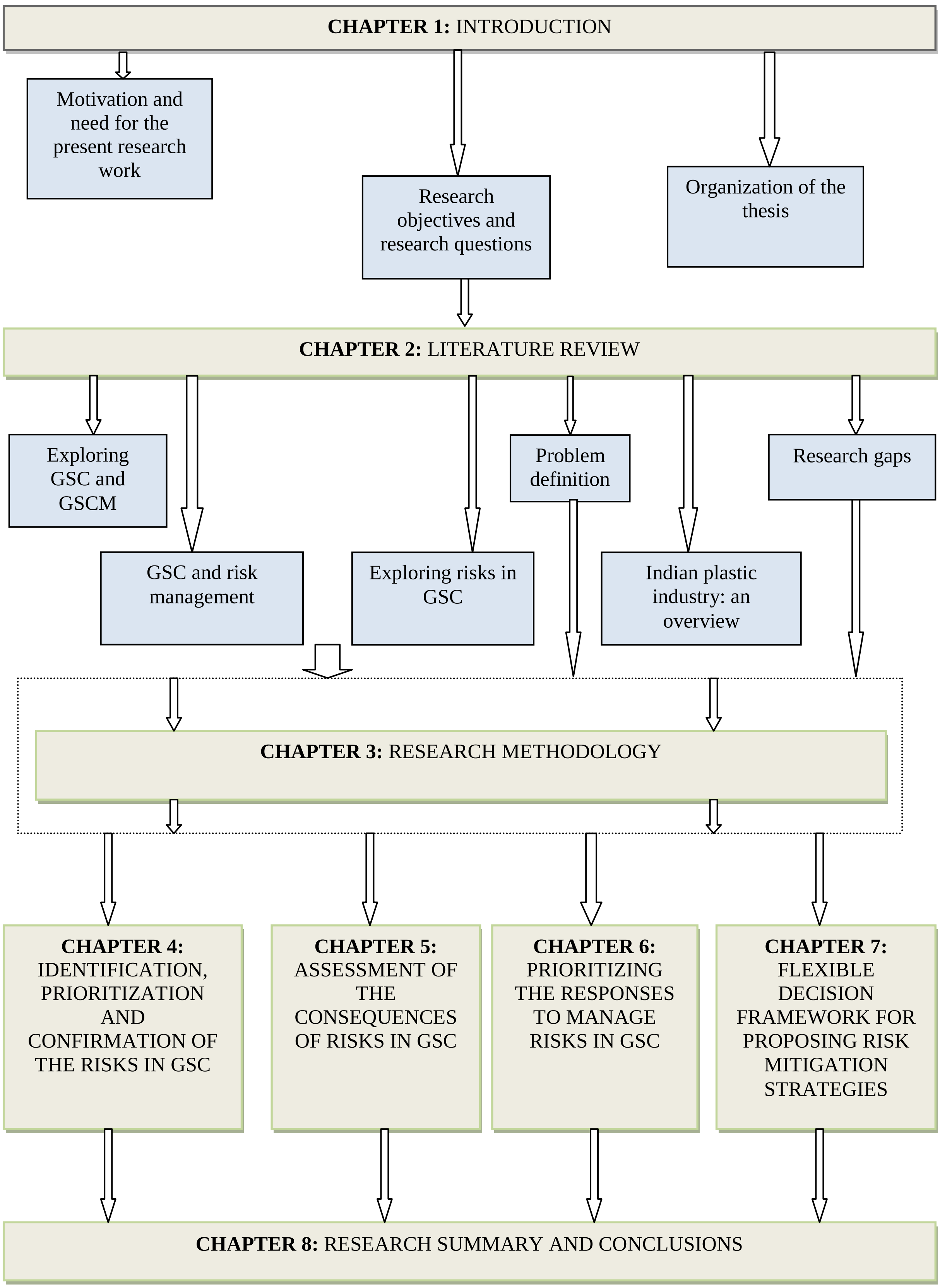


Figure 1.3 Organization of Thesis

1.8 Conclusions

This study is an attempt to identify the mechanism to increase the effectiveness of GSC, so that it can sustain under risks and uncertainties from an industrial context. In the present chapter, an outline of the study is provided. To begin with, after the brief introduction of the supply chain management, green supply chain management and risks in GSC, the purpose and need of the study is given. Following this, research questions were derived to achieve the objectives of the present study. At the last section, the complete organization of the thesis is provided. Further, all sections mentioned in this chapter are discussed in detail in the subsequent chapters of the thesis.

CHAPTER 2

REVIEW OF LITERATURE

The present chapter provides a critical analysis of relevant literature. In the intial part of this chapter, the literature related to GSCM and risks involved in implementation of the GSC business initiatives is presented. Further, a comparison between SCM and GSCM was provided. Also, this chapter revealed the implementation of GSCM in both the global and Indian perspective. Furthermore, it is attempted to understand and recognize the risks in GSC for accomplishing the desired objective. In the later part of this chapter, a brief introduction of the Indian plastic sector is illustrated. Finally, various identified research gaps are given, which will be helpful in achieving the objectives of this research. It is followed by the problem undertaken in this work.

2.1 Literature Review at a Glance

2.1.1 Research methodology used in literature review

Fink (2013) stated that "a literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded document". The following objectives are achieved with the help of a thorough analysis of literature:

1. Relevant patterns, themes and issues are recognized and summarized.

2. A conceptual framework and corresponding theory for green supply chain and sustainability are developed.

Due to the voluminous amount of literature on GSCM and sustainability, it is not possible and feasible to search every research paper/article. To maximize the output from the literature review, only newly emerging issues narrowly defined should be considered (Seuring and Muller, 2008). Both qualitative and quantitative aspects need to be analyzed to understand the content of literature in the area.

2.1.2 Literature search and selection perspective

Research on sustainability, GSC and supply chain has amplified from past one or two decade. Current and relevant papers were selected based on the following criteria:

1. Papers should include environmental sustainability and green and its implementation in supply chain and risk management in a green supply chain as well. However, the keywords used for data collection include “Supply Chain”, “Green”, “Environmental”, “Sustainability”, “Sustainable”, “Risk” and “Risk Analysis/Evaluation and Management”. Combinations of these keywords were used including (1) Green and Risk and Supply Chain, (2) Environmental and Sustainable and Risk, (3) Sustainability and Risk and Supply Chain (4) Risk Analysis/Evaluation and Green and Supply Chain and (5) Risk Management and Sustainability and Green. Green supply chain can be defined mainly from two perspectives of operations and design. It is kept in mind that both aspects are completely covered by the keywords chosen during the searching. For example green supply chain manufacturing/production, operations, purchasing, sourcing, performance measurement, product development, reverse logistics, and product design are all covered by “Green Supply Chain”. Since green supply chain management has emerged from environmentally sustainable development, other possible sustainability-related keywords, instead of “Green”, were also used in the search attempts from a risk management viewpoint.

It should be noted that closed-loop supply chains were not included in this work to assist further bound the efforts to those papers focusing on green and sustainability oriented supply chains.

2. Scrutinizing the collected papers and literature for further analysis. Review of literature was conducted by searching key words as mentioned above. Further, in this analysis, Google scholar and Google search databases have been used to collect articles published in journals, conference proceedings and books. All articles were considered to be representative of the current body of knowledge associated with GSCM, GSCM adoption and implementation, and risk management and GSC form a risk management viewpoint.

2.2 GSCM Nomenclature and Definitions

The "green supply chain" term was suggested for the first time by the manufacturing research consortium of Michigan University in 1996 to study the environmental impacts and resource optimization of manufacturing supply chain (Hanfield et al., 2002). In the literature, the definition of GSC varies according to each researcher perception; it varies from green purchasing to integrated supply chain. GSCM is expressed as the addition of environmental contemplation in the business. It has been stated as a useful measure to increase the ecological performance of the enterprise and to reduce the environmental risks (Zhu et al., 2005).

The application of green practices in the supply chain also helps in improving the ecological proficiency of organizations and their associates. Also, efficient implementation of GSCM in any organization plays a crucial role in acquiring and maintaining competitive gains (Zhu et al., 2005). The objective of the GSC is to turn the whole supply chain into green so that it would help the organizations to achieve their environmental objectives. Further, many scholars and professionals had defined the GSCM in their way in accordance with their field of research. A few of them are given as follows (for details refer Table 2.1):

Table 2.1 GSCM Definitions Proposed by Various Scholars and Professionals

S.N.	Researchers (Year)	GSCM Definitions
1	Godfrey (1998, p244)	"GSCM is as the practice of monitoring and improving environmental performance in the supply chain".
2	Gilbert (2001)	"GSCM is integrating environmental thinking into conventional SCM".
4	Zsidisin and Siferd (2001)	"The set of SCM policies held, actions taken and relationships shaped in response to issues related to the natural environment with regard to the design, acquisition, production, distribution, use, re-use and disposal of the firm's goods and services".
3	Hervani et. al. (2005)	"GSCM is the summation of green purchasing, green manufacturing/materials management, green distribution/marketing and reverse logistics".
5	Zhu and Sarkis (2006)	"GSCM covers all the phases of the product's life cycle from design, production and distribution phases to the use of products by the end users and its disposal at the end of the product's life cycle".
6	Srivastava (2007)	"Integrating environmental thinking into SCM, including product design, material sourcing and selection, manufacturing processes, delivery of the final products to the consumers, and end-of-life management of the product after its useful life".

Table 2.1 Contd...

S.N.	Researchers (Year)	GSCM Definitions
7	Davies and Hochman (2007)	"GSCM is a rigorous effort throughout the company and is more than simply putting some green practices in place, but rather a consistent, holistic improvement of the environmental performance of all levels of management and on the shop-floor".
8	Rettab and Ben Brik (2008)	"Green supply chain is a managerial approach which tries to minimize a product or service's environmental and social impacts or footprint".
9	Zhu et al. (2008a)	"GSCM ranges from green purchasing to integrated life-cycle management SC flowing from supplier, through to manufacturer, customer, and closing the loop with reverse logistics".
10	Sarkis et al. (2011)	"The integration of environmental concerns in the inter-organizational practices of the supply chain management, including reverse logistics".
11	Diabat and Govidan (2011)	"GSCM may be a good way to balance the environmental, economic and social benefits".
12	Kim et al. (2011)	"A set of practices intended to effect, control and support environmental performance by allocating possible human material resources and redefining organizational responsibilities and procedures".
13	Parmigiani et al. (2011)	"The impact of supply chains on environmental performance".
14	Buyukozkan and Cidci (2012)	"A way for firms to achieve profit and market share objectives by lowering environmental impacts and increasing ecological efficiency".
15	Andic et al. (2012)	"Minimizing and preferably eliminating the negative effects of the supply chain on the environment".
16	Ahi and Searcy (2013)	"The integration of environmental thinking into SCM practices".

2.3 Difference between the Conventional SCM and GSCM

Rao and Holt (2005), in their work expressed that GSCM is an important organizational philosophy, which acts as a significant player in encouraging efficiency and synergy between allies. There are several benefits on adoption and implementation of GSCM in business, which can be listed as: maximization of environmental performance, minimum waste generation, cost savings resulting in increased profit and market-share objectives etc. A GSC aims at reducing the wastes within the industrial system to conserve resources, energy, and lower the emission of hazardous gases and toxins into the environment. With regard to this, GSC intiatives can identify and provide measures to limit the environmental impact of SC activities and processes within an organization. In addition, GSCM has been proven to be an effective mean to diminish waste at various levels in business activities (Srivastava, 2007). Conventional SCM are mainly concentrated on the objective of cost effectiveness while GSCM targets the economic-ecological balance objective. SCM normally concentrates more on controlling the final product, no matter how much harmful effects they can cause to environment during manufacturing processes. GSCM also takes into account the human toxicological effects. One may differentiate between GSCM and conventional SCM by means of various criteria (for details refer Table 2.2) (Porter and van der Linde 1995; Beamon, 1999; Gilbert, 2001; Hervani et al. 2005; Orsato 2006; Srivatava 2007; Zhu et al. 2008a,b; Ho et. al., 2009; Hussain, 2011)

Table 2.2 Difference between the Conventional SCM and GSCM

S. N.	Criteria	Conventional SCM	GSCM
1	Area of concern and benefit focus	Economic	Ecological - Economic
2	Supplier selection criteria	Price is the prime factor — easily switch suppliers	Consider ecological perspectives of suppliers — long-term relationships
3	Collaboration and Visibility	Low	High
4	Cost effectiveness	Low	High
5	Flexibility and Speed	High	Low
6	Operation nature	Concern with forward loop operation	Closed loop operation nature (repair, remanufacturing, recycling, reuse, etc.)
7	Thought of concurrent engineering	Missing	Present

2.4 Green Supply Chain and Green Supply Chain Management

In SC network, a vast amount of research has focused on achieving green perceptions in supply chains (Godfrey, 1998; Green et al., 1998; Nelson et al., 2012). It is also supported by the findings obtained in the study of Min and Kim (2012) that literature is growing over the GSCM from past few years. GSCM has been described as an idea to incorporate eco-friendly measures at every definite operation of a supply chain network design, such as, green procurement and purchasing of material, green manufacturing strategies and techniques, distribution networks, green marketing, etc. (Green et al., 1996, 2000; Hervani et al., 2005; Sarkis, 2006; Srivastava, 2007; Sarkis et al., 2011). Adding of 'green' practices in supply chains includes dealing with interactions between supply chain management and the environment (Narasimhan and Carter, 1998; Beamon, 1999; Rao and Holt, 2005; Vachon and Klassen, 2006; Zhu and Sarkis, 2006; Kumar and Chandrakar, 2012). Further, the green practices also reveal an effect on designing of product and process (Porter and van der Linde, 1995; Adler, 2006), procurement and purchasing (Green et al., 1998; Srivastava, 2007; Zhu et al., 2008b), manufacturing/environmental conscious manufacturing or remanufacturing practices of products (Gungor and Gupta, 1999; Linton et al., 2007), marketing and logistics operations (transportation) of products to the end users and green and reverse logistics for closing the loop of supply chain (Hervani et al., 2005; Zhu et al., 2008a; Singh, 2011) and objective of economic performance in supply chain planning (Siegel, 2010; Kumar et al., 2012). Additionally, issues focused on GSC research include strategic decision for greening the supply chains (Zhu et al. 2011), and performance measurement of GSC (Sarkis et al., 2011).

Zsidisin and Sirferd (2001) and Diabat and Govindan (2011) expressed GSCM as, the set of SCM directions and policies, in response to concern related to the natural environment with regard to the design, acquisition, production, distribution, use, re-use and disposal of the firm's goods and services. GSCM practices have often been persisted with highly visible organizations and companies within customer-focused industries (Hall, 2000). Hoejmose et al., (2012), in their work concluded that environmental performances are dominant on the basis of the position of the organization in the supply chain i.e. the organization is either in business-to-consumer (B2C) or business-to-business (B2B) market, which in turn is influenced by the consumer pressure and organizations environmental efforts. Further, it has also been mentioned that implementing GSCM not only result in improved organizational competitive position, but it may also be crucial in the enhanced ecological image (Yang et al., 2011). That is well justifying the need of GSCM implementation is any organization. However, a brief summary on the work related to GSCM initiatives/adoption in business is given in Table 2.3.

Table 2.3 A Brief Summary on the Work Related to GSCM Initiatives/Adoption

S. N.	Researcher (Year)	Area studied in the context of GSCM
1	Lamming and Hampson (1996)	Green procurement and purchasing
2	Walton et al. (1998)	Green procurement and purchasing
3	Sarkis (1998)	Design for the environment, life cycle analysis, and reverse logistics
4	Beamon (1999)	Eco-design, reverse logistics
5	Min and Galle (2001)	Green procurement and purchasing
6	Rao (2002)	Green supply chain initiatives in South East Asia
7	Hervani et al. (2005)	Green purchasing, green manufacturing /materials management, green distribution /marketing, reverse logistics
8	Ravi and Shankar (2005)	Reverse logistics
9	Rao and Holt (2005)	Competitiveness and economic performance enhancement
10	Sheu et. al. (2005)	Green logistics
11	Srivastva (2007)	Green operations, green design, green manufacturing, reverse logistics and waste management
12	Zhu et al. (2008b)	Internal environmental management, green purchasing, cooperation with customers including environmental requirements, eco design and investment recovery
13	Ilgin and Gupta (2010)	Environmentally conscious product design, reverse and closed-loop supply chains, remanufacturing, and disassembly
14	Bai and Sarkis (2010)	Green supplier selection
15	Diabat and Govindan (2011)	GSCM implementation
16	Lin et al. (2011)	GSCM performance measurement
17	Olugu (2011)	GSCM performance measurement

Table 2.3 Contd..

S. N.	Researcher (Year)	Area studied in the context of GSCM
18	Wang et al. (2012)	Green initiatives adoption and implementation
19	Sheu and Chen (2012)	Governmental financial intervention and GSCM
20	Min and Kim (2012)	Provided extensive literature review on GSCM evolution, current trends and future research directions
21	Govindan et al. (2013)	GSCM practices
22	Luthra et al. (2014a)	Explores GSCM implementation critical success factors
23	de Sousa Jabbour (2015)	Green human resource management and green supply chain management relationship
24	Ana Beatriz Lopes de Sousa Jabbour (2015)	GSCM genesis understanding

2.5 Green Supply Chain Management: A Global Perspective

Maximizing the productivity by satisfying the customer needs was the prime aim of earlier structure supply chains (Chopra and Meindel, 2001). However, after mid of twentieth century due to the uprising of quality and supply chain, organizations have acknowledged the significance of ecological thinking and sustainability in business (Thompson, 2002; Srivastava, 2007; Seuring and Muller, 2008). With regard to this, almost 40,000 companies all over the globe have implemented ISO 14001 Environmental Management System (EMS) (Zhu and Sarkis, 2006). Due to the increased pressure from the community and environmentally conscious consumers, there are many regulatory bodies on international platform which keep an eye on the working practices of multi-national companies and ensure their operations within the framework of environmentally friendly means. Government led environmental programs like United State Environmental Protection Agency (EPA), Waste Electronics and Electrical Equipment Directives (WEEE), Restriction of Hazardous Substances Directives (RoHS), etc. are some of the examples of the initiatives taken by various developed nations. Besides, ISO 14001 are the standards for Environment Management System, devised by International Organization for Standardization in 2004.

Several different factors like increasing ecological awareness among masses, competitiveness, ecological image, stringent legislative policies, government pressures, etc. acting as means to organizational supply chains have become more and more important (Zhu and Sarkis, 2006; Mohanty and Prakash, 2014; Mathiyazhagan et al., 2014). As a result, many business corporations, electrical and electronics industries, private corporations, retailing industries, such as Xerox, Ford, Panasonic, IBM, HP, Motorola, Sony, Fujitsu, Wal-Mart, etc. have adopted green practices in their supply chain process with an aim to reduce the overall ecological impact of their business activities (Sarkis, 2003; Adler, 2006; Hsu and Hu, 2008; Zhu et al., 2012). In addition, the initiative of the European Union (EU) for proscribing the usage of six hazardous substances was distinguished in direction to enhance the environmental performance of businesses (Zhu and Sarkis, 2006). To cater environmental and regulatory requirements, traditional supply chain management, has been evolved as green supply chain management (Luthra et al., 2010; Ahi and Searcy, 2013). It will not only help to build green image, but it also help to fetch the major business avenues.

GSCM initiatives are among one of the important decisions, which is needed to be taken by the organizations for achieving economic, social, and environmental goals (or sustainability) in business (Gunasekaran and Gallear, 2012). Green supply chains can be understood as "integration of environmental considerations into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumer, and end-of-life management of green products" (Wee et al. 2011, p. 603).

Additionally, a wide acceptability of GSCM is being recorded in literature as a strategic decision approach for improving the ecological performance and business sustainability all across the globe among industries – including mining industries, manufacturing industries, automobile industries, etc (Muduli and Barve, 2013; Luthra et al. 20014a,b; Govindan et al., 2014). Increasingly, industries understand the importance of environmental management as the key strategic issue which can have the potential impact on the organizational performance.

GSCM has been described as an important mean to enhance organizational ecological-economic performances, while remaining competitive in the market. There are various researchers and professionals have been contributed in the field of GSCM/green initiatives from a supply chain context. For instance, Green at al. (1996) in their study declared that the green initiative is an important decision which is needed to be taken by the organizations for transformation. It has also been mentioned that drives of legislative compliance and cost reduction are most common and universal drivers for such change. Rao (2002) studied the green initiatives taking place in South-East Asia catering three questions; given as (1) what are the initiatives taken by ISO 14001 certified companies to enhance environmental performances? (2) How they are helping suppliers to turn green? (3) What is the linkage between implementing GSCM and competitiveness? Their study showed that the leading companies in that region have started implementing GSCM, and a positive relationship is found for all three questions raised in their study. Rao and Holt (2005) conducted another study considering the companies in South East Asia to identify potential linkages between GSCM, as an initiative for improvement in economic-environmental performances and competitiveness. They confirmed that greening the different phases of the SC leads to an integrated GSC, which ultimately leads to an increase in overall performances. Hervani et al. (2005), in their study, presented an overview related to various issues regarding environmental (green) supply chain management performance measurement. Handfield et al. (2005) developed a framework for environmental supply chain strategic decision making by means of interview based approach using the data from companies of US, UK, Japan and Korea. Besides, conclusions were devised to help firms to change their current SC practices and to successfully integrate environmental issues into their supply chain strategy may be into upstream and downstream members of supply chain. Vachon and Klassen (2006) extended the “collaborative paradigm” between the upstream and downstream members of the supply chain. Antecedents (both plant-level and supply chain characteristics) of GSC practices are examined and also the importance of both logistical (tactical level) and technological (strategic level) were determined. Srivastava (2007) conducted a literature survey on GSCM and classified the related literature on the basis of methodology and approach adopted. An illustration of the various mathematical tools and techniques used by various authors was also provided. Paulraj (2007) in their research work, focused on the critical issues pertaining to corporate environmental strategy by means of empirical methodology. Besides, the subsequent testing of any significant differences in corporate environmental strategy and green practices across the clusters was also covered. They declared that firms aiming to meet legislative requirements should focus on their own environmental practices rather than paying attention on supplier side. But to be proactive, competitive and meet the ‘social’ challenges of environmental safeguarding, supplier development must be considered. Holt and Ghobadian (2009) examined the extent and nature of GSCM in the UK manufacturing sector. In this context, various factors that influence the green initiatives have been studied. Most influential pressures identified in their study were legislative and internal drivers. While, least influential pressures were societal drivers and SC pressures from customers. Findings of their study stated that organizations that have progressive environmental attitude are operationally more active. Zhu et al. (2010) aimed to study about the experience of large Japanese companies for environmental practices and GSCM. They declared that Japanese large manufacturers are more active in implementing GSCM practices than Chinese manufacturers. Customer cooperation with environmental considerations, eco-design, green purchasing and investment recovery are some of the GSCM practices implemented by Japanese firms compared to Chinese manufacturers. Mollenkopf et al. (2010), tried to extend the concept of GSC from a conventional supply chain perspective. They studied the relationship among lean, green and global supply chain strategies with emphasis on the concurrent implementation of these three strategic initiatives by means of literature review. This was the first literature on green, lean, and global supply chain strategies all together and the author emphasized that implementing all three together will result in more effectiveness. Azevedo et al. (2011) explored the positive and negative relationship between the most important green practices considered by the supply chain managers and their influence on supply chain performances in context of the automobile industry. The important green practices highlighted in their study were, reverse logistics, minimizing waste, ISO 14001 etc. Also, the most important performance measures are given as, environmental cost, quality, customer satisfaction, efficiency, etc. Walker and Jones (2012) examined the gap between theoretic and reality situation with firms often accused of paying green lip service to sustainable SCM. They also investigated various supply chain management sustainability issues, including, what factors influence sustainable supply chain management, and how practice might change in the future. Diabat, et al. (2013) explored the practices and performances of the GSCM and considerd the relationship between green supply chain practices and performance outcomes. Fuzzy multiple criteria decision-making (MCDM) and TOPSIS methods were used to analyze the result. According to their study, automotive industry has the strongest drivers and pressure to implement GSCM. Most important performances were internal environmental, followed by intangible outcomes, operational, positive economic and negative economic performances. Meacham et al. (2013) proposed an operational model to study the impact of an organization’s capability by sharing information among and between SC partners. The main focus was to build an efficient green information channel that helps in improving the environmental performance of an orgainzational GSC. Sharing information with supply chain partners and capabilities of green information systems enhances environmental performance. Mangla et al. (2013) treated GSC as a concept of handling the issues related to returning and recovering the value of products via closing the loop of the forward supply chain. In addition, GSCM has also been linked to human resource management to achieve organizational sustainability and truly sustainable supply chains (de Sousa Jabbour, 2015).

GSCM concept is more prevalent in developed nations due to the strict norms and many other factors, whereas, only few organizations are practicing GSCM in developing nations like India, which may be due to various reasons. A brief look on the concept of GSCM in Indian organizations is discussed in next sub-section.

2.6 Green Supply Chain Management: An Indian Perspective

The traditional SC was managed with the objectives of reducing cost and improving service with little concern with environmental dimensions (Simpson et al., 2007; Sarkis et al., 2011). However, over time, external pressures such as coercive pressure, peer pressure and mimetic pressure have forced organizations to design supply chain networks which take into account environmental dimensions (Srivastava, 2007; Guide and Van Wassenhove, 2009; Gunasekaran and Spalanzani, 2012). In the last decade, the concept of closed loop supply chains has emerged, reflecting the profit recovery available from value added components, product reuse, and business opportunities in recycling (Guide and Van Wassenhove, 2009; Soleimani et al., 2014). Despite the environmental awareness, which emerged in the USA in the 1960s and subsequently spread throughout the world (Zhu et al., 2011; Nelson et al., 2012), countries like India and China have been late in responding to the environmental call; however, most firms in India have now integrated environmental dimensions into their corporate policies, although, some have yet to implement these.

India is a highly populated country and contains approximately 17.5% of the world's population. Due to increasing competition, industrialization, and globalization, manufacturing business organizations are growing at much faster pace (Singh et al., 2008), and thus, leading to the generation of an enormous amount of hazardous and non-hazardous waste. The growth in population will be fed by equally unprecedented natural resource consumption and environmental impacts. The GSCM issue is important for the reason that recent studies have revealed that the majority of the world's manufacturing will be carried out in Asia continent within the next 20 years (Hu and Hsu, 2010).

India occupies 4th position in top ten worst polluting countries of the world (Actions for Planets, 2012). Further, as per Environmental Performance Index (EPI) 2014 report, India is ranked at 155 positions out of 178 countries, which supports the fact that the initiatives being devised for the environmental improvement are significantly insufficient in India. However, there has been an improvement of 5.4% from the last year trend. Still, there are significant chances of improvement possible in the environmental sector. In the 11th and 12th five year plan environment responsibility have been given due importance. Yet, there is strong requirement to increase awareness of green practices in supply chain and their benefits. C Esty, Director of the Yale Center for Environmental Law and Policy in their statement has argued that "India's low rank on the EPI should be an alarm to Indian government and concerned authorities at all levels (The Economic Times, 2012). Hence, there is a need to take necessary steps in increasing environment sustainable practices to improve environmental performance of Indian business organizations. On the other hand, yet, there is lack of competency and knowledge among Indian organizations supply chains in terms of adoption of GSCM and sustainability in the business (Gupta and Palsule-Desai, 2011). It is mainly due to the lack of awareness of sustainability among Indian consumers (Das, 2012). The other reason behind this could be the lack of willingness for paying quality worth for environmentally friendly products (Ishaswini and Datta, 2011).

It is also stated that industries at small and medium levels in India are playing very important role in Indian economy by contributing approximately 45% of industrial output and 40% of export with millions of job avenues every year. So, there is a need that the government and the buying firms particularly large scale industries (LSI) must pay more attention to the small scale industries (SME) suppliers because generally SME lack the resources, information, experts or other necessary tools to deal with the environmental related issues. Moreover, they have little know-how about the tools and techniques and they hesitate to reach out for help without some external stimulus. So, SME suppliers can prove to be a bottleneck in pursuing the goal of greening the supply chain. Due to the increased pressure from various formal and informal channels, various industries are accepting this fact as the need of the hour and are trying to implement it throughout the network to reap the benefits and building brand image to sustain competition and increase their market share to earn more profits.

GSCM is an approach to improve performance of the process and products according to the requirements of the environmental regulations (Hsu and Hu, 2008). Currently, Indian organizations have started, inculcating environmentally friendly practices into the traditional supply chain because of the increased pressure from the regulatory bodies, customers, competitiveness, etc. (Mathiyazhagan et al., 2014) (e.g. the goal of 20% reduction in emissions by 2020 due to pressure from developed countries). At this point of view, many researchers and practitioners are playing their part by means of their studies in the area of GSCM in Indian context; other details are given in Table 2.4.

Table 2.4: GSCM Implementation in Indian Context: A Brief Status

S. N.	Researchers (Year)	Contribution	Sector/Industry investigated
1	Srivastva (2007)	Analyzed the literature on GSCM	-
2	Mudgal et al. (2009)	Identified and evaluated various enablers in Indian industries perspectives	Manufacturing
3	Mudgal et al. (2010)	Modelled the barriers of GSC practices	Manufacturing
4	Toke et al. (2010)	Analyzed the GSCM research agenda	-
5	Brave and Muduli (2011)	Analyzed the challenges to adopt environmental management practices	Mining
6	Choudhary and Seth (2011)	Integrated the green practices in supply chains	-
7	Diabat and Govidan (2011)	Developed an interactive model of the eleven drivers affecting the implementation of GSCM	Aluminium company
8	Kushwaha (2011)	Sustainable development through strategic GSCM	-
9	Luthra et al. (2011)	Evaluated eleven barriers in GSCM	Automobile
10	Qadri et al. (2011)	Identification of drivers for GSCM	Manufacturing
11	Nimawat and Namdev (2012)	Provided an overview of GSCM	-
12	Toke et al. (2012)	Analyzed the factors in GSCM	Manufacturing
13	Kumar et al. (2013)	Explored the customer involvement in GSCM	-
14	Mathiyazhagan et al. (2013)	Explored twenty-six barriers specifically for initiating and adopting GSCM	Auto Component Manufacturing
15	Muduli and Barve (2013)	Sustainable development practices: a GSCM approach	Mining

Table 2.4 Contd...

S. N.	Researchers (Year)	Contribution	Sector/Industry investigated
16	Muduli et al. (2013)	Examined various barriers to GSCM	Mining Industries
17	Mohanty and Prakash (2014)	Empirically analyzed the GSCM practices	Micro, Small and Medium enterprises
18	Mangla et al. (2013)	Analyzed fourteen variables related to the product recovery mechanism in the GSC system	Paper mill industry
19	Luthra et al. (2014)	Analyzed the critical success factors to achieve high GSCM performances	Automobile
20	Mangla et al., (2014)	Explored different performance focused variables relevant to GSCM implementation	Paper mill industry
21	Diabat et al. (2014)	Analysis of enablers for implementation of sustainable supply chain management	Textile industry
22	Mathiyazhagan et al. (2014)	Ranked thirty-six pressures related to GSCM adoption	Manufacturing industries
23	Anand and Parthiban (2014)	Evaluated the GSC factors using DEMATEL	Manufacturing industries
24	Malviya and Kant (2014)	Predicted the success possibility for GSCM implementation	Automobile company
25	Mitra and Dutta (2014)	Presented a comprehensive analysis on GSCM practices and their impact on performance	manufacturing firms
26	Govindan et al. (2014)	Identified twenty-six common barriers in GSCM adoption	Manufacturing industries

Table 2.4 Contd..

S. N.	Researchers (Year)	Contribution	Sector/Industry investigated
27	Xu et al. (2013)	Presented a relative study of the pressures in GSCM adoption	Automobile, Chemical, and Textile and Electrical & Electronics industries
28	Luthra et al. (2015)	Analyzed the critical success factors in GSCM adoption	Mining industry

2.7 Modeling Approaches Used in GSCM

Various researchers utilized different modelling techniques/methodologies addressing issues in the field of GSCM. A brief review of various modelling techniques used in GSCM by means of literature is given in Table 2.5.

Table 2.5 An Overview of the Modeling Techniques Used in the Field of GSCM

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed	Industry covered, Country
1	Chien and Shih (2007)	Structural Equation Modeling (SEM)	Relationship between GSCM practices and organization performance	Electrical and electronic industry, Taiwan
2	Mudgal et al. (2009)	Interpretive Structural Modelling (ISM)	Interactions among the enablers to implement GSCM	Manufacturing industry, India
3	Faisal (2010)	ISM	A hierarchy based structural model of the enablers of sustainability in a supply chain	-
4	Hu and Hsu (2010)	Explanatory Factor Analysis (EFA)	Critical factors for successful implementation of GSCM practices	Electrical and electronic industry, Taiwan
5	Mudgal et al. (2010)	ISM	Modeling the barriers of green supply chain	Manufacturing industry, India
6	Shang et al. (2010)	EFA	Critical GSCM capability dimensions and firm performance	Electronic industry, Taiwan
7	Diabat and Govindan (2011)	ISM	An analysis of the drivers affecting the implementation of GSCM	Aluminum company, India
8	Naini et al. (2011)	Evolutionary game theory and the balanced scorecard	Performance measurement system for environmental supply chain management	-
9	Luthra et al. (2011)	ISM	Analysis of barriers to implement GSCM practices	Automobile industry, India

Table 2.5 Contd..

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed	Industry covered, Country
10	Abdallah et al. (2012)	Mixed integer programming	Carbon trading and environmental sourcing in a GSC	Computer assembly and distribution company, U.S.A.
11	Balasubramanian (2012)	ISM	The barriers to the adoption of GSCM practices	Construction industry, U.A.E.
12	Giovanni and Vinzi (2012)	SEM	The relationships between environmental management and performances	Manufacturing industry, Italy
13	Green et al. (2012)	SEM	The impact of GSCM practices on performances	Manufacturing industry, U.S.A.
14	Oluwafemi and Oyatoye (2012)	Analytic Hierarchy Process (AHP)	The impact of corporate social responsibility actions on organizational performance	Manufacturing firms, Nigeria.
15	Pishvaee and Razmi (2012)	Multi-objective fuzzy mathematical programming	Environmental supply chain network design	Medical needle and syringe manufacturer, Iran
16	Lin (2013)	Decision Making Trial and Evaluation Laboratory (DEMATEL)	Carbon management model of supplier selection in GSCM	Electronics case company, Taiwan
17	Luthra et al. (2013)	AHP	Ranking of strategies to implement GSCM practices	Manufacturing industry, India

Table 2.5 Contd..

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed	Industry covered, Country
18	Mangla et al. (2013)	ISM	Analyzed key decision variables for sustainability-focused green product recovery systems	Plastic industry, India
19	Mathiyazhagan et al. (2013)	ISM	Barrier analysis in implementing GSCM	Auto component manufacturing, India
20	Muduli et al. (2013)	Graph theoretic approach	Analysis of barriers to GSCM	Mining industry, India
22	Wang and Chan (2013)	Fuzzy AHP and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)	Assessing improvement areas when implementing GSC initiatives	Multinational clothing company, U.K.
23	Bhattacharya et al. (2014)	Fuzzy Analytical Network Process (ANP)	Green supply chain performance measurement framework	-
24	Diabat et al. (2014)	ISM	Influential enablers for implementation of SSCM	Textile industry, India
25	Jabbour et al. (2014)	EFA and SEM	The relationship between maturity of environmental management and the adoption of GSCM	Electro-electronic industry, Brazil
26	Govindan et al. (2014)	AHP	Barrier analysis for GSCM	Indian Industries

Table 2.5 Contd..

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed	Industry covered, Country
27	Luthra et al. (2014a)	EFA and Interpretive Ranking Process (IRP)	Critical success factors to implement GSCM towards sustainability	Automobile industry, India
28	Mirhedayatian et al. (2014)	Data Envelopment Analysis (DEA)	Evaluation of GSCM practices	Soft drink companies, Iran
29	Dubey et al. (2015)	Confirmatory Factor Analysis (CFA) and hierarchical regression analyses	The relationships between leadership, operational practices, institutional pressures and environmental performance in GSCM	Rubber goods industry, India
30	Luthra et al. (2015)	ISM	Analysis of interactions among CSFs to implement GSCM towards sustainability	Automobile industry, India
31	Rostamzadeh et al. (2015)	Fuzzy Vise Kriterijumska Optimizacija I Kompromisno Resenje) (VIKOR)	Evaluation of GSCM practices	Laptop manufacturer case company, Malaysia
32	Wu et al. (2015)	Fuzzy DEMATEL	Exploring decisive factors in GSC practices under uncertainty	Automobile manufacturing industry, Vietnam

2.8 GSC and Risk Management

It is very difficult to say exactly what will happen in the future, as there are risks in all operations (Chopra and Sodhi, 2004; Waters, 2007). From the point of view of managers and business analysts, risk has been expressed as a threat that something might happen to disrupt normal activities or it may prevent their occurrence as planned, viz. there is a risk that a new product will not be sold, that a project will not be successful, that the costs of raw materials will increase, etc. From an operational and supply chain perspective, risk has been described as variance from expected outcomes and negative events in disruptions to supply chain**,** which can reduce the effectiveness and efficiency of activities (Gurnani et al., 2012; Hora and Klassen 2013) and processes along a supply chain (Chopra and Sodhi, 2012). From the point of view of business organizations, supply chain management can be understood as a managerial approach that accounts for the movement of materials/resources/goods throughout the product life-cycle (right from the supplying of the raw materials to till the product reaches to final customers) (Chopra and Meindel, 2007). In contrast to this, GSCM has been stated as the inclusion of the environmental aspect into conventional SCM (Ahi and Searcy, 2013).

Risks to the GSC can be defined as occurrence of unforeseen events those might affect the green material movement and even disrupt the proposed flow of eco-friendly materials and finished green products from their point of origin to the point of consumption in business. Its consequences could be delay in deliveries, damage of goods, financial problems, business loss, etc. (Ma et al., 2012). Therefore, risk is an important term for the organizational GSC, as incapability in managing the risks would decrease the overall performance (Qianlei, 2012).

In order to adopt GSCM practices efficiently, several different risks and risk driving factors associated with the initiation and adoption of different green initiatives were determined from a SC context. The supply chain has some difficulties and challenges in adoption of the green trends as several external and internal risks are associated with the implementation of GSCM at industrial standpoint (Ma et al., 2012). A few of external and internal risks are market pressure at local or global level, environment resource constraints, lack of government policy support, economic fluctuations, information asymmetry risk, lack of measurement of enterprise environmental performance, problems related to enterprise staff quality, lack in green technology level, etc. (Ma et al., 2012). Qianlei (2012) have listed several risks in green products agricultural GSC based on systematic analysis, and emphasized on the management of these risks for improving GSC effectiveness. The various risks identified in their study were supply risks, demand risks, process risks, technology risks, information flow risks, knowledge flow risks, network risks, logistics risks, legal risks, natural environmental risks, cultural risks, economic risks, contingency risks, etc.

Yang and Li (2010), described the operation of GSC, and provided several factors and sub-factors of the risks relevant to green initiatives in business. The various risk factors mentioned in their study given as supply risk, demand risk, organization risks, system control risk, market environment risk, etc. While, the failure of key supplier, issues related to the quality of supply, key customer failure risk, error in forecasting, partnership risks, moral hazard risks, industry volatility risks, information control risks, economic issues, etc. have been listed as risk sub-factors in GSCM adoption (Yang and Li, 2010). Dan-Li et al. (2011) projected a model to investigate risks in manufacturing practices of GSC and listed that three types of uncertainty might occur in GSCM namely, convergence uncertainty, operation uncertainty and green uncertainty. Wang et al. (2012) developed a risk assessment model useful in decision analysis of aggregative risk when applying different green initiatives in the case of a fashion industry supply chain. Various criteria enlisted in their study are cost, flexibility, assurance to supply, delivery, quality, manufacturing, purchasing, etc. (Sarminento and Thomas, 2010).

2.9 Modeling Approaches Used in GSC and Risk Management

Various researchers utilized different modelling techniques/methodologies addressing risks in the field of GSC and GSCM. A brief review of various modelling techniques used in GSC for managing its risks by means of literature is given in Table 2.6.

Table 2.6 An Overview of the Modelling Techniques Used in GSC and Risk Management

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed
1	Hsu et al. (2008)	Fuzzy Analytic Hierarchy Process (FAHP)	Risk evaluation of green components in supply chain
2	Hu et al. (2009)	Failure Mode & Effect Analysis (FMEA) and FAHP	Risk evaluation of green components to hazardous substance
3	Yang and Li (2010)	FAHP	Green supply chain risk assessment in a circular economy
4	Yen and Zeng (2010)	FMEA	Material risk assessment in a green supply chain
5	Dan-li et al. (2011)	Grey theory	Risk assessment of green supply chain in Chinese manufacturing industry
6	Li (2011)	FAHP	Knowledge transfer risk evaluation of a green supply chain
7	Liu and Tsai (2012)	Quality Function Deployment (QFD), Fuzzy Analytic network Process (FANP) and FMEA	Risk assessment for occupational hazards in the construction industry
8	Ma et al. (2012)	Fuzzy comprehensive evaluation method	Assessment of GSCM risk
9	Wang et al. (2012)	FAHP	Risk assessment of implementing green initiatives in the fashion supply chain
10	Chen et al. (2013)	Structural Equation Modeling (SEM)	Supply chain operational risk mitigation through collaboration

2.10 Exploring Risks in GSC

For managerial viewpoint, risk is a threat that something might happen to disturb typical and normal activities or stop things happening as intended (Waters, 2007). Risks to the green supply chain are unforeseen events that might affect the green or environmentally friendly material movement, and even disturb the proposed flow of green materials and products from their point of origin to the point of consumption in business. Some of the risks related to GSC are partnership risks, management policy failures, supplier failures, key customer failures, etc. (Yang and Li, 2010; Ma et al., 2012). These risks might cause delays, missed deliveries, financial irregularities, and damage goods or somehow affect smooth operations. Therefore, it is important to understand and manage the risks in GSC for accomplishing the desired objective (Ma et al., 2012). In the present research work, thirteen risks in the context of GSC, based on literature resource, were identified (for details refer Table 2.7). Based on the meaning and similarities, these risks were grouped into five categories, namely Operational risks, Supply risks, Product recovery risks, Financial risks, and Demand risks. The governmental related risks have also been included in addition to above listed five categories of risk (for details refer Chapter 4, Table 4.1). However, the political risks have not been included in this work, and it is due to instability in political system in Indian context. It should be noted that a traditional supply chain may consist of above-mentioned risks, for instance, supply risks, demand risks, etc. (Chopra and Sodhi, 2004; Waters, 2007). However, readers should not be mystified as green/environment is not a key area of concern in the traditional supply chain system (Srivastava, 2007). Further, the risks identified in this work belong to the entire supply chain i.e. upstream and downstream. Nonetheless, the thirteen recognized GSC specific risks are defined and given in Table 2.7, while, the five categories of risks in GSC are described in the subsequent sub-sections.

2.10.1 Operational risks (O)

The operational or process risk depends upon the operations or process involved in the manufacturing of a green product. There are several internal operations for a green product like utilization of green methodology such as green materials, methods, operations, machines, process, which needs to be implemented properly for effective GSCM practices (Green et al., 2000; Perron, 2005; Luthra et al., 2011). Operational risk in GSC context can be defined as the risk of loss resulting from inadequate or failed internal green processes, operations, methods, workforce, systems, etc. Besides, the issues related to labor or employees' knowledge in adopting green practices might also source operational risks in GSC (Sarkis, 2006; Xu et al., 2013; Muduli et al., 2013).

2.10.2 Supply risks (S)

Supplying environmental friendly material (green raw material or recycled material) for producing green finished product is an important function of GSC (Luthra et al. 2011), as any disruption in supply may reduce the ecological-economic advantages. It considerably depends upon organizational environmental collaboration with suppliers along with the problems at supplier end, as their awareness, knowledge, approach and willingness regarding green practices would be crucial for organizations in adopting the efficient GSCM concept (Lippmann, 1999; Hall, 2000; Luthra et al., 2011; Mathiyazhagan et al., 2013).

2.10.3 Product recovery risks (PR)

In recent yeras, increasing interest in product return, recovery, and the distribution of recovered products has led to enormous contributions in the area of closing the loop of GSC (Hervani et al., 2005). Recovery of products is difficult due to its dependency on large number of uncertain or indecisive factors (Mangla et al., 2013). In the present research work, product recovery risks are given as the risks relevant to returning and the recovery end of the products composed product recovery risk in GSC. These types of risks have a tendency to disrupt the GSC product recovery mechanism. It includes issues on reverse logistics network design, gate keeping for viewing and screening of damaged and defective return products at the entry point of reprocessing stations, inefficient Extended Producer Responsibilities (EPR) policies, while introducing ecological concern in a product life cycle, and in-process inventory and capacity planning issues at collection and reprocessing stations.

2.10.4 Financial risks (F)

Considering the objective of greening the supply chain, it is difficult to trade off between the cost involved (involved in green adoption and implementation) and the value obtained. Thus, it is crucial to have financial initiation and support for any organization in implementing GSC practices. Failure of or poor financial plans and controls will definitely disturb the GSC functioning, and results in decreased performance. Financial concerns for GSC include issues related to sourcing of funds, market fluctuations and currency exchange rates, and costing issues (Mudgal et al., 2010; Luthra et al., 2011).

2.10.5 Demand risks (D)

Demand of the green product is crucial in deciding its business value. In the pull-based strategy of the supply chain, demand recognizes the production. Hence, a too small or large demand of green products will affect the business accordingly. Thus, GSC demand risks can be expressed as the risks containing uncertainties linked to the demand for green products. However, demand function for the green products generally depends on the customer behaviour about green, market dynamics, environmental cooperation and collaboration among manufacturer and customer, competitors' strategies and approach regarding green adoption, etc. (Zhu et al., 2008a; Paulraj, 2009; Holt and Ghobadian, 2009).

Table 2.7 Defining GSC Specific Risks within Respective Categories with Sources

GSC specific risks	Description	Sources
Operational risks (O)		
1. Machine, equipment or facility failure (O1)	Any interruption due to failure of machine, equipment or facility will affect GSC effectiveness at industrial standpoint	Yang and Li (2010), Wang et al. (2012)
2. Design risks (O2)	It corresponds to the imprecision or flaws in designing of green process methodology like mismanaged green material, operations, methods, etc.	Yang and Li (2010), Qianlei (2012), Ma et al. (2012)
3. Scarcity of skilled labor (O3)	The lack of understanding and or knowledge of green operations and method among workforce will lower the organizational GSC performance	Yang and Li (2010), Ma et al. (2012)
Supply risks (S)		
4. Procurement costs risks (S1)	Procurement of green and or eco-friendly raw material may add to costs at supplier end, and so, their environmental performance may be affected	Yang and Li (2010), Qianlei (2012)

Table 2.7 Contd...

GSC specific risks	Description	Sources
5. Key supplier failures (S2)	Failure of any key supplier can halt the functioning of an organizational GSC	Yang and Li (2010), Wang et al. (2012)
6. Supplier quality issues (S3)	The issues of quality at supplier's end will affect GSC efficiency at industrial perspective	Ma et al. (2012), Wang et al. (2012),
Product recovery risks (PR)		
7. Reverse logistics design risks (PR1)	Risks relevant to reverse logistics network design can disturb the adoption of effective GSC practices in business	Mangla et al. (2013)
8. Gate keeping design failures (PR2)	It represents the uncertainties related to viewing, inspection and screening of damaged and defective return products at the entry point of reprocessing stations	Mangla et al. (2013)
Financial risks (F)		
9. Sourcing of funds (F1)	Any problem related to fund sourcing and its basis would certainly influence the objective of adoption of effective GSC practices in business	Yang and Li (2010), Qianlei (2012)

Table 2.7 Contd...

GSC specific risks	Description	Sources
10. Inflation and currency exchange rates (F2)	Inflation and variations in currency exchange rates would affect the financial concerns, and thus, GSC effectiveness may be affected	Yang and Li (2010)
Demand risks (D)		
11. Bullwhip effect risks (D1)	The green demand information distortion within the GSC, known as the bullwhip effect. It makes difficult for the organizational GSC to estimate the green product demand, and results in decreased performance	Yang and Li (2010), Qianlei (2012).
12. Market dynamics (D2)	Market dynamics are the result of collective market resources and preferences. For this reason, market dynamics have a significant effect on green product demand and affect GSC efficiency in turn.	Ma et al. (2012)
13. Key customer failures (D3)	Failure of any key customer will have a significant effect on efficient GSCM adoption and implementation	Yang and Li (2010), Qianlei (2012)

2.11 Indian Plastic Industry: An Overview

One of the biggest challenges for each industry in current market is the rising need for integrating environmentally friendly aspects into SC practices. In recent years, India has become a rising economy in the corporate world. On purchase power parity basis, India has its place in top five global economies and is expected to be the third largest by the year 2020. In case of India, plastic industrial sector has become one of the fastest growing business sectors. Indian plastics industry business is expanding at an incomparable pace. In addition, Indian plastic industrial sector has made noteworthy achievements in the nation ever since it made a promising beginning with the start of production of polystyrene in 1957. The industry is growing at a rapid pace and the per capita consumption of plastics in India has increased several times. At present, the Indian plastics industries are spread across the country, provided employment to around 4 million people. It operates more than 30,000 processing units, of which 85 - 90 per cent are small and medium scale enterprises.

Different international business organizations from various sectors such as electronics, food processing, packing, automobiles, healthcare, have set-up large production houses in Indian perspective. As a result, demand for plastics products is speedily growing and it is expected that India will appear as one of the fastest growing business markets in the world. Besides, it is also expected that there are huge opportunities for the plastic industry in India in the recent years. This would necessitate business organizations initiatives to promote investments, raise the market share, enhance quality standards, improve global involvement, and encourage Indian industry, to adapt world class technology and manufacturing methods and standards. The export of Indian plastics is increasing rapidly from US$ 7.2 billion to US$ 10 billion in the year 2014-15. India is one of the most promising exporters of plastics among developing countries. The Indian plastics industry is involved in producing and exporting a variety of raw materials, plastic woven sacks and bags, Polyvinyl Chloride (PVC) leather cloth, plastic molded goods, polyester films, laminates, writing instruments, packaging material, consumer goods, sanitary fittings, electrical and electronic accessories, laboratory and medical surgical instruments, etc.

It has been noticed that the global trend and competitions in the plastic industrial sector proposes a great pressure to consider green or ecological influence in the supply chain planning process. It not only offer enough prospects for green and sustainable operations, such as reprocess, reuse, and recycling of plastic based products, but also significantly reduces the consumption of resources, minerals, energy, in business activities (Plastic Europe, 2009). Considering this, the plastic industrial sector needs to be involved in improving its ecological performance and in developing a sustainable and environmental friendly culture. However, the managers/business professionals may face different and or several risks in GSCM network design. Under these considerations, to help organizations in this sector to adopt effective green initiatives, it is important to manage and reduce the convolution of risks in GSC.

2.12 Research Gaps Identified for This Work

It has been recognized that literature is growing on the GSCM and sustainability over the past two decades as mentioned in the study conducted by Fahimnia et al. (2015). This study undertook 884 research articles related to GSCM published during a period of 21 years, i.e. between 1992 and December 31, 2013. Their work presents a progression of the influential GSC and sustainability research articles and further aims to contribute to the subject via mapping the relationships amongst the higher impact contributions. Further, considering the research interests in the area of GSCM in the past years, Min and Kim (2012) also presented an extensive review of literature on GSCM and illustrated that GSCM cuts across various boundaries i.e., industrial activities, integrating purchasing, procuring, producing, and delivery processes from a supply chain context. Moreover, out of total articles published as highlighted in their study, there are very few articles from developing countries, especially from India. Besides, mostly articles among these mainly covers the analysis of success factors, drivers, barriers, pressures and attributes, in the adoption and implementation of green trends from a supply chain context (Diabat and Govindan, 2011; Luthra et al., 2014a,b; Govindan et al., 2014). However, in the 12th five years plan (2012-2017), it has also been mentioned that green and sustainable development and growth is the need of the hour to improve environmental performances in Indian context. Under these considerations, this concept needs to be studied thoroughly to help business organizations to implement green in their respective business, and to assist Indian organizations to improve the environmental-economic performances and sustainability in business (Diabat and Govindan, 2011; Govindan et al., 2014).

GSCM offers means to achieve the objective of enhancement in ecological-economic performance of the supply chain (Beamon, 1999). However, still, organizations are reluctant in adoption of green initiatives in their supply chain planning process (Govindan et al., 2014). One of its reasons is inadequacy in their knowledge of green and economic benefits obtained from adoption and implementation of GSCM. Another reason is an incomplete understanding of what is responsible for green adoption to fail in the supply chain. It is due to because the initiatives of green at various aspects of business involve several complexities and risks (Wang et al., 2012). Therefore, it calls for to conduct the process of risk identification, analysis, and management for improving the GSC effectiveness. In addition, the topic of risk analysis and management in GSC in literature is still unexplored (Yang and Li, 2010; Dan-Li et al., 2011; Ma et al., 2012). Hence, it is considered as an obvious gap of research in GSC context. In this research work, an attempt is made to fill this gap in GSC in Indian perspective. Additionally, a collection of papers to illustrate the research gaps identified for this study are given in Table 2.8.

Table 2.8 A Brief Summary of the Previous Works to Address/Identify Research Gaps

S.N.	Researchers (Year)	Contribution	Scope for future work
1	Handfield et al. (1997)	Demonstrated the application of environmental management fundamentals to the complete set of activities across the whole customer order cycle, including design, purchasing, production, packaging, logistics, distribution, etc.	There is a great scope for researchers on environmentally related research in the operations management field
2	Beamon (1999)	Examined the environmental factor that lead to the development of an extended environmental supply chain, and proposes a generic course of action to achieve and maintain the GSC	This extension i.e. GSC presents an additional level of complexity to SC design. It may increase the complexities related to strategic and operational GSC decisions that can be explored in future studies
3	Srivastava (2007)	Provided a systematic literature over need, importance, evolution and various aspects and practices of GSC along with the issues of reverse logistics (RL)	Numerous opportunities in research area of GSCM from design to end of life management of products can be explored further
4	Simpson and Samson (2008)	Provided an understanding of what might be the most appropriate GSCM strategy for a particular product, process, or industry context	Optimal green process and GSCM strategies become more complex and involve greater levels of relationship risk, investment and uncertainties that needs to be explored

Table 2.8 Contd...

S. N.	Researcher (Year)	Modeling techniques used	Issues addressed
5	Zhu et al. (2008a)	Presented results for a cross-sectional survey with manufacturers in four typical Chinese industrial sector, i.e., Petroleum, Chemical, Power, Electrical, Electronic and Automobile, to analyze the GSCM adoption and implementation and relate them to closing the traditional SC loop	Uncertainties and risks are associated to economic, ecological performance while applying the GSCM practices and closing the forward supply loop
6	Hu et al. (2009)	Analyzed the risks of green components in compliance with the EU for the Restriction of Hazardous Substance (RoHS) directive for an electronic manufacturer in Taiwan	Difficulties in criteria selection may still pose as challenges for future research
7	Yang and Li (2010)	Presented a framework to make an assessment for the GSC risk to provide a reliable basis and assurance for the supply chain selection and risk control of organization	GSC risk assessment is an important part of supply chain management, but still it lacks the procedures to be followed and interactions among and between the risks can be investigated
8	Yen and Zeng (2010)	A hierarchical green material risk assessment approach is proposed. As a result, organizations can assess and prioritize the material risk	The interaction and among risk in GSC may be explored further

Table 2.8 Contd...

S.N.	Researchers (Year)	Contribution	Scope for future work
9	Dan-Li et al. (2011)	Presented a risk evaluation model of GSC for manufacturing firm and provide reference on how to avoid risk occurrence from a SC context	Needs to develop a model for the evaluation and management of manufacturing green supply chain, so non-green or simply supply chain risk management evaluation cannot be separately assessed. Simulation analysis can be explored to found more realistic results
10	Ma et al. (2012)	Analyzed the sources of risk in GSCM fundamentally and constructs a risk evaluation system owing to the classification of sources. Also, makes a quantitative analysis to the risk of GSC with the fuzzy comprehensive evaluation method	Analysing and managing of the risk helps in reducing the vulnerability of the supply chain and makes a scientific planning from an industrial context
11	Zou and Couani (2012)	Identified the various risks and risk factors linked to green initiatives in building construction. Besides, developed strategies to manage the risks for improving the green performance of the construction industry's supply chains	Identification of risk factors and issues could be further explored in detail and may be considered as a future research scope in other sectors
12	Wang et al. (2012)	GSC involves a lot of uncertainty and risk factors, and for the purpose this study proposes a decision model for evaluating different green initiatives in the fashion industry	The model can be extended to enable life cycle assessments covering all aspects and uncertainties associated with the implementation of green initiatives in the supply chain

2.13 Problem Definition

In a strategic view, GSC initiatives offer means to achieve the objective of enhancement in ecological-economic performance of the supply chain (Beamon 1999; Sarkis, 2003; Rao and Holt 2005). At the same time, the GSC networks are becoming more complex due to the occurrence of risks. Every production and business activity in GSC includes different risks and risk driving factors. These risks and risk factors would be responsible for causing disturbances in GSC, and results in decreased performance (Qianlei, 2012). Therefore, it is significant to conduct the process of risk identification, analysis and management for improving the GSC effectiveness (Yang and Li, 2010; Wang et al., 2012). In addition, the topic of risk analysis and management in GSC in literature is still uncharted (Yang and Li, 2010; Dan-Li et al., 2011; Ma et al., 2012). Hence, it is considered as an obvious gap of research in GSC context, justifying the need of this research work and will help in managing the risks relevant to an efficient implementation of GSC initiatives on various levels in business. Considering the need as well as to justify the purpose of this study, the research problem under taken in this work is stated as:

"Analysis and Management of Risks in Green Supply Chain".

2.14 Conclusions

In this chapter, an effort is made to address the issue of implementation of GSC initiatives amongst the business organizations. In the initial part of this chapter, a brief introduction of the GSC and GSCM and various issues related to GSCM adoption and implementation are given. A literature review presented different definitions of GSCM. A comparison between traditional SCM and GSCM has also been illustrated with the help of literature. Also, a review on modelling approached used in GSCM was presented. Further, based on the literature, the risks associated with the GSC were recognized. The concept of risks management in GSC has also been covered in the subsequent sections. A literature review is an essential part of any research to recognize the theoretical content of the developing research field and provides direction towards theory building. In the later part of this chapter, an overview of Indian plastic sector is provided to help organizations in this sector to adopt effective green initiatives by managing and reducing the convolution of risks in GSC. This chapter shows the various gaps in the literature, which grounds the problem undertaken for this work. To resolve the problem and fulfil the desired objectives, this chapter provides a strong foundation for the need of a GSC risk analysis and management model to formulate the flexible decision strategies for managing the green initiatives successfully from an industrial context.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter discusses the research methodology used for analyzing and managing the GSC risks in the Indian plastic manufacturing business organizations. In the initial part of this chapter, a conceptual model is proposed to reveal the approach to risk management in GSC. It is followed by the research methodology to achieve the raised research objectives and questions. This chapter also discusses the research methods used in this study. The detail on sample design is described as well. The data collection procedure and data analysis to interpret the information are provided in the later part of this chapter.

3.1 Proposed Research Model

The proposed research model to manage the risks in GSC is shown in Figure 3.1. It consists of various steps, such as, Identification and risk management; Risk identification; Risk Analysis; Risk Management; and Continuous improvements. The detailing for these steps is given in the next sub-sections. For the perspective of managers and practitioners, the model contribution is two-fold, (1) to assist in formulating the short term and long term decision strategies to manage GSC risks and (2) to suggest means to implement them in a systematic way helpful in adoption and effective implementation of GSCM.

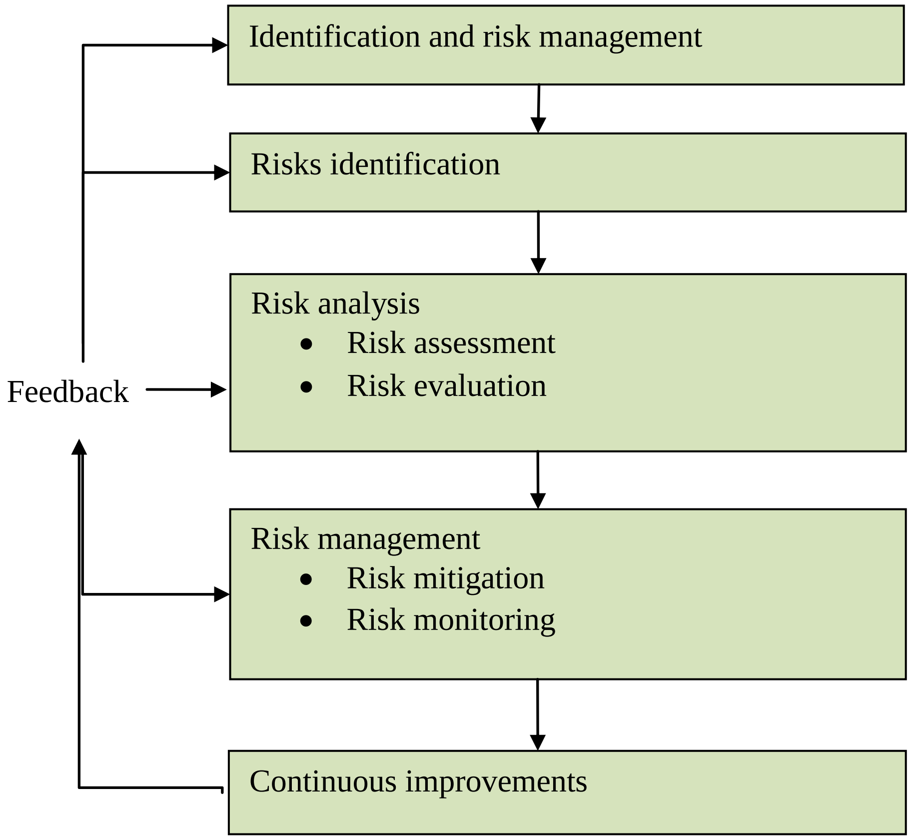


Figure 3.1 Proposed Research Model

3.1.1 Identification and risk management

In this step, the system to be analyzed is defined. The probable risks associated with the GSC are to be identified based on the critical review of literature and opinion gathered from the experts.

3.1.2 Risk identification

In case of GSCM, which is expressed as incorporating the green initiatives at each supply chain activity may involve several risks linked to its various operations (from raw material procurement to product end-of-life management) (Ma et al., 2012). Risk in GSC probably poses a threat to its typical and stable operations (Qianlei, 2012). Thus, a risk based GSC may have a significant influence on the organizational green initiative decisions in terms of material supply disruptions, quality issues and failures, increased negative ecological impacts, reduced performances and even may result in business loss. Additionally, it may also misalign organizational social, environmental, and economic business goals. Therefore, it is necessary to identify the risks related to GSC to achieve high ecological-economic benefits and to effectively managing initiation and implementation of different green initiatives in business. Authors have identified/defined the various risks in GSC based on the literature and experts inputs. The details in this regard are given in Chapter 2 and Chapter 4.

3.1.3 Risk analysis

After identifying the risks, the next stage is to estimate their possible impact (Chandrashekaran and Gopalakrishnan, 2008). The impact depends on two parameters, given as, the likelihood that a risk will occur, and the severity of consequences when it does occur. The managers can prioritize risks in accordance with the impact and decide future course of action. Then, they should focus on the strategies to reduce the impacts of risks. The output is a prioritized list of risks and their expected consequences. The identified risks have been prioritized in Chapter 4 and their impacts have been assessed in Chapter 5 of this research work. Once the risk analysis is completed, possible risks and an evaluation of these risks in terms of their impacts can be given from a GSC context.

3.1.4 Risk management

Managing of risks generally consists of processes, like, risk mitigation, assigning responsibility for management of the risk, and risk monitoring and/or iteration for continuous improvement from a GSC context. In order to manage a GSC, there is a need to decide how to act upon when the risk occurs. The managers must consider the seriousness of risks and should consider different ways of dealing with them. The various responses to manage risks in GSC are proposed and prioritized in Chapter 6. In addition, there are various mitigation strategies that can be employed to deal with different types of risk. There are many types of strategies, but three common ones are prevention (to reduce the probability of a risky event occurring), mitigation (to reduce the consequences) and response (waiting to evaluate actual events before deciding on a response). Therefore, it is important to recognize and analyze an appropriate mitigation strategy. The various mitigating strategies to manage risks in GSC are proposed and analyzed by developing a decision model. The details in this regard are given in Chapter 7. At the end, to have continuity of each and every flow of material/goods in a GSC, the adaptability of chain need to be monitored and continually improved.

3.2 Research Objectives and Questions

The research work aims to fulfil two objectives. To achieve these two objectives, seven research questions are raised. The research objectives and questions raised are given as below:

Objective I: Identifying, understanding, and analyzing risks in green supply chains from industrial perspective.

To achieve the stated objective I, four research questions are raised (i.e. RQ1, RQ2, RQ3, and RQ4) as follows:-

RQ1: What are the risks and risk driving factors, which need to be considered in a GSC?

RQ2: How the identified risks are evaluated, prioritized, and confirmed for effective adoption and implementation of GSCM?

RQ3: In what way, the interpretive logic for dominance of one risk over the others is interpreted?

RQ4: How the probable consequences of risks in GSC are accessed?

Objective II: Effective management of green supply chain risks

To achieve this objective, three research questions are raised (i.e. RQ5, RQ6 and RQ7) as follows:-

RQ5: What responses need to be proposed and prioritized not only to diminish the effect of identified risks but also to prevent from happening in managing the GSC efficiently?

RQ6: What strategies need to be proposed to develop a risk mitigation decision framework in a GSC?

RQ7: In what way, the variables (actors and actions in relation to process and performance) involved in the GSC risk mitigation are analyzed?

It can be seen from the proposed research model (refer Figure 3.1) that the functions Risk identification and Risk analysis will assist to address Objective I. On the other hand, the function Risk management will help to address the Objective II, and would accomplish the desired outcome of this research work.

3.3 Research Methodology

In the present work, a qualitative case study based approach is used as a methodology to achieve the desired outcome. Case-study research has been recognized as a significant research tool in the area of operations management (Yin, 1994, 2003). Case study based research is crucial in understanding the real-life happenings (Patton and Appelbaum, 2003; Yin, 2009). It has also been declared that the case studies are very useful in circumstances, where a limited amount of research is available (Eisenhardt, 1989). In addition to this, Voss et al. (2002) argued that the qualitative case study research devises to be an important analysis mechanism for showing the cognitive mechanism, the feasible prospects and eventuality/possible outcome effects on the system by considering the holistic view of the system. It also enables face-to-face communications and interactions with managers, as a result of which, an in-depth insight can be attained for a problem (Subramanian et al., 2010). Obtaining this information is important to understand the contemporary issues and, more significantly, provides opportunities to get through knowledge on the topic to be studied.

3.4 Research Methods Used in This Work

Twenty five risks were recognized from literature and by receiving inputs from the experts. These identified risks have been analyzed with the help of fuzzy AHP, a qualitative and quantitative analysis tool. It proposes an analysis procedure to model and prioritize the identified risks for managing the GSC efficiently. To confirm the ranking obtained through the fuzzy AHP, it has been proposed to use the interpretive ranking process (IRP). The approach of IRP also assist to know the interpretive logic for dominance of one risk over the other for each pair wise comparison, which otherwise, remains opaque to the implementer as if using the AHP method (Sushil, 2009a,b). The confirmed risks were evaluated to determine their effects in term of time, quality, economic, brand image, etc. Monte Carlo Simulation approach is proposed and used for this purpose. After identifying the possible impacts, using the fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), the appropriate response measures to manage the risks and their consequences were proposed and prioritized in GSC. Further, to manage the GSC risks appropriately, a SAP-LAP (Situation Actor Process – Learning Action Performance) based model was used to propose various risk mitigation strategies from a GSC context. In addition to this, to interpret interactions between the variables involved in SAP-LAP based flexible decision model, the methodology of IRP was used. In that way, the objective of this research work has been accomplished in several explicit steps with the help of five research methods. A brief overview for the research methods by uncovering previous contributions made by various authors in the area has been discussed. The five proposed methods for this work are:

1) Fuzzy AHP method
2) Interpretive Ranking Process
3) Monte Carlo Simulation
4) TOPSIS/Fuzzy TOPSIS
5) SAP-LAP

3.4.1 AHP/fuzzy AHP

The AHP has been suggested as a very useful technique for analyzing the decision problems (Saaty, 1980; Yadav and Goel, 2008). According to the procedure of this methodology, the whole problem can be solved by dividing it into various levels, consists of goal, criteria/factors, sub-criteria/sub-factors, and alternatives of the study (Jyoti et al., 2008; Dey et al., 2001). Based on which, the structural decision hierarchy of the concerned problem can be developed. It provides an effective and logical measure to the SC professional and analysts to examine the problem by estimating their relative concern in the system. Regarding some other MCDM methods like (ELimination and Choice Expressing the REality), TOPSIS, ANP, these methods have a limited recognition in their applicability recognized by the scientific group of people (Agarwal et al., 2006; Harputlugil et al., 2011). While, regarding ANP, AHP method is a linear evaluation type method and simpler than ANP (Harputlugil et al., 2011). In AHP, if, the factors to be analyzed are controllable factors, then, Data Envelement Analysis (DEA) may be an effective tool to use (Nagarur and Rajbhandari, 2001).

Due to these merits, the AHP method has been greatly accepted and widely used as a multi criteria decision-making method for analyzing different systems such as Engineering/Design, Education, Supply chain management, etc (Vaidya and Kumar, 2006; Chang et al., 2007; Zayed et al., 2008; Qureshi et al., 2009; Govindan et al., 2014). However, different scholars and practitioners have criticized the technique of AHP, which was mainly due to its ineffectiveness in dealing with human based qualitative assessments (Ishizaka and Labib, 2009; Wang et al., 2012).

To increase the credibility of the AHP method in such conditions, it is proposed to mix the fuzzy concepts with the AHP. In that way, a fuzzy based AHP approach has been proposed and used in this research for prioritizing the risks in GSC. Various scholars and practitioners have used the AHP and fuzzy AHP analysis to deal different normal and fuzzy surroundings. A summary on the use of AHP and fuzzy AHP analysis in the GSCM is given in the Table 3.1.

Table 3.1 Summary on the Use of AHP and Fuzzy AHP Analysis in GSCM

S.N.	**Researcher (Year)**	**Use of AHP/fuzzy AHP**	**Contribution**
1.	Hsu and Hu (2008)	fuzzy AHP	Prioritized four dimensions and twenty approaches for implementing green practices in electronic industry
2.	Zhang and Zhiwei (2009)	fuzzy AHP	Analyzed the performance of GSC
3.	Sarminento and Thomas (2010)	AHP	Identified the improvement areas when implementing green initiatives
4.	Yang and Li (2010)	fuzzy AHP	Proposed a GSC risks analysis model for a manufacturing organization
5.	Wang et al. (2012)	fuzzy AHP	Developed a model to access risk in different green initiatives in fashion industry supply chain
6.	Muralidhar et al. (2012)	fuzzy AHP	Evaluated the GSCM strategies under the fuzzy surroundings
7.	Toke et al. (2012)	AHP	Analyzed the success factors in GSCM implementation
8.	Odeyale et al. (2013)	fuzzy AHP	Proposed a framework to evaluate and select an effective GSCM strategy in a cement manufacturing industry
9.	Rostamy et al. (2013)	fuzzy AHP	A GSCM evaluation model been proposed for publishing industry under the fuzzy surroundings
10.	Luthra et al. (2013)	AHP	Identified and ranked the strategies to implement GSCM in Indian manufacturing industry

Table 3.1 Contd..

S.N.	Researcher (Year)	Use of AHP/fuzzy AHP	Contribution
11.	Somsuk (2014)	fuzzy AHP	Prioritized the drivers of sustainable competitive advantages in GSCM
12.	Mathiyazhagan et al. (2014)	AHP	Analyzed different pressures in GSCM in Indian industries context
13.	Govindan et al (2014)	AHP	Analyzed different barriers in GSCM in Indian industries perspective

In this work, fuzzy AHP approach is used to model and prioritize the identified risks for managing the GSC effectively. The procedural steps for the fuzzy AHP method are discussed in Chapter 4. The use of fuzzy AHP provides means to deal with human bias and subjectivity. However, the ranking obtained for the GSC risks should be tested for confirmation. Besides, the interpretive logic for dominance of one risk over the other for each pair wise comparison needs to be explored and understood for better understanding of the risk analysis. To deal with this, IRP methodology has been used and is being discussed in the next section.

3.4.2 Interpretive ranking process

Interpretive Ranking Process (IRP) has been introduced and used as a flexible decision approach by Sushil (2009a). It is a kind of ranking method that uses the strength of both the intuitive process and the rational choice process of decision making. This approach builds on the strengths of the paired comparison approach (Warfield, 1974; Saaty, 1980) which minimizes the cognitive overload. It uses interpretative matrix as a basic tool and make paired comparison of interpretation in the matrix (Haleem et al., 2012). Sushil (2005, 2009b) proposed the utility of interactive technique in decision making, which may help the managers to interpret and analyze the managerial problems efficiently. It helps in ranking the considered variables by combining the advantages of both the rational choice process and the intuitive process of decision-making. IRP method may also be applied to rank related factors in the light of their performance outcomes comparing to interpretive structural modelling (ISM) methodology procedure that limits itself by considering those factors only (Haleem et al. 2012). ISM is an interactive learning process, in which different and directly related factors are organized into a structural model (Mandal and Deshmukh, 1994; Faisal et al., 2006, 2007c; Singh et al., 2007; Thakkar et al., 2007; Charan et al., 2008; Ramesh et al., 2010).

An interpretative matrix and pair wise comparison of interpretation in the matrix has been used as an essential means in the methodology of IRP (Luthra et al. 2014a). IRP technique has been recognized as a strategic flexible decision making approach for the managers and decision makers, and have a scope of applicability in various business areas and in supply chains, where the managers needs to formulate flexible decision plans and strategies for obtaining performance improvements in the respective domain (Sushil, 2009a,b; Luthra et al., 2014a).

In IRP methodology, there is no need to determine the degree of dominance for paired comparisons. The users may also confirm the internal validity in IRP methodology through the vector logic of the dominance relationships in the form of a dominance system graph (Sushil 2009a). There are some studies available in the literature, which illustrates the use of IRP methodology, and are summarized as given in Table 3.2.

Table 3.2 Summarizing Studies on Use of IRP with Sources

S.N.	Researchers (Year)	Description of their work	Integration/Linkage of IRP with other research methods
1	Sushil (2009a)	This work introduced the novelty and utility of IRP approach as a flexible decision tool to develop interpretive models of decision-making such as sense making, mental models, organizational culture models, etc.	SAP-LAP
2	Haleem et al. (2012)	Analyzed the critical success factors associated with the world-class manufacturing practices	ISM
3	Luthra et al. (2014a)	Proposed a decision framework to analyze critical success factors to implement GSCM towards sustainability in Indian automobile industries	Factor Analysis
5	Ware et al. (2014)	Modelled a flexible supplier selection (FSS) problem by integrating the qualitative and quantitative models for supplier selection problem	Mixed Integer Nonlinear Programming (MINLP) and AHP

The steps of the Interpretive Ranking Process (IRP) (Sushil, 2009a) are discussed in Chapter 4. While, the flow diagram for the Interpretive Ranking Process is shown in Figure 3.2.

For the perspective of this work, IRP has made two-fold contributions. First, IRP is used to confirm the fuzzy AHP based risks ranking and to help managers in understanding the appropriate and viable rational for dominance when evaluating two risks relevant to an effective GSCM adoption and implementation. Second, using the IRP, it is aimed to obtain the ranking of the variables, i.e., actors and actions in relation to process and performance identified through SAP-LAP based GSC risk mitigating strategies decision model. It would help the managers and practitioners to interpret the influence of key strategic actions on the performance and to improve the effectiveness of the processes by building some robust and flexible strategies for managing risks in GSC.

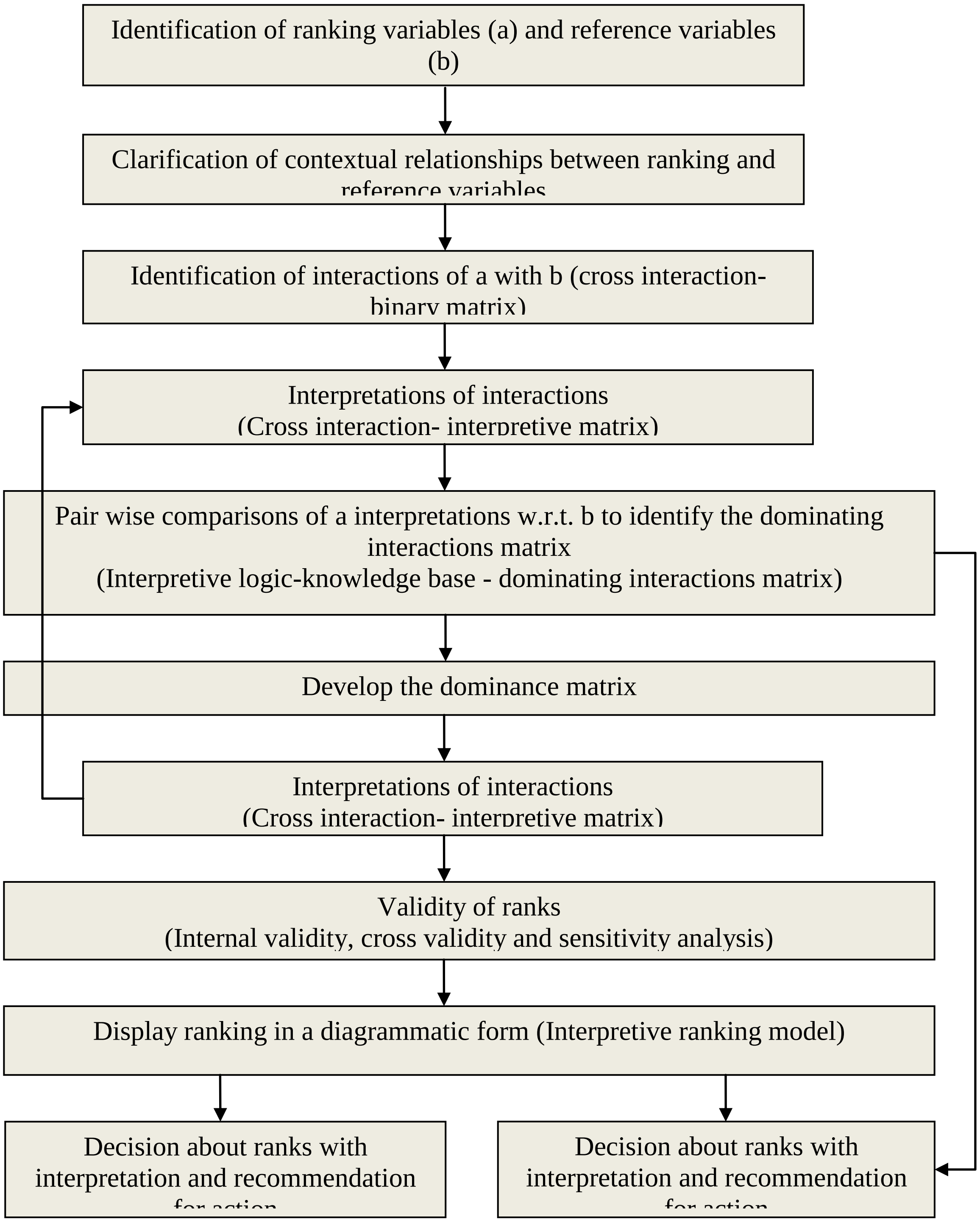


Figure 3.2 Flow Chart of Interpretive Ranking Process (Sushil, 2009a)

3.4.3 Monte Carlo simulation

Monte Carlo Simulation (MCS) is a computer based mathematical approach and named after on a scientist named Monte Carlo. This technique was first used for manufacturing of atom bomb. A huge recognition has been observed for MCS after its application in World War II. After that, it is majorly preferred for modelling of various physical and theoretical network systems.

Simulation is a technique that allows replicate the operation of a system over time (Gopalakrishnan et al., 2007). It is an effective tool to use where variance exists. In case of a SC, the variance or variability may be measured in terms of supplier reliability, demand forecast, material quality, etc. In this situation, simulation provides an edge over optimization. As, in optimization process, it is very difficult to capture the dynamics when variance is a key driver in supply chain.

MCS approach typically assists policy makers for analyzing risk, in terms of quantitative evaluation and decision choice. It is useful in conducting risk analysis procedure for a system by considering uncertainty in the parameters. This uncertainty has been captured by means of defined probability distribution functions for the parameters. It is noted that probability distributions is said to be a well systematic way to describe uncertainty linked to parameters in the process of risk analysis. Once the probability distribution functions are set with their ranges, the outcome may be computed by using various iterations. In each set of iteration, different results may be obtained with the help of different set of inputs. These iterations will go on continuously and may be performed thousand times based on the uncertainties of parameters and range assigned to them. In this sense, distributions of probable outcome values have been produced by MCS analysis. Once again, probability distributions are responsible for this. Consequently, parameters should have distinctive probabilities of different obtained outcomes. In the view of this, MCS offers a comprehensive outlook of the possibilities that may occur (in terms of what). By means of this analysis, it not only predicts the possibilities that could happen, but also anticipate what is going to happen.

MCS analysis has many plus points compared to deterministic analysis. Some of them are given as, reveals the extreme scenario of the results/outcome, and recognizes the input that has an utmost effect on end result, etc. MCS approach has been widely find its applications in different areas, for example, manufacturing, project management, energy, finance, engineering, environment, transportation, etc. The use of MCS in SCM as used by various researchers is given in Table 3.3.

Table 3.3 Summarizing Studies on Use of MCS with Sources

S.N.	Researchers (year)	Description of their work	Integration/linkage of MCS with other research methods
1	Jellouli and chatelet (2001)	Reported a methodology to adopt for optimizing the SC inventory management taking into account parameters characterizing the uncertain environment	Genetic Algorithm
2	Jung et al. (2004)	Proposed a simulation based optimization approach to SCM under demand uncertainty	Optimization approach
3	Deleris and Erhun (2005)	Proposed a framework for risk management in supply networks	What-if scenario analysis
4	Wong et al. (2008)	Measured the SC performance in the real environment in stochastic environment	DEA
5	Schmitt and Singh (2009)	Proposed a vulnerability assessment model for a large consumer products company	Discrete-Event Simulation
6	Vilko and Hallikas (2012)	Analyzed the risk impacts in terms of delays in the chain	FMEA

It is important to evaluate the risks identified in this work to know their impacts on GSC. Hence, MCS is utilized in this work to analyze the impacts of the risk measured in terms of time delay and disturbance (refer chapter 5 for more details).

3.4.4 TOPSIS/fuzzy TOPSIS

Hwang and Yoon (1981) have proposed the methodology of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). It helps to maximize the benefit criteria/attributes and minimize the cost criteria/attributes. The benefit criteria/attributes generally represent a situation of maximization, while the cost criteria/attributes generally represent a situation of minimization. In order to obtain the best alternative, the value closest to the ideal solution and farthest from the negative ideal solution will be selected (Wang and

Elhag, 2006). Different researchers have successfully used the TOPSIS method to analyze different multi criteria problems (Büyüközkan et al., 2008; Dağdeviren et al., 2009; Amiri, 2010; Joshi et al., 2011; Aydogan, 2012). Despite of this, the methodology of TOPSIS has been criticized widely for its inability to deal the subjectivity and vagueness associated with the assessment of human beings (Dagdeviren et al., 2009; Afshar et al., 2011).

Therefore, fuzzy concepts can be integrated into the TOPSIS method (Choudhary and Shankar, 2012). Fuzzy TOPSIS is combination of, the fuzzy linguistic variables and of TOPSIS technique. The fuzzy linguistic variable generally represents in the form of linguistic expression in natural language (Mahapatra and Shekhar, 2013). In many real life situations, the judgments formulated by a decision-maker are often characterized by vagueness (Jain et al., 2009). Thus, fuzzy based TOPIS methodology has been introduced to deal with such decision analysis problems. The procedural steps of the fuzzy TOPSIS technique are discussed in Chapter 6.

Fuzzy TOPSIS technique is employed in this work, to analyze appropriate responses of the risks from a GSC context. By using the methodology of the fuzzy TOPSIS, the priority of the responses in a successful accomplishment of GSC business initiatives is determined. It will not only improve the performance of adoption and implementation of green initiatives in SC scenario, but also manage the consequences of risks in GSC. There are some studies available in the literature, which illustrates the use of TOPSIS/Fuzzy TOPSIS approach, and are summarized as given in Table 3.4.

Table 3.4 Summarizing Studies on Use of TOPSIS/Fuzzy TOPSIS with Sources

S.N.	Researcher (Year)	Use of TOPSIS/fuzzy TOPSIS	Contribution
1	Wang and Elhag (2006)	fuzzy TOPSIS	Bridge risk assessment in construction industry
2	Dağdeviren et al. (2009)	fuzzy TOPSIS	Weapon selection in defence industries
3	Büyüközkan and Çifçi (2012a)	fuzzy TOPSIS	Strategic analysis of electronic service quality in healthcare industry
4	Büyüközkan and Çifçi (2012b)	fuzzy TOPSIS	Evaluating green suppliers in a GSC in Turkey automobile case company
5	Kannan et al. (2013)	fuzzy TOPSIS	Supplier selection and order allocation in GSC
6	Muralidhar et al. (2013)	TOPSIS	Assortment of GSCM strategies in cement industry
7	Shen et al. (2013)	fuzzy TOPSIS	Evaluating green supplier's performance in GSC
8	Wang and Chan (2013)	fuzzy TOPSIS	Assessing improvement areas when implementing GSC initiatives in multinational clothing company, U.K.
9	Kannan et al. (2014)	fuzzy TOPSIS	Selecting green suppliers based on GSCM practices in a Brazilian electronics company
10	Şengül et al. (2015)	fuzzy TOPSIS	Ranking of renewable energy supply systems in Turkey

3.4.5 SAP-LAP (Situation Actor Process- Learning Action Performance)

SAP–LAP (Situation Actor Process - Learning Action Performance), a holistic and flexible managerial approach, was proposed by Sushil, in 1997. SAP-LAP analysis is a systematic approach that helps in developing of either generic/specific models with respect to any example (Sushil, 1997, 2000). Such context will be holistic, and synthesizing of various competing schools of thought. Also, it will be rationally helpful in building such types of decision-making structure. The SAP-LAP model has been described as the basis of flexible system management having three essential entities in any management perspective, situation, actor, and process (Sushil, 1997). In developing of a managerial SAP-LAP framework, 'Situation' represents the state to be deal with. 'Actor(s)' are the individual contributors; those act together with a particular situation for its performance. 'Process' or 'processes' denotes the adaptations to recreate the situation (Sushil, 2001a, b). The interaction and combination of the SAP stems the formation of LAP. 'Learning' denotes the various issues to be learnt from SAP. It has been stated that SAP–LAP framework is very useful in summarizing the strategies of any system from a managerial context (Sushil, 2000). The SAP-LAP based framework has been widely used by many researchers to manage various situations at different conditions (Sushil, 2001a,b; Majumdar and Gupta, 2001; Palanisamy, 2012; Mahajan et al., 2013; Kumar et al., 2013). However, there are some studies available in the literature, which illustrates the use of SAP-LAP approach, and are summarized as given in Table 3.5.

The SAP-LAP based models are generally dynamic in nature. Additionally, there are several advantages of using SAP-LAP analysis in comparison to traditional techniques, such as SWOT (Strengths, Weaknesses, Opportunities, and Threats), and PEST (Political, Economic, Social and Technological) analysis. These are given as better understanding of the problem, analyzing of the prospects related to problem, and changing of these prospects into reality (Arshinder et al., 2007). Figure 3.3 presents the various steps in a generic conceptual SAP-LAP framework. SAP-LAP is proposed as an important framework for analyzing the adoption of GSCM initiatives in an organization. It will help in framing of strategic action on implementation of GSCM initiatives to enhance the ecological-economic performances.

This work has used the SAP–LAP technique to develop a decision framework to analyze the risk mitigation strategies in GSC. However, the interpretation of the interactive relationships among the variables of the SAP–LAP based model relatively lacks in this process. Therefore, in this study, SAP–LAP approach is linked with a novel ranking method, i.e., IRP. It overcomes the issues of decision-making in SAP–LAP methodology and helps in evaluating the SAP–LAP model by determining the ranks of actors and actions w.r.t. process and performance respectively. The other details regarding the use of SAP-LAP and IRP methodologies are given in the Chapter 7.

Table 3.5 Summarizing Studies on Use of SAP-LAP with Sources

S.N.	Researcher (Year)	Contribution	Application
1	Majumdar and Gupta (2001)	Development of internet and e-business technology	Indian car manufactures
2	Arshinder et al. (2007)	Analysis of the coordination in supply chain	An automotive parts manufacturer
3	Suri (2008)	Strategy implementation of e-governance	Indian fertilizers companies
4	Thakkar et al. (2008)	Implementation of information technologies	Indian manufacturing SMEs
5	Shukla et al. (2011)	Evaluation of supply chain coordination issues	Indian automotive components manufacturers
6	Palanisamy (2012)	Building the information systems flexibility	Indian SMEs sector
7	Siddiqui et al. (2012)	Evaluation of total quality management, flexible systems and proper strategic planning practices in supply chain	Gas organizations of India
8	Kumar et al. (2013)	Evaluation of coordination issues for flexibility in supply chain of SMEs	Indian SMEs
9	Luthra et al. (2014c)	Analysis of GSCM implementation issues	Indian automobile organization

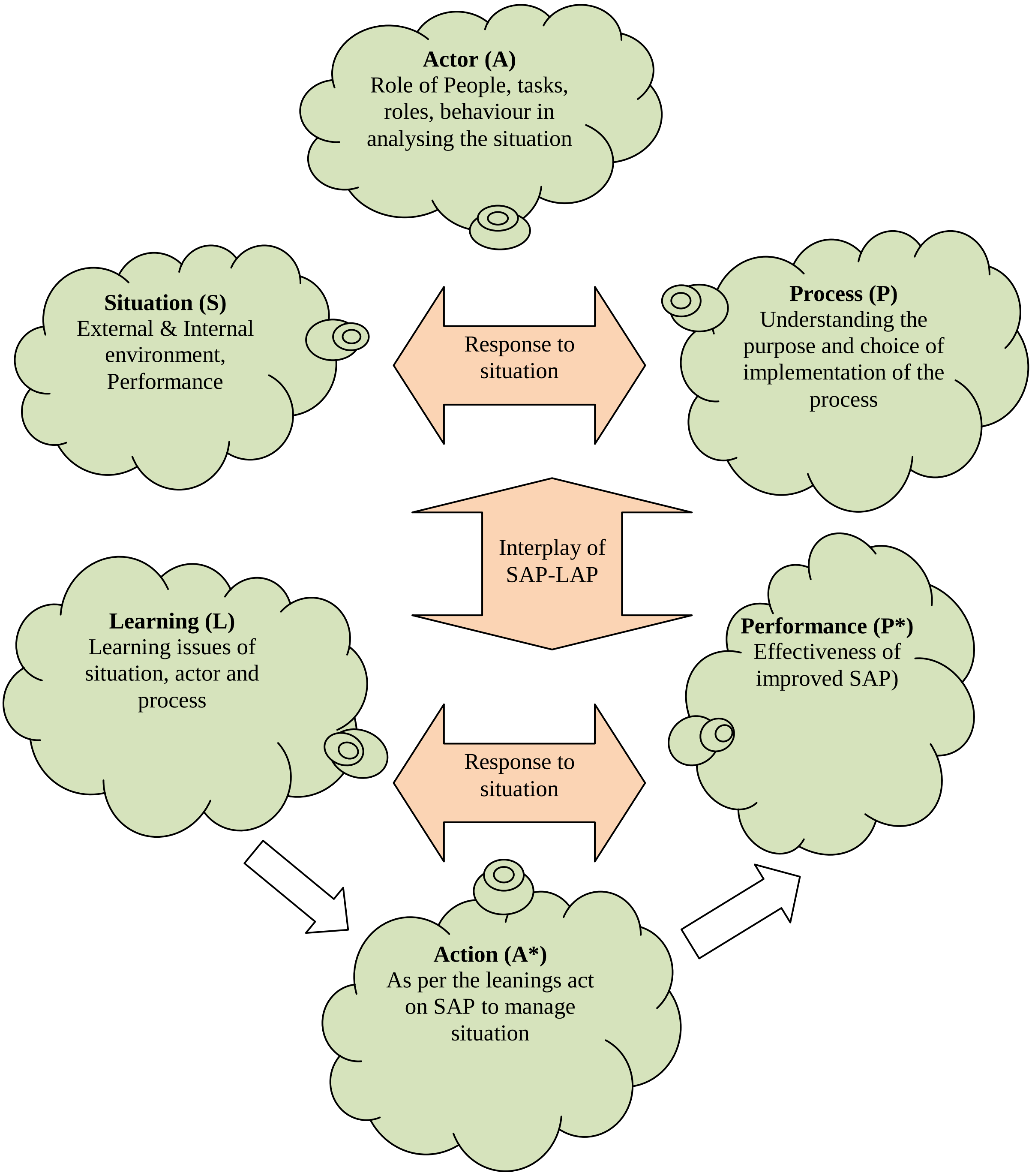


Figure 3.3 Generic Conceptual SAP-LAP Framework

3.5 Sample Designs

The selection of suitable and feasible samples is necessary to fulfil the objective of research. Sampling techniques are generally categorized into two categories: probability sampling and non-probability sampling. There could be several stages in the sampling design such as, defining the target population, determining the sampling frame, selecting the sampling technique, estimating the sample size, etc. (Malhotra and Dash, 2009). The main concern during the sample selection is whether the sample is industry specific or not. These are arguments that the sample should be taken from a wide range of industries. However, literature and expert judgement uncovers that each industry faces specific challenges. Hence, the sample should be industry specific, which gives more applicability to the research findings for that industry (Diabat and Govindan, 2011). Another concern regarding the selecting of the sample is linked to the kind of respondents needed for the research. The accomplishment of research depends on the selection of suitable respondents. In this work, respondents have been selected from middle level and senior level managers of the plastic manufacturing business organizations. In order to get an inference of the organization's perception towards green initiatives decisions of the SC, more than one response has been taken from one organization. The adoption of GSC initiatives into organization operations and policies and extending to supply chain is strategic in nature. Hence, only middle to senior level managers have been selected as the respondents. These respondents were expected to be involved in SC operation of the organization.

3.6 Target Population

The target population is defined in terms of elements, sampling units, extent and time (Malhotra and Dash, 2009). The target population for the present work is given as below:

Elements – managers (middle or lower level managers)

Sampling units – plastic manufacturing business organizations

Time – March 2013 to December 2013.

Extent – India.

3.7 Elements - managers

Primary data was collected by personnel interview for the present work. The elements of the study are managers of plastic manufacturing business organizations in India. Since the adoption and extension of GSC initiatives requires strategic decision making, only middle level and top level managers were targeted for the responses. The second reason for the selection of middle and top level managers was that strategic decision makers could provide the appropriate information regarding the decisions of adoption and implementation of green initiatives at various levels of business in the supply chain (Lai et al., 2008).

In the process of data collection, a decision making team of 16 experts was formed. It consists of SC middle and senior level managers, environmental representatives, and professionals of supply chain members. The selection of experts was decided on the basis of certain criteria such as their individual industrial and consultancy experiences, qualification level (helpful in decision making skills), expertise in area, (their background), risk managing capabilities (risk seeking or averse) etc. Selected experts are highly skilled personals in their domain and having good SC managing skills. A brief demographic profile of the respondents of the organizations under consideration is given in the next section.

3.8 Sampling Unit – Why Plastic Manufacturing Business Organizations

According to Sarkis (20011), ‘the natural environment and the manufacturing are becoming inextricably linked’. These reasons make it imperative to know the probable mechanism for managing the GSC efficiently in the plastic manufacturing business organizations. Indian plastic industrial sector is becoming an emerging business sector in the corporate world, however, at the same time, also facing competitive, regulatory and community pressures to move towards greening their SCs and to become sustainable. Being as a reference to the GSC, it not only incorporates the ecological thinking in the business, but also, ensures the sustainable development of the industries - including manufacturing, automobile, mining, etc. (Beamon, 1999; Muduli et al., 2013; Luthra et al., 2014a). There are tremendous opportunities for Indian plastic industry in the future due to fact that India would become the leading global focus for producer of plastic and it’s based products, etc (for details refer Table 3.6). Asia is world’s largest plastics consumer from last few past years, and responsible for 30% of the global consumption (Global Plastics Industry, 2013). Following China, India accounts second significant fastest growing consumers and offer a huge opportunities of business by reducing waste and improving environmental performances. All India Plastics Manufacturers Association (AIPMA) report estimates that plastics is one of the major contributors to India’s gross domestic product (GDP) and the consumption of plastic will increase to almost 2-3 times a year in 2020 from the existing 8 million tons a year in India (Plastic News, 2013).

Table 3.6 Role of Plastic Industry in the Indian Economy

S. N.	Criteria	Current Scenario
1	Size	Apporoximately 22,000 plastic processing units and 150 plastic processing machinery manufacturers
2	Turnover	1,33,245 Crores (INR)
3	Percentage in World Market	In year 2006, The world plastic export was US$ 375 billion and the share of India was less than 1% with exports of worth US$ 3.187 billion. In year 2013-14, exports of plastics stood at around US$ 7,916.94 million, compared to US$ 7,088.08 million in in India in 2012-13
4	Employment (Direct/Indirect)	9.5 Millions
5	Market Capitalization	Plastic is one of the major contributors to India's GDP. It is moving towrads 8% GDP growth

Source: http://www.indianmirror.com/indian-industries/plastic.html

With escalating competition in the market and the stable drive to improve our living standards, the scope for use of plastic products is bound to increase manifold in the future (Koushal et al., 2014). In contrast to manufacturing sector, the recycling sector also has its own importance in plastic industry. The recycling sector can employ approximately eight times more people compared to plastics manufacturing sector.

Due to the increasing share of long-life products in the economy, and subsequently in the volume of waste generated, the share of recycling will decrease to 35% over the next three decades. The total waste available for disposal (excluding recycling) will increase at least 10-times by the year 2030 (current level is 1.3 million tonnes) (Mutha et al., 2006; Ghosh et al., 2013). Notably, recycling is the primary reprocessing (recovery) operation in GSC under study. Major plastic, recycle and reuse sources are such as tub, plastic pallets, bags, packaging materials, bottles, trays, containers, etc. From this, it can be noticed that the plastic industrial sector proposes a great pressure to consider green influence in the SC planning process. It is resulting in a huge ecological-economic benefit because of a significant reduction in the consumption of resources is noticed there in its industrial activities by means of GSCM adoption and implementation.

From last one or two decades, plastic has become a significant key business activity in terms of, either in benefits for society and community or in providing necessary raw materials for delivering daily usable items to the end users. In addition, in present scenario, plastic and its related activities play a crucial role in achieving technological and medical advancements. However, a significant negative impact of plastic industrial sector in terms of degradation of environment, and pollution of land, water, air, soil quality, is significantly recognized. In this context, the need arises to put this subject under investigation to ensure green trends in business of plastic industrial sector. However, the managers and business professionals may face different and or several risks in GSCM network design. Therefore, it is opted to analyze the plastic manufacturing business organizations in India from a GSC risk management viewpoint.

In this work, four ancillary plastic manufacturing business organizations operational in the northern region of India are identified and examined. The organizations produce plastic molded components, which are used in various sectors like automotive, household, engineering, and consumer durable sector. The components are manufactured as per specifications provided by different companies and are in conformity with international standards. The organizations promises to be pioneers in the field of plastic products manufacturing and aims to become a leading plastic manufacturing in international and national market. Managers of the business organizations under consideration has desire to improve the GSC success rate. Each organization under consideration is IS0 14000 certified organization. The organization's manager's target was threefold: first, commit move towards eco-friendly system and adopting environmental concern activities in the GSC planning process to reduce the wastage. Second, maximize the gains in terms of Economic, and the Environment advantages at operational, tactical and strategic level in business. Third, manage the initiation and effective implementation of different green initiatives in the business scenario. In the meantime, managers' were observing several risks in GSCM network design. Thereby, the business organizations under consideration have desire to list, analyze and manage the risks associated with GSC to improve its ecological-economic performance. The organization's managers were greatly conscious to design a sustainable business culture. It forms the grounds for significance of considering of these organizations in this research work. A brief description of business organizations under consideration is given in Table 3.7.

Table 3.7 Brief Description of Business Organizations under Consideration

Business Characteristics	**A**	**B**	**C**	**D**
Turnover (in INR)	150-200 Million	Approximately 100 Million	More than 5 Million	50 Million
Employees	More than 1500	More than 1000	More than 200	450-500
Year of establishment	1993	2000	2011	1967
Certifications	**OHSAS 18001;** ISO 16949 and IS0 14000	**ISO 9000; ISO 14001**	ISO 9000; ISO 14000	ISO/TS 16949; ISO/IEC 27001
Products manufactured type/ specialization	Injection molding, Plastic Molding, Painting, etc.	Manufacturing of Polymer, Plastic Products, Mud Guards, Plastic Mirror Covers	Domestic plastic based product such as kitchen containers, plastic stools, chairs, automotive plastic molded components, syringes, etc.	Emblems (Electroplated, Painted), Automotive Plastic molded components, Wheel Trims & Wheel Covers, Decorative Body side molding, Assemblies Control Brackets, Dash Board Components, Auto Electricals Assemblies, Door Handle, etc.
Type of business	Manufacturer, supplier	Manufacturer, supplier	Manufacturer, supplier	Manufacturer, supplier
EMS	Yes	Yes	Yes	Yes

In order to examine the business organizations under consideration, a decision making team was formed (refer Section 3.12). The demographic profile of the respondents involved in the decision making team is given as below:

3.8.1 Demographics analysis for the respondents

This section analyzed and discussed the information relevant to respondents profile considered for this research. This information includes respondents professional qualification level, respondents work experience, respondent's expertise in the area. The details are given as below:

3.8.1.1 Respondents Professional Qualification Level

The professional qualification of respondents is considered very crucial for accomplishing the desired objective. It shows their competency in decision making. Table 3.8 shows the findings with respect to professional qualification of respondents. In addition, for more clarity, a pie chart has been drawn to reveal the information as shown in Figure 3.4.

Table 3.8 Respondents Professional Qualification Level

Professional Qualification of Respondents	**Frequency**	**Percent**
Graduate	02	12.50
Post Graduate	12	75.00
Doctorate	00	00
Others	02	12.50
Total	**16**	**100**

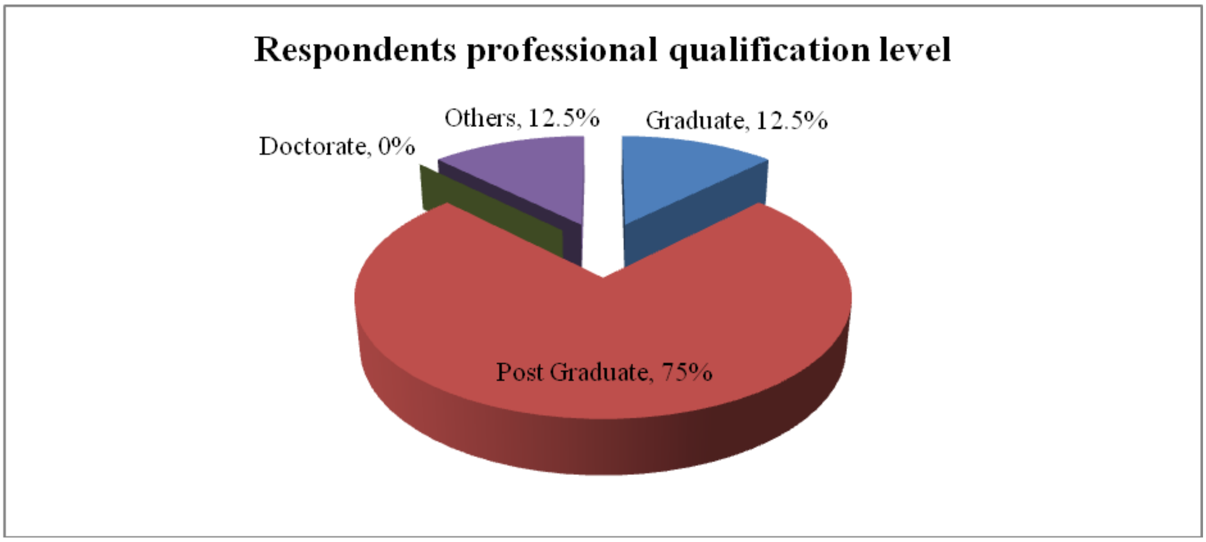


Figure 3.4 Respondents Professional Qualification Level

Figure 3.4 shows that the almost seventy five percent (75%) of respondents are post graduate, almost twelve percent (12%) are graduate and remaining have other qualifications like diploma in engineering etc. Above Figure 3.4 shows that eighty seven percent (87%) of respondents are having professional qualifications graduate and post graduate. It reveals a good association of respondents having knowledge on the subject areas.

3.8.1.2 Respondents Industrial and Consultancy Experience

Respondent's industrial and consultancy experience is important to access their knowledge of GSCM adoption. Data collected on work experience of respondents (in years) is revealed in Table 3.9. The information in Table 3.9 is illustrated in a pie chart as shown in Figure 3.5.

Table 3.9 Respondents Industrial and Consultancy Experience (In Years)

Respondents Industrial and Consultancy Experience (In Years)	**Frequency**	**Valid percent**
Less than 5 years	01	6.25
5-10 years	08	50.00
11-15 years	03	18.75
16-20 years	04	25.00
Total	**16**	**100**

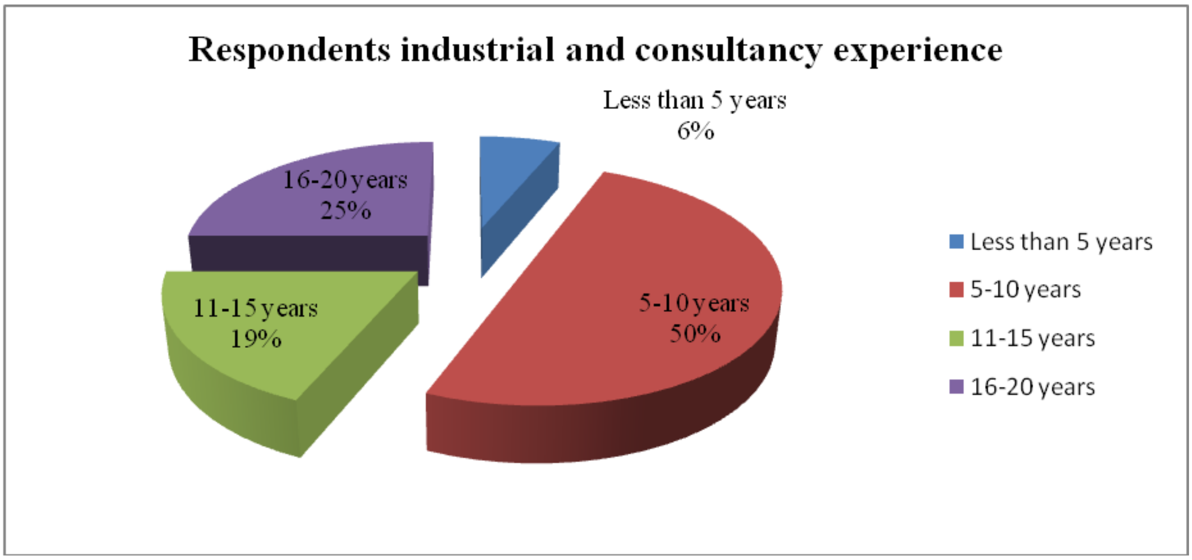


Figure 3.5 Respondents Industrial and Consultancy Experience (In Years)

Approximately twenty five percent (25%) of respondents are having experience between 16-20 years, nineteen percent (19%) are between 11-15 years, fifty percent (50%) are between 5-10 years, and six percent (6%) are having experience less than five years. Meaning that, sixty four percent (94%) of respondents are having experience more than 5 years. It provides a reasonable association of respondents with higher experience.

3.8.1.3 Respondents Background (In Numbers)

Respondent's background is important to have right information on GSCM adoption. Data collected on respondents' background are presented in Table 3.10.

Table 3.10 Respondents Background (In Numbers)

Respondent Background (In Numbers)	**Frequency**	**Valid percent**
SC senior managers	08	50
Environmental representatives	04	25
Professionals of SC members	04	25
Total	**16**	**100**

The information in Table 3.10 is illustrated in a pie chart as shown in Figure 3.6

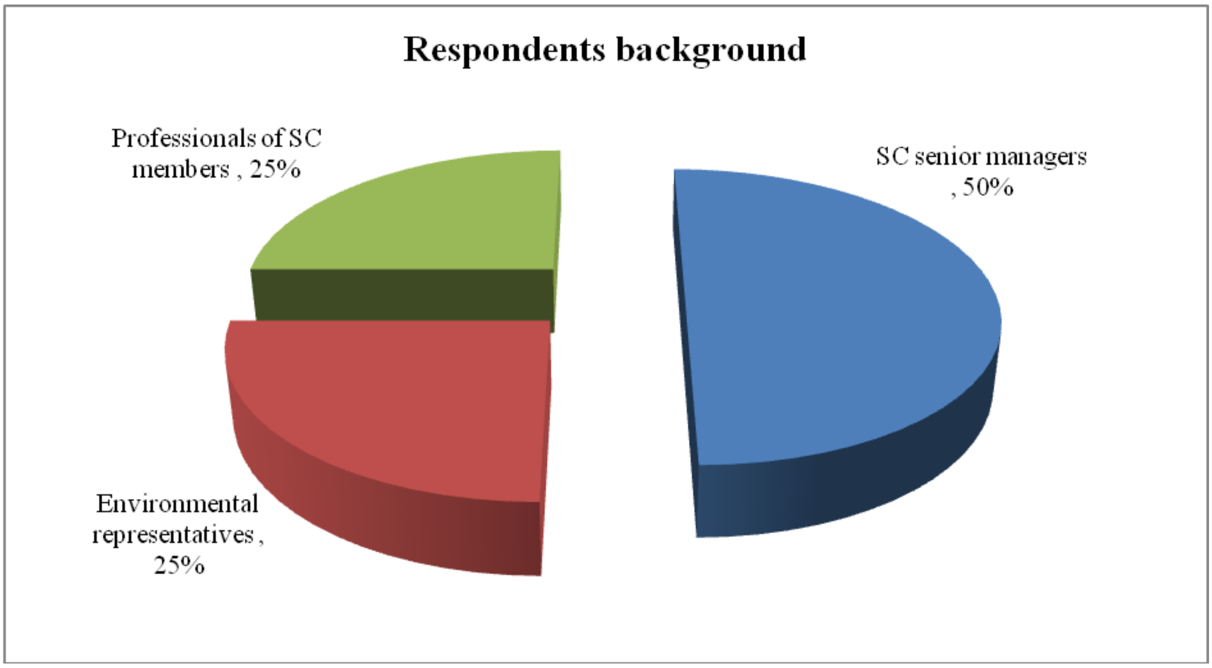


Figure 3.6 Respondents Background (In Numbers)

There are fourteen percent (50%) of respondents belongs to SC senior manager's category, twenty five percent (25%) of respondents are Environmental representatives, and twenty five percent (25%) of respondents are Professionals of SC members. After finalizing the decision making team, the next task was to collect the data. The details for the procedure adopted in this research work for data collection has been given in the next section.

3.9 Data Collection Procedures

This is an exploratory research type, as there is lack of research on the subject focused. The case study proves to be quite useful for demonstrating cognitive behaviour, the probable possibility and contingency effects that further provide empirical grounds for their explanation (Voss et al., 2002). Data collection was done with the following objectives:

1) To identify the most common risks related to adoption of efficient GSC initiative (see Chapter 4 for more details).
2) To analyze and evaluate the listed risks for ascertaining and confirming of their priority (see Chapter 4 for more details).
3) To assess the impacts of the listed risks measured in terms of time delay and disturbances in GSC (see Chapter 5 for more detail).

4) To propose and analyze the response measures and the mitigation strategies to manage the risks in GSC (see Chapter 6 and Chapter 7 for more detail).

The main source to collect the data to fulfil the aim of this research is the manufacturing organizations operational in the northern region of India. In the beginning, 10 plastic manufacturing business organizations were contacted. The organizations were contacted through personal visit, email, telephonic calls, along with a cover letter of supervisor (Appendix A). This cover letter contained introduction of researcher and aim of the research. Different approaches were used to get responses from the organization's respondents and also were guaranteed for privacy of their data. Several follow-ups have been conducted through e-mails, telephone calls, etc. Then finally, 4 organizations were agreed to take part in the process, were shortlisted.

The data needed for the present research work was collected through several sources: archival data, which included organization websites and company log records and documents, interviews with managers, and visual information observed.

1) Archival data was analyzed prior to the visit, and it was complemented during the visit in companies. It provides general information about products, production lines and improvement systems. Ideally, multiple sources of evidence are helpful in aspects such as triangulation, detailed understanding of the phenomena, etc.
2) The experts were contacted and interviewed personally for collecting the necessary qualitative and quantitative data needed for this study. Typically, the first interviews were done in person at the site of the organizations under consideration. The duration of interview was approximately 45–60 min. Subsequent interviews were conducted via telephone for logistical reasons. Since a personal contact was established in initial meetings. Thus, it has been estimated that the validity of the results as not being affected by utilizing phone interviews in subsequent interviews. Detailed notes have been taken during the interviews. Immediately after the interviews, further notes were compiled about the overall impression of the interviewer. It assists in uncovering some ideas and relevant facts about the systems, which allows focusing on the key aspects that needed to be assessed.
3) The organizations were visited several times. It was usually led by middle managers or the production manager, who showed and explained how they performed tasks and carried out different green initiatives on various levels in business.

In the process of data collection, a decision making team of sixteen experts was formed as mentioned in Section 3.12. After finalizing the decision making team, the next task was to collect the data. Finally, the expert responses were collected and data was gathered. The collected responses were further used for the research purpose. Finally, data were collected in approximately 9 months during the period of March 2013 to December, 2013. And, data from multiple industries by taking the case of four plastic manufacturing business organizations (sample size equals to 4) is used in this research work. For examining the quality of research design, the proposed case study approach has also been tested through construct validity. Construct validity represents the degree of identifying accurate operational measures for the concepts being studied, and to increase the construct validity, the multiple sources of evidence correspondent to each of the important elements in the designs were investigated (Singh and Sharma, 2014). It is useful in confirming the related information and verifying the reliability of data was obtained. This tactic has been recognized as an appropriate technique during data collection (Eisenhardt, 1989).

3.10 Data Analysis

Data from various sources was collected, reviewed, and analyzed to accomplish the desired objective. There may be a variety of specific data analysis method or methods to analyze the data to reach tentative conclusions and to answer the research questions. Various decision making analysis methods are used in this work (refer Section 3.8) to analyze the data collected from the various plastic manufacturing organizations operational in India. The detailed application of these research methods along with their findings is given in subsequent chapters.

3.11 Conclusions

This chapter discusses the research methodology used for analyzing and managing the GSC risks. In the initial part of this chapter, a conceptual model is proposed that reveal the approach for managing the risks in GSC. In the later part, a brief detail on the research methodology adopted for this work is provided to achieve the raised research objectives and questions. A critical analysis of the research methods proposed and used in this study is also given in the subsequent section. It will provide an overview of the various tools and techniques towards effective analysis and management of risks to implement GSC initiatives. It has also been concluded that multi criteria decision making (MCDM) methods have a significant part in analyzing GSCM network models and problems. The detail on research methodology includes the data collection method, sample design, etc. The data collection procedure and data analysis to interpret the information has also been provided. The next chapter will discuss understanding of the risks to implement GSC initiatives by using the fuzzy AHP and IRP methods. It will help business organizations to know the most important risk in GSC context.

CHAPTER 4

IDENTIFICATION, PRIORITIZATION AND CONFIRMATION OF THE RISKS IN GSC

The identification of risks and their subsequent analysis in the GSC are very important to know and understand. The present chapter analyzes the risks relevant to adoption and effective implementation of GSC initiaitves. Initially, six categories of risks and twenty-five specific risks, associated with the GSC, were identified. Later, the fuzzy Analytic Hierarchy Process (AHP), a qualitative and quantitative analysis was used to analyze the identified risks for determining of their priority. The used fuzzy AHP approach is also useful in dealing with the human subjectivity in the risk analysis. To analyze the risks ranking obtained through the fuzzy AHP, the methodology of Interactive ranking process (IRP) is applied. The methodology of IRP also enables the decision makers to understand the interpretive logic for dominance of one risk over the other for each pair wise comparison. In this chapter, an effort is made to know the most important risk in GSC context, and model proposed may offer logical means to understand the significance of different risks in the strategic decision processes.

4.1 Introduction

Due to increase in environmental awareness, competitiveness and strict governmental policies, the approach of incorporating GSCM, to conserve resources and sustainable production, is gradually becoming more imperative for organizations. GSCM initiatives may be of great value to the firms as well as to the external environment (Siegel, 2010; Eltayeb et al. 2011), and generates economic benefits in long run (Kumar et al., 2012). GSCM can be described as the integration of green component to each activity of supply chain, i.e., green procurement and purchasing, green design, green manufacturing, green marketing, green distribution, the end of product life management, etc. (Min and Kim, 2012).

Part of this chapter has been published/accepted for publication in

- Recycling Resources and Conservation 2015; Online at: (http://dx.doi.org/10.1016/j.resconrec.2015.01.001)
- Sustainable Production and Consumption- Official Journal of the European Federation of Chemical Engineering Part E, 1 (1), 67- 86.
- Global Journal of Flexible Systems Management, 16 (1), 19-35
- International Journal of Operational Research **(forthcoming)**
- In: Proceedings of GLOGIFT 13, IIT Delhi, India, pp. 575-583

However, the successful accomplishment of GSC production and business activities is relatively difficult due to involvement of different risks. The first objective of the present chapter is to identify the various risks associated with the GSC. The second objective of this chapter is to propose an analysis procedure to model, prioritize, and confirm the risks for managing the GSC efficiently. However, analyzing the risk is not simple due to the presence of inaccurate and vague data (Wang et al., 2012). To cope the uncertainty and imprecision in the process of analyzing risk, it is proposed to integrate the fuzzy set theory with the AHP method. AHP is the most commonly used technique for prioritizing the multi-criteria decision system (Saaty 1980), but it has the limitation of capturing the sound judgment in decision-making due to the involvement of linguistic data (Ishizaka and Labib, 2009). Therefore, it is proposed to integrate fuzzy concepts with AHP to meet the above objectives of the present work. To test the ranking obtained through the fuzzy AHP, the methodology of interactive ranking process (IRP) is applied. It enables the policy makers to understand the interpretive logic for dominance of one risk over the other for each pair wise comparison, which otherwise, remains opaque to the implementer as if using the AHP method (Sushil, 2009a).

4.2 Identification of Risks in GSC

Based on literature review, thirteen risks in the context of GSC were identified (for details refer Table 2.1, mentioned in Chapter 2). Based on the meaning and similarities, these risks were grouped into five categories, namely Operational risks, Supply risks, Product recovery risks, Financial risks, and Demand risks. Different organizations might have a different viewpoint about adoption and implementation of GSC business practices (Zhu and Sarkis, 2006). Moreover, different countries may have a different opinion regarding GSCM adoption; environmental guidelines and regulating policies may also vary from country to country (Mathiyazhagan et al. 2013), as regulation and policies generally depends upon country politics, culture, people, etc. Therefore, Indian business organizations would also have different viewpoint regarding GSCM adoption and implementation (Mudgal et al., 2010; Govindan et al., 2014), and in this manner, different Indian organizations may face different green supply chain risks in implementing different GSC practices in their respective business. Hence, the same risk may be differently important to the individual organization with respect to its priorities, capabilities, resource, etc. To deal with this, thus, multiple Indian business organizations were identified in the present study. The data from the identified business organizations were collected for listing common risks, as agreed upon by all the industries, in the implementation aspects of GSC initiatives. One category of the risk was added to the initially selected five categories of the risks. In addition, several specific risks (twelve specific risks) were included in the initially identified list of thirteen risks (for details refer Table 4.1, Section 4.6.1). In this way, various most common risks were listed based on inputs from experts and literature resource. Further, an analysis of identified risks with an aim to prioritize them for determining their relative concern under uncertain surrounds by using the fuzzy AHP approach and the IRP technique is conducted.

4.3 Proposed Framework

The proposed framework to accomplish the above stated objective is illustrated in Figure 4.1. Based on the critical review of literature and expert's inputs, the common risks related to implementation of GSCM are identified (Phase 1). Based on inputs received from the experts, these risks are evaluated using fuzzy AHP and IRP approaches. The identified risks were analyzed to determine their respective priority by using the fuzzy AHP, a qualitative and quantitative analysis (Phase 2). To test the ranking obtained through fuzzy AHP method, the methodology of IRP is used (Phase 3). Thus, the AHP and the IRP methods when applied together will give a more clear illustration useful for organizations to plan both the tactical or operational and the strategic flexible decision plans. The details regarding fuzzy AHP and IRP methods are given in the following sections.

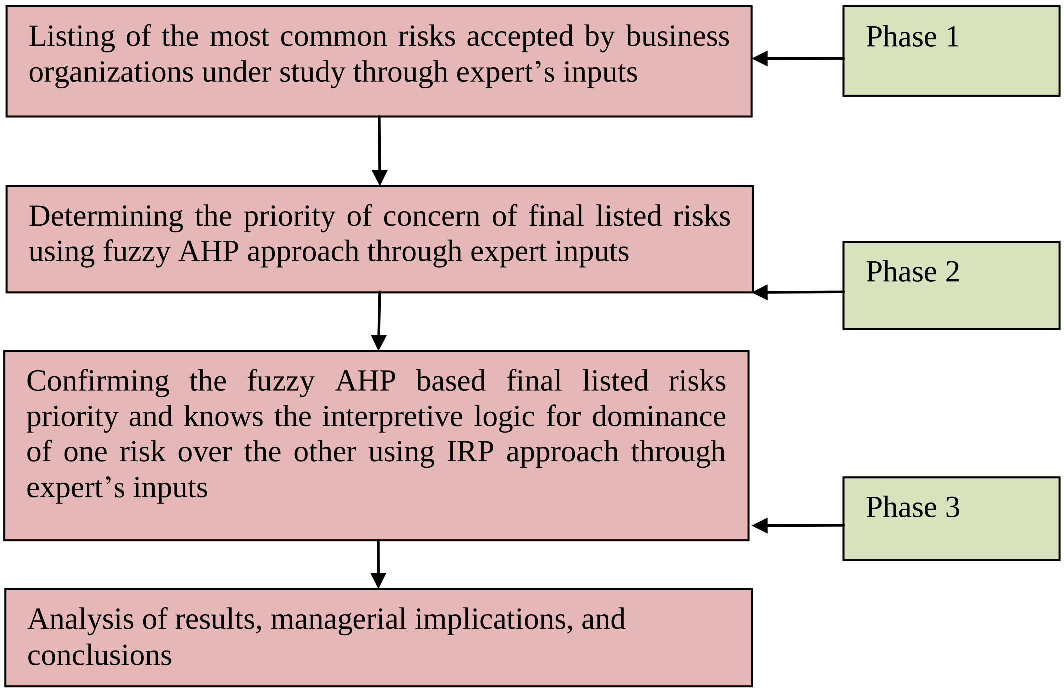


Figure 4.1 Proposed Framework

4.4 Fuzzy AHP approach

The methodology of AHP enables managers to analyze the complicated system and provides assistance in evaluating the human judgment primarily based on system factors by marking their priority (Sarminento and Thomas, 2010). Under this excellence, AHP methodology has been widely utilized by various researchers in different sectors such as education, industry, manufacturing, engineering, etc. for solving different multi-criteria decision problems (Vaidya and Kumar, 2006; Chang et al., 2007; Zayed et al., 2008; Qureshi et al., 2009; Luthra et al., 2013; Mathiyazhagan et al., 2013; Govindan et al., 2014). Human judgment based factors always entails subjectivity and ambiguity, and in this situation, methodology of AHP is not a suitable selection (Chan et al., 2008; Bhatti et al., 2010). To manage the issues, it is proposed to use the fuzzy set theory with the AHP method (Hu et al., 2009; Jakhar and Barua, 2013). The approach provides means to handle the inherent uncertainty and vagueness of human decision-making practice, and enables the decision makers to know the decision problems by offering necessary flexibility and robustness in decision-making (Chan et al., 2008). These merits of the developed approach facilitate its use in real situations for making effective decisions.

Based on these merits, a fuzzy AHP approach is used in the research. In addition, the fuzzy judgments of decision-makers are transformed into the exact numbers by using the fuzzy numbers. The flow diagram for preparing the fuzzy AHP based analysis model is shown in Figure 4.2, and procedural steps of using the fuzzy AHP approach are described (Wang et al., 2007; Chan et al. 2008) as below:

- Step 1: The objective of the study, i.e., to analyze the risks in the green supply chain, is defined.

- Step 2: Fuzzy set theory is logically helpful in providing clear information for analyzing the problem under vague and ambiguous surroundings (Zadeh, 1965). In theory of fuzzy set, if a group of object is described by 'X', and 'x' with values $(x_1, x_2, x_3 \dots \dots \dots x_n)$ represents the generic element of ‘X’, then, the fuzzy set 'M' for this object set is represented by $\{(x, \mu_M(x)) \mid x \in X\}$ (Dubois and Prade, 1979).

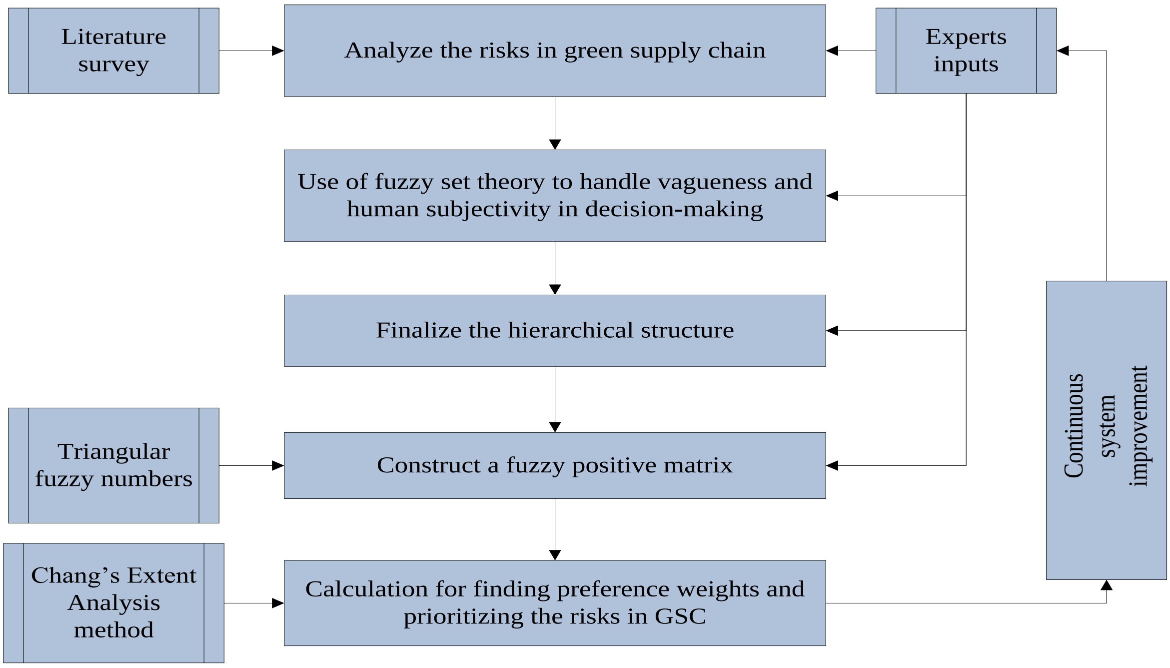


Figure 4.2 Flow Diagram for Fuzzy AHP Based Analysis Model

Source: modified Wang et al. (2007)

Additionally, μ_M (x) represents its function that operates over a scale of real numbers, usually ranged to the interval [0, 1]. Further, a triangular fuzzy number (TFN) is a special kind of fuzzy number, and mostly preferred for practical applications (Zimmerman, 1996). For any triangular fuzzy number (a, b, c) its membership function is expressed as mathematically (μ_M (x)) as given in Equation (4.1), where a ≤ b ≤ c. While, the graphical illustration of membership function for TFN is given in Figure 4.3. Moreover, (a, b, c) represents the lower, mean and upper boundary of the TFN. If, $O_1 = (a, b, c)$ and $O_2 = (p, q, r,)$, are two triangular fuzzy numbers. These two TFNs can be equal if and only if a = p, b = q, c = r. Further, the algebraic operations for these two TFNs are given as follows:

$$O_1 + O_2 = (a, b, c) + (p, q, r) = (a + p, b + q, c + r)$$

$$O_1 - O_2 = (a, b, c) - (p, q, r) = (a - p, b - q, c - r)$$

$$O_1 \times O_2 = (a, b, c) \times (p, q, r) = (a \times p, b \times q, c \times r)$$

$$O_1 \div O_2 = (a, b, c) \div (p, q, r) = (a \div p, b \div q, c \div r)$$

$$-O_1 = -(a, b, c) = (-c, -b, -a)$$

$$\mu_M(x) = \begin{cases} 0, & x \le a, \\ \frac{x-a}{b-a}, & x \in [a,b], \\ \frac{x-c}{b-c}, & x \in [b,c], \\ 0, & x > c, \end{cases} \quad ...(4.1)$$

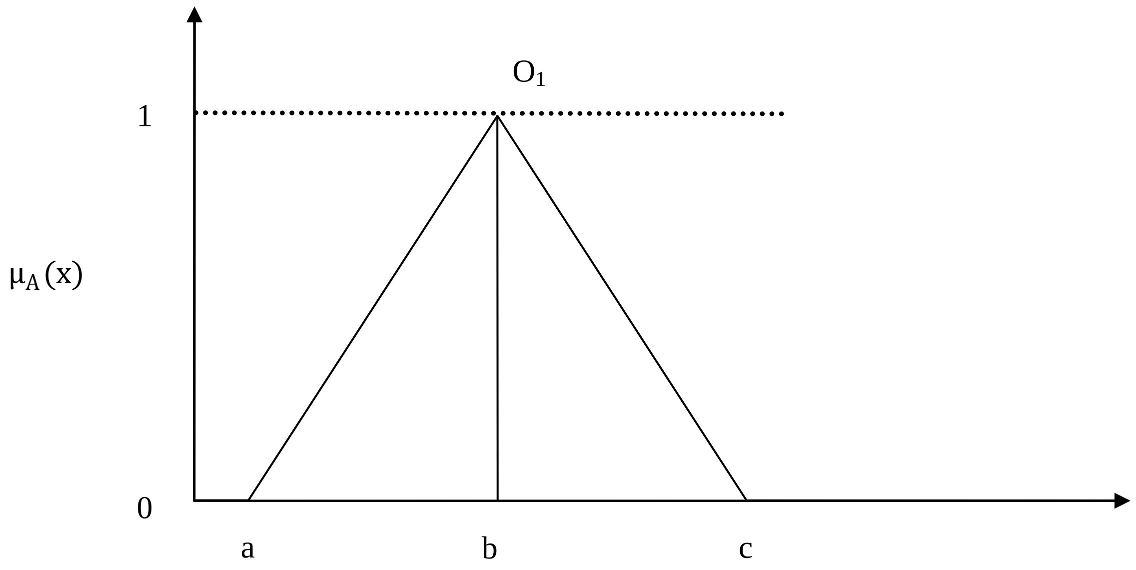


Figure 4.3 Membership Function for the Triangular Fuzzy Number

Sources: modified Zimmerman (1996)

- Step 3: Derive the hierarchical structure. Considering the linguistic judgments provided by experts, the pair-wise assessment matrix is derived.
- Step 4: Construct the fuzzy positive matrix. To transform the linguistics expressions into definite values, the pair-wise assessment matrices are replaced with equivalent positive triangular fuzzy numbers, which might be illustrated as $K = [z_{ij}]_{n\times m}$. Further, the fuzzy entries in fuzzy positive matrices are represented by, $z_{ij} = (a_{ij}, b_{ij}, c_{ij})$, and in this relation positive fuzzy numbers satisfies the following property.
  $a_{ij} = \frac{1}{a_{j_i}}, b_{ij} = \frac{1}{b_{j_i}}, \ c_{ij} = \frac{1}{c_{j_i}}$, where, i and j = 1, 2 ………………k.
- Step 5: Calculations for finding the preference weights are performed. It needs to aggregate fuzzy numbers into crisp values, which allows analysts to calculate the preference weights for each factor and sub-factor, and determines their relative concern. To meet the purpose, this study has used Chang's Extent Analysis method. This method has been widely accepted to calculate fuzzy aggregate weights for the fuzzy input pair-wise assessment matrices (Chan et al., 2008). For more details of extent analysis

method, readers can refer the studies of Chang (1992) and Chan et al. (2008). The details of some essential calculations of extent analysis method as described by Chang (1992) and Chan et al. (2008) are given as following:

If extent analysis values for the i^{th} object is represented by $O_{g_i}^1, O_{g_i}^2, O_{g_i}^3, \ldots\ldots.. O_{g_i}^p$, in this case their corresponding fuzzy synthetic extent would be represented as below in Equation (4.2).

$$S_i = \sum_{j=1}^{o} O_{g_i}^j \times \left[\sum_{i=1}^{n} \sum_{j=1}^{o} O_{g_i}^j\right] \quad \text{...(4.2)}$$

In addition, for considering the minimum and maximum values for fuzzy number, the degree of possibility for two fuzzy numbers is represented as in Equation (4.3).

$$V(O_1 \geq O_2) = \sup\left[\min\left(\mu_{o_1}(x), \mu_{o_2}(y)\right)\right];\ x, y \in R, \text{ and } x \geq y \quad \text{...(4.3)}$$

Noted that, if, $x \geq y$ and $f_{o_1}(x) = f_{o_2}(y) = 1,$ then $V(O_1 \geq O_2) = 1$. Since O_1 and O_2 are two convex fuzzy numbers, therefore, it posses the properties as given in Equations (4.4 – 4.5), given as below:

$$V(O_1 \geq O_2) = 1 \qquad \text{if } o_1 \geq o_2; \quad \text{...(4.4)}$$

$$V(O_1 \geq O_2) = hgt(O_1 \cap O_2) = f_{o_1}(m) \quad \text{...(4.5)}$$

While 'm' could be viewed as the ordinate of the highest intersection point M between μ_{o_1}, μ_{o_2} (refer Figure 4.4). Further, M is given with the help of an expression illustrated in Equation (4.6).

$$V(O_1 \geq O_2) = hgt(O_1 \cap O_2) \quad = (a - r)/(q - r) - (b - a) \quad \text{...(4.6)}$$

The degree of possibility for 'k' convex fuzzy numbers O_i $(i = 1,2 \ldots\ldots..k)$ is calculated with the help of Equation (4.7).

$V(O \geq O_1, O_2, \ldots\ldots O_k) = V[(O \geq O_1) \text{ and } (O \geq O_2) \text{ and} \ldots\ldots\text{and } (O \geq O_k)] = \min V(O \geq O_i)$, $i = 1,2,3, \ldots\ldots\ldots\ldots k$. ...(4.7)

Furthermore, with the help of Equation (4.8), it is assumed that:

$z'(C_i) = \min V(S_i \geq S_k)$, for $k = 1,2,\ldots\ldots n$; $k \neq i$; ...(4.8)

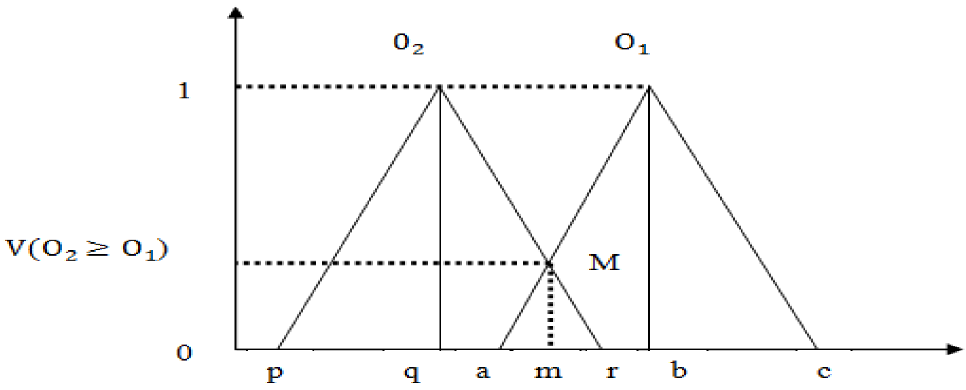


Figure 4.4 Representation of Intersection between O_1 and O_2

Sources: modified Chan et al. (2008)

Now, the weight vector is given through the expression given in Equation (4.9).

$$W' = (z' (C_1),(C_2), (C_3)\ldots \ldots \ldots \ldots (C_i))^T \quad \ldots(4.9)$$

Where C_i (i=1,2,........n) are the elements.

After normalizing, the normalized fuzzy weight vectors for the system is given with the help of Equation (4.10), While, 'W' is a non-fuzzy number.

$$W= (z' (C_1),(C_2), (C_3)\ldots\ldots\ldots\ldots(C_n))^T \quad \ldots(4.10)$$

4.5 Interpretive ranking process

The methodology of Interpretive Ranking Process (IRP) has established by Sushil in 2009. Sushil (2005; 2009a) has proposed the utility of interactive technique in decision making, which may help the managers to interpret and analyze the managerial problems effectively and efficiently. It helps in ranking the considered variables by combining the advantages of both the rational choice process and the intuitive process of decision-making. IRP methodology enables the decision makers to overcome the limitations of the above-mentioned individual methods that make it a novel ranking method. The IRP method utilizes the logic of the pair wise comparison approach (Warfield, 1974; Saaty, 1980), and thus minimizes the possibilities of cognitive overload. Further, an interpretative matrix and pair wise comparison of interpretation in the matrix has been used as an essential means in this methodology (Luthra et al., 2014a). IRP technique has been recognized as a strategic flexible decision making approach for the managers and decision makers, and have a scope of applicability in various business areas and in supply chains, where the managers needs to formulate flexible decision plans and strategies for obtaining performance improvements in the respective domain (Sushil, 2009a; Luthra et al., 2014a). There are very few studies available in the literature that reveals the uses the IRP methodology (Sushil, 2009a; Haleem et al., 2012).

IRP method has been proposed as meaningful tool in comparison to several other multi criteria decision-making methods. Compared to the AHP, IRP method enables the decision makers to spell out the interpretive logic for dominance of one element over the other for each pair wise comparison, which otherwise, remains unexplored in the AHP method (Sushil, 2009a). In IRP methodology, there is no need to determine the degree of dominance for paired comparisons. The users may also confirm the internal validity in IRP methodology through the vector logic of the dominance relationships in the form of a dominance system graph (Sushil, 2009a).

The procedural steps of IRP (Sushil 2009a) are summarized as follows:

1) Identification and finalization of two sets of variables-one to be ranked with reference to the other, e.g. GSC risks and expected performance outcome.
2) Formation of a cross-interaction matrix between the identified variables (GSC risks and expected performance outcome).
3) Development of an interpretive matrix based on the cross-interaction matrix.
4) Transformation of the interpretive matrix into an interpretive logic of pair wise comparisons and dominating interactions matrix by interpreting the dominance of one interaction over the other.
5) Computation of the ranking and interpret the ranks in terms of dominance of number of interactions.
6) Validation of the ranks derived.
7) Representation of the derived ranking through an interpretive ranking model.
8) Interpretation of the ranking order and recommending actions based on the derived ranking.

The above proposed flexible decision model based on the fuzzy AHP and IRP methods is applied to a real-world problem; other details are given in the next section.

4.6 An Application Example of the Proposed Model

4.6.1. Phase – I: Identification of the most common risks in GSC

Initially and based on the critical review of literature, five categories of risks (O, S, PR, F, and D) and thirteen specific risks (O1, O2, O3, S1, S2, S3, PR1, PR2, F1, F2, D1, D2, and D3) were identified (refer Chapter 2). These five categories of risks and thirteen specific risks were briefed to the experts, and they were asked to identify the other important category of risks and specific risks, if any, which they consider might be important w.r.t. the specific organization where they work. After discussion with experts (by collecting their response on the response sheet), one category of risk, i.e. Government and Organizational related risks (GO) and twelve specific risks (six specific risks belongs to GO category risk and other six belongs to initially identified categories of risks) were included (for details, refer Table 4.1). Details about response sheet are given in an Appendix B. Thus, six categories of risks and twenty-five specific risks were identified for the present research work.

Table 4.1 Summarizing the Most Common GSC Specific Risks within Respective Categories with Sources

GSC Specific risks	Description	Sources
Operational risks (O)		
1. Machine, equipment or facility failure (O1)	Any interruption due to failure of machine, equipment or facility will affect GSC effectiveness at industrial standpoint	Yang and Li (2010), Wang et al. (2012)
2. Design risks (O2)	It corresponds to the imprecision or flaws in designing of green process methodology like mismanaged green material, operations, methods, etc.	Yang and Li (2010), Qianlei (2012), Ma et al. (2012)
3. Scarcity of skilled labor (O3)	The lack of understanding and or knowledge of green operations and method among workforce will lower the organizational GSC performance	Yang and Li (2010), Ma et al. (2012)
4. Green technology level (O4)	Managers should have sound knowledge and understanding about the prologue and the applicability of new green technology in business	Expert's opinion
Supply risks (S)		
5. Procurement costs risks (S1)	Procurement of green and or eco-friendly raw material may add to costs at supplier end, and so, their environmental performance may be affected	Yang and Li (2010), Qianlei (2012)
6. Key supplier failures (S2)	Failure of any key supplier can halt the functioning of an organizational GSC	Yang and Li (2010), Wang et al. (2012)
7. Supplier quality issues (S3)	The issues of quality at supplier's end will affect GSC efficiency at industrial perspective	Ma et al. (2012), Wang et al. (2012),

Table 4.1 Contd...

GSC Specific risks	Description	Sources
8. Green raw-material supply disruptions (S4)	Industries are facing issues related to disruptions in supply of green or eco-friendly raw material	Expert's opinion
Product recovery risks (PR)		
9. Reverse logistics design risks (PR1)	Risks relevant to reverse logistics network design can disturb the adoption of effective GSC practices in business	Mangla et al. (2013)
10. Gate keeping design failures (PR2)	It represents the uncertainties related to viewing, inspection and screening of damaged and defective return products at the entry point of reprocessing	Mangla et al. (2013)
11. Take-back obligations risks (PR3)	Product take-back obligation influences the collection procedure and affect the product recovery mechanism in GSC accordingly	Expert's opinion
12. Inventory and capacity design risks at reprocessing centres (PR4)	The risk factors relevant to the design of inventory and capacity at reprocessing centers will appear complexities for green product recovery system	Expert's opinion
Financial risks (F)		
13. Sourcing of funds (F1)	Any problem related to fund sourcing and its basis would certainly influence the objective of adoption of effective GSC practices in business	Yang and Li (2010), Qianlei (2012),
14. Inflation and currency exchange rates (F2)	Inflation and variations in currency exchange rates would affect the financial concerns, and thus, GSC effectiveness might be affected	Yang and Li (2010)

Table 4.1 Contd...

GSC Specific risks	Description	Sources
15. Financial restriction (F3)	Failure of or poor financial plans and controls will definitely disturb the GSC functioning	Expert's opinion
Demand risks (D)		
16. Bullwhip effect risks (D1)	The green demand information distortion within the GSC, known as the bullwhip effect. It makes difficult for the organizational GSC to estimate the green product demand, and results in decreased performance	Yang and Li (2010), Qianlei (2012).
17. Market dynamics (D2)	Market dynamics are the result of collective market resources and preferences. For this reason, market dynamics have a significant effect on green product demand and affect GSC efficiency in turn.	Ma et al. (2012)
18. Key customer failures (D3)	Failure of any key customer will have a significant effect on efficient GSCM adoption and implementation	Yang and Li (2010), Qianlei (2012)
19. Competing risks (D4)	Industries are under tremendous risks due to huge competition in the market. Thus, competitors approach and strategy regarding green would affect the green product demand uncertainties at industrial perspective	Expert's opinion
Governmental and Organizational related risks (GO)		
20. Management policy failures (GO1)	It represents the risks at managerial end in terms of failure of management policies and plans in adopting GSC practices in business	Expert's opinion

Table 4.1 Contd...

GSC Specific risks	Description	Sources
21. Government policy risks (GO2)	Failed or poor governmental policies and directions in terms of governmental environmental support level will definitely influence the adoption of efficient GSC practices at industrial viewpoint	Expert's opinion
22. Information asymmetry risk across GSC members in hierarchy (GO3)	Distortion and irregularities in information flow across GSC members can disrupt the effective GSCM adoption in business	Expert's opinion
23. Lack in enterprise strategic goals (GO4)	Without considering the GSCM strategic view, it would be difficult for industries to accomplish the GSC business activities successfully	Expert's opinion
24. Legal risks (GO5)	Legal risk is risk from indecisiveness due to legal actions, or ambiguity in the applicability or interpretation of contracts, laws, or regulations in implementation of GSC practices	Expert's opinion
25. Partnership risks (GO6)	Disputes between the partners and the members have a tendency to disturb the functioning of GSC	Expert's opinion

4.6.2 Phase – II: Fuzzy AHP application results to establish the priority of listed risks

The categories of risks and specific risk were analyzed for determining of their respective priority. There is human subjectivity and an inherent uncertainty in analyzing the GSC risks, and therefore, a fuzzy AHP methodology is used for this purpose. In fuzzy AHP approach, the pair-wise assessment matrices are developed at two levels, i.e., for the risks at category level, and for the specific risks at the specific risks level. Based on the study of Wang et al. (2007), a nine-point scale is used to frame the required pair-wise assessment.

- Step 1: Finalization of the hierarchical structure: The process of interaction and consultation with experts of the business organizations under consideration helped in developing the hierarchical structure as shown in Figure 4.5. It consists of three levels, i.e., goal of analyzing risks in GSC at level- I, six categories of risks and twenty-six specific risks at level II and III respectively.
- Step 2: Construction of the fuzzy positive matrix: Based on the study of Wang et al. (2007), a fuzzy linguistic scale was provided to the experts. It contains linguistic expressions for evaluating the interactions among categories of risks and specific risks in effective adoption of GSC practices. Pair-wise assessment matrices were finalized based on the majority of the experts' opinion. All pair-wise assessment matrices, representing the expert's linguistic judgments were further transformed into a positive fuzzy number matrix using the standard TFNs (refer Table 4.2). The constructed fuzzy pair-wise assessment matrix for categories of risks is given in Table 4.3.

Table 4.2 Fuzzy Linguistic Scale (Wang et al. 2007)

Uncertain judgment	**Fuzzy score**
Approximately equal	1/2,1,2
Approximately x times more significant	x-1, x, x+1
Approximately x times less significant	1/x+1, 1/x, 1/x-1
Between y and z times more significant	y, (y + z)/2, z
Between y and z times less significant	1/z, 2/(y + z), 1/y

Note: The value of x ranges from 2, 3...9, whereas the values of y and z can be 1, 2......9, and y<z.

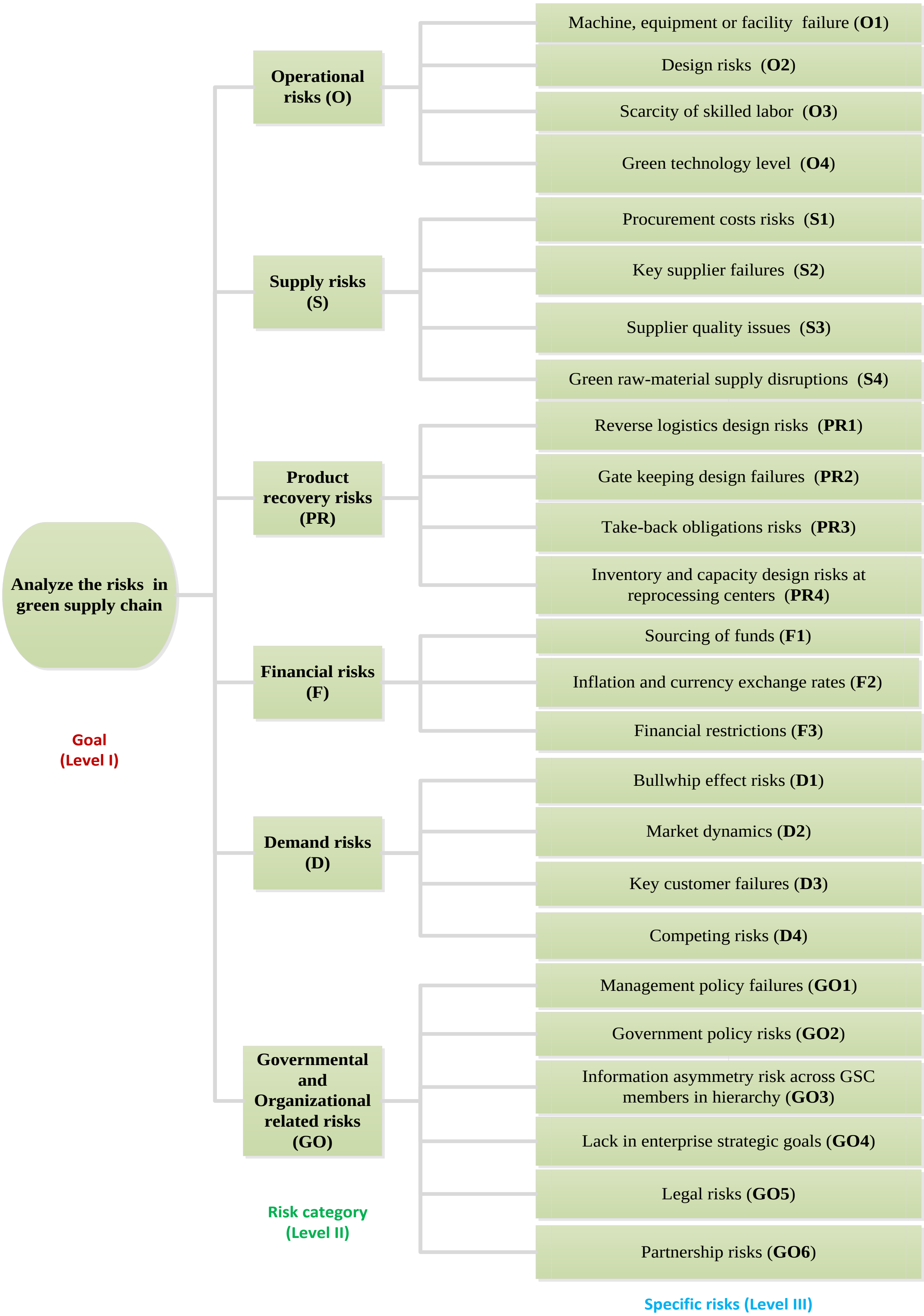


Figure 4.5 Fuzzy AHP Based Hierarchical Structure

Table 4.3 Triangular Fuzzy Number Based Pair-Wise Judgment Matrix for GSC Risk Category

	O			S			PR			F			D			GO		
O	1.00	1.00	1.00	1.00	2.00	3.00	3.00	3.50	4.00	0.33	0.50	1.00	2.00	3.00	4.00	0.33	0.50	1.00
S	0.33	0.50	1.00	1.00	1.00	1.00	1.00	2.00	3.00	3.00	3.50	4.00	0.33	0.40	0.50	0.33	0.50	1.00
PR	0.25	0.29	0.33	0.33	0.50	1.00	1.00	1.00	1.00	0.33	0.40	0.50	3.00	4.00	5.00	2.00	2.50	3.00
F	1.00	2.00	3.03	0.25	0.29	0.33	2.00	2.50	3.03	1.00	1.00	1.00	2.00	3.00	4.00	2.00	3.00	4.00
D	0.25	0.33	0.50	2.00	2.50	3.03	0.20	0.25	0.33	0.25	0.33	0.50	1.00	1.00	1.00	1.00	2.00	3.00
GO	1.00	2.00	3.03	1.00	2.00	3.03	0.33	0.40	0.50	0.25	0.33	0.50	0.33	0.50	1.00	1.00	1.00	1.00

Note: O – Operational risks; S - Supply risks; PR - Product recovery risks; F - Financial risks; D - Demand risks; GO - Governmental and Organizational related risks.

- Step 3: Computation of the preference weights: The preference weights for each category of risk and its specific risks were calculated using Chang's Extent Analysis method. It has been calculated by using the Equations (4.2) – (4.10) as mentioned in Section 4.4.1. The associated S_i values can be computed through Equation (4.2), as follows:

S_1 = (7.3300, 10.0000, 13.0000) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.1076, 0.1941, 0.3474)

S_2 = (5.6600, 7.4000, 9.5000) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.0831, 0.1436, 0.2539)

S_3 = (4.9100, 6.1900, 7.8300) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.0721, 0.1201, 0.2092)

S_4= (6.2500, 8.7900, 11.3900) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.0917, 0.1706, 0.3044)

S_5= (3.7000, 4.4100, 5.3600) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.0543, 0.0856, 0.1432)

S_6= (2.9100, 5.2300, 8.0600) × $\left(\frac{1}{68.1400},\frac{1}{51.5200},\frac{1}{37.4200}\right)$ = (0.0427, 0.1015, 0.2154)

Using Equation (4.3) – (4.7), the degree of possibility for two fuzzy numbers is given as,

$V(S_1 \geq S_2) = \frac{(0.0831-0.3474)}{(0.1941-0.3474)-(0.1436-0.0831)} = 1$

$V(S_1 \geq S_3) = 1$

$V(S_1 \geq S_4) = 1$

$V(S_1 \geq S_5) = 1$

$V(S_1 \geq S_6) = 1$

$V(S_2 \geq S_1) = \frac{(0.1076-0.2539)}{(0.1436-0.2539)-(0.1941-0.1076)} = 0.7434$

$V(S_2 \geq S_3) = \frac{(0.0721-0.2539)}{(0.1436-0.2539)-(0.1201-0.0721)} = 1$

$V(S_2 \geq S_4) = \frac{(0.0917-0.2539)}{(0.1436-0.2539)-(0.1706-0.0917)} = 0.8579$

$V(S_2 \geq S_5) = \frac{(0.0543-0.2539)}{(0.1436-0.2539)-(0.0856-0.0543)} = 1$

$V(S_2 \geq S_6) = \frac{(0.1778-0.2539)}{(0.1436-0.2539)-(0.1015-0.1778)} = 1$

$V(S_3 \geq S_1) = 0.5786$

$V(S_3 \geq S_2) = 0.8429$

$V(S_3 \geq S_5) = 0.6994$

$V(S_3 \geq S_5) = 1$

$V(S_3 \geq S_6) = 1$

$V(S_4 \geq S_1) = 0.8933$

$V(S_4 \geq S_2) = 1$

$V(S_4 \geq S_3) = 1$

$V(S_4 \geq S_5) = 1$

$V(S_4 \geq S_6) = 1$

$V(S_5 \geq S_1) = 0.2470$

$V(S_5 \geq S_2) = 0.5089$

$V(S_5 \geq S_3)) = 0.6733$

$V(S_5 \geq S_4) = 0.3773$

$V(S_5 \geq S_6) = 0.8634$

$V(S_6 \geq S_1) = 0.5379$

$V(S_6 \geq S_2) = 0.7586$

$V(S_6 \geq S_3) = 0.8851$

$V(S_6 \geq S_4) = 0.6416$

$V(S_6 \geq S_5) = 1$

Then, by using the Equation (4.8), the results obtained are shown as:

$z'(C_1) = \min V(S_1 \geq S_{2,}S_{3,}, S_{4,}S_{5,}S_6)$ = min (1, 1, 1, 1, 1) = 1

$z'(C_2) = \min V(S_2 \geq S_{1,}S_{3,}, S_{4,}S_{5,}, S_6)$= min (0.7434, 1, 0.8579, 1, 1) = 0.7434

$z'(C_3) = \min V(S_3 \geq S_{1,}S_{2,}, S_{4,}S_{5,}S_6)$= min (0.5786, 0.8429, 0.6994, 1, 1) = 0.5786

$z'(C_4) = \min V(S_4 \geq S_{1,}S_{2,}, S_{3,}S_{5,}S_6)$= min (0.8933, 1, 1, 1, 1) = 0.8933

$z'(C_5) = \min V(S_5 \geq S_{1,}S_{2,}, S_{3,}S_{4,}S_6)$= min (0.2470, 0.5089, 0.6733, 0.3773, 0.8634) = 0.2470

$z'(C_6) = \min V(S_6 \geq S_{1,}S_{2,}, S_{3,}S_{4,}S_5)$= min (0.7434, 1, 0.8579, 1, 1) = 0.7434

Considering these calculated minimum weight vectors, which are further operated to obtain the normalized value and weight vector by means of Equations (4.9) - (4.10), As a result, the weight vectors for the categories of risks (i.e., 0.2507, 0.1863, 0.1449, 0.2236, 0.0607 and 0.1338) have been established.

In that way, preference weights were calculated for each category of risk and for specific risks, and are given in the Table 4.4 and Table 4.5 respectively. The preference weights provide ground for prioritizing the categories of risks and specific risks that would be useful in updating the expert's database regarding efficient adoption of GSC initiatives, and thus, the system can be improved continuously.

Table 4.4 Ranking of Categories of Risks

Risk category	**Preference weights**	**Ranking**
O	0.2507	1
F	0.2236	2
S	0.1863	3
PR	0.1449	4
GO	0.1338	5
D	0.0607	6

Table 4.5 Final Ranking for Specific Risks

Risk category	Specific risks	Relative preference weights	Relative ranking	Global preference weights	Global ranking
O	O1	0.1595	4	0.03999	11
	O2	0.3177	2	0.07965	3
	O3	0.1956	3	0.04904	8
	O4	0.3272	1	0.08203	2
S	S1	0.1944	4	0.03622	13
	S2	0.2454	3	0.04572	10
	S3	0.2528	2	0.04710	9
	S4	0.3054	1	0.05690	6
PR	PR1	0.1724	3	0.02498	17
	PR2	0.1683	4	0.02439	18
	PR3	0.2399	2	0.03476	14
	PR4	0.4184	1	0.06063	5
F	F1	0.3390	2	0.07580	4
	F2	0.2478	3	0.05541	7
	F3	0.4122	1	0.09217	1
D	D1	0.2504	2	0.01520	21
	D2	0.1206	4	0.00732	25
	D3	0.2385	3	0.01448	22
	D4	0.3915	1	0.02376	19
GO	GO1	0.2718	1	0.03637	12
	GO2	0.2067	3	0.02766	16
	GO3	0.1633	4	0.02185	20
	GO4	0.2212	2	0.02956	15
	GO5	0.0798	5	0.01067	23
	GO6	0.0572	6	0.00765	24

Note: O – Operational risks; S - Supply risks; PR - Product recovery risks; F - Financial risks; D - Demand risks; GO - Governmental and Organizational related risks.

4.6.3 Phase III: IRP application results: It confirm the fuzzy AHP based final listed risks priority and to know the interpretive logic for dominance of one risk over the other

- Step 1: Identification and finalization of two sets of variables: In the present work, six categories of risks (O, S, PR, F, D, and GO) relevant to GSC and four expected performance (P1, P2, P3, and P4) measures by implementing efficient GSCM concept are identified (refer Table 4.6). Further, the expected performance measures were finalized through literature resource and in discussion with the expert of decision making team. The four expected performance measures are – Environmental performances (P1), Economic performances (P2); Operational performances (P3); Competitiveness performance (P4). Considering environmental performances, various scholars have distinguished the significance of improving environment performances by adopting of green trends in a supply chain context (Rao et al., 2002; Zhu and Sarkis, 2004; Zhu et al., 2007a,b; Zhu and Sarkis, 2007; Zhu et al., 2008a; Zhu et al., 2010; Eltayeb et al., 2011; Toke et al.,, 2012). It has also been stated that environmental performances denotes the organization's performance according to their environmental responsibilities (Kleindorfer et al., 2005; Yang et al., 2011). There is a need to improve the environmental performances in Indian plastic sector in terms of extent of recycling, waste and emission reductions, etc. Regarding economic performance, it can be understood in terms of expected financial benefits resulting from GSCM implementation (Eltayeb et al., 2011). Implementation of GSCM in Indian plastic sector has been expected to improve economic performances, in terms of increase in productivity, decrease costs of material, reduction in energy consumption, increased market share, etc. (Zhu and Sarkis, 2007; Zhu et al., 2010; Eltayeb et al., 2011). On the other hand, operational performance represents the improvement in operational activities with the help of GSCM adoption from an industrial viewpoint (Eltayeb et al., 2011). Many researchers recognized an increase in an organizational operational performances by means of green initiatives in a supply chain context (Rao, 2002; Zhu and Sarkis, 2004; Zhu et al., 2010; Eltayeb et al., 2011; Gunasekaran and Spalanzani, 2012; Yusuf et al., 2013). Operational performances may contain environmental quality improvements of products/processes, reduction in waste, decrease of environmental accidents penalties, increased customers' satisfaction and loyalty, etc. Competitiveness performance denotes the improvement in the competitive performance by implementing green trends in an organizational GSC. Over the past few years, literature indicated that GSCM helps organizations in gaining competitive edge with respect to its competitors those whom are lagging in GSCM adoption (Zhu and Sarkis, 2007; Mudgal et al., 2009; Yusuf et al., 2013). It has also been declared that the organizations are adopting GSCM initiatives to enhance their business prospects and achieving sustained competitive advantage (Eltayeb et al., 2011).

The evaluation of risks to determine their priority to implement an efficient GSCM concept is considered as actions to achieve selected performance measures in this work.

Table 4.6 Risks and Expected Performance Measures Utilized for IRP

Listing of the risks in adoption and effective implementation of GSCM	**Expected performance measures by implementing effective GSCM concept**
1: Operational risks (O) 2: Supply risks (S) 3: Product recovery risks (PR) 4: Financial risks 5: Demand risks (D) 6: Governmental and Organizational related risks (GO)	1: Environmental performances (P1) 2: Economic performances (P2) 3: Operational performances (P3) 4: Competitiveness performance (P4)

- Step 2: Construction of cross-interaction matrix: To represent the relationship between each category of risk and expected performance measure, a cross-interaction matrix is constructed. In this matrix, the entry '1' signifies the presence of relationship between the compared categories of risk while '0' signify no relationship (Hill and Warfield, 1972). Based on this logic, a cross-interaction binary matrix is developed as shown in Table 4.7. The basis of the development of cross-interaction matrix was inputs received from the experts of decision making team.

Table 4.7 Cross-Interaction Matrix of Risks and Expected Performances for Implementing Effective GSCM Concept

Risks involved in implementing GSCM	**Expected Performances by implementing effective GSCM concept**			
	Environmental (P1)	Economic (P2)	Operational (P3)	Sustainable competitiveness (P4)
O	1	1	1	1
S	1	1	1	0
PR	1	1	0	1
F	0	1	1	1
D	0	1	0	1
GO	1	1	0	0

- Step 3: Derive an interpretation of interactions: By gathering the expert's opinion in corresponds to the entry '1' in terms of contextual relationship between the paired category of risk in the cross-interaction binary matrix, a cross-interpretive matrix is developed (Sushil, 2009a,b) as shown in Table 4.8. For example, (Operational risk (O) with respect to Performance (P2) is interpreted as 'Implementation of effective green practices and processes helps in gaining the economic edge'.

Table 4.8 Interpretive Matrix of Risks and Expected Performances for Implementing Effective GSCM Concept

Performances **Risks**	**Environmental (P1)**	**Economic (P2)**	**Operational (P3)**	**Sustainable competitiveness (P4)**
Operational risks (O)	Usage of accurate green procedures and process results in enhanced environmental performance	Implementation of effective green practices and processes helps in gaining the economic edge	Managing issues relevant to green methods, processes and practices enhances the operational performance in GSC	Adoption of effective green procedure and process at operational level will add to the competitive edge
Supply risks (S)	Commitment of supplier would improve the organizational ecological performance	Managing the issues at supply end are important for economic gains	Good quality and environmental friendly material will improve the GSC operational efficiency	-
Product recovery risks (PR)	Product recovery process provides option to reuse/recycle, the material/products that enhances the ecological performance	The process of recovering the material and or product will provide economic advantages	-	Adoption of product recovery procedure and process may improve company brand image in market

Table 4.8 Contd…

Performances Risks ↳	Environmental (P1)	Economic (P2)	Operational (P3)	Sustainable competitiveness (P4)
Financial risks (F)	-	Managing the financial concerns will generate economic advantages for an organizational GSC	Managing financial issues would enhance the GSC operational performance	Planned GSCM financial decisions can offer competitive edge at industrial viewpoint
Demand risks (D)	-	Demand for green product will generate economic benefits	-	Managing the issues in relevancy to product demand would be crucial in enhancing the competitiveness performance
Governmental and Organizational related risks (GO)	Well designed and effective governmental policies and planning for issues related to organizational GSC will improve its ecological performance	There is a huge opportunity for organizations to enhance their economic gains, if by regulating government environmental directions and organization's policies towards achieving sustainability in business	-	-

- Step 4: Development of pair wise comparisons: The main risk criteria (categories of risks) were compared with the reference variables (performances areas) in a pair-wise manner, by using the interpretive matrix. For instance, Demand risk (D) is compared with Supply risk (S) with respect to various performances P1, P2, P3 and P4, respectively, and the interpretive logic of dominating interaction between D and S with respect to different performances is given in the knowledge base as shown in Appendix C. Inputs of the expert were used to determine the dominance of a pair of category of risk with respect to the performance. It should be noted that the ranking variables have not been compared directly in the above-paired comparison, and however, their interaction with respect to reference variable is compared. For example, the strategic action (i.e. to manage risks for increasing the GSC success rate) D and S with respect to various performance measures have been compared rather than comparing D and S directly. A summarized dominating interaction is shown in Table 4.9.

Table 4.9 Dominating Interaction Matrix for Implementing Effective GSCM Concept

	Dominating	**O**	**S**	**PR**	**F**	**D**	**GO**
Being Dominated	O	-	P2, P3, P4	P1, P2, P3	P1, P3, P4	P1, P2, P3	P2, P3, P4
	S	P1	-	P1, P2, P3	P1	P1, P2, P3	P1, P2, P3
	PR	P4	P4	-	P1, P2	P1, P4	P1, P2
	F	P2	P2, P3, P4	P2, P3, P4	-	P2, P3	P2, P3, P4
	D	P4	P4	P2, P4	P4	-	P2
	GO	P1	P1, P2	P1, P2	P1, P2	P1	-

Note: O – Operational risks; S - Supply risks; PR - Product recovery risks; F - Financial risks; D - Demand risks; GO - Governmental and Organizational related risks.

- Step 5: Construction of dominance matrix: The dominating interactions are summarized in a matrix, named as dominance matrix. The dominance matrix gives the number of cases in which one ranking variable dominates or being dominated by other ranking variable. The net dominance for a ranking variable i.e. action has been computed as (D – B). Where D (i.e., sum of rows) represents the total no. of cases where these ranking variable (s) dominate all other ranking variables, and B *(*i.e., sum of column*)* represents the total number of cases in which a particular ranking variable has been dominated by all other ranking variables (Sushil, 2009). For example, for Operational risk (O), there are total 15 cases where this category of risk dominates (D) among other category of risk and five cases in which this particular category of risk is dominated by (B) other category of risk. The positive net dominance value signify that the particular risk has dominated in most of cases than being dominated, whereas the net negative dominance value denote that the particular risk is being dominated in most cases than dominating other risks (Mangla et al. 2014). Using the value of net positive dominance, the categories of risk for the problem were prioritized and ranking has been done in descending order. Additionally, the category of risk with highest negative net dominance is ranked lower as these are being dominated more by other category of risk. For instance, the risk O obtains highest net positive dominance value, and therefore, it is ranked first. The results are summarized in Table 4.10.

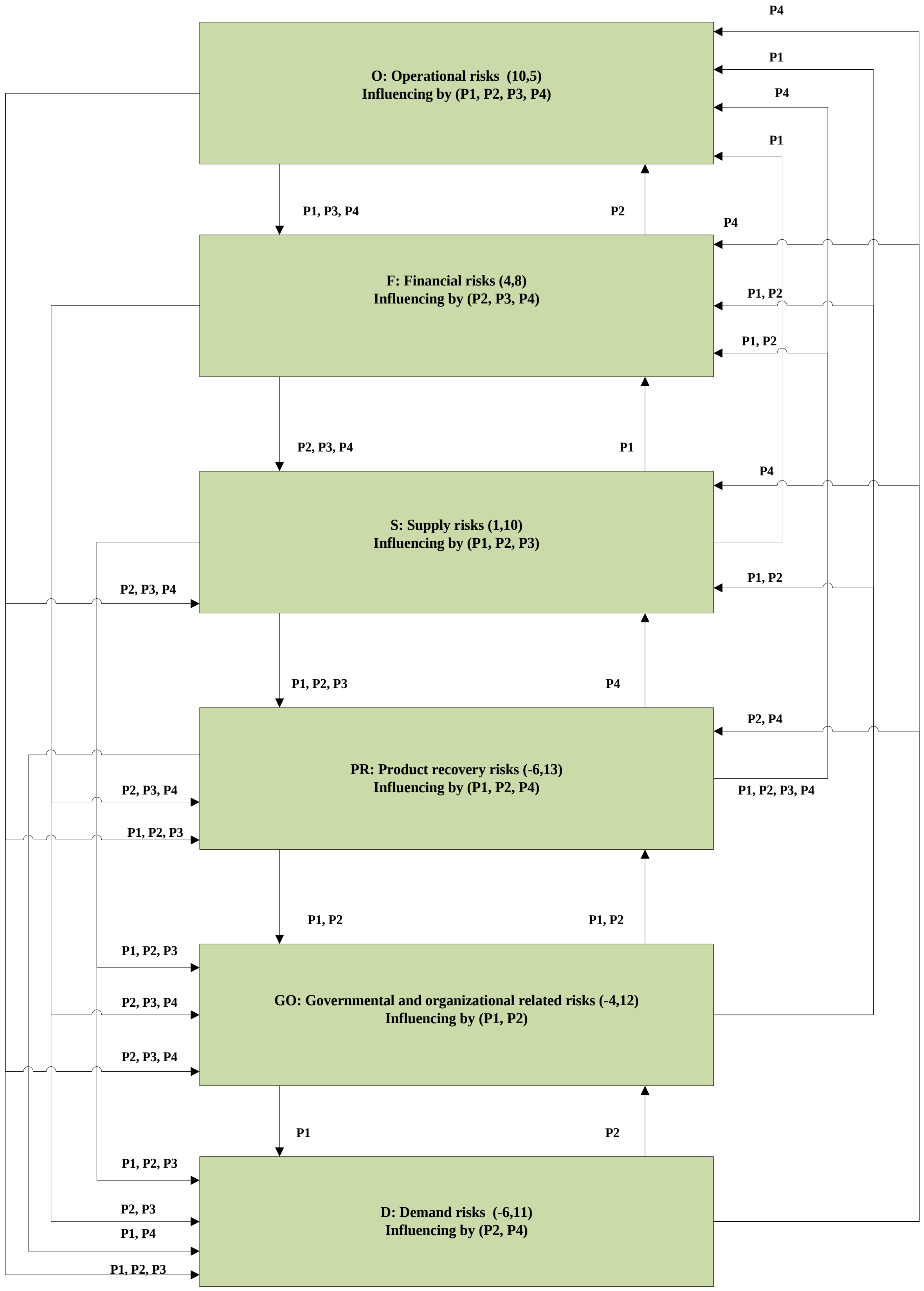
Table 4.10 Dominance Matrix for Implementing Effective GSCM Concept

Dominating → Being dominated ↓	**O**	**S**	**PR**	**F**	**D**	**GO**	**Number of cases dominating (D)**	**Net dominance (D-B)**	**Rank dominating**
O	-	3	3	3	3	3	15	10	***I***
S	1	-	3	1	3	**3**	11	1	***III***
PR	1	1	-	1	2	2	7	-6	***IV***
F	1	3	3	-	2	3	12	4	***II***
D	1	1	2	1	-	1	6	-6	***VI***
GO	1	2	2	2	1	-	8	-4	***V***
(B)[a]	5	10	13	8	11	12	59/59		

Note: [a] Number of cases being dominated.

- Step 6: To draw interpretive ranking model: Interpretive ranking model is a diagrammatical representation (Figure 4.6) of the derived final ranks of the ranking risks. The arrow in this diagram represent the reference variable (s) in which cases a particular ranking variable is dominating the other ranking variables. In addition, the numbers dominating and number being dominated are displayed in brackets for all variables. This will help to interpret how each risk is influencing various performances. The IRP model shown in Figure 4.6 suggests that risk O (Operational risk) has highest rank. This clearly indicates that for any organization wishing to improve GSC processes and performances, the mitigation of operational risks is crucial. The ranking order of the remaining risks is as follows: F > S > PR > GO > D. Here, the arrow from O to S demonstrates that O is dominating S for performances P1, P2, P3 and P4. For all the risks, the numbers dominating and numbers being dominated are summarized within brackets. For example, for risk O, the numbers dominating and dominated are shown as (15, 5). The interactive ranking model of the variables (i.e., risks v/s performances) to build a robust GSC system is shown in Figure 4.6.

The ranking model of risks v/s performances interprets the roles of different risks in the strategic decision processes and interprets the influence of key strategic actions on the performance. It also clarifies the dominating roles played by various risks, which will be useful for managers in developing a logical approach for improving the effectiveness of the processes in implementing GSC initiatives. It will be helpful in setting strategic priorities in enhancing the performance in key areas of managing risks in GSC context.



P1, P2, P3, P4 represents the Performances.

Figure 4.6 Interpretive Ranking Model of Risks in Effective GSCM Adoption

4.7 Comparison of Results Obtained through Fuzzy AHP and IRP and Managerial Implications

The fuzzy AHP analysis results point out that operational risk is the most prioritized risk with an overall priority value of 0.2507. Operational risk in GSC context can be expressed as the risk of loss resulting from inadequate or failed internal green processes, systems, from an organization perspective. It shows that managers and planners should analyze green methods and operations with priority when implementing GSC initiatives in their respective business.

The global ranking for the specific risks, based on their respective global preference weights, was also determined, and is shown in Table 4.5. The global preference weights for the specific risks were calculated by multiplying their preference weights with preference weights of their respective category of risk. The comparison of results obtained from the fuzzy AHP and IRP analysis in terms of their preference order is given as O > F > S > PR > GO > D (refer Table 4.11). It corresponds to a reasonable consistency in the findings of the present research work. Further, the research findings were discussed with the experts with an objective to have further insights to manage and reduce the consequence of the risks in GSC initiatives adoption, which in turn will improve the GSC robustness, and hence, enhancement in the ecological-economic performance.

Table 4.11 Comparison of Ranking of Risks through Fuzzy AHP and IRP

Categories of risk	Ranking through fuzzy AHP	Ranking through IRP
O	1	1
F	2	2
S	3	3
PR	4	4
GO	5	5
D	6	6

Note: O – Operational risks; S - Supply risks; PR - Product recovery risks; F - Financial risks; D - Demand risks; GO - Governmental and Organizational related risks.

The operational risk category (O) holds first rank, and thus, occupies the highest priority in reference to other risk categories. The four specific risks related to this risk category are, Machine, equipment or facility failure (O1), Design risks (O2), Scarcity of skilled labor

(O3), Green technology level (O4). The highest priority stands for O4. Business organizations under consideration are lacking in technology need for smooth adoption of efficient GSC practices, and thus, facing various risks and uncertainties related to technology, the right knowledge, applicability and up gradation. Hence, to have an efficient GSCM concept, the organizations need to develop and upgrade green technology being used in their specific sectors (Mudgal et al., 2009; Toke et al., 2012). O2 comes second in this category, meaning that imprecision or flaws in designing of green process methodology in the selected organizations. Additionally, an effective and precise designing of green operations, process and methods in green manufacturing, green labelling, green packaging, are essential in managing the disruptions at operational level in GSC (Lai et al., 2010). Thus, managers should take this issue at higher priority level. While, O3 holds third place in this category, i.e., the organizations are also facing the risks related to workforce knowledge and proficiency regarding green, and, finding difficulties in adopting the efficient GSC initiatives accordingly. Therefore, managers must support and arrange training programs for their employees to build their competency regarding adoption of GSC initiatives (Muduli et al., 2013). Next, in this category is O1, which suggests that the organizations under consideration are exposed to disruptions due to the failure of any machine, equipment or facility at the shop floor in implementing GSC initiatives.

Financial risk category (F) comes second in the priority list, and plays a crucial role in adopting an efficient GSCM concept. It suggests that the various associated activities in implementation of GSC initiatives have a tendency to influence cash flow and payments, which can affect organizational financial concerns accordingly (Yang and Li, 2010). Therefore, managers need to put directed efforts to manage and reduce the consequences of financial risks and its related concerns in GSC. This category has three specific risks. Financial restrictions (F3) risk occupies the highest importance. This implies that the organizations under consideration are facing the risks related to financial restrictions and checks in adopting GSC practices in their business. While, the other two risks in this category, i.e., Sourcing of funds (F1) and Inflation and currency exchange rates (F2) risks have occupied second and third priority respectively. It means that financial sources are important concerns in building efficient green initiatives (Orsato, 2006; Mudgal et al., 2009). In view of this, for managing GSC financial risks, managers may develop different strategies, for instance, establishment of financial resources and capabilities and the development of contingency plans (Luthra et al., 2011; Qianlei, 2012).

Supply risk category (S) occupies third place in the priority list. Supplying appropriate environmental friendly material (green raw material or recycled material) for producing green finished product is an important function of GSC (Toke et al., 2012), as any disruption in supply can cause a reduction in organizational ecological-economic advantages (Qianlei, 2012). It depicts that suppliers have an important role in increasing the GSC effectiveness (Lippmann, 1999). Hence, managers should carefully consider the risks related to the suppliers. In this category, Green raw-material supply disruptions (S4) hold the highest priority. It means that the disruption of green raw material is typically frequent in business of organizations under consideration. For this reason, it is suggested to managers that they should interact with suppliers, and organizational-supplier environmental collaboration can be established to smoothen the green material supply (Diabat and Govindan, 2011). However, organizations under consideration are also lacking in quality of green material supplied by suppliers, as S3 comes next to S4. Losses due to failure of or poor quality at supplier's end will definitely affect the GSC performance (Wang et al., 2012). A key supplier failure (S2) is the next risk in this category. It shows that organizations under consideration are also exposed to the losses due to the failure of the key suppliers. There could be, however, several of the reasons behind the failure of suppliers such as natural disaster, supplier bankruptcy, etc (Waters, 2007). Thus, in this situation, to manage and reduce its consequences, the organizations' managers can prefer the strategy of multiple supplier policy in their business. Procurement costs risks (S1) is prioritized next to S2. Supplier commitment in supplying the eco-friendly material is important in enhancing the GSC performance (Toke et al., 2012). However, due to some economic concerns like green material procurement and purchasing costing issues, it may be difficult for suppliers to maintain their environmental commitment. To deal with this, managers should interact with suppliers to make them understand the benefits of being green and the organizations may initiate some policies and motivational programs, and reward systems to enhance the supplier's ecological commitment (Hall, 2001). It will be helpful in managing the uncertainties related to procurement and purchasing cost risks in GSC.

Product recovery risk category (PR) acquired the fourth importance level. Recovering the value of products is not simple in GSC due to involvement of different risk factors (Mangla et al., 2013). Thereby, managers are suggested to look the uncertainties associated with recovery of used (collected) products in improving the GSC efficiency. There are four specific risks in this category. Among them, Inventory and capacity design risks at reprocessing centres (PR4) got the highest priority. Thus, managers should consider the reprocessing centre inventory and capacity designs risks, logically and considerably. The Take-back obligations risks (PR3) is ranked next to PR4. It illustrates that organizations under consideration are lacking in the responsibilities for the waste collection, resulting out of their products once they are scrapped. The Reverse logistics network design risks (PR1) comes next in the priority list. It consists of the returned product network route and size, location and type of collection centre, etc. Organizations may develop and practice better reverse logistics designs to ease the product recovery risks associated with GSC. It will be useful in increasing the effectiveness of GSC (Mangla et al., 2013). Finally, the Gate keeping design risks (PR2) is last in the list. It represents that the organizations are facing several disturbing events at collecting centres in screening, inspection and sorting of collected products for reuse or recycle.

Governmental and Organizational related risk category (GO) occupies the second last place in the priority list. Various risks such as failed or poor governmental policies and directions in terms of governmental environmental support level, together with the uncertainties in the behaviour of different links related to organizational GSC through expert's inputs were included in this category. The Management policy failure (GO1) is at the top ranking. Involvement, support and commitment at managerial level are very important in adopting the GSC initiatives (Mudgal et al., 2009; Diabat and Govindan, 2011). Lack in enterprise strategic goals (GO4) risk comes next in this category. It indicates that organizations under consideration are lacking in terms of GSCM strategic objectives and planning in business. Under this consideration, it would be difficult to adopt and implement efficient GSC initiatives. Hence, it needs a great managerial concern. Next, in the priority list, in this category, is the Government policy risks (GO2). Being as a reference to this, organizations are also facing the uncertainties related to governmental support and policies in adopting an effective GSCM concept. Governmental support in implementing GSC practices is significant at business perspective (Massoud et al., 2010). Thus, the establishment of well-defined and environmental supportive governmental directions would be significant for organizations in reducing the convolution of the risks related to effective GSCM adoption. Next, specific risk in this category is Information asymmetry risk across GSC members in hierarchy (GO3). Lack of an effective information system network can delay different GSC activities, and results in declined efficiency (AlKhidir and Zailani, 2009). Therefore, managers need to design the information network carefully. A legal risk (GO5) is prioritized next to GO3. Organizations under consideration are also lacking in decisions based on legal actions, or certainty in the applicability or interpretation of contracts, laws, or regulations in adoption of GSC initiatives. It needs to be managed to increase the GSC efficiency (Qianlei, 2012). Finally, Partnership risks (GO6) comes at last. Disputes between partners and the members of the supply chain may also disturb organizations under consideration in efficient GSCM adoption and implementation.

Demand risk category (D) holds the last place in priority list. In the pull-based strategy of the supply chain, demand recognizes the production (Waters, 2007). Hence, a too small or large demand of green products will affect the business accordingly. To maximize GSC ecological-economic gains, it is crucial to have green product demand in the market. This category contains four specific risks. The competing risk (D4) is ranked first. It indicates that the business organizations under consideration are under tremendous risks due to huge competition in the market. Thus, competitors approach and strategy regarding GSC initiatives would affect the green product demand. The Bullwhip effect risks (D1) comes next in this category. It represents the level of green demand information distortion within the GSC (Yang and Li, 2010). It makes difficult for the organizational GSC to estimate the green product demand, and results in decreased performance. Therefore, managers should develop some improved measures for accurate demand forecasting. In addition, it needs to strengthen the information network system, and managers should ensure an effective sharing of information relevant to green product demand for managing the demand distortion risks in GSC. The next risk, i.e. Key customer failures (D3) indicates that the organizations GSC effectiveness may be decreased significantly due to failure of any key customer. The customers have been recognized as an important variable or factor in implementing the successful GSCM initiatives (Diabat and Govindan, 2011; Toke et al., 2012; Muduli et al., 2013). Therefore, customer reliability and their awareness about green are important in managing the green product demand related risks in the context of GSC. Last, in the priority list is Market dynamics (D2). Market dynamics are the result of collective market resources and preferences. For this reason, market dynamics have a significant effect on green product demand and affect the GSC efficiency in turn.

4.8 Sensitivity Analysis

Among all categories of risks, the operational risk category receives the highest priority weight. Therefore, it is capable enough to influence the other categories of risk. Based on the study of Chang et al. (2007) suggested that small changes in relative weights would give large changes in the final ranking. As, human judgment input is utilized to calculate the weights for the listed categories of risks and specific risks, thereby, it is recommended to test the final ranking by varying the weights of all the categories of risks (Govindan et al., 2014). The sensitivity analysis thus may provide a further insight to the causes of risks in adoption and effective implementation of GSC initiatives. To illustrate the sensitivity analysis the effect of an incremental change in value from 0.1 to 0.9, to the operational category risk (O), was determined as shown in Table 4.12. The results of the sensitivity analysis indicate that the maximum relative change happened in the Product recovery risk category (refer Table 4.12). Further, due to variation in risk category weights, the specific risk weights and their final ranking also varied. In sensitivity analysis, when operational category risk value is 0.1, the first rank is acquired by F3, while, D2 holds the last rank. Risk F3 holds the first rank until the operational category risk value reaches to the normal value (0.2507). From 0.3 to 0.9, the first rank is acquired by O4, and the ranks of other risks vary in the same manner (for details refer Table 4.13). Ranking or priority for specific risks based on sensitivity analysis is illustrated in Figure 4.7. It can infer that, priority (rank) of the specific risks varies with respect to the change in operational category risk. At this stance, it may be concluded that operational category risk is very important in adopting an effective and robust GSC concept, and so, needs greater managerial concentration. If the managers are able to reduce and or manage the operational risks and its related concerns in implementing the GSCM concept, it will be quite useful in managing and reducing the consequences of the other risks relevant to GSCM adoption, which may further lead to gain in economic-ecological performance of the organizations.

Table 4.12 Risk Category Values When Increasing Operational Category Risk

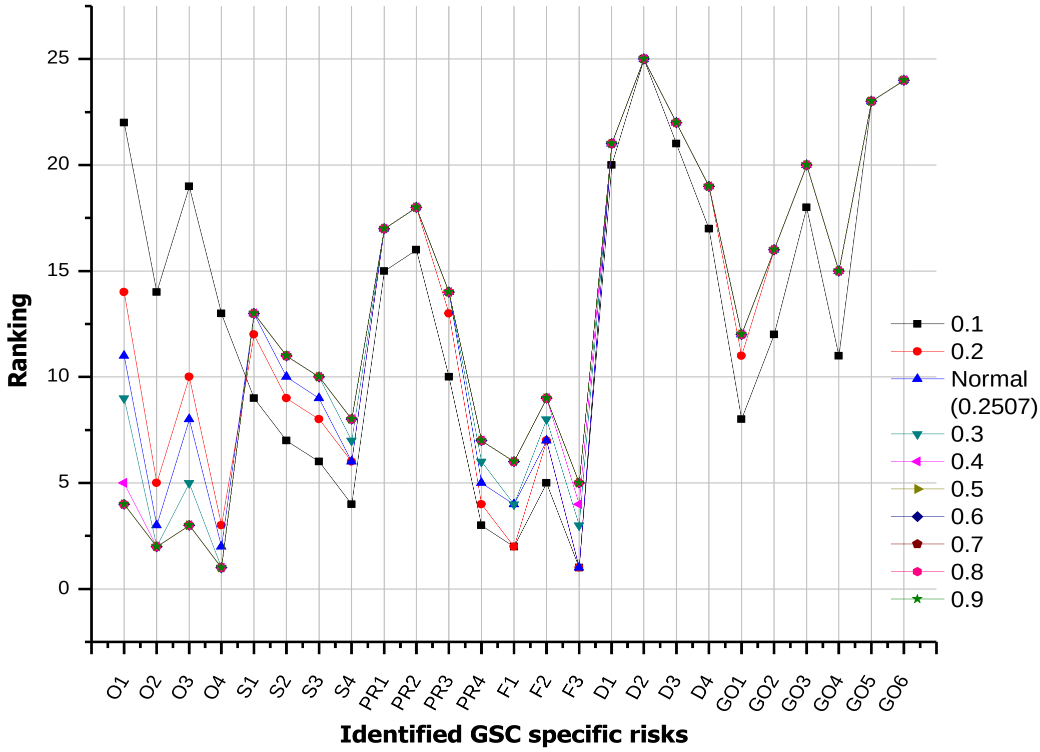
Listed risk category	**Values of preference weights for listed risk category**								
O	**0.2507**	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
S	**0.1863**	0.2237	0.1989	0.1740	0.1492	0.1243	0.0995	0.0746	0.0497	0.0249
PR	**0.1449**	0.1740	0.1547	0.1354	0.1160	0.0967	0.0774	0.0580	0.0387	0.0193
F	**0.2236**	0.2685	0.2387	0.2089	0.1790	0.1492	0.1194	0.0895	0.0597	0.0298
D	**0.0607**	0.0729	0.0648	0.0567	0.0486	0.0405	0.0324	0.0243	0.0162	0.0081
GO	**0.1338**	0.1607	0.1428	0.1250	0.1071	0.0893	0.0714	0.0536	0.0357	0.0179
Total	**1**	1	1	1	1	1	1	1	1	1

Note: O – Operational risks; S - Supply risks; PR - Product recovery risks; F - Financial risks; D - Demand risks; GO - Governmental and Organizational related risks.

Table 4.13 Ranking for Specific Risks by Sensitivity Analysis When Operational Risk Changes from 0.1 to 0.9

Listed specific risk	Operational risk category values in performing the sensitivity analysis test									
	0.1	**0.2**	**Normal (0.2507)**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
O1	22	14	11	9	5	4	4	4	4	4
O2	14	5	3	2	2	2	2	2	2	2
O3	19	10	8	5	3	3	3	3	3	3
O4	13	3	2	1	1	1	1	1	1	1
S1	9	12	13	13	13	13	13	13	13	13
S2	7	9	10	11	11	11	11	11	11	11
S3	6	8	9	10	10	10	10	10	10	10
S4	4	6	6	7	8	8	8	8	8	8
PR1	15	17	17	17	17	17	17	17	17	17
PR2	16	18	18	18	18	18	18	18	18	18
PR3	10	13	14	14	14	14	14	14	14	14
PR4	3	4	5	6	7	7	7	7	7	7
F1	2	2	4	4	6	6	6	6	6	6
F2	5	7	7	8	9	9	9	9	9	9
F3	1	1	1	3	4	5	5	5	5	5
D1	20	21	21	21	21	21	21	21	21	21
D2	25	25	25	25	25	25	25	25	25	25
D3	21	22	22	22	22	22	22	22	22	22
D4	17	19	19	19	19	19	19	19	19	19
GO1	8	11	12	12	12	12	12	12	12	12
GO2	12	16	16	16	16	16	16	16	16	16
GO3	18	20	20	20	20	20	20	20	20	20
GO4	11	15	15	15	15	15	15	15	15	15
GO5	23	23	23	23	23	23	23	23	23	23
GO6	24	24	24	24	24	24	24	24	24	24

Note: O1, O2, O3.....GO4, GO5, GO6 are the GSC risks identified in the study.



O1, O2, O3.....GO4, GO5, GO6 are the GSC risks identified in the study

Figure 4.7 Ranking for Specific Risks When Increasing Operational Risk Category Value via Sensitivity Analysis

4.9 Conclusions

Today, organizations need a methodology to evaluate the risks and to build the logical planning to configure GSCM business systems efficiently. This study proposes a flexible structural operational model for risks evaluation in GSC using fuzzy AHP and IRP methodologies. The fuzzy AHP is useful in prioritizing or ranking risk in GSC under fuzzy environment. While, to test the ranking obtained through the fuzzy AHP method, the methodology of IRP is applied. The methodology of IRP also facilitates the managers and planners to understand the interpretive logic for dominance of one risk over the other for each pair wise comparison, which otherwise, remains opaque to the user/implementer as if using the AHP method.

The proposed fuzzy AHP and IRP based flexible, evaluation model is analyzed in Indian plastic sector. Based on literature and in consultation with experts, six categories of risks and twenty five risk specific risks has been identified, which were further analyzed to determine their relative concern.

The priority wise concern for the identified six categories of risks is given as, O-F-S-PR-GO-D, i.e., operational category risks are the most important and need a greater managerial concern as compared to other categories of risks in enhancing the GSC robustness and ecological-economic benefits. The priorities for specific risks were also derived. Finally, sensitivity analysis was conducted to examine the stability of priority ranking for the identified category of risks and specific risks.

The model proposed would provide an opportunity to the managers and practitioners to manage risks in GSC and certainly, the findings of this study would be significant for enhancing the overall economic-ecological performance.

CHAPTER 5

ASSESSMENT OF THE CONSEQUENCES OF RISKS IN GSC

There may be significant losses in performance because of the occurrence of the risks in GSC. If the risk not assessed and managed accurately, it may even results in a huge loss in business. Managers and practitioners need to act timely to assess and manage the GSC risks to improve the ecological-economic performance. In this chapter, an attempt is made to access the risks linked to GSC. The effect has not only been made to capture the uncertainty, but also to analyze the risks. The analysis has been done by Monte Carlo simulation (MCS) approach, which helps in revealing of the impacts of risk.

5.1 Introduction

In supply chain management, risk is all about 'disturbance and disruption' in various activities of supply chain and that results to some undesired happenings or consequences (Harland et al., 2003). Looking for more objective and quantitative definition, risk is given in the form of loss, which can be expressed in terms of relationship of probability of that loss and significance of that loss to the individual or to the organization/system. Thus, for an event (i) - $\mathrm{Risk_i = P\,(Loss)_i \times I\,(Loss)_i}$, where, Risk is the function of probability (P) of the loss occurred and the significance of its consequences (I).

The objective of this chapter is to access the potential consequences of risks in GSC. For accessing the GSC identified risks such as Operational, Supply, Product recovery, Financial, Demand, and Governmental and Organizational related, initially, the uncertainties related to the risks are explored. Later, it is followed by a risk evaluation procedure to access the disruption impacts of these risks using MCS approach. This methodical approach helps in understanding of the probable risks and consequences to emerge in GSC.

Part of this chapter has been published/accepted for publication in

- *Procedia Engineering 97, 2186-2194*
- *NITIE POMS International Conference, Mumbai. Dec 18-21, NITIE, Mumbai, India, pp. 177-182*
- *XVIII Annual International Conference of the Society of Operations Management (SOM) 2014*

5.2 Proposed Framework

To achieve the above stated objective, a framework is proposed as shown in Figure 5.1. The risks were analyzed in terms of their effects on the green supply chain. The framework consists of three steps. In the first step, the various risks related to GSC were identified. In the second step, the identified risks were assessed using expert’s inputs. In the third step, MCS approach is used to analyze the impacts of the risk measured in terms of time delay and disturbance. It will be useful to draw a more in-depth understanding on the probable consequences.

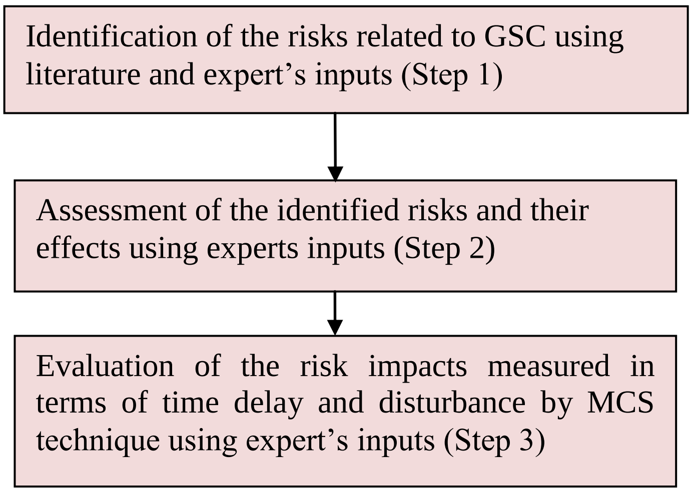


Figure 5.1 Proposed Framework

5.3 An Application of the Proposed Framework

The proposed framework was applied to a real world problem. The details of applying of the proposed framework based on three steps mentioned above, and with respect to the business organizations under consideration are illustrated as follows:

5.3.1 Identification of the risks related to GSC

Based on literature and expert’s inputs, a total of six categories of risks and twenty five specific risks in GSC were identified (refer Chapter 4). The identified risks were further evaluated to know their effects on the green supply chain.

5.3.2 Assessment of the identified risks and their consequences

There are several forms of risks in SC. Risk may be operational and occur frequently, but considered minor due to its reduced negative consequences. It is due to the reason the particular risk may cause disturbances in SC, but not serious ones. However, if the risks occur all together, it may have then some serious consequences. The risk may be disruptive and denoted by low probability and high consequence events. These types of events have an ability to disrupt the flow of material and products at any time (Tang, 2006). After identifying the risks, an evaluation procedure is conducted to access their effects with regard to the GSCs under consideration. The opinion of the experts participated in the decision making team were important to access the risk impacts. Therefore, first of all, on discussion with the experts, the probability of occurrence of the identified risks (Operational, Supply, Product recovery, Financial, Demand, and Governmental and Organizational related) and their possible impacts were estimated. Thus, a nine point scale that analyzes the probability of occurrence of the risks and their impacts is designed (for scale refers Table 5.1). The basis of designing of this scale was the study of Vilko and Hallikas, (2012) and inputs received from the experts. According to the scale, 3 denote low probability of occurrence or low impact and 9 denotes a very high probability of occurrence or high impact.

Table 5.1 Linguistic Scale Used for Data Collection

Linguistic scale	**Description**	**Corresponding probability value**
1	No/minor	.0001
3	Low	.0045
5	moderate	.0025
9	High	.01

Source: modified (Vilko and Hallikas, 2012)

The risk effects were classified into five dimensions - Time, Brand image, Economic, Health and Safety, and Quality. Time-based effects are generally measured in terms of delay and disruption. It mainly denotes the delay and disruption in the flow of material/products in green supply chain. It is noted that managers of business organizations under consideration uses a combination of words i.e. ‘delay and or disturbance’ and ‘disruption’ to know the time based effects of risk. Thus, in this work, the time-based effects were measured in terms of delay/disturbance and disruption. The disruption was acknowledged as a breakdown in GSC. It represents that the material and products do not reach to the final customer by the time. From the perspective of delay and disturbance, it may have significantly different consequences in different stages of SC. In this work, for example, the GSCs under consideration could be delayed or disturbed for several days or even a week without severe consequences. But if a vehicle which is used a mean of transportation is late by 1 hour at its time window, the downstream SC may be affected seriously. The delay/disturbance impacts of the risks has been modelled in the terms of triangular distributions indicating the lowest, the most likely and the highest impact (Vilko and Hallikas, 2012). While the Brand image effects on the organizations' GSC under consideration result from the damage to their market value. From the perspective of economic based effects, SC disruptions may have long-term negative effects on an organization's financial performance (Tang, 2006). The economic effects on the organizations' GSC under consideration are represented through finance attributable to the risks and costs associated with their management. The Health and Safety based effects concerns with the harm and or damage to human resources caused by the GSC risks. At the end, quality based effects are represented as damage to the quality of products/materials in GSC.

The probability of occurrence of the operational risks and their effects were assessed as given in Table 5.2. The expert's response with respect to the GSC operational risks and their impacts were obtained for this. Finally, a risk score (RS), as shown in the last column of the table is calculated. It was calculated by multiplying the sum product of the probability of the occurrence by the risk impacts measures. For example, the probability of the occurrence of risk O4 (Green technology level) is 9 (moderate) and the sum of its risk impact measures is 16, thus, the corresponding risk score is computed as 144. In assessing the GSC operational risk impacts, the Green technology level inadequacy (O4) risk has got the highest risk score, and thus, obtains the highest ranking. The ranking order of the remaining risks through the value of RS is given as O2 – O3 – O1. Their respective RS values are 70, 66, and 50 (for details refer Table 5.2). Further, amongst all dimensions of risk based effects, the time based dimension is the maximum one to be affected. It causes the regular delay and disruption in the flow of green material and products. Also, in time based dimension, time delay/disturbance is the most serious impact of GSC operational risks. By virtue of which, green material and products do not reach to the final customer on time. Further, economic dimension is the next one to follow after time based dimension. Disruption, brand image and quality based dimension are equally affected. It represents that the operational risks cause equal damage to the green material and products smooth flow, organizational market value, and to the quality of green product/material. Health and safety dimension comes next. It means that the operational risks cause less damage to the human resources while implementing green initiatives in the SC scenario.

Table 5.2 Operational Risks and Their Effects

Description of operational risks	**Probability of occurrence of operational risks**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	costs	Harm/damage	Unfavorable/ poor	
Machine, equipment or facility failure (O1)	5	3	1	1	3	1	1	50
Design risks (O2)	5	3	3	1	5	1	1	70
Scarcity of skilled labor (O3)	3	9	3	3	3	1	3	66
Green technology level (O4)	9	3	1	3	5	1	3	144

Note: O1, O2, O3, O4 are the GSC operational risks identified in this study.

Based on the value of RS, the ranking order of supply risks in terms of their impacts is given as S3 – S2 – S4 – S1. It shows that the Supplier quality issues (S3) plays a key role in improving the GSC success rate. Further, time based dimension is the highly affected dimension compared to other dimensions of risk effects. Time delay/disturbance is the most significant impact of GSC supply risks. It suggests that, there is frequent delay in supplying of green raw material and products with regard to the GSCs under consideration. Economic based dimension is the next one to follow as shown in Table 5.3. It means that supply risks affects financial decisions in adopting GSC initiatives significantly. Due to occurrence of supply risks, a huge loss may be observed among organizations under consideration in their market share. Brand image dimension come next to economic dimension. Disruption, quality, and health and safety follow the brand image dimension. Hence, a significant managerial attention is needed to manage these impacts of risks in GSC.

Table 5.3 Supply Risks and Their Effects

Description of supply risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	costs	Harm/damage	Unfavorable /poor	
Procurement costs risks (S1)	1	1	1	1	3	1	1	8
Key supplier failures (S2)	3	9	5	5	5	1	3	84
Supplier quality issues (S3)	5	5	3	5	3	3	3	110
Green raw-material supply disruptions (S4)	3	3	3	3	5	1	1	48

Note: S1, S2, S3, S4 are the GSC supply risks identified in this study.

Using the value of risk score, the impacts of product recovery risks were estimated. The ranking order of product recovery risks in terms of their impacts is given as PR4 – PR3 – PR2 – PR1 as shown in Table 5.4. It indicates that Inventory and capacity design risks at reprocessing centers (PR4) highly affects the GSC business initiatives. The maximum impact was shown on time based dimension with regard to the impacts of product recovery risks. It illustrates that time delay/disturbance is the most significant impact of GSC product recovery risks. Product recovery risks have a tendency to disrupt the functioning of the GSCs under consideration, as time disruption, economic and brand image dimension comes next to time delay/disturbance. The product recovery risks emerges several financial issues in GSCM adoption and implementation. Among various financial issues it may include inventory managing related decisions, capacity planning, etc. The product recovery risks have significant influence on Brand image dimension. Therefore, occurrence of product recovery risks may result in damage to the organizational market share and value. Finally, Quality, and Health and safety, follow the disruption, financial, and brand image dimension of risk based effects.

Table 5.4 Product Recovery Risks and Their Effects

Description of product recovery risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	costs	Harm	Unfavorable/ poor	
Gate keeping design failures (PR1)	1	1	3	1	3	1	3	12
Reverse logistics design risks (PR2)	3	9	5	5	5	1	3	84
Take-back obligations risks (PR3)	5	5	3	5	3	1	3	100
Inventory and capacity design risks at reprocessing centers (PR4)	9	3	3	3	3	1	1	126

Note: PR1, PR2, PR3, PR4 are the GSC product recovery risks identified in this study.

The ranking order of financial risks in terms of their impact is given as F3 – F2 – F1. This ranking was decided on the basis of risk score as given in Table 5.5. According to the table, financial restriction (F3) risks are crucial in adopting and implementing of GSC business initiatives. Manager's needs to check the issues related to financial restrictions and controls in adopting GSC initiatives. With regard to the effects of financial risks, the maximum impact was seen on time based dimension. It illustrates that time delay/disturbance is the most significant impact of GSC financial risks. Economic and brand image are equally affected dimensions of risk based effects. It means that financial irregularities in implementation of GSC initiatives not only influence the organizational economic decisions and cash flows, but also affects the market image from the organization's point of view. Disruption comes after the economic and brand image dimension. It means that the financial problematic situations and issues have a tendency to disrupt the adoption of GSC initiatives, and thus, results in a huge loss in business. Quality, and Health and safety come next to disruption dimension. Therefore, it is important for managers to manage the issues related to quality of products and human resources development for effective GSCM adoption.

Table 5.5 Financial Risks and Their Effects

Description of financial risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	costs	Harm/damage	Unfavorable/ poor	
Sourcing of funds (F1)	1	1	1	1	3	1	1	8
Inflation and currency exchange rates (F2)	3	9	5	5	5	1	3	84
Financial restriction (F3)	5	5	3	5	3	3	3	110

Note: F1, F2, F3, are the GSC financial risks identified in this study.

Based on the value of risk score, the ranking order of demand risks in terms of their impact is given as D4 – D1 – D2 – D3. It means that Competing risks (D4) play a key role in improving the GSC effectiveness. In today's era of competition and globalization, competitors approach and strategy regarding GSC initiatives have a significant effect on green product demand and affects the performance of an organizational GSC in turn. Taking into account the impacts of demand risks, time based dimension is highly affected as shown in Table 5.6. Further, time delay/disturbance is the most significant impact of GSC demand risks. Brand image and economic dimensions are equally affected and come next to time delay/disturbance. It means that managing the demand risks and its driving factors are crucial from the organization's point of view, as it not only affects their market value, but also affects the financial decisions. Time disruption is the next to Brand image and economic dimensions. It has been stated that demand estimates the production in the pull-based system of the supply chain (Waters, 2007). Thus, an inaccurate estimation and forecasting of green product demand may distort the functioning of an organizational GSC. Quality, and Health and safety come next to Time disruption. Hence, it is important for managers to manage these impacts of risks in GSC.

Table 5.6 Demand Risks and Their Effects

Description of demand risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	Costs	Harm	Unfavorable/poor	
Bullwhip effect risks (D1)	5	9	3	5	5	1	3	130
Market dynamics (D2)	3	3	1	3	3	1	1	36
Key customer failures (D3)	1	3	9	5	3	1	1	22
Competing risks (D4)	9	5	1	3	5	3	3	180

Note: D1, D2, D3, D4 are the GSC demand risks identified in this study.

Finally, the impacts of governmental and organizational related risks were estimated. The basis of estimating the impacts of this risk was the value of RS, which is given in Table 5.7. The ranking order of governmental and organizational related risks in terms of their impacts is given as GO1 – GO3 – GO4 – GO2 – GO5 – GO6. Management policy failures (GO1) risk has a crucial part in improving the GSC effectiveness. Involvement and commitment at managerial level are significant in adopting the GSC initiatives (Mudgal et al., 2009). Regarding the impacts of governmental and organizational related risks, the maximum impact was seen on time based dimension. It illustrates that time delay/disturbance is the most significant impact of GSC governmental and organizational related risks. Poor governmental regulations and policies in terms of governmental environmental support level, together with the uncertainties in the behaviour of different links related to organizational GSC have a tendency to disturb the flow of material/products in GSC. The economic dimension is next to the time delay/disturbance. It indicates that governmental and organizational related risks may emerge severe financial problems and costing issues in GSCM adoption and implementation. Quality based risk effects, is the next one to follow. Besides, disruption and brand image are equally affected dimensions of risks based effects. The occurrence of governmental and organizational related risks may stop working the functioning of an organizational GSC, and thus, result in decreased market share and value. Finally, Health and safety follows the time disruption and brand image dimensions of risk based effects. Therefore, a significant managerial attention is needed to reduce these impacts of risks in managing the GSC efficiently.

Table 5.7 Governmental and Organizational Related Risks and Their Effects

Description of governmental and organizational related risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**
		Delay/disturbance	Disruption	Damage	Costs	Harm/Damage	Unfavorable/ poor	
Management policy failures (GO1)	5	9	5	5	5	1	5	150
Government policy risks (GO2)	5	3	1	1	5	1	1	60
Information asymmetry risk across GSC members in hierarchy (GO3)	9	5	3	1	3	1	3	144
Lack in enterprise strategic goals (GO4)	5	3	3	3	5	1	3	90
Legal risks (GO5)	3	3	3	3	3	1	5	54
Partnership risks (GO6)	1	5	3	5	3	1	5	22

Note: GO1, GO2, GO3, GO4, GO5, GO6 are the GSC governmental and organizational related risks identified in this study.

Further, a simulation (MCS) based approach, was used, which evaluates the cumulative risk impact of delay and disturbance; other details are given in next sub-section.

5.3.3 Use of simulation approach: MCS application

To model the delay impact of the risks, the simulation approach is used (Vilko and Hallikas, 2012). Time measure is used to model risk probability and impact. Particularly, the variation in the distribution of possible outcomes, their likelihood, and their subjective values are examined. The benefit of using simulation is that it assists to recognize extreme risk scenarios (Nemuth, 2008), which is due to the reason that it can assign a choice of ratings to a particular factor or variable (e.g., min, average, and max). The triangular distribution is more commonly used in MCS. It generally provides the knowledge of the minimum and maximum and a "most likely" in relation to the value to be modelled. The triangle distribution is also termed a "lack of knowledge" distribution. The main benefit of using MCS compared to other methods is that it addresses the uncertainty related to that problem. To feed the inputs needed for MCS, the expert inputs were used.

Graphical version @Risk 6.0 illustrates the risk assessment with the help of MCS and computes the risks and uncertainties related to possible outcome. It also reveals many different possible future scenarios, and provides probabilities and risks associated with each different scenario. @Risk Student Version was used in this work. It is due to the following reasons: 1) Student version is freely available; 2) It is capable to accomplish the desired objective of this work. MCS assists in providing a comprehensive view of future in terms of what may happen. Also, it assists managers in terms of best decision making under uncertainty – either to take that or to avoid that one. In @ Risk 6.0 graphical version, the triangle distribution is written as RiskTriang.

In assessing the operational risks, initially, the probability measure for its specific risks with respect to its risk-probability measure was computed. The delay/disturbance impacts of each operational risk on GSC performance were measured by inputs received from the experts as shown in Table 5.8.

Table 5.8 Summary on Probability of GSC Operational Risks and its Impacts in Terms of Delay/disturbances

Description of operational risks	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		min	average	max
Machine, equipment or facility failure (O1)	0.0025	0.25	0.5	1
Design risks (O2)	0.0025	0	0.25	0.5
Scarcity of skilled labor (O3)	0.0045	1	2	5
Green technology level (O4)	0.01	1	3	7

Note: O1, O2, O3, O4 are the GSC operational risks identified in this study.

Later, the delay impacts (inputs) were sampled and modelled as probability distributions using input probability distributions. The triangular distribution is used as input probability distribution. MCS cluster of samples that are denoted by iteration was considered, and the resulting outcome is noted accordingly. In this work, single simulation and 20,000 iterations were used to analyze the uncertain conditions for the GSC operational risks, and the outcome (its probability distribution – triangular distribution) is shown in Figure 5.2. Multiplying the probability measures of the risk by the delay/disturbance distributions (impact) estimates the risk weights. Each risk probability is multiplied by the delay/disturbance impact and illustrated as a distribution. According to the MCS approach, the sum weight of all the risks provides the profile of the selected risk. The shown delay/disturbance profile of the risk impacts were analyzed at 95% confidence interval. It means that there is a probability that the resulting interval contains the population mean at 95% of the cases. As mentioned above, MCS enables not only in predicting the possibilities that could happen, but also in anticipating what is going to happen. The mean for the outcome, i.e. delay/disturbance profile of the GSC operational risk impacts comes out to be 0.0507. The minimum and maximum values for the delay/disturbance profile are given as 0.0180 and 0.0908. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0283 and 0.0774. The corresponding range for the delay/disturbance profile can be given as the difference between maximum and minimum values recorded during the analysis and is equal to 0.0491. The standard deviation comes out to be 0.0130. It gives an idea of how close the entire set of data is to the average value. Further, the variance for the process comes out to be positive and equals to 0.000169. Thus, it can be interpreted that, data taken is able to give an extreme scenario for assessing the GSC operational risk impacts measured in terms of time delay/disturbance along with the capturing of uncertainty related to that (refer Figure 5.2).

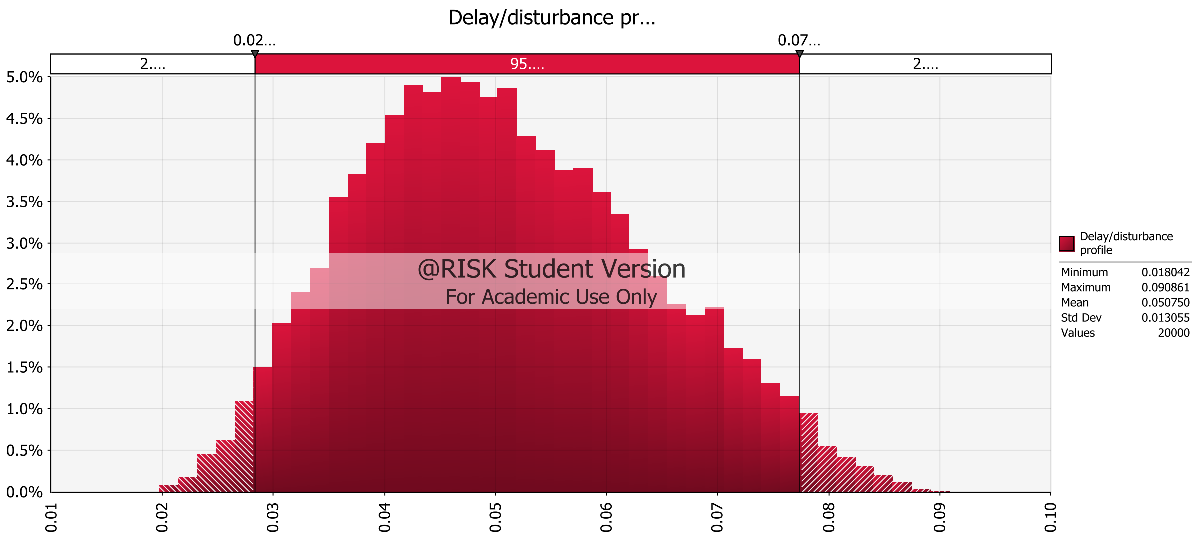


Figure 5.2 Simulation Results of GSC Operational Risk Impacts (Delay/disturbance Profile)

Following the procedure as mentioned above, the delay/disturbance impacts of each supply risk on GSC performance were measured as shown in Table 5.9.

Table 5.9 Summary on Probability of GSC Supply Risks and its Impacts Measured in Terms of Time Delay/disturbances

Description of supply risks	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		min	average	max
Procurement costs risks (S1)	0.0001	0	0.5	1
Key supplier failures (S2)	0.0045	1	4	7
Supplier quality issues (S3)	0.0025	1	40	90
Green raw-material supply disruptions (S4)	0.0045	0.25	0.5	1

Note: S1, S2, S3, S4 are the GSC supply risks identified in this study.

The uncertain conditions for the GSC supply risks, and the outcome (its probability distribution) was analyzed and is shown in Figure 5.3. The mean for the outcome, i.e. its delay/disturbance profile comes out to be 0.1298. The minimum and maximum values for the delay/disturbance profile are given as 0.0168 and 0.2540. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0455 and 0.2199 (refer Figure 5.3). The corresponding range for the delay/disturbance profile is given as 0.1744.

The standard deviation comes out to be 0.0459. The variance for the process comes out to be 0.002106.

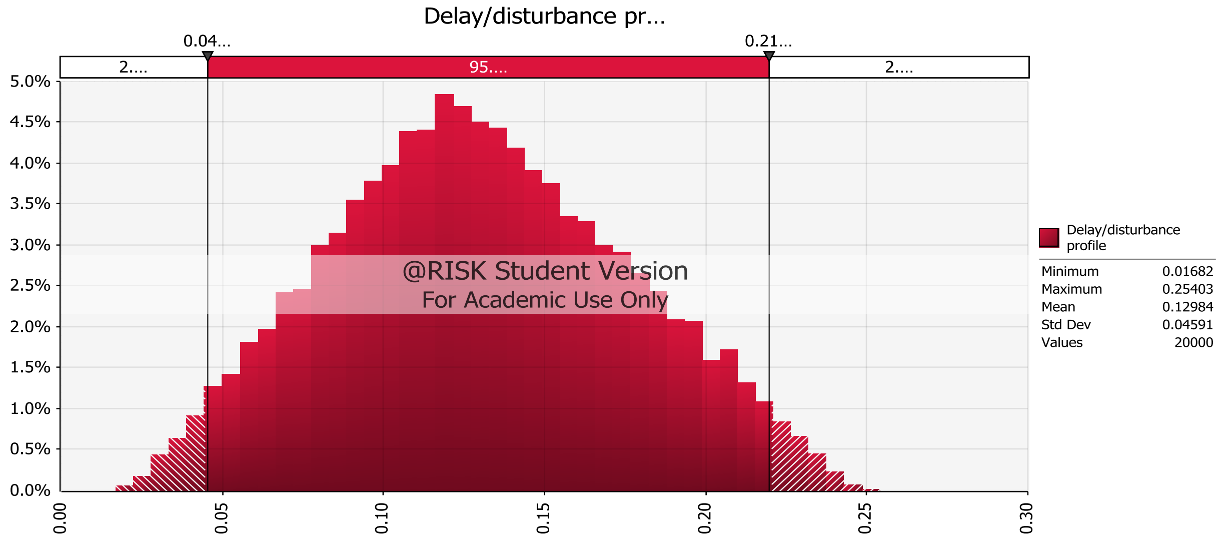


Figure 5.3 Simulation Results of GSC Supply Risk Impacts (Delay/disturbance Profile)

Similarly, the delay/disturbance impacts of each product recovery risk on GSC performance were measured as shown in Table 5.10.

Table 5.10 Summary on Probability of GSC Product Recovery Risks and its Impacts Measured in Terms of Time Delay/disturbances

Description of product recovery risks	Probability of occurrence	Delay/disturbance in terms of time (days)		
		min	average	max
Gate keeping design failures (PR1)	0.0001	1	2	3
Reverse logistics design risks (PR2)	0.0045	1	5	10
Take-back obligations risks (PR3)	0.0025	1	10	20
Inventory and capacity design risks at reprocessing centers (PR4)	0.01	1	3	7

Note: PR1, PR2, PR3, PR4 are the GSC product recovery risks identified in this study.

The uncertain conditions for the GSC product recovery risks and the outcome (its probability distribution) are analyzed as given in Figure 5.4. The mean for the outcome, i.e. its delay/disturbance profile comes out to be 0.0867. The minimum and maximum values for the delay/disturbance profile are given as 0.0310 and 0.1522. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0536 and 0.1226.

The corresponding range for the delay/disturbance profile is equal to 0.0690. The standard deviation comes out to be 0.0178. The variance for the process comes out to be 0.000317.

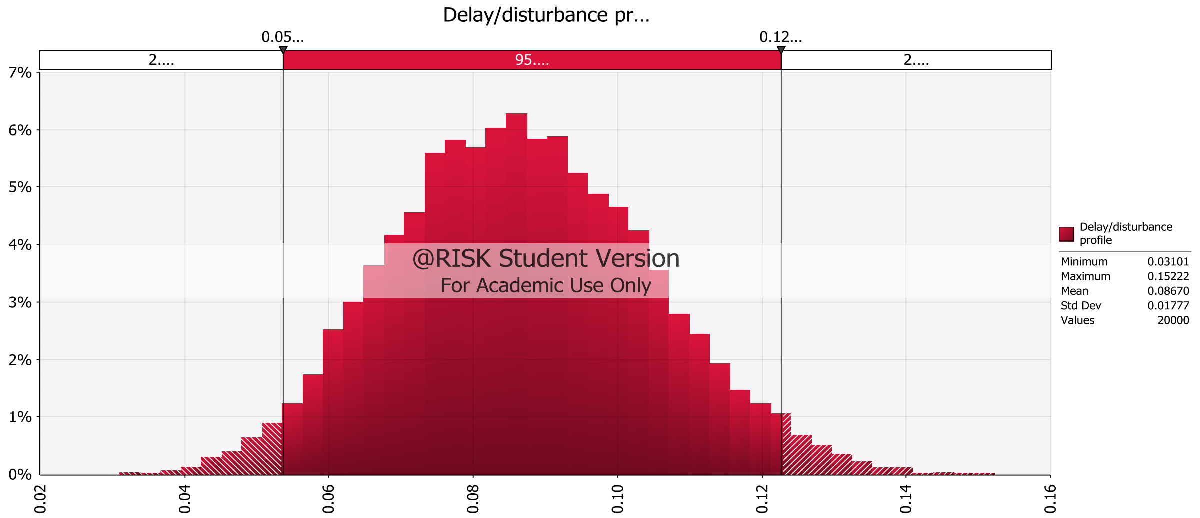


Figure 5.4 Simulation Results of GSC Product Recovery Risk Impacts (Delay/disturbance Profile)

Further, the delay/disturbance impacts of each financial risk on GSC performance were measured as shown in Table 5.11.

Table 5.11 Summary on Probability of GSC Financial Risks and its Impacts Measured in Terms of Delay/disturbances

Description	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		min	average	max
Sourcing of funds (F1)	0.0045	1	5	10
Inflation and currency exchange rates (F2)	0.0025	1	3	7
Financial restriction (F3)	0.01	1	15	30

Note: F1, F2, F3, are the GSC financial risks identified in this study.

In case of GSC financial risks, the mean for the outcome, i.e. its delay/disturbance profile comes out to be 0.1865. The minimum and maximum values for the delay/disturbance profile are given as 0.0322 and 0.3430. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0733 and 0.3016. The corresponding range for the delay/disturbance profile is equal to 0.2283 as given in Figure 5.5. The standard deviation comes out to be 0.06. Further, the variance for the process comes out to be 0.0036.

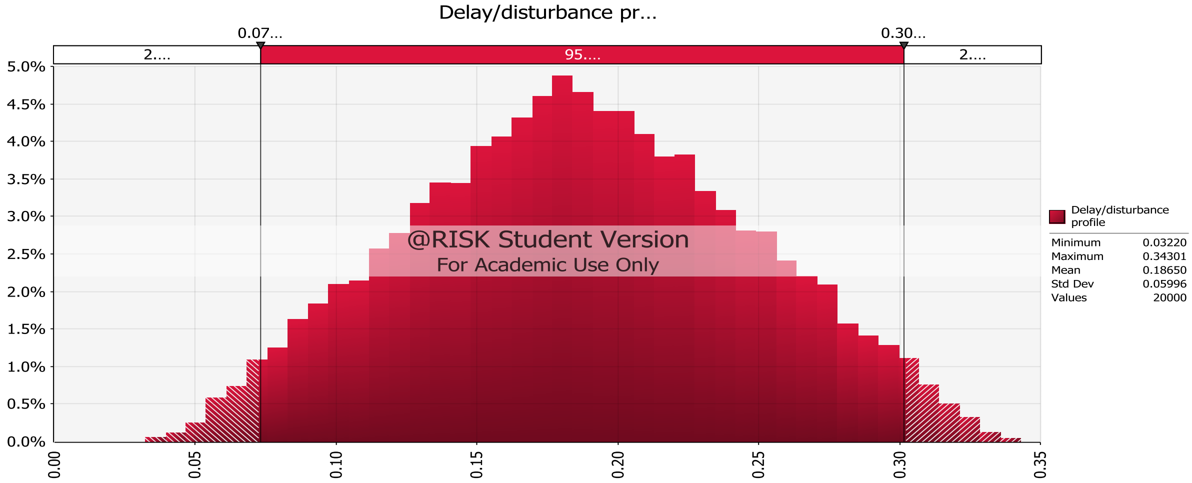


Figure 5.5 Simulation Results of GSC Financial Risk Consequences (Delay/disturbance Profile)

Furthermore, the delay/disturbance impacts of each demand risk on GSC performance were measured as shown in Table 5.12.

Table 5.12 Summary on Probability of GSC Demand Risks and its Impacts Measured in Terms of Delay/disturbances

Description	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		min	average	max
Bullwhip effect risks (D1)	0.0025	1	40	90
Market dynamics (D2)	0.0045	1	4	7
Key customer failures (D3)	0.0001	0	0	1
Competing risks (D4)	0.01	1	3	7

Note: D1, D2, D3, D4 are the GSC demand risks identified in this study.

The mean for the outcome, i.e. GSC demand risks impacts delay/disturbance profile comes out to be 0.1639. The minimum and maximum values for the delay/disturbance profile are given as 0.0366 and 0.3050. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0770 and 0.2565. The corresponding range for the delay/disturbance profile is equal to 0.1795. The standard deviation comes out to be 0.0475 (for details refer Figure 5.6). The variance for the process comes out to be 0.00226.

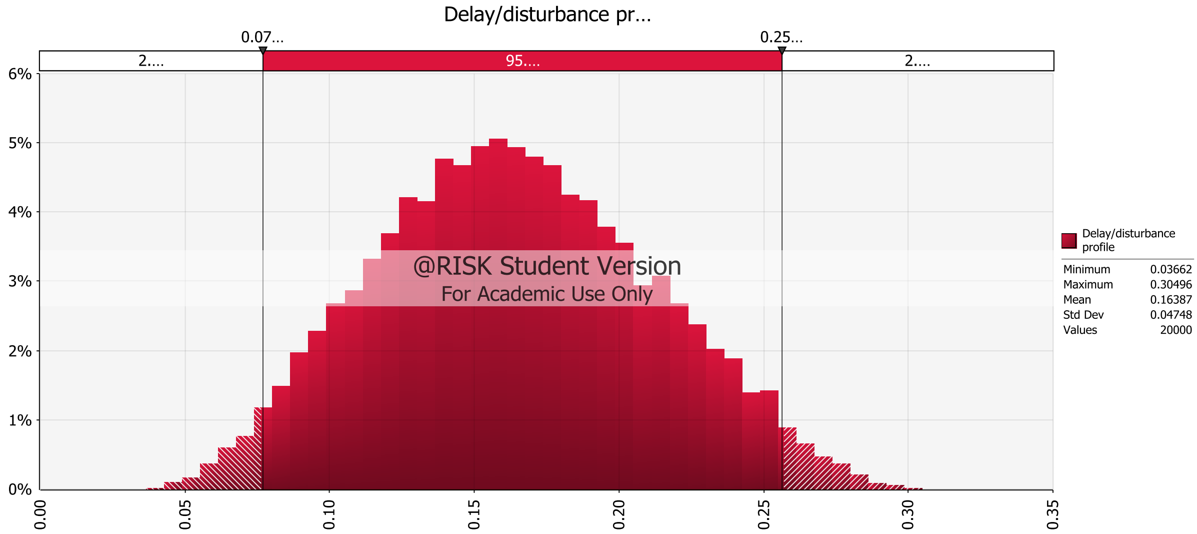


Figure 5.6 Simulation Results of GSC Demand Risk Impacts (Delay/disturbance Profile)

Finally, the delay/disturbance consequence of each Governmental and Organizational related risk on GSC performance were measured as shown in Table 5.13.

Table 5.13 Summary on Probability of GSC Governmental and Organizational Related Risks and its Impacts Measured in Terms of Delay/disturbances

Description	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		min	average	max
Management policy failures (GO1)	0.0025	1	5	10
Government policy risks (GO2)	0.0025	0.5	1	2
Information asymmetry risk across GSC members in hierarchy (GO3)	0.01	1	2	5
Lack in enterprise strategic goals (GO4)	0.0025	1	3	7
Legal risks (GO5)	0.0045	0	0.25	0.5
Partnership risks (GO6)	0.0001	0	0.5	1

Note: GO1, GO2, GO3, GO4, GO5, GO6 are the GSC governmental and organizational related risks identified in this study.

In case of GSC Governmental and Organizational related risks, the mean for the outcome, i.e. its delay/disturbance profile comes out to be 0.0745. The minimum and maximum values for the delay/disturbance profile are given as 0.0244 and 0.1324. For 95% confidence interval, the minimum and maximum values for delay/disturbance profile are given as 0.0397 and 0.1115 (refer Figure 5.7). The corresponding range for the delay/disturbance profile is equal to 0.0718. Further, the variance for the process comes out to be positive and equals to 0.00035.

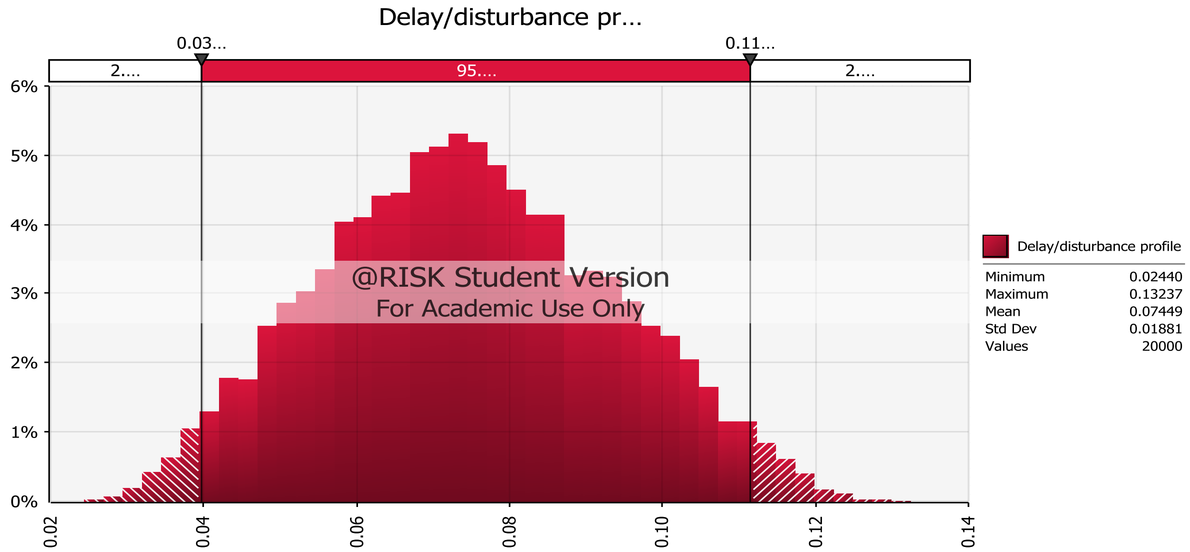


Figure 5.7 Simulation Results of GSC Governmental and Organizational Related Risk Impacts (Delay/disturbance Profile)

A detailed summary report of simulation results of risks identified in this work such as operational, supply, product recovery, financial, demand, and governmental and organizational related, is illustrated in Appendix D. The summary report contains the stressed inputs, and the corresponding statistics of the monitored output: Mean, Minimum, Maximum, Mode, Standard Deviation, Variance, Kurtosis, Skewness, 5th Percentile and 95th Percentile.

Besides, an advanced sensitivity analysis test (Sensitivity Tornado) was also performed by means of @Risk 6.0 software. The sensitivity analysis is a mean to identify the significant input. It also provides what is "driving or most important" to the point of view of possible outcome and risk estimates. In the present work, the sensitivity analysis is conducted in terms of change in output statistic. In a simple way, it determines the effect of inputs (risks) on the mean of the output (delay/distribution profile of the risk impacts) as shown in Figure 5.8. The results of a sensitivity analysis are illustrated as a "tornado" type chart. In which, longer bars at the top represent the most significant input variables. From the GSC operational risks point of view, the ranking order in terms of their effect on output mean is given as O4 – O3 – O1 – O2 (refer Figure 5.8). It indicated that risk O4 (Green technology level) is the most important input in case of GSC supply risks. The concerned authority is therefore suggested to manage this risk to improve the GSC success rate.

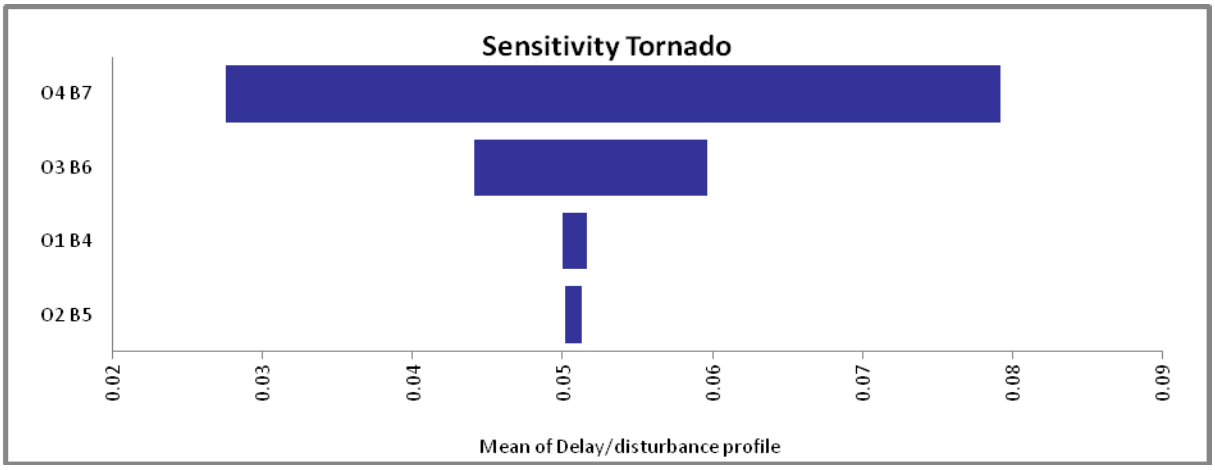


Figure 5.8 Sensitivity Analysis Results of Output Mean of GSC Operational Risks Impacts (Delay/disturbance Profile)

According to the sensitivity analysis, the ranking order for supply risks in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as S3 – S2 – S4 – S1. It indicated that risk S3 (Supplier quality issues) is the most important input in case of GSC supply risks as shown in Figure 5.9.

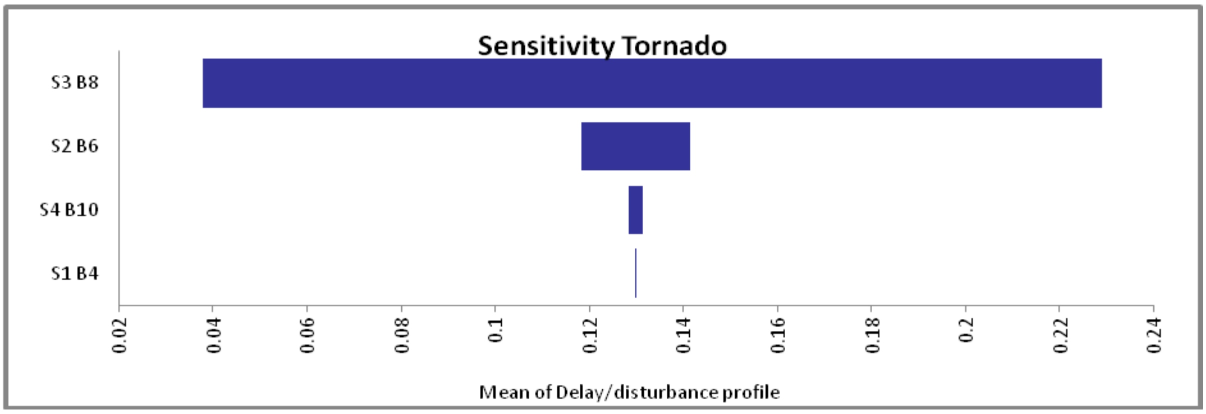


Figure 5.9 Sensitivity Analysis Result of Output Mean of GSC Supply Risks Impacts (Delay/disturbance Profile)

Based on the sensitivity analysis, the ranking order for product recovery risks in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as PR4 – PR3 – PR2 – PR1. The risk Inventory and capacity design risks at reprocessing centers (PR4) are recognized as the most important input in case of GSC product recovery risks as shown in Figure 5.10.

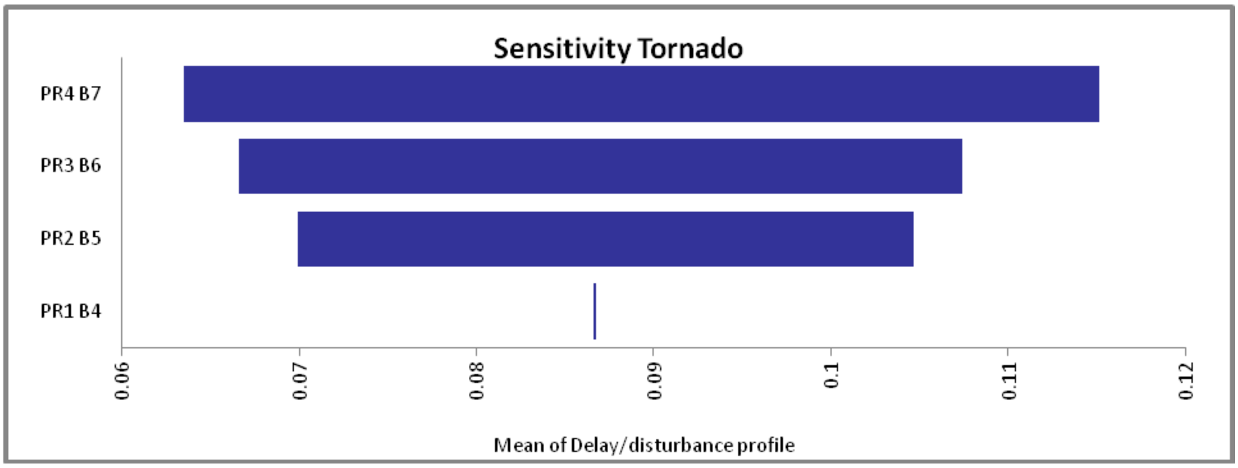


Figure 5.10 Sensitivity Analysis Result of Output Mean of GSC Product Recovery Risks Impacts (Delay/disturbance Profile)

According to the sensitivity analysis, the ranking order for financial risks in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as F3 – F1 – F2. The risk F3 (Financial restriction) is recognized as the most important input in case of GSC financial risks as shown in Figure 5.11.

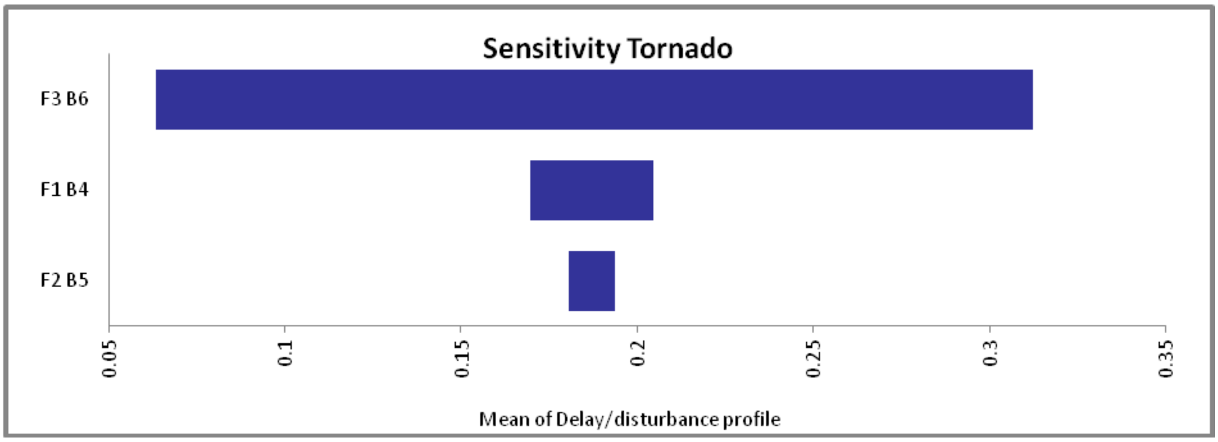


Figure 5.11 Sensitivity Analysis Result of Output Mean of GSC Financial Risks Impacts (Delay/disturbance Profile)

According to the sensitivity analysis, the ranking order for demand risks in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as D1 – D4 – D2 – D3. The Bullwhip effect risks (D1) is recognized as the most important input in case of GSC demand risks as shown in Figure 5.12.

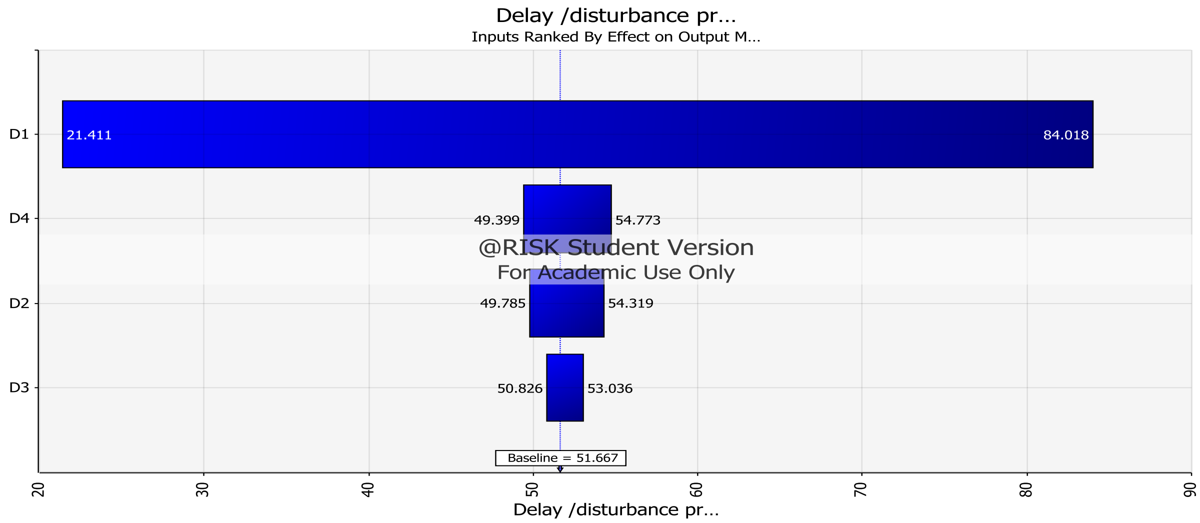


Figure 5.12 Sensitivity Analysis Result of Output Mean of GSC Demand Risks Impacts (Delay/disturbance Profile)

According to the sensitivity analysis, the ranking order for governmental and organizational related risks in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as GO1 – GO4 – GO3 – GO2 – GO5 – GO6. The risk Management policy failures (GO1) has been recognized as the most important input in case of GSC Governmental and Organizational related risks as shown in Figure 5.13.

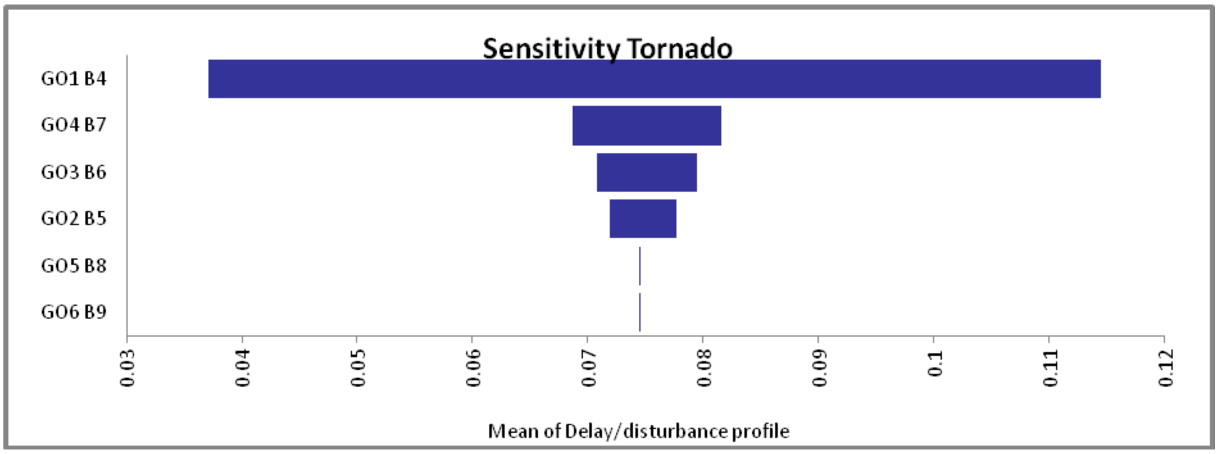


Figure 5.13 Sensitivity Analysis Result of Output Mean of GSC Governmental and Organizational Related Risks Impacts (Delay/disturbance Profile)

Further, the change in output mean across the range of input values of GSC operational risk was also analyzed and is given in Figure 5.14. According to the figure, a maximum change in output mean is observed for risk O4 (Green technology level), which is followed by risk O3 (Scarcity of skilled labor). Thus, risk O4 is the most important operational risk in implementing GSC business initiatives. There has not been much difference in the output mean across the range of input values for risk O1 (Machine, equipment or facility failure) and O2 (Design risks) as shown in Figure 5.14.

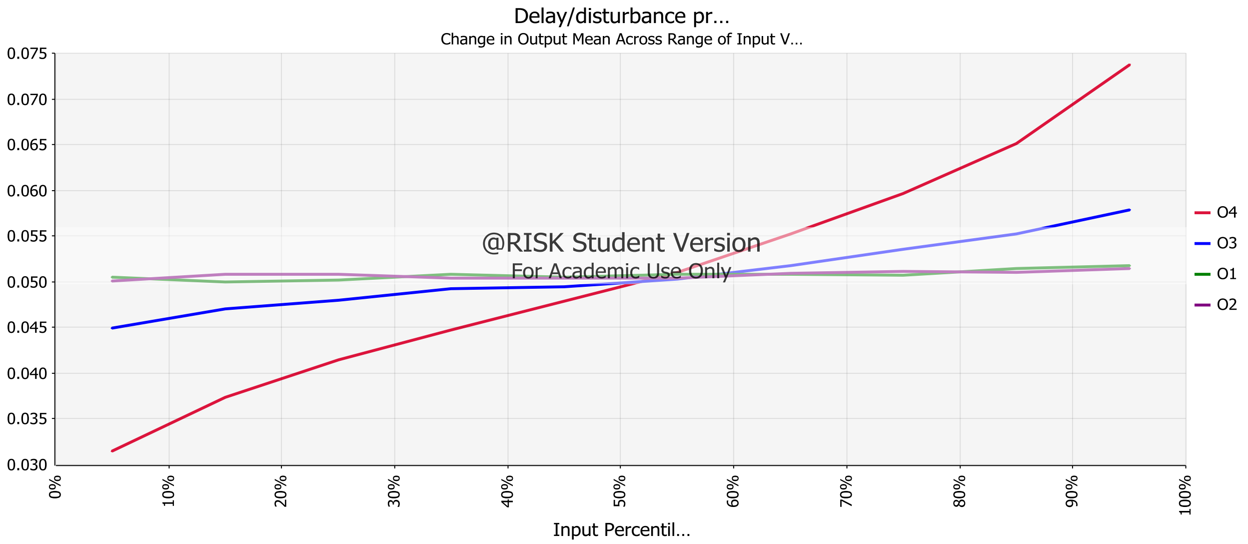


Figure 5.14 Change in Output Mean Across Range of Input Values of GSC Operational Risks

The change in output mean across the range of input values of GSC supply risk is given in Figure 5.15. A maximum change in output mean is observed for risk S3 (Supplier quality issues). Thus, risk S3 is the most important supply risk in implementing GSC business initiatives. It is followed by risk S2 (Key supplier failures). There has not been much difference in the output mean across the range of input values for risk S4 (Green raw-material supply disruptions) and S1 (Procurement costs risks) as shown in Figure 5.15.

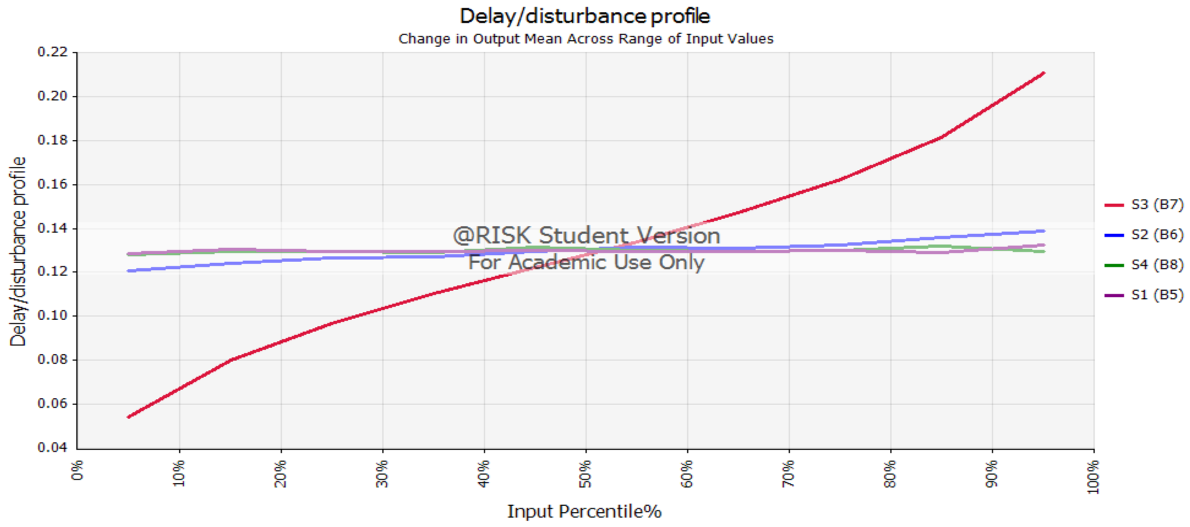


Figure 5.15 Change in Output Mean Across Range of Input Values of GSC Supply Risks

The change in output mean across the range of input values of GSC product risk is shown in Figure 5.16. A maximum change in output mean is observed for risk PR4 (Inventory and capacity design risks at reprocessing centers). Thus, risk PR4 is the most important product recovery risk in implementing GSC business initiatives. It is followed by risk PR2 (Reverse logistics design risks).

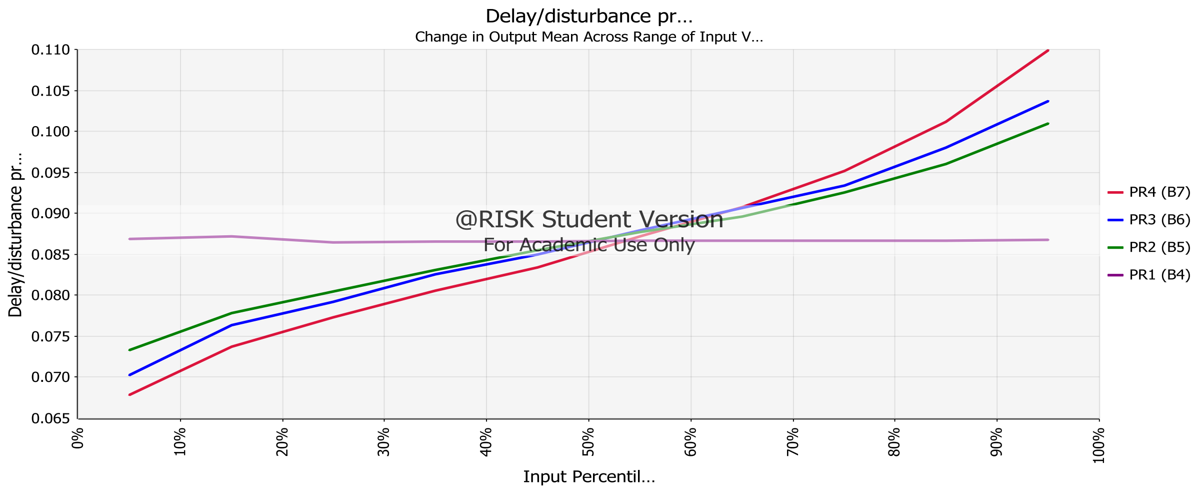


Figure 5.16 Change in Output Mean Across Range of Input Values of GSC Product Recovery Risks

The change in output mean across the range of input values of GSC financial risk is given in Figure 5.17. A maximum change in output mean is observed for risk F3 . Thus, risk F3(Financial restriction) is the most important financial risk in implementing GSC business initiatives. It is followed by risk F1 (Sourcing of funds).

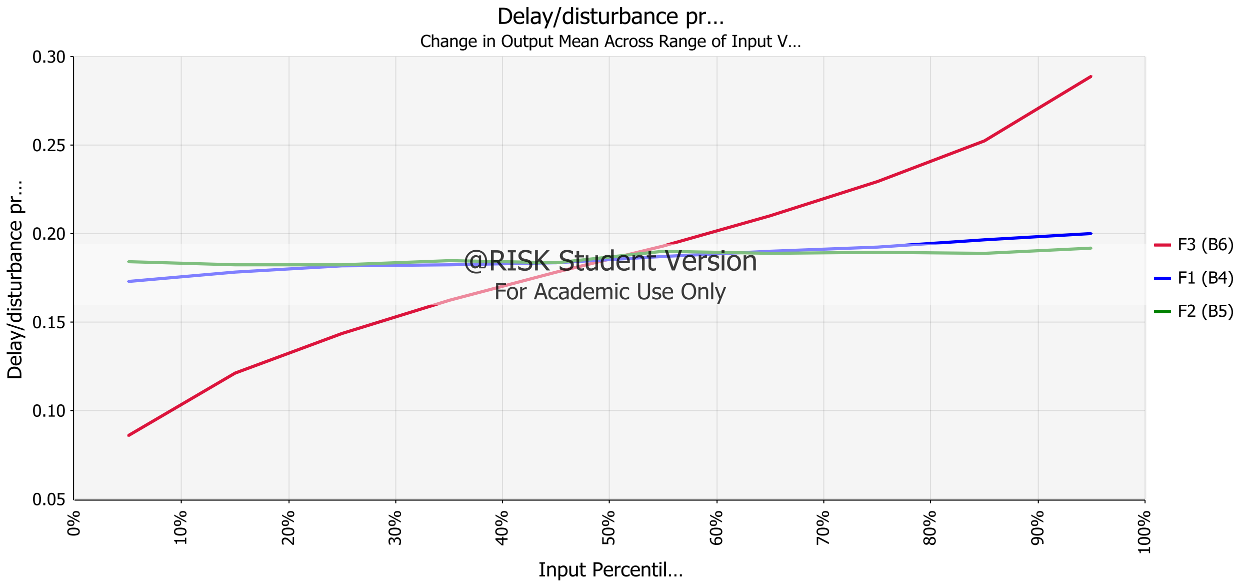


Figure 5.17 Change in Output Mean Across Range of Input Values of GSC Financial Risks

The change in output mean across the range of input values of GSC demand risk is given in Figure 5.18. A maximum change in output mean is observed for risk D1. Thus, risk D1 (Bullwhip effect risks) is the most important demand risk in implementing GSC business initiatives. It is followed by risk D4 (Competing risks).

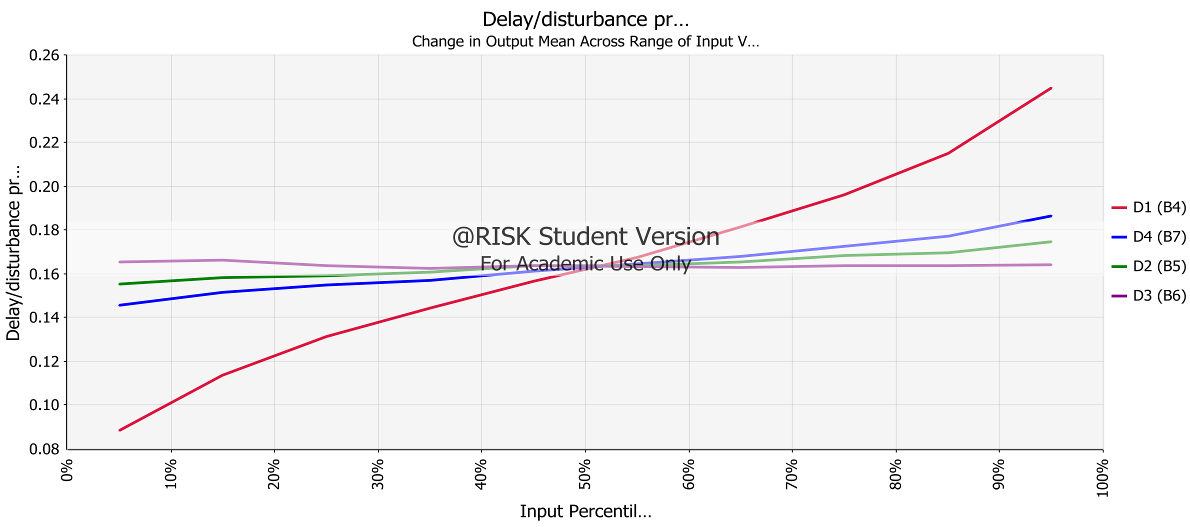


Figure 5.18 Change in Output Mean Across Range of Input Values of GSC Demand Risks

The change in output mean across the range of input values of GSC governmental and organizational related risk is given in Figure 5.19. A maximum change in output mean is observed for risk GO1 (Management policy failures). It means it is the most important governmental and organizational related risk in implementing GSC business initiatives.

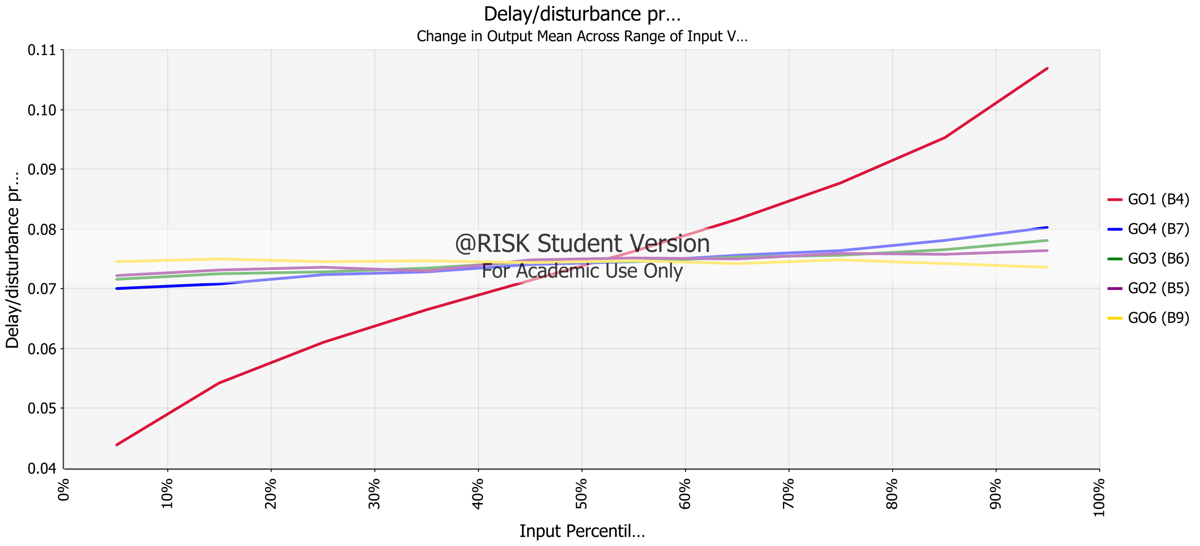


Figure 5.19 Change in Output Mean Across Range of Input Values of GSC Governmental and Organizational Related Risks

5.4 Assessing the GSC Risk: A Holistic View

In a holistic view, it could be significant to assess the risk in GSC. It may also provide a comprehensive understanding of the risk assessment in GSC. Therefore, the risks identified in this work were accessed collectively to establish their effects on the green supply chain. Based on the scale mentioned in Table 5.1 and inputs received from the experts, the probability of occurrence of the risks and their effects was measured as given in Table 5.14. Using the probability of occurrence of the risks and their effects, risk score (RS), is calculated. The Competing risks (D4) risk has got the highest RS equals to 180, and thus, obtains the highest ranking. With regard to the impacts of risks, the ranking of the remaining risks was obtained and is shown in Table 5.14. The time based dimension is the maximum one to be affected compared to other dimensions of risk effects. It means that time delay and disruption is the most serious impact of GSC risks. Its consequences could be delay in deliveries, damage of products, etc. (Ma et al., 2012). Economic dimension is the next one to follow after time based dimension. It is important to have financial initiation and support for any organization in implementing GSC initiatives. Failure of or poor financial concerns will definitely disturb the GSC functioning, and results in decreased performance. Time disruption, is the next one to follow. It may disturb normal activities or stop things happening as intended in an organizational GSC in adopting an effective GSCM concept. Brand image come next to time disruption. The risks identified in GSC may cause loss in business, and even reduce the market share from the organization's point of view. Finally, Quality, and Health and safety come next to Brand image. It indicates that risks in GSC may emerge issues related to quality of material/product and human resources development for effective GSCM adoption. Thus, it is important to access and manage the GSC risks for accomplishing the desired objective.

Table 5.14 GSC Risks and Their Impacts: A Holistic View

Description of GSC risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**	**Rank**
		Delay/ disturbance	Disruption	Damage	Costs	Harm/damage	Unfavorable /poor		
Machine, equipment or facility failure (O1)	5	3	1	1	3	1	1	50	14
Design risks (O2)	5	3	3	1	5	1	1	70	10
Scarcity of skilled labor (O3)	3	9	3	3	3	1	3	66	11
Green technology level (O4)	9	3	1	3	5	1	3	144	3
Procurement costs risks (S1)	1	1	1	1	3	1	1	9	19
Key supplier failures (S2)	3	9	5	5	5	1	3	84	9
Supplier quality issues (S3)	5	5	3	5	3	3	3	110	6
Green raw-material supply disruptions (S4)	3	3	3	3	5	1	1	48	15

Table 5.14 Contd...

Description of GSC risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**	**Rank**
		Delay/ disturbance	Disruption	Damage	costs	Harm/damage	Unfavorable /poor		
Gate keeping design failures (PR1)	1	1	3	1	3	1	3	12	18
Reverse logistics design risks (PR2)	3	9	5	5	5	1	3	84	9
Take-back obligations risks (PR3)	5	5	3	5	3	1	3	100	7
Inventory and capacity design risks at reprocessing centers (PR4)	9	3	3	3	3	1	1	126	5
Sourcing of funds (F1)	1	1	1	1	1	3	1	1	19
Inflation and currency exchange rates (F2)	3	3	9	5	5	5	1	3	9
Financial restriction (F3)	5	5	5	3	5	3	3	3	6

Table 5.14 Contd...

Description of GSC risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**	**Rank**
		Delay/ disturbance	Disruption	Damage	Costs	Harm/damage	Unfavorable /poor		
Bullwhip effect risks (D1)	5	9	3	5	5	1	3	130	4
Market dynamics (D2)	3	3	1	3	3	1	1	36	16
Key customer failures (D3)	1	3	9	5	3	1	1	22	17
Competing risks (D4)	9	5	1	3	5	3	3	180	1
Management policy failures (GO1)	5	9	5	5	5	1	5	150	2
Government policy risks (GO2)	5	3	1	1	5	1	1	60	12
Information asymmetry risk across GSC members in hierarchy (GO3)	9	5	3	1	3	1	3	144	3

Table 5.14 Contd...

Description of GSC risks	**Probability of occurrence**	**Time**		**Brand image**	**Economic**	**Health and Safety**	**Quality**	**Risk score (RS)**	**Rank**
		Delay/ disturbance	Disruption	Damage	Costs	Harm/damage	Unfavorable /poor		
Lack in enterprise strategic goals (GO4)	5	3	3	3	5	1	3	90	8
Legal risks (GO5)	3	3	3	3	3	1	5	54	13
Partnership risks (GO6)	1	5	3	5	3	1	5	22	17

Note: O1, O2, O3,..........GO4, GO5, GO6 are the identified GSC risks in this study.

Monte Carlo simulation approach is used to model the delay/disturbance impact of the risks in GSC in a holistic view. It helps to evaluate the cumulative risk impacts of time delay/disturbance. The delay/disturbance impacts of each risk on GSC performance were measured by receiving the inputs from the experts as shown in Table 5.15. These impacts (inputs) were modelled as probability distributions by means of input probability distributions.

Table 5.15 Summary on Probability of GSC Risks and its Impacts Measured in Terms of Delay/disturbances in a Holistic View

Description of GSC risks	**Probability of occurrence**	**Delay/disturbance in terms of time (days)**		
		Min	Average	Max
Machine, equipment or facility failure (O1)	0.0025	0.25	0.5	1
Design risks (O2)	0.0025	0	0.25	0.5
Scarcity of skilled labor (O3)	0.0045	1	2	5
Green technology level (O4)	0.01	1	3	7
Procurement costs risks (S1)	0.0001	0	0.5	1
Key supplier failures (S2)	0.0045	1	4	7
Supplier quality issues (S3)	0.0025	1	40	90
Green raw-material supply disruptions (S4)	0.0045	0.25	0.5	1
Gate keeping design failures (PR1)	0.0001	1	2	3
Reverse logistics design risks (PR2)	0.0045	1	5	10
Take-back obligations risks (PR3)	0.0025	1	10	20
Inventory and capacity design risks at reprocessing centers (PR4)	0.01	1	3	7
Sourcing of funds (F1)	0.0045	1	5	10
Inflation and currency exchange rates (F2)	0.0025	1	3	7
Financial restriction (F3)	0.01	1	15	30
Bullwhip effect risks (D1)	0.0025	1	40	90
Market dynamics (D2)	0.0045	1	4	7
Key customer failures (D3)	0.0001	0	0	1

Table 5.15 Contd...

Description of GSC risks	Probability of occurrence	Delay/disturbance in terms of time (days)		
		Min	Average	Max
Competing risks (D4)	0.01	1	3	7
Management policy failures (GO1)	0.0025	1	5	10
Government policy risks (GO2)	0.0025	0.5	1	2
Information asymmetry risk across GSC members in hierarchy (GO3)	0.01	1	2	5
Lack in enterprise strategic goals (GO4)	0.0025	1	3	7
Lack in enterprise strategic goals (GO4)	0.0025	1	3	7
Legal risks (GO5)	0.0045	0	0.25	0.5

Note: O1, O2, O3,..........GO4, GO5, GO6 are the identified GSC risks in this study.

Single simulation and 20,000 iterations were used to analyze the uncertain conditions for the GSC risks in a holistic view. The outcome (its probability distribution) is shown in Figure 5.20. The shown delay/disturbance profile of the risk impacts were analyzed at 95 % confidence interval. The mean for the outcome, i.e. delay/disturbance profile comes out to be 0.6709. The minimum and maximum values for the delay/disturbance profile are given as 0.3210 and 0.9975. The minimum and maximum values for delay/disturbance profile are given as 0.4920 and 0.8530. The corresponding range for the delay/disturbance profile is equal to 0.3610. The standard deviation comes out to be 0.0926. The variance for the process comes out to be 0.008574. It signifies that the data taken is able to give an extreme scenario for assessing the impacts of GSC risk along with the capturing of uncertainty related to that (for details refer Figure 5.20).

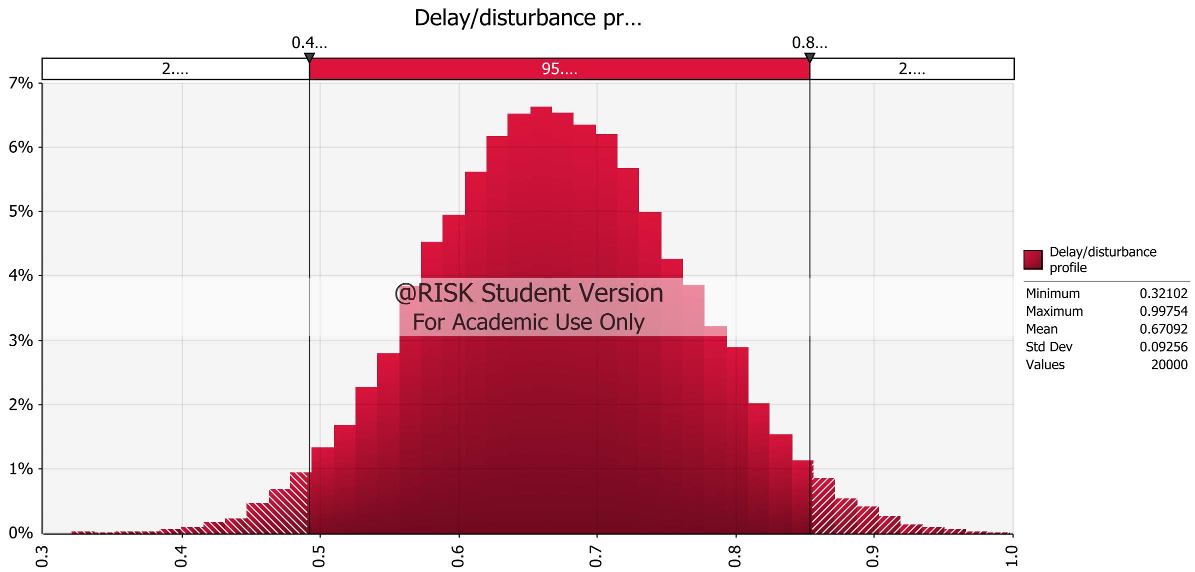


Figure 5.20 Simulation Results of GSC Risk Impacts in a Holistic View (Delay/disturbance Profile)

The ranking order of GSC risk in terms of their effect on the mean of the output (delay/distribution profile of the risk impacts) is given as F3 – S3 – D1 – PR4 – D4 – O4 – GO3 – PR3 – PR2 – F1. The Financial restrictions (F3) are recognized as the most important as shown in Figure 5.21. Therefore, the concerned authority is suggested to manage this risk to improve the GSCM adoption.

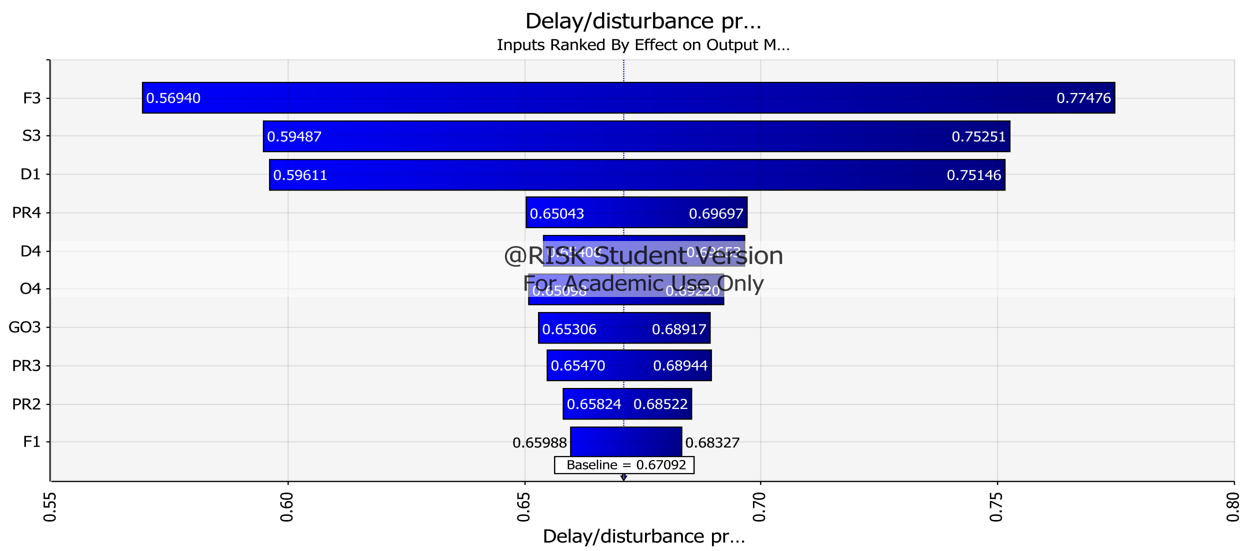


Figure 5.21 Sensitivity Analysis Results of Output Mean of GSC Risks Impacts in a Holistic View (Delay/disturbance Profile)

5.5 Conclusions

The work presented in this chapter extends the viewpoint of managing risks in GSC. It will help to maximize the GSC ecological-economic gains, and ensures sustainability in business. The contribution of this chapter is threefold: first, the various risks related to the GSC were measured to access their effects. Second, the impacts of the risks specifically in terms of time delay/disturbance were assessed. Third, the impacts of the risks specifically in terms of time delay/disturbance were assessed taking a holistic view of the GSC.

As mentioned above, the risks were accessed to analyze their effects on the GSCs of considered business organizations. The risks effects were classified into five dimensions such as Time, Brand image, Economic, Health and Safety, and Quality. Among them, it is observed that time based dimension is highly affected and has received highest impacts. The time based effects was measured in terms of time delays/disturbances and disruption. Besides, time delay/disturbance is the most serious impact of GSC risks. The risks effects were accessed by means of inputs received from the experts that are unable to provide extreme scenario. Under these considerations, the MCS approach is used. MCS approach was used to analyze the risks and their impacts on the performance of GSC. In addition, it also helps to capture the uncertainties in the inputs. A sensitivity analysis test was performed to capture the impacts of risks on the delay/disturbance profile mean. The developed GSC risk assessment framework will serve as a decision making tool for SC managers for analyzing the risks more efficiently towards effective implementation of GSCM in business. It is believed that findings of this study may provide a more in-depth understanding on the probable risks and consequences to emerge in GSC.

.

CHAPTER 6

PRIORITIZING THE RESPONSES TO MANAGE RISKS IN GSC

The present chapter proposes a model, by using an integrated approach based on the fuzzy Analytic Hierarchy Process (AHP) and the fuzzy Technique for Order Performance by Similarity to Ideal Response (TOPSIS) method to prioritize the responses in GSC to manage its risks under the fuzzy environment. The fuzzy AHP is useful in deciding the importance weights of the GSC risks. While, by using the fuzzy TOPSIS, the priorities of the responses in a successful accomplishment of GSC business initiatives are determined.

6.1 Introduction

Production and business activities in GSC engage several types of risks. Some of the GSC risks are – supply risks, demand risks, operational risks etc. The occurence of these risks can reduce the efficiency of a structure GSC (Wang et al., 2012). Thus, it is needed to concentrate on developing some appropriate responses and concrete strategies to manage and reduce the convolution of risks in GSC. Further, to improve the performance of adoption and implementation of green in supply chain, a set of reasonable and viable response measures need to be proposed and prioritized. This chapter aims in achieving the two objectives, given as below:

- To propose the responses to manage the risks associated with the GSC in adoption and effective implementation of the green initiatives in the supply chain.
- To prioritize the responses in managing the GSC efficiently.

The prioritization of responses of the risks in GSC is a multi-criteria decision making (MCDM) problem (Tabucanon, 1988). Due to the presence of fuzziness and unclearness in the data, there exist difficulties in the process of prioritizing the responses of risks. To ease the process and for removing the inherent imprecision and ambiguity, it is proposed to use the theory of fuzzy sets (Zadeh, 1965) for the above purpose.

Part of this chapter has been published/accepted for publication in

- Sustainable Production and Consumption- Official Journal of the European Federation of Chemical Engineering Part E, 1 (1), 67- 86.

This work proposes to utilize the fuzzy analytic hierarchy process (AHP) and fuzzy technique for order performance by similarity to ideal response (TOPSIS) methods to prioritize the responses of risks in GSC.

6.2 Solution Methodology

To accomplish the desired objectives raised in this chapter, an integrated methodology based on fuzzy AHP and fuzzy TOPSIS is used as a solution methodology. The fuzzy AHP method helps in computing the importance weights of the GSC risks, and the fuzzy TOPSIS technique was utilized to analyze appropriate responses of risks and to obtain their performance rating. The TOPSIS method is used because of the reasons (Wang and Chang, 2007) mentioned as: (1) the computational process is simple and easy to understand; (2) it is an easily understandable and rational method; (3) the concept in TOPSIS, enables the detection of the best alternative for all criteria depicted in computational procedure; (4) the inclusion of importance weights into computation practice. In addition, fuzzy TOPSIS reduces the computational time and eliminates several computational steps to be performed in AHP - fuzzy AHP methodology (Dagdeviren et al., 2009). The AHP - fuzzy AHP are logical to apply to the situation where there exist a less number of criteria and alternatives, available to a system. Otherwise, the number of pair wise evaluation matrices will be higher than a reasonably threshold. For instance, if there are x criteria for which importance weights have to be determined and y alternatives, in that case, there are $x \times y \times (y-1)/2$ pair wise evaluation comparisons need to be formed in accordance with the procedure of AHP- fuzzy AHP methodology (Shipley et al., 1991). Thus, to avoid the big number of pair wise comparisons, the methodology of fuzzy TOPSIS is utilized to prioritize or rank alternatives. Besides, the fuzzy set theory concept helps in removing the inherent imprecision and ambiguity in the process (Zadeh, 1965). The other details are given in the subsequent sub-sections.

6.2.1 Use of fuzzy set theory

In this era of globalization, the business organizations are facing several complexities in decision-making due to lack in exactness in the data. Human involvement in evaluating multi-criteria decision problems typically includes qualitative judgments. The human judgments are generally expressed in linguistic statements instead of crisp value. In this regard, fuzzy methodology is logically helpful in providing clear information for analyzing the problem under such unclear surroundings (Zadeh, 1965).

Fuzzy logic helps in capturing the human linguistic judgments and provides assistance in converting these linguistic statements into crisp values using fuzzy numbers (Susilawati et al., 2015). The current research uses triangular fuzzy number (TFN), which is mostly preferred for practical applications (Zimmerman, 1996; Chang et al., 2007). If, $O_1 = (a, b, c)$ and $O_2 = (p, q, r,)$, are two triangular fuzzy numbers. The details for the TFN have already been given in Chapter 4. While, the distance between the two TFNs can be calculated with the help of Equation 6.1, as given below:

$$d(O_1\ O_2) = \sqrt{\frac{1}{3}\ [(a-p)^2 + (b-q)^2 + (c-r)^2]} \qquad ...(6.1)$$

6.2.2 Fuzzy AHP

The fuzzy AHP has been recognized as a well-accepted technique to adequately handle the inherent uncertainty and human subjectivity involved in the decision-making practice (Chan et al., 2008; Hu et al., 2009; Kaya and Kahraman, 2010; Choudhary and Shankar, 2012; Buyukozkan and Cifci, 2012; Wang et al., 2012; Jakhar and Barua, 2013). In the present work, it is proposed to utilize the fuzzy AHP methodology that determines the importance weights of risks. The detailed description about fuzzy AHP has already been given in Chapter 4.

6.2.2.1 Algorithm for fuzzy AHP

The fuzzy AHP is a well-known and scientific decision making tool. Its algorithm can be explained through steps given below:

- Step 1: Design the scale of relative importance to construct the pair wise comparison matrix: The TFNs are used to improve the classical nine-point scaling design. In order to deal with the vagueness and unclearness involved in human based linguistic assessments, the five fuzzy score are defined as shown in Table 6.1.

Table 6.1. Fuzzy Linguistic Scale Used for Determining the Pair Wise Evaluation Matrix

Linguistic variables	**Fuzzy score**
Approximately equal	1/2,1,2
Approximately x times more important	x-1, x, x+1
Approximately x times less important	1/x+1, 1/x, 1/x-1
Between y and z times more important	y, (y + z)/2, z
Between y and z times less important	1/z, 2/(y + z), 1/y
Note: The value of x ranges from 2, 3...9, whereas the values of y and z can be 1, 2......9, and y<z.	

Sources: Wang et al. (2007)

- Step 2: Develop the fuzzy evaluation matrix: The human judgment linguistics assessments transformed into a fuzzy evaluation matrix through TFN. A positive fuzzy evaluation matrix (A) is calculated by taking the average of the pair wise comparisons from decision group, which is illustrated as $A = [y_{ij}]_{n\times m}$.

  Where, y_{ij} represents the fuzzy entries in the constructed fuzzy positive matrix, i.e., (a_{ij}, b_{ij}, c_{ij}), and in this relation positive fuzzy numbers satisfies the following property: $a_{ij} = \frac{1}{a_{j_i}}, b_{ij} = \frac{1}{b_{j_i}}, \; c_{ij} = \frac{1}{c_{j_i}}$, where, i and j = 1, 2 ………………z, i.e., no. of criteria.

- Step 3: Determination of importance weights: it needs to aggregate fuzzy numbers into crisp values. This crisp value enables the decision makers to find out the weights of risks that help in determining their relative importance. To compute the weights of risks, this study has used Chang's Extent Analysis method. This method has been widely accepted to calculate fuzzy aggregate importance weights for the fuzzy input pair-wise evaluation matrix (Viswanadham and Samvedi, 2013). The detailed description about Chang's Extent Analysis method has already been given in Chapter 4.

6.2.3 Fuzzy TOPSIS

Hwang and Yoon (1981) have proposed the methodology of TOPSIS. It is a multi-criteria analysis method that enables policy makers to know responses from a set of alternatives. The reason behind this is explained as that the best alternative would have the farthest distance from the negative ideal response (NIS) and the smallest from the positive ideal response (PIS) (Kuo et al., 2007; Sun, 2010). The negative ideal response is a response that maximizes the cost criteria and minimizes the benefit criteria. On the other hand, the positive ideal response is a response that minimizes the cost criteria and maximizes the benefit criteria.

Various researchers have successfully used the TOPSIS method to analyze different multi criteria problems (Büyüközkan et al., 2008; Dağdeviren et al., 2009; Amiri, 2010; Aydogan, 2012). In real-life situations, it is very difficult to measure human judgments in crisp values. Thus, linguistic values could be better option to use in this situation. Fuzzy concepts can be helpful to measure linguistic values. Therefore, in this work, fuzzy concepts have been integrated into the TOPSIS method (Choudhary and Shankar, 2012). In addition, the fuzzy TOPSIS technique is an appropriate method to analyze the multi criteria problem under fuzzy surroundings (Dağdeviren et al., 2009; Viswanadham and Samvedi, 2013; Patil and Kant, 2014). Various computational steps considered in employing the fuzzy TOPSIS method are given (Kuo et al., 2007; Büyüközkan et al., 2008; Sun, 2010) as below:

- Step 1: Determine the importance weights of the evaluation criteria: the methodology of fuzzy AHP is used to determine the importance weights of the evaluation criteria, which are denoted by w_j (j = 1, 2,…., n).
- Step 2: Select the linguistic preferences for the alternative with reference to criteria and derive the fuzzy performance matrix: The problem can be expressed as: if, m denotes a set of possible alternatives represented A = (A_1, A_2…,A_m) and C denotes a set of possible criteria represented C=(C_1, C_2…,C_n) for which these alternatives have to be evaluated. Further, if there are K decision makers, then the evaluation rating of each expert D_k (k = 1, 2,…., K) for each alternative A_i (i=1,2,…,m) w.r.t. criteria C_j (j=1,2,…,n) are represented by $R_k = x_{ijk}$ (i= 1,2,....m; j=1,2,....n; k=1,2,....K) with membership function represented by $\mu\tilde{R}k(x)$. The fuzzy performance matrix for the alternatives ($\tilde{F}$) is developed by using the Equation (6.2), and is represented as follows:

$$\tilde{F} = \begin{matrix} A_1 \\ A_2 \\ \\ \\ A_m \end{matrix} \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & .. & .. & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & .. & .. & \tilde{x}_{2n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ \tilde{x}_{m1} & \tilde{x}_{m2} & .. & .. & \tilde{x}_{mn} \end{bmatrix} \quad ...(6.2)$$

However, the perception toward implementation of response measures of risks in GSC context varies in accordance with the individual experience, intuition, and knowledge of the experts. This research has used the method of average value to find the aggregate value of the fuzzy performance score (i.e., aggregated fuzzy decision matrix) xij for k experts with regard to the same evaluation criteria, given as, $\tilde{x}_{ij}^{k} = 1/k(\tilde{x}_{ij}^{k} + \tilde{x}_{ij}^{k} + \tilde{x}_{ij}^{k} +$

$\cdots\tilde{x}_{ij}^{k}$). Where, $\tilde{x}_{ij}^{k}$ is the performance rating of alternative A_i, in reference to criteria C_j performed by k^{th} decision maker or expert, and $\tilde{x}_{ij}^{k} = (\tilde{a}_{ij}^{k}, \tilde{b}_{ij}^{k}, \tilde{c}_{ij}^{k})$.

- Step 3: Derive the normalized fuzzy performance matrix: In order to convert the scale of different criteria into a comparative and comparable unit of measurements, the raw data is normalized. The normalized fuzzy performance matrix $\tilde{R}$ is represented as following:

  $\tilde{R} = [r_{ij}]_{m\times n}$, where i=1,2,……,m; j=1,2,….,n. Further, r_{ij} is given by using the expressions written below in Equation (6.3) and Equation (6.4).

  $$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max c_{ij} \qquad \text{(benefit effective criteria)} \qquad ...(6.3)$$

  $$r_{ij} = \left(\frac{a_j^*}{c_{ij}}, \frac{a_j^*}{b_{ij}}, , \frac{a_j^*}{a_{ij}}, \right) \text{ and } a_j^* = \min a_{ij} \qquad \text{(cost effective criteria)} \qquad ...(6.4)$$

- Step 4: Derive the weighted normalized matrix: The weighted normalized matrix $\tilde{v}$ for criteria is calculated by multiplying the importance weights (w_j) of decision criteria with the entries of the normalized fuzzy decision matrix $\tilde{r}_{ij..}$ The details for calculating the normalized matrix is given in Equation (6.5).

  $$\tilde{V} = [\tilde{v}_{ij}]_{mxn\,;} \qquad \text{(where } \tilde{v}_{ij} = \tilde{r}_{ij} . w_j) \qquad ...(6.5)$$

- Step 5: Compute the fuzzy positive ideal response (FPIS, A^*) and the fuzzy negative ideal response (FNIS, A^-): The fuzzy positive ideal response (FPIS, A^*) and the fuzzy negative ideal response (FNIS, A^-) are calculated using the expressions as given in Equation (6.6) and Equation (6.7).

  $$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots., \tilde{v}_n^*) \qquad ...(6.6)$$

  $$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots., \tilde{v}_n^-) \qquad ...(6.7)$$

  Where, $\tilde{v}_j^*$= (0,0,0) and $\tilde{v}_j^-$= (1,1,1) ; j=1,2,….,n.

- Step 6: Computation of distance of each alternative from FPIS and FNIS: The distance (d_i^+, d_i^-) of each weighted alternative from the FPIS and FNIS is calculated using the Equation (6.8) and Equation (6.9).

  $$d_i^+ = \sum_{j=1}^{n} dv\,(\tilde{v}_{ij}, \tilde{v}_j^*) \qquad ...(6.8)$$

$$d_i^- = \sum_{j=1}^{n} dv\,(\tilde{v}_{ij}, \tilde{v}_j^-) \quad ...(6.9)$$

- Step 7: Determination of closeness coefficient of each alternative: The value of closeness coefficient denotes the distance of alternative from the FPIS and the FNIS. The closeness coefficient (D_i) of each alternative is computed with the help of Equation (6.10).

$$D_i = \frac{d_i^-}{(d_i^- + d_i^+)} \quad ...(6.10)$$

- Step 8: Ranking of the alternatives: Based on the values of closeness coefficient, the different alternatives considered in the system are ranked. Highest value is ranked first, and thereafter, it follows a decreasing order.

6.3 The Proposed Model

Based on the fuzzy AHP and fuzzy TOPSIS methods, a model is proposed for prioritizing the response of risks in effective adoption and implementation of the GSC initiatives. The proposed model consists of three stages as described in the following sub-sections:

6.3.1 Stage 1: Identification of the responses to manage the risks for effective implementation of the GSC initiatives

In the first stage, a decision-making team consists of experts having expertise in various managerial functions, such as purchasing, planning, quality, production, finance, inspection, and environmental management was formed. The decision making team will be helpful in identifying and finalizing the responses to manage the risks for effective implementation of the green initiatives in the supply chain. Based on literature and expert's inputs, the risks associated with the GSC were selected. At the same time, the alternatives (responses) of the risks in GSC also finalized. A decision hierarchy consisted of four levels, the goal of research at Level 1; the main criteria at Level 2; the sub-criteria at Level 3; the alternative represented at Level 4 was constructed.

6.3.2 Stage 2: Computation of the importance weights of criteria and sub-criteria

The importance weights of the risk criteria and sub-criteria of risk were calculated by using the fuzzy AHP. To compute the importance weights of the risk and its sub-criteria, the pair wise evaluation matrix, a linguistic scale was used to obtain the experts judgement (for linguistic scale refer Table 6.1 mentioned in Section 6.2.2.1). Using this scale, the final pair-wise evaluation matrix of both the risk criteria and sub-criteria of risk were constructed. Finally, based on the pair-wise evaluation matrix, weights of the risks were calculated.

6.3.3 Stage 3: Evaluation of the responses (i.e., alternatives) of risks in adoption and effective implementation of the GSC initiatives and determination of their priority

Priority of the responses of risks to manage the GSC effectively was determined using fuzzy TOPSIS method. For determining the rating of responses of risks, a linguistic scale was utilized, which is given in Table 6.2. Priority of the response was determined on the basis of the values of closeness coefficient ($D_{i)}$. The D_i values were calculated by using the fuzzy TOPSIS method. The illustration of the proposed model for prioritizing the responses of risks in GSC is shown in Figure 6.1.

Table 6.2 Linguistic Scale Used for Responses Rating (Wang et al. (2007))

Linguistic variables	**Fuzzy score**
Important	1/2,1,2
Approximately x times more important	x-1, x, x+1
Approximately x times less important	1/x+1, 1/x, 1/x-1
Between y and z times more important	y, (y + z)/2, z
Between y and z times less important	1/z, 2/(y + z), 1/y

Note: The value of x ranges from 2, 3...9, whereas the values of y and z can be 1, 2......9, and y<z.

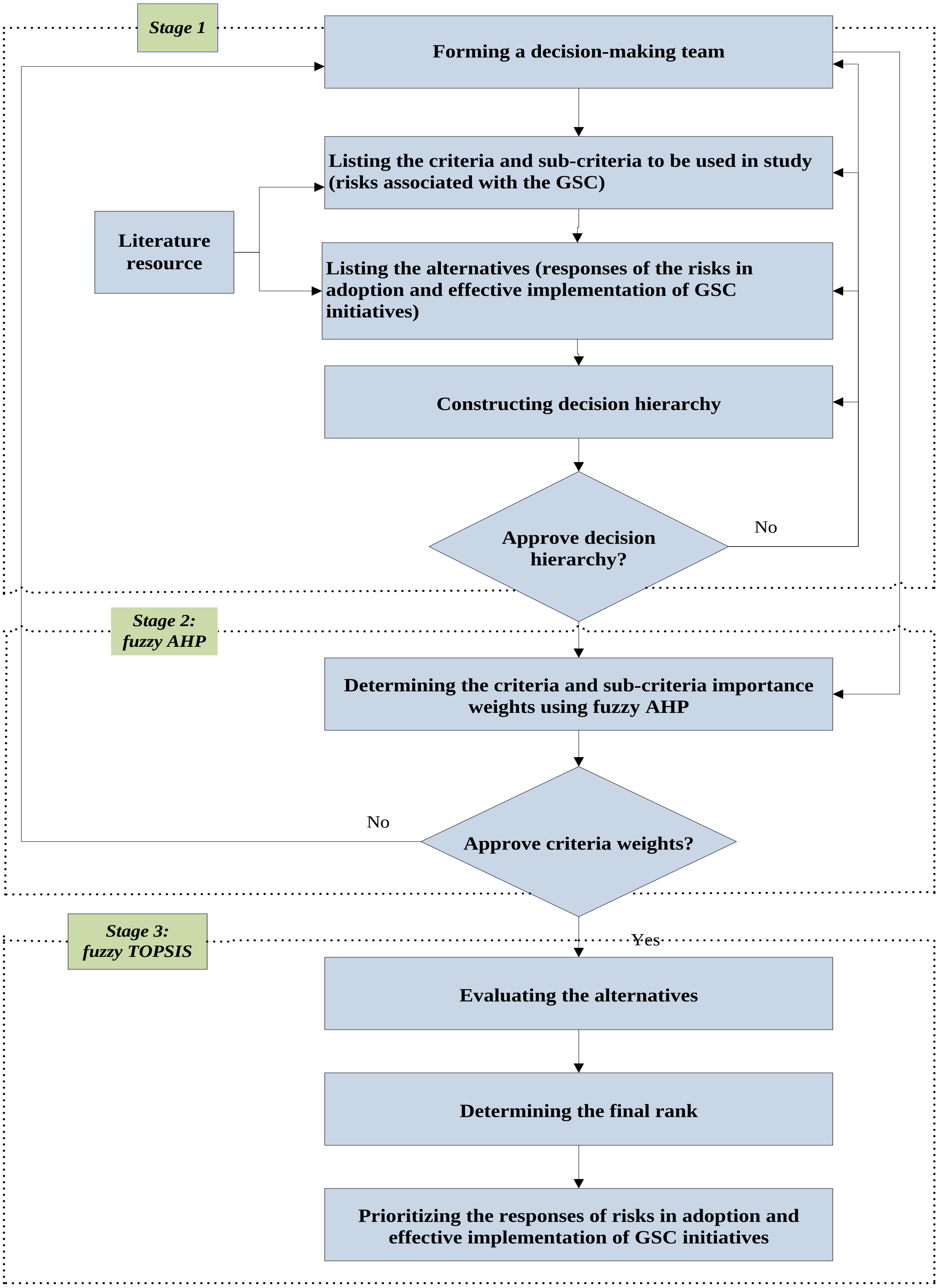


Figure 6.1 Illustration of the Proposed Model for Prioritizing the Responses of Risks

6.4 An Application

The proposed network model was applied to a real world problem. An application of the proposed model is described through three stages given in the earlier section, and with respect to the business organizations under consideration is illustrated as follows:

6.4.1 Identification of the responses to manage the risks for effective adoption and implementation of the GSC initiatives

The six categories of risks and twenty-five specific risks associated with the GSC were identified (refer Chapter 4). The categories of risks and the specific risks are termed as risk criteria and sub-criteria of risk. These risk criteria and sub-criteria were validated for an agreement through an interactive discussion with the experts of decision-making team; other details have already been given in Chapter 4.

In order to manage these risks, 17 responses were identified as given in Table 6.3. These responses were collected through literature and inputs received from the experts of the decision-making team.

In that way, twenty-five risk sub-criteria and seventeen responses, to manage the risks, were decided, and a decision hierarchy was constructed to address the problem as shown in Figure 6.2. It consists of four levels - Prioritizing responses of the risks in adoption and implementation of green in the supply chain (the goal of research) at Level 1; Risks (the main criteria used in this research) at Level 2; Risks (sub-criteria used in this research) at Level 3; Responses (proposed alternatives) represented at Level 4.

After the approval of the constructed decision hierarchy by the experts of decision-making team, the importance weights of the criteria recognized in this study were determined.

Table 6.3 Responses of Risks in Adoption and Their Description

Responses	**Description**
Establishment of motivational programs for supplier to built their commitment about green (**R1**)	The initiation of motivational programs will be quite useful in building the supplier's commitment in adopting of the green trends in the organizational supply chain
Use of information technology in tracking the returning of products to foster the product recovery (**R2**)	Information system can be effective in tracking the returning of products by use of bar code, EDI, RFID, etc., and thereby GSC product recovery performance will improve
Adoption of product take-back responsibilities (**R3**)	Product take-back obligations influences the collection procedure and improves the product recovery process in GSC
Provision of well-defined and environmental supportive governmental policies and directions (**R4**)	Establishment of well-defined and environmental supportive governmental directions would be significant for industries. Efficient legislative directions and governmental policies in terms of providing some incentives and subsidies and or exempting the tax on green product may be helpful in solving the various uncertain issues related to adoption of GSC initiatives
Improved forecasting (**R5**)	Accurate forecast through improved forecasting method and techniques are significant to stabilize the demand risk in GSC in business
Multiple supplier policy (**R6**)	Policy of multiple supplier helps in resolving the supplier risks and certainly improves the economic-ecological gains in GSC at industrial perspective

Table 6.3 Contd...

Responses	Description
Incorporation of environmental practices in company policies and mission at strategically (**R7**)	In a strategic view, it is significant to include environmental concepts in company policies and mission for achieving better GSC performances from the industrial standpoint
Establish an efficient information network system for effective green information sharing among partners and across the hierarchy (**R8**)	An efficient interactive information network will reduce the risks of information asymmetry between supply chain partners and members across the hierarchy. It will be crucial in implementing an effective GSCM thought in business
Training and education of employee to increase their competency regarding green (**R9**)	The understanding and knowledge of green operations and method among employees is important to increase the success rate of GSC
Flexibility in design to process and operational level (**R10**)	The strategy of flexibility in design at process and operational level is significant in managing the GSC operations and will be useful in improving the overall performance
Awareness and education of the customers about green (**R11**)	Ecological consciousness of consumers is one of the significant factors for organizations to increase the GSC effectiveness
To develop and upgrade on technology being used in the specific sectors for implementation of green (**R12**)	Managers should have sound knowledge and understanding of the applicability of new technology in various sectors for effective implementation of green in the supply chain
Establishing a well designed reverse logistics system (**R13**)	Reverse logistics has been recognized as a significant operation in GSC perspective in recovering the resources via closing the forward supply loop

Table 6.3 Contd...

Responses	Description
Conduct seminar and some programs to educate supply chain partners and members about green (**R14**)	Conducting seminar and education program can be significant in updating the knowledge of supply chain members and partners, and it would be helpful in enhancing the GSC success rate
Commitment of top management and support of lower and middle level managers (**R15**)	The commitment of top management and support at managerial level, (i.e. at lower and middle level) is important in adopting efficient green trends in the supply chain
Building organizational-supplier environmental collaboration and partnerships (**R16**)	Building of environmental collaboration and partnerships among organization and supplier is useful in enhancing the ecological performance of suppliers and certainly would reduce the disruptions at the supplier end in GSC
Establishment of financial resources, capabilities and contingency plans (**R17**)	Establishment of financial resources, capabilities and contingency plans are very important from the industrial point of view in adoption and implementation of efficient GSC intiatives/practices

Sources: Combined result of the studies of Green et al. (1996, 2000), Roarty (1997), Lippmann (1999), Beamon (1999), Hillary (2000), Hall (2000), Sarkis (2003, 2006), Hervani et al. (2005), Zhu et al. (2005, 2008a,b), Adler (2006), Zhu and Sarkis (2006), Orsato (2006), Walker et al. (2008), Marsillac (2008), Hsu and Hu (2008), Mudgal et al. (2009), Holt and Ghobadian (2009), AlKhidir and Zailani (2009), Hu and Hsu (2010), Yang and Li (2010), Diabat and Govindan (2011), Toke et al. (2012), Wang et al. (2012), Meacham et al. (2013), Muduli and Barve (2013), Muduli et al. (2013), Shen et al. (in press), and inputs of the experts of the decision-making team.

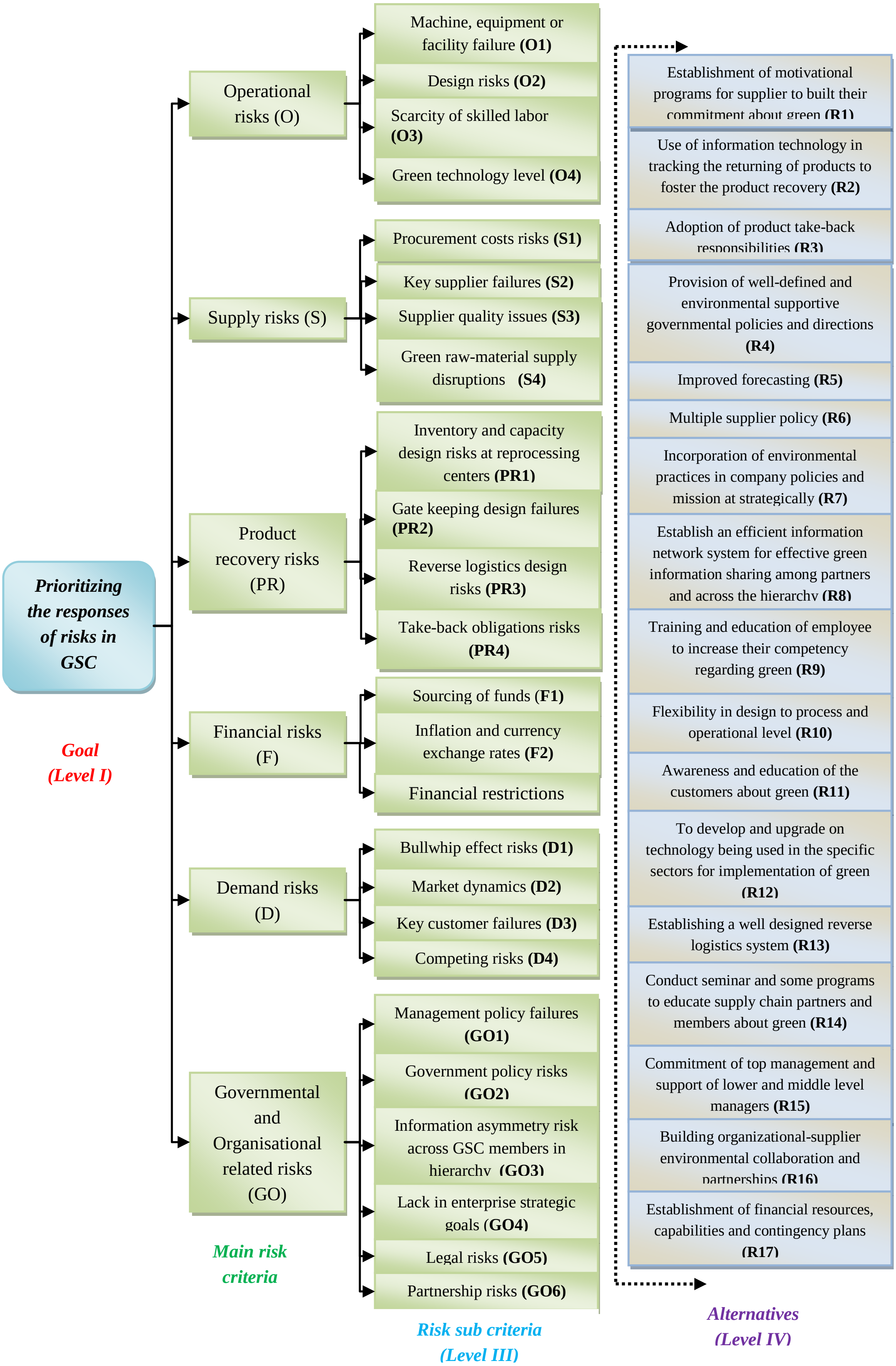


Figure 6.2 Decision Hierarchy for Prioritizing the Responses of Risks

6.4.2 Computation of the importance weights of criteria and sub-criteria

The weight for each main risk criteria and sub criteria were computed by using Chang's Extent Analysis method. The calculated importance weights of the risk criteria and sub criteria are given in the Table 6.4. The other details regarding the calculation of the importance weights of the risk criteria and of sub criteria has already been given in Chapter 4. After the approval of calculated weights of the risk criteria and its sub-criteria by decision-making team, the ranking of the responses of risks recognized in this study were determined.

Table 6.4 Listing and Final Ranking of Categories of Risks and Specific Risks

Categories of risk (GSC risk criteria)	Importance weights	Rank	Specific risks (GSC risks sub criteria)	Relative weights	Relative rank	Global weights	Global rank
Operational risks (O)	0.2507	1	Machine, equipment or facility failure (O1)	0.1595	4	0.03999	11
			Design risks (O2)	0.3177	2	0.07965	3
			Scarcity of skilled labor (O3)	0.1956	3	0.04904	8
			Green technology level (O4)	0.3272	1	0.08203	2
Supply risks (S)	0.1863	3	Procurement costs risks (S1)	0.1944	4	0.03622	13
			Key supplier failures (S2)	0.2454	3	0.04572	10
			Supplier quality issues (S3)	0.2528	2	0.04710	9
			Green raw-material supply disruptions (S4)	0.3054	1	0.05690	6
Product recovery risks (PR)	0.1449	4	Inventory and capacity design risks at reprocessing centers (PR1)	0.1724	3	0.02498	17
			Gate keeping design failures (PR2)	0.1683	4	0.02439	18
			Reverse logistics design risks (PR3)	0.2399	2	0.03476	14
			Take-back obligations risks (PR4)	0.4184	1	0.06063	5
Financial risks (F)	0.2236	2	Sourcing of funds (F1)	0.3390	2	0.07580	4
			Inflation and currency exchange rates (F2)	0.2478	3	0.05541	7
			Financial restrictions (F3)	0.4122	1	0.09217	1

Table 6.4 Contd...

Categories of risk (GSC risk criteria)	Importance weights	Rank	Specific risks (GSC risks sub criteria)	Relative weights	Relative rank	Global weights	Global rank
Demand risks (D)	0.0607	6	Bullwhip effect risks (D1)	0.2504	2	0.01520	21
			Market dynamics (D2)	0.1206	4	0.00732	25
			Key customer failures (D3)	0.2385	3	0.01448	22
			Competing risks (D4)	0.3915	1	0.02376	19
Governmental and Organizational related risks (GO)	0.1338	5	Management policy failures (GO1)	0.2718	1	0.03637	12
			Government policy risks (GO2)	0.2067	3	0.02766	16
			Information asymmetry risk across GSC members in hierarchy (GO3)	0.1633	4	0.02185	20
			Lack in enterprise strategic goals (GO4)	0.2212	2	0.02956	15
			Legal risks (GO5)	0.0798	5	0.01067	23
			Partnership risks (GO6)	0.0572	6	0.00765	24

6.4.3 Evaluation of the responses of risks and determination of their priority

In this stage, the experts in the decision team were asked to make a fuzzy performance matrix based on linguistic variables illustrated in Table 6.2 given in Section 6.3.3. The inputs of the experts were collected on a response sheet. Details about response sheet are given in an Appendix E. In the fuzzy evaluation matrix, the identified responses were compared with respect to each of the identified risk. The linguistic expressions were replaced with TFN and the fuzzy performance matrix was constructed. In this way, the fuzzy performance matrix of each expert was constructed. The fuzzy performance matrix given by the expert 1 is given in Table 6.5.

Table 6.5 Fuzzy Performance Matrix for the Responses of Risks in GSC (Given By Expert 1)

	O1	**O2**	**O3**	**…**	**…**	**GO4**	**GO5**	**GO6**
R1	(1/2,1,2)	(1,2,3)	(1/3,1/2,1)	…	…	(1,3/2,2)	(1/2,2/3,1)	(1,2,3)
R2	(3,7/2,4)	(2,5/2,3)	(2,3,4)	…	…	(3,7/2,4)	(2,5/2,3)	(1/2,1,2)
R3	(1,2,3)	(1/2,1,2)	(1/2,2/3,1)	…	…	(2,5/2,3)	(1/2,1,2)	(1,2,3)
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
R15	(3,4,5)	(2,3,4)	(2,5/2,3)	…	…	(3,4,5)	(3,4,5)	(2,5/2,3)
R16	(1,2,3)	(1,2,3)	(1/2,1,2)	…	…	(2,3,4)	(2,5/2,3)	(2,3,4)
R17	(1/2,1,2)	(1,2,3)	(2,3,4)	…	…	(2,3,4)	(3,4,5)	(4,5,6)

Note: R1, R2..........R16, R17 represents the responses, and O1,O2,O3.............GO5,GO6 represents the GSC risks.

Finally, by taking an average of the fuzzy evaluation matrices of the experts, an aggregate fuzzy performance matrix was derived as shown in Table 6.6. A fuzzy normalized performance matrix was formed as illustrated in Table 6.7. In the present research work, various risk criteria and its sub-criteria in GSC have been listed, and it was proposed to manage these risks. Hence, a fuzzy normalized performance matrix was formed using Equation (6.4). For instance, the normalized fuzzy performance matrix with regard to response R1 and risk O1 is given as,

$$r_{ij} = \left(\frac{0.33}{2}, \frac{0.33}{1.2},, \frac{0.33}{0.7}, \right) = (0.165, 0.275, 0.471) \qquad \text{(by taking cost effective criteria)}$$

These calculations were repeated for the remaining risks for response R1, and are given in Table 6.7. Then, a fuzzy weighted performance matrix was constructed by multiplying the importance weights of criteria computed by fuzzy AHP with the elements of the fuzzy normalized performance matrix, and is shown in Table 6.8. For instance, the fuzzy weighted performance entry with regards to response R1 and risk O1 based on Equation (6.5) is given as,

$\tilde{V} = 0.0399 \times (0.165, 0.275, 0.471) = (0.006, 0.010, 0.018)$

These calculations were repeated for the remaining risks for response R1, and are given in Table 6.8.

Table 6.6 Aggregate Fuzzy Performance Matrix for the Responses of Risks in GSC

	O1	**O2**	**O3**	**…**	**…**	**GO4**	**GO5**	**GO6**
R1	(0.7,1.2,2)	(1,2,3.4)	(0.5,0.5,1.2)	…	…	(1,1.78,2)	(1/2,0.66,0.9)	(0.89,1.9,3)
R2	(2.78,3.5,3.91)	(2,2.91,3)	(1.9,3,3.82)	…	…	(3.1,3.5,4.2)	(2.1,2.71,3.5)	(0.5,1.1,2)
R3	(1.1,2,3.2)	(0.5,1.2,2)	(0.45,0.66,1.64)	…	…	(2.12,2.5,3.56)	(0.5,1.1,2.89)	(1.1,2,3.5)
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
R15	(2.67,4,5.34)	(1.9,3,4.21)	(2,2.5,3.1)	…	…	(3.2,4,5.45)	(2.6,4,5.67)	(2.1,2.5,3.4)
R16	(0.92,2.1,3.2)	(1,2.21,3)	(0.6,1,1.95)	…	…	(1.9,3,4.4)	(2,2.7,3.23)	(1.9,3,4.50)
R17	(0.45,1,2.12)	(1.12,1.93,3)	(2.1,3.41,4.3)	…	…	(2.2,3,4.56)	(2.8,4.3,5.5)	(4.4,5,6.32)

Note: R1, R2..........R16, R17 represents the responses, and O1,O2,O3.............GO4,GO5,GO6 represents the GSC risks.

Table 6.7 Normalized Fuzzy Performance Matrix for the Responses of Risks in GSC

	O1	**O2**	**O3**	**…**	**…**	**GO4**	**GO5**	**GO6**
R1	(0.165,0.275,0.471)	(0.097,0.165,0.33)	(0.275,0.66,0.66)	…	…	(0.165,0.185,0.33)	(0.367,0.22,0.66)	(0.11,0.173,0.370)
R2	(0.109,0.122,0.154)	(0.143,0.147,0.215)	(0.112,0.143,0.226)	…	…	(0.102,0.12,0.138)	(0.122,0.158,0.204)	(0.215,0.390,0.86)
R3	(0.078,0.125,0.227)	(0.125,0.208,0.5)	(0.155,0.373,0.555)	…	…	(0.070,0.1,0.117)	(0.086,0.227,0.5)	(0.071,0.125,0.227)
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
R15	(0.046,0.062,0.093)	(0.059,0.083,0.131)	(0.080,0.1,0.125)	…	…	(0.045,0.062,0.078)	(0.044,0.062,0.096)	(0.073,0.1,0.119)
R16	(0.103,0.157,0.358)	(0.11,0.149,0.33)	(0.169,0.33,0.55)	…	…	(0.075,0.11,0.173)	(0.102,0.122,0.165)	(0.073,0.11,0.173)
R17	(0.094,0.2,0.444)	(0.066,0.101,0.178)	(0.046,0.05,0.095)	…	…	(0.043,0.066,0.091)	(0.036,0.046,0.071)	(0.0316,0.04,0.045)

Note: R1, R2..........R16, R17 represents the responses, and O1,O2,O3.............GO4,GO5,GO6 represents the GSC risks.

Table 6.8 Weighted Normalized Fuzzy Performance Matrix for the Responses of Risks in GSC

	O1	**O2**	**O3**	**…**	**GO4**	**GO5**	**GO6**
R1	(0.006,0.010,0.018)	(0.007,0.013,0.026)	(0.013,0.032,0.032)	…	(0.004,0.005,0.009)	(0.003,0.002,0.007)	(0.001,0.001,0.002)
R2	(0.004,0.004,0.006)	(0.011,0.011,0.017)	(0.0055,0.007,0.011)	…	(0.003,0.003,0.004)	(0.001,0.001,0.002)	(0.001,0.002,0.006)
R3	(0.003,0.004,0.009)	(0.009,0.016,0.039)	(0.007,0.018,0.027)	…	(0.002,0.002,0.003)	(0.001,0.002,0.005)	(0.001,0.001,0.001)
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
R15	(0.001,0.002,0.003)	(0.004,0.006,0.010)	(0.003,0.004,0.006)	…	(0.001,0.001,0.001)	(0.001,0.001,0.001)	(0.001,0.001,0.001)
R16	(0.004,0.006,0.014)	(0.008,0.011,0.02)	(0.008,0.016,0.026)	…	(0.002,0.003,0.005)	(0.001,0.001,0.001)	(0.001,0.001,0.001)
R17	(0.003,0.007,0.017)	(0.005,0.008,0.0142)	(0.002,0.002,0.004)	…	(0.001,0.001,0.002)	(0.001,0.001,0.001)	(0.001,0.001,0.001)

Note: R1, R2..........R16, R17 represents the responses, and O1,O2,O3............GO4,GO5,GO6 represents the GSC risks.

In this work, it is proposed to manage the GSC risks. Therefore, the fuzzy positive ideal response (FPIS, A^*) and the fuzzy negative ideal response (FNIS, A^-) are given as $\tilde{v}_j^* = (0,0,0)$, $\tilde{v}_j^- = (1,1,1)$ respectively for each of these risk criteria. The distance (d_i^+, d_i^-), of each of the alternative were calculated from these FPIS and FNIS using the Equations (6.8) – (6.9). For example, the distances $d(A_1,A^*)$ and $d(A_1,A^-)$ w.r.t. response R1 and risk O1 from FPIS and FNIS are calculated as follows:

$$d(A_1,A^*) = \sqrt{\frac{1}{3}\left[(0-0.006)^2+(0-0.010)^2+(0-0.018)^2\right]} + \sqrt{\frac{1}{3}\left[(0-0.07)^2+(0-0.013)^2+(0-0.026)^2\right]} + \ldots\ldots + \sqrt{\frac{1}{3}\left[(0-0.003)^2+(0-0.002)^2+(0-0.007)^2\right]} + \sqrt{\frac{1}{3}\left[(0-0.001)^2+(0-0.001)^2+(0-0.002)^2\right]} = 0.2966$$

$$d(A_1,A^-) = \sqrt{\frac{1}{3}\left[(1-0.006)^2+(1-0.010)^2+(1-0.018)^2\right]} + \sqrt{\frac{1}{3}\left[(1-0.07)^2+(1-0.013)^2+(1-0.026)^2\right]} + \ldots\ldots + \sqrt{\frac{1}{3}\left[(1-0.003)^2+(1-0.002)^2+(1-0.007)^2\right]} + \sqrt{\frac{1}{3}\left[(1-0.001)^2+(1-0.001)^2+(1-0.002)^2\right]} = 24.7299$$

These calculations were repeated for the remaining risks for response R1, and are given in Table 6.9. Further, based on distances $d(A_1,A^*)$ and $d(A_1,A^-)$, the closeness coefficient of R1 is computed using the Equation (6.10), and is given as :

$$D_1 = \frac{24.7299}{(0.2966+24.7299)} = 0.9881$$

In the same way, distances $d(A_1,A^*)$ and $d(A_1,A^-)$ were calculated for each of the response, and the corresponding closeness coefficient (D_i) was computed. To develop and upgrade on technology being used in the specific sectors for implementation of green (R12) response obtains the highest D_i value of equal to 0.9952. While, Use of information technology in tracking the returning of products to foster the product recovery (R2) response obtains the lowest highest D_i value of equal to 0.98607. Finally, using D_i values, the ranking for the risk responses or alternatives was made as shown in Table 6.9.

Table 6.9 Summary of Closeness Coefficient (D_i) and Final Ranking of the Responses

Responses	d_i^+	d_i^-	D_i	**Ranking**
R1	0.29660	24.72994	0.98815	16
R2	0.34868	24.68157	0.98607	17
R3	0.27602	24.75396	0.98897	15
R4	0.26686	24.75773	0.98934	13
R5	0.26529	24.76190	0.98940	12
R6	0.24827	24.77610	0.99008	8
R7	0.17420	24.83936	0.99304	4
R8	0.24632	24.77591	0.99016	7
R9	0.27337	24.75040	0.98908	14
R10	0.13077	24.87965	0.99477	3
R11	0.25310	24.77112	0.98989	10
R12	0.11997	24.88868	0.99520	1
R13	0.26005	24.76403	0.98961	11
R14	0.25200	24.77320	0.98993	9
R15	0.13016	24.88133	0.99480	2
R16	0.21397	24.80693	0.99145	6
R17	0.20397	24.82216	0.99185	5

Note: R1, R2..........R16, R17 represents the responses.

6.5 Discussion of the Results

It is difficult to declare, which responses are more significant to manage the risks in adopting effective GSC initiatives. However, the prioritizing of these responses by utilizing fuzzy AHP and fuzzy TOPSIS methods are useful in this situation. In the present work, an integrated fuzzy AHP-TOPSIS approach has been extended to the Indian business orgnaization under consideration to improve their effectiveness in adoption and implementation of the green initiatives in the supply chain. Therefore, a set of appropriate and feasible responses are proposed to the business organizations under study to manage and reduce the consequences of the risks in GSC.

According to the findings of this work, twenty-five risks and seventeen responses were recognized through literature and in consultation with experts. The importance weights of the risks were identified using the fuzzy AHP method. These weights were used to give priority to responses of the risks in GSC by using the fuzzy TOPSIS method.

The fuzzy TOPSIS based preference order of responses of risk in GSC is illustrated in Table 6.9. According to the values of D_i, the priority of concern of the responses of the risks in GSC are given as, R12-R15-R10-R7-R17-R16-R8-R6-R14-R11-R13-R5-R4-R9-R3-R1-R2. To develop and upgrade on technology being used in the specific sectors for implementation of green (R12) obtains the highest rank. Thus, managers of the business organizations under consideration should consider the response (R12) at priority in effective implementation of GSCM. The commitment of top management and support of lower and middle level managers (R15) comes next to R12 in priority in adopting an efficient GSCM thought. Further, Flexibility in design to process and operational level (R10) and Incorporation of environmental practices in company policies and mission at strategically (R7) occupies the third and fourth place of priority, and so on up to Use of information technology in tracking the returning of products to foster the product recovery (R2), which obtains the last rank.

To increase the managerial utility of this research, the research findings were discussed with the decision making team with an objective to have further insights to implement the responses of risks relevant to effective GSCM implementation, which in turn will improve the GSC effectiveness. Therefore, managers are suggested that they should formulate the proposed responses in accordance with their priority and implement them in a systematic way as defined through the rank assigned in this study.

6.5.1 Sensitivity analysis

To check the robustness of the proposed model, it is suggested to conduct the sensitivity analysis (Patil and Kant, 2014). In sensitivity analysis, the ranking of the responses of risks were monitored with regard to the changes in the importance weights of identified risks. Therefore, in this research, the total twenty-one experiments have been performed; details are given in Table 6.10.

In the first 20 experiments, the importance weights of each risk was set as higher one by one, while the weights of other risks are set to low and assigned at equivalent importance or equal values as shown in Table 6.10. According to the findings of sensitivity analysis, the weight of the risk O1 (Machine, equipment or facility failure) is taken as 0.6 and the weights of the remaining 24 risks (experiment-1) are given equal importance, thus assigned equal importance weights for them. The importance weights is calculated by dividing the 0.4 with total number of remaining risk (0.4/24 = 0.01667). In experiment number 21, all the risks are treated as equally important, and so, they are assigned equal weights, calculated as 1 divided by total number of risks (1/25 = 0.04). The changes in the importance weights of the risk may reflect changes in both the closeness coefficient and the final ranking of the responses of risks. In sensitivity analysis, out of 21 experiments, response (R12) has obtained the highest value of closeness coefficient in 10 experiments (in experiments number 1-3, 6, 8, 10-12, 16-17). While, response (R15) has received the highest score in 7 experiments (i.e. in experiments number 5, 7, 9, 13, 19-21). Concerning to the other 4 experiments, response (R10) acquired the highest score and thus obtained the first rank among other responses. According to sensitivity analysis, in the majority of experiments (approximately 50% of times), response (R12) has obtained the highest rank among all risk responses. Hence, it can be concluded that the proposed network model is robust, and the ranking of the responses of risks relevant to effective implementation of GSCM is relatively stable to the change in the weights of the risks as shown in Figure 6.3.

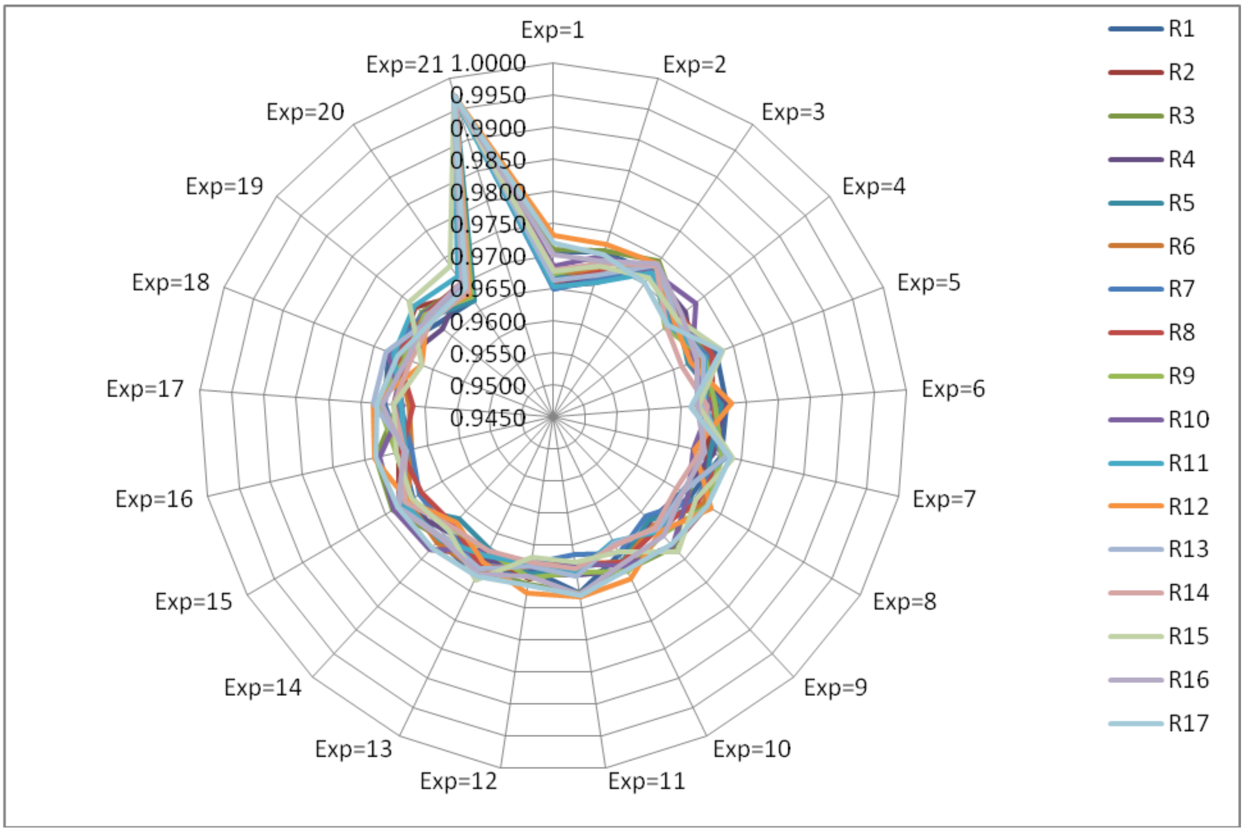


Figure 6.3 Score of Closeness Coefficient through Sensitivity Analysis

Table 6.10 Summary of Results of Sensitivity Analysis Test

Description of the experiments	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17
Exp 1: WO1=0.60, WO2-WGO6=0.01667	0.9869	0.9905	0.9918	0.9922	0.9799	0.9922	0.9935	0.9915	0.9922	0.9950	0.9928	0.9962	0.9911	0.9921	0.9960	0.9908	0.9902
Exp 2: WO2=0.60, WO1, WO3-WGO6=0.01667	0.9897	0.9900	0.9882	0.9913	0.9783	0.9936	0.9947	0.9924	0.9899	0.9912	0.9920	0.9956	0.9935	0.9898	0.9956	0.9914	0.9942
Exp 3: WO3=0.60, WO1-WO2,WO4-WGO6=0.01667	0.9817	0.9906	0.9880	0.9925	0.9890	0.9913	0.9921	0.9899	0.9924	0.9957	0.9846	0.9961	0.9889	0.9847	0.9958	0.9888	0.9933
Exp 4: WO4= 0.60, WO1-WO3, WS1-WGO6=0.01667	0.9920	0.9877	0.9913	0.9879	0.9873	0.9941	0.9939	0.9904	0.9891	0.9960	0.9917	0.9959	0.9900	0.9922	0.9956	0.9936	0.9958
Exp 5: WF1=0.60, WO1-WO4, WF2-WGO6=0.01667	0.9864	0.9785	0.9927	0.9918	0.9783	0.9925	0.9926	0.9832	0.9918	0.9950	0.9922	0.9956	0.9918	0.9898	0.9962	0.9945	0.9904
Exp 6: WF2=0.60, WO1-WF1,WF3-WGO6=0.01667	0.9810	0.9884	0.9934	0.9824	0.9873	0.9920	0.9939	0.9924	0.9919	0.9954	0.9825	0.9958	0.9915	0.9925	0.9954	0.9939	0.9929
Exp 7: WF3=0.60, WO1-WF2,WS1-WGO6=0.01667	0.9850	0.9827	0.9938	0.9899	0.9794	0.9837	0.9867	0.9811	0.9791	0.9958	0.9833	0.9956	0.9808	0.9815	0.9963	0.9937	0.9894
Exp 8: WS1=0.60, WO1-WF3,WS2-WGO6=0.01667	0.9920	0.9792	0.9936	0.9915	0.9905	0.9837	0.9913	0.9889	0.9843	0.9953	0.9919	0.9959	0.9931	0.9923	0.9944	0.9949	0.9909
Exp 9: WS2=0.60, WO1-WS1,WS3-WGO6=0.01667	0.9917	0.9808	0.9892	0.9927	0.9916	0.9923	0.9947	0.9922	0.9919	0.9899	0.9932	0.9942	0.9919	0.9943	0.9955	0.9914	0.9942
Exp 10: WS3=0.60, WO1-WS2,WS4-WGO6=0.01667	0.9889	0.9872	0.9919	0.9887	0.9906	0.9926	0.9949	0.9922	0.9885	0.9941	0.9809	0.9957	0.9927	0.9935	0.9954	0.9936	0.9939
Exp 11: WS4=0.60, WO1-WS3,WPR1-WGO6=0.01667	0.9805	0.9898	0.9803	0.9920	0.9913	0.9933	0.9953	0.9919	0.9916	0.9950	0.9918	0.9964	0.9917	0.9937	0.9963	0.9864	0.9911
Exp 12: WPR1=0.60, WO1-WS4,WPR2-WGO6=0.01667	0.9920	0.9861	0.9839	0.9929	0.9900	0.9922	0.9936	0.9917	0.9919	0.9954	0.9930	0.9964	0.9930	0.9943	0.9954	0.9936	0.9954
Exp 13: WPR2=0.60, WO1-WPR1,WPR3-WGO6=0.01667	0.9855	0.9899	0.9879	0.9930	0.9876	0.9907	0.9918	0.9890	0.9917	0.9963	0.9917	0.9959	0.9881	0.9895	0.9963	0.9910	0.9940
Exp 14: WPR3=0.60, WO1-WPR2,WPR4-WGO6=0.01667	0.9892	0.9831	0.9880	0.9915	0.9809	0.9898	0.9940	0.9923	0.9922	0.9960	0.9921	0.9956	0.9898	0.9927	0.9951	0.9937	0.9909
Exp 15: WPR4=0.60, WO1-WPR3,WGO1-WGO6=0.01667	0.9889	0.9808	0.9846	0.9820	0.9916	0.9842	0.9938	0.9923	0.9830	0.9939	0.9893	0.9923	0.9820	0.9842	0.9905	0.9864	0.9824
Exp 16: WD1=0.60, WO1-PR4,WD2-WGO6=0.01667	0.9915	0.9868	0.9881	0.9930	0.9904	0.9937	0.9945	0.9919	0.9912	0.9892	0.9921	0.9965	0.9927	0.9928	0.9955	0.9933	0.9910
Exp 17: WD2=0.60, WO1-D1,WD3-WGO6=0.01667	0.9896	0.9808	0.9934	0.9917	0.9901	0.9920	0.9949	0.9919	0.9828	0.9951	0.9931	0.9959	0.9820	0.9898	0.9957	0.9908	0.9939
Exp 18: WD3=0.60, WO1-WD2,WD4-WGO6=0.01667	0.9847	0.9873	0.9841	0.9889	0.9904	0.9842	0.9827	0.9893	0.9891	0.9955	0.9890	0.9953	0.9820	0.9923	0.9954	0.9936	0.9952
Exp 19; WD4=0.60, WO1-D3,WGO1-WGO6=0.01667	0.9916	0.9802	0.9919	0.9916	0.9873	0.9921	0.9917	0.9836	0.9917	0.9937	0.9833	0.9942	0.9918	0.9935	0.9956	0.9936	0.9951
Exp 20: WGO1=0.60, WO1-D44,WGO1-WGO6=0.01667	0.9926	0.9898	0.9935	0.9918	0.9905	0.9936	0.9941	0.9922	0.9915	0.9954	0.9893	0.9959	0.9930	0.9933	0.9964	0.9936	0.9950
Exp 21: WO1-WGO6=0.04	0.9988	0.9986	0.9990	0.9990	0.9987	0.9990	0.9993	0.9990	0.9989	0.9994	0.9989	0.9995	0.9990	0.9991	0.9995	0.9992	0.9993

6.6 Conclusions

This chapter suggest a structural model to prioritize or rank responses of the risks in GSC. The proposed approach helps managers in overcoming the problem of human subjectivity and an inherent uncertainty in the GSC risk management process. The methodology of fuzzy AHP is helpful in deciding the importance weights of the GSC risks, and the fuzzy TOPSIS technique is utilized to determine the responses' priority. The weights obtained from the fuzzy AHP method was used as input in the fuzzy TOPSIS technique, and the identified appropriate responses of risks were ranked to obtain the priorities in terms of their implementation. It will certainly improve the business effectiveness by implementing appropriate responses of the risks in adoption of the green initiatives in the supply chain.

Based on literature survey and inputs received from the experts of decision-making team, seventeen responses of risks relevant to the implementation of GSC initiatives were finalized. The selected responses were prioritized based on their respective rank using integrated fuzzy AHP-TOPSIS approach. To develop and upgrade on technology being used in the specific sectors for implementation of green, response (R12) obtains the highest priority, meaning that, it is the highest rank response to manage risk and its consequences. Thus, managers should focus this response at priority in managing the risks in GSC.

The findings of this work would not only helpful in managing the risks relevant to an effective implementation of GSCM, but also useful in enhancing the ecological-economic gains. At the end, a sensitivity analysis was conducted to examine the robustness of the proposed model.

CHAPTER 7

FLEXIBLE DECISION FRAMEWORK FOR PROPOSING RISK MITIGATION STRATEGIES

This chapter develops a decision framework that enables to analyze the risk mitigation strategies in GSC. The methodology of SAP-LAP (Situation Actor Process- Learning Action Performance) is developed for this purpose. The SAP-LAP based model lacks in interpretation of the relationship among variables. Therefore, SAP-LAP approach is linked with other method i.e., Interactive Ranking Process (IRP), which helps in evaluating the SAP-LAP model by determining the ranks of actors and actions w.r.t. process and performance respectively.

7.1 Introduction

Green and sustainability issues have an increasing popularity among researchers and practitioners. GSCM has been acknowledged as a key factor to promote organizational sustainability (Zhu et al., 2011; Gunasekaran and Gallear, 2012). GSCM initiatives may be of great value to the firms as well as to the external environment (Eltayeb et al., 2011). With the passage of time, GSC networks are becoming more complex due to the occurrence of different risks and risk driving factors. Thus, risk management and mitigation in GSC needs significant managerial attention. The present chapter seeks to develop a managerial framework for GSC risk mitigation strategies to manage GSCM activities. This chapter is aimed to achieve two objectives. The first objective is to develop a decision framework, which analyzes the risk mitigation strategies in GSC. To achieve this, it is suggested to use the methodology of SAP-LAP (Situation Actor Process- Learning Action Performance), which has been widely accepted as a flexible approach (Sushil, 2000; Majumdar and Gupta, 2001; Palanisamy, 2012). It is an intuitive process of decision-making, but having some limitations in terms of validity, transparency, cognitive overload, etc (Sushil, 2009b). The interpretation of the interactive relationships among the variables of the SAP-LAP based framework lacks in this process, and thus may distort the process of decision making. To deal with this, it is proposed to rank the SAP-LAP variables (Sushil, 2009b).

Part of this chapter has been published/accepted for publication in

- Global Journal of Flexible Systems Management, 15(3), 203-218

The second objective of this chapter is to analyze the variables (actor, process, action and performance) involved in SAP-LAP framework to facilitate the managers in improving the ecological-economic performance. The ranking of the variables, i.e., actors and actions were done in relation to process and performance identified through SAP-LAP methodology. To obtain the ranking of the variables, the IRP technique is used. The research presents the findings via an intuitive and interpretive decision technique to address important issues in understanding of risk and mitigation strategies in GSC.

7.2 Developing of Conceptual Framework for Building Strategies to Manage the Risks: SAP-LAP Application

Sushil, in 1997 introduced a flexible managerial approach, named as SAP–LAP process, which is logically supportive to build such types of decision-making structure. The SAP-LAP model has been described as the basis of flexible system management having three essential entities in any management perspective, i.e., situation, actor, and process (Sushil, 1997).

It has been stated that the performance of GSC is highly affected by the occurrence of risks and risk driving factors within a network (Yang and Li, 2011; Zou and Couani, 2012). Ma et al. (2012) studied the various risks in GSCM. Some of them are given as market uncertainties, supplier failure, financial issues, etc. Thus, managers should seek to develop a suitable outline for structural strategies, which would be useful in mitigating such risks and their driving factors. In this context, the SAP–LAP framework can be a very effective tool to outline the strategies of the different managerial system (Sushil, 2000).

In building a managerial SAP-LAP framework, ‘Situation’ represents the state to be deal with. ‘Actor(s)’ are the individual contributors, or members, which interact with a particular situation for its performance. ‘Process’ or ‘Processes’ represents the makeover process to recreate the situation (Sushil, 2001a,b). The interaction and synthesis of the SAP leads to the development of LAP. ‘Learning’ represents the various issues to be learnt from SAP.

Based on the learnt issues, managers can act and make actions to improve the overall performance of the system. The SAP-LAP based framework has been widely used by many researchers to manage various situations (Sushil 2001a, b; Majumdar and Gupta, 2001; Palanisamy, 2012; Mahajan et al., 2013; Kumar et al., 2013). For example, in developing internet and e-business technology in Indian car manufactures (Majumdar and Gupta 2001), in analyzing the coordination in an automotive parts manufacturer supply chain (Arshinder et al., 2007), in evaluating the issue involved in implementation of IT in Indian manufacturing SMEs (Thakkar et al., 2008). Kumar et al. (2013) examined the coordination issues for flexibility in supply chain of SMEs. Palanisamy (2012) developed the information systems flexibility by taking the case of SME sector. Luthra et al. (2014c) developed a model to analyze the critical factors in GSCM implementation towards sustainability in Indian automotive sector.

Based on discussion with the experts, a managerial framework for building strategies to manage risks in GSC is developed in this work by using the SAP-LAP approach. More details on how to develop a SAP–LAP framework is given in subsequent sub-sections.

7.2.1 Situation

7.2.1.1 Reaching the Situation of Building Risks Mitigation Strategies for GSC

GSCs networks are becoming complex due to the occurrence of different risks and unceratin factors (Simpson and Sampson, 2008; Ma et al., 2012). Additionally, greening of the supply chain is influenced by many factors, such as governmental influence, customer requirements, management commitment level, technology level globalization, etc. Any incorrect implication of these factors such as management commitment level, technology level etc. could reduce the overall efficiency of GSC. The whole GSC can further be disrupted if managers do not take measures to manage these uncertain factors in a timely manner. Thus, this research work focuses on developing a SAP-LAP based conceptual model to build risk mitigation strategies for GSC as shown in Figure 7.1.

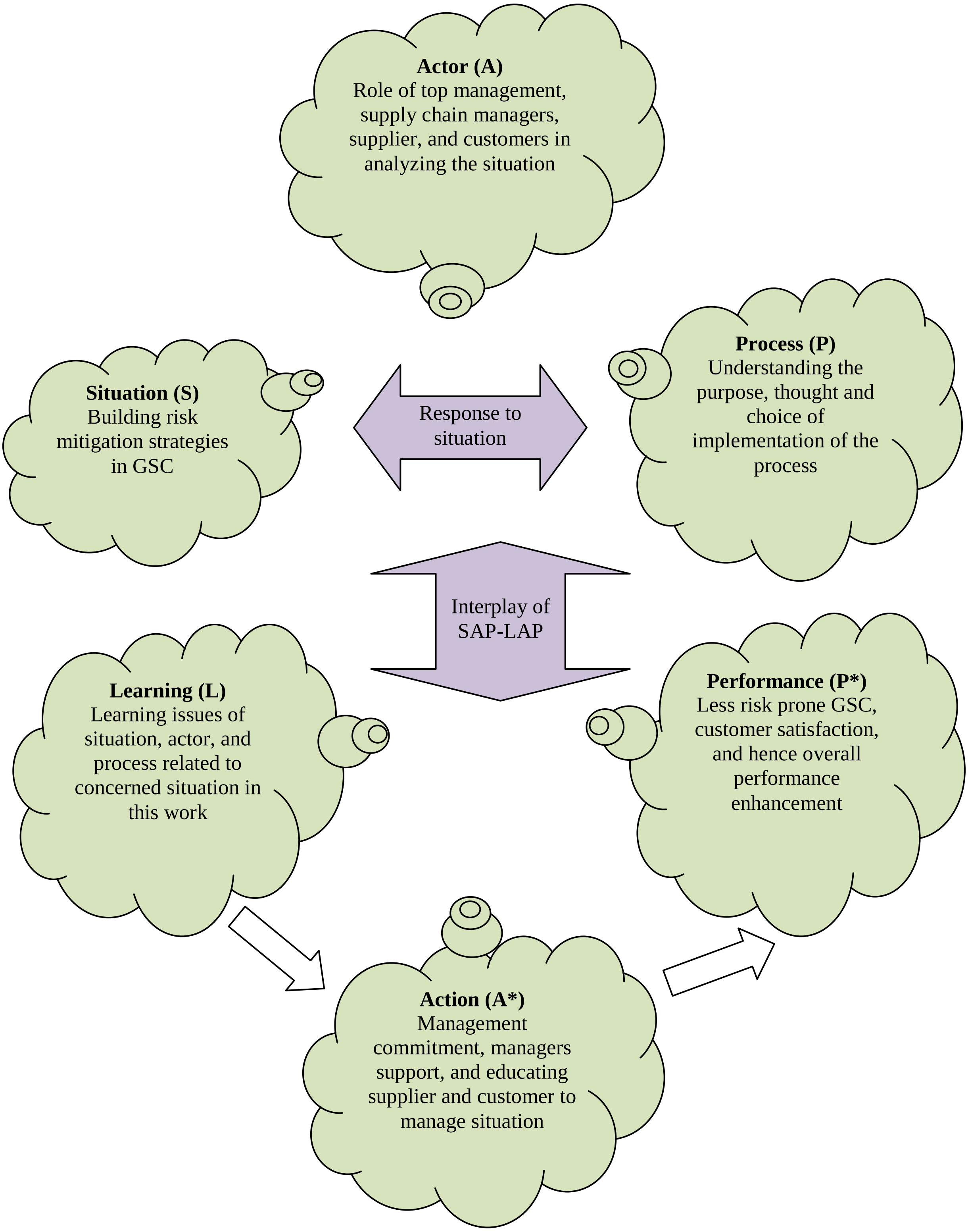


Figure 7.1 SAP-LAP Based Conceptual Framework to Build Risk Mitigation Strategy

Source: Inputs received from the experts

7.2.1.2 What is happening now and What is Expected to Happen

Although it is already the 21st century, there is still a lack of discussion on risks and disturbances in GSC (Ma et al., 2012). There may be several problems and uncertainties in implementing the GSC initiatives in business (Qianlei, 2012). It could be financial problems, poor/weak enforcement of environmental laws, lack of knowledge, lack of awareness and lack of technical competence (Siaminwe et al., 2005). The organizations are also lacking in contingency plans to manage these kinds of problems (Yang and Li, 2010). Thus, it is very important for organizations to evaluate their own strengths and weaknesses to optimize the use of resources, to understand the requirements of globalized and market behaviour and make plans for a contingency period (Simpson and Sampson, 2008). The knowledge on risk and risk mitigation strategies for GSCs are therefore needed to be defined and understood to reduce, avoid, and manage the risks. Hence, it is important for organizations to identify the risks in GSC, and implement measures to diminish the consequences; otherwise overall efficiency may be reduced.

7.2.2 Actors

7.2.2.1 Global Outlooks on Building Risk Mitigation Strategies

Based on experts' inputs, the important actors who are involved and contribute to building risk mitigation strategies for GSC are suppliers, customers, supply chain managers, and top management as shown in Figure 7.1. Further, building risk mitigation strategies is not only the task of individual actors, but also requires a collective and integrative initiative from all actors involved in the GSC.

7.2.2.2 Roles and Capabilities Exhibited by the Actors

Supply chain managers should share risk issues and mitigation strategies with top management, as their commitment and agreement is necessary in initiating and implementing risk mitigation strategies to manage issues in GSC. Further, managers should be capable of providing reactions on constant changes in business environment, and be able to predict the capabilities and limitations of the current system. Accordingly, decisions regarding supplier selection and options for keeping redundant suppliers should be taken. For a successful business, the managers and planners must be capable of understanding the global situations in greening the supply chains. The customers should also be significantly involved by considering their responsibilities in building and managing risk mitigation strategies. Further, it would be beneficial, if risk mitigation strategies could be aligned with business objectives.

7.2.2.3 In What Domains the Freedom of Choice is Available for the Actors

Although the customers and suppliers contribute equally in the building risk mitigation strategies framework in GSC, but still, organizations have freedom of choice in their decision. The commitments and degree of involvement of the actors and the expectations from managers could signify the range of freedom of choice for these. Likewise, the commitment and approach of suppliers towards risk issues in GSC also assists planners in making decisions on their selection.

The decision on whether to involve the customers and suppliers or not only depends on the manager’s choice. Accordingly, if they are involved, who, when, and how these should be included is another choice domain for the manager that provides flexibility in the process. However, the freedom of choice for top management is the decisions of the selected expertise in the domain i.e. supply chain managers, and the allocation of resources should be sufficient when formulating risk mitigation strategies (Qianlei, 2012). Further, top management should be careful in their freedom of choice, as in case of any flaw, there might be possibility of deviations in GSC risk mitigation strategies from the discussed approach.

7.2.3 Process

7.2.3.1 Risk Mitigation/Managing Strategy and its Need in GSC

Risk mitigation is a process focusing on events that might happen and managing them if they have happened. Therefore, it is crucial to adopt a precise strategy to mitigate these risks in the context of GSC. The schematic representation of risk mitigation strategies for GSC is presented in Figure 7.2. This is built on previous research in field of supply chain and risk management (e.g. Miller, 1992; Martha and Subbakrishna, 2002; Juttner et al., 2003; Sheffi, 2005; Gurnani et al., 2012), and extending it to the perspective of GSC. The suggested risk mitigation strategies were validated from a subsequent discussion with experts. To reduce the complexity, strategies are categorized into two approaches, proactive and reactive approaches. These approaches are further expanded.

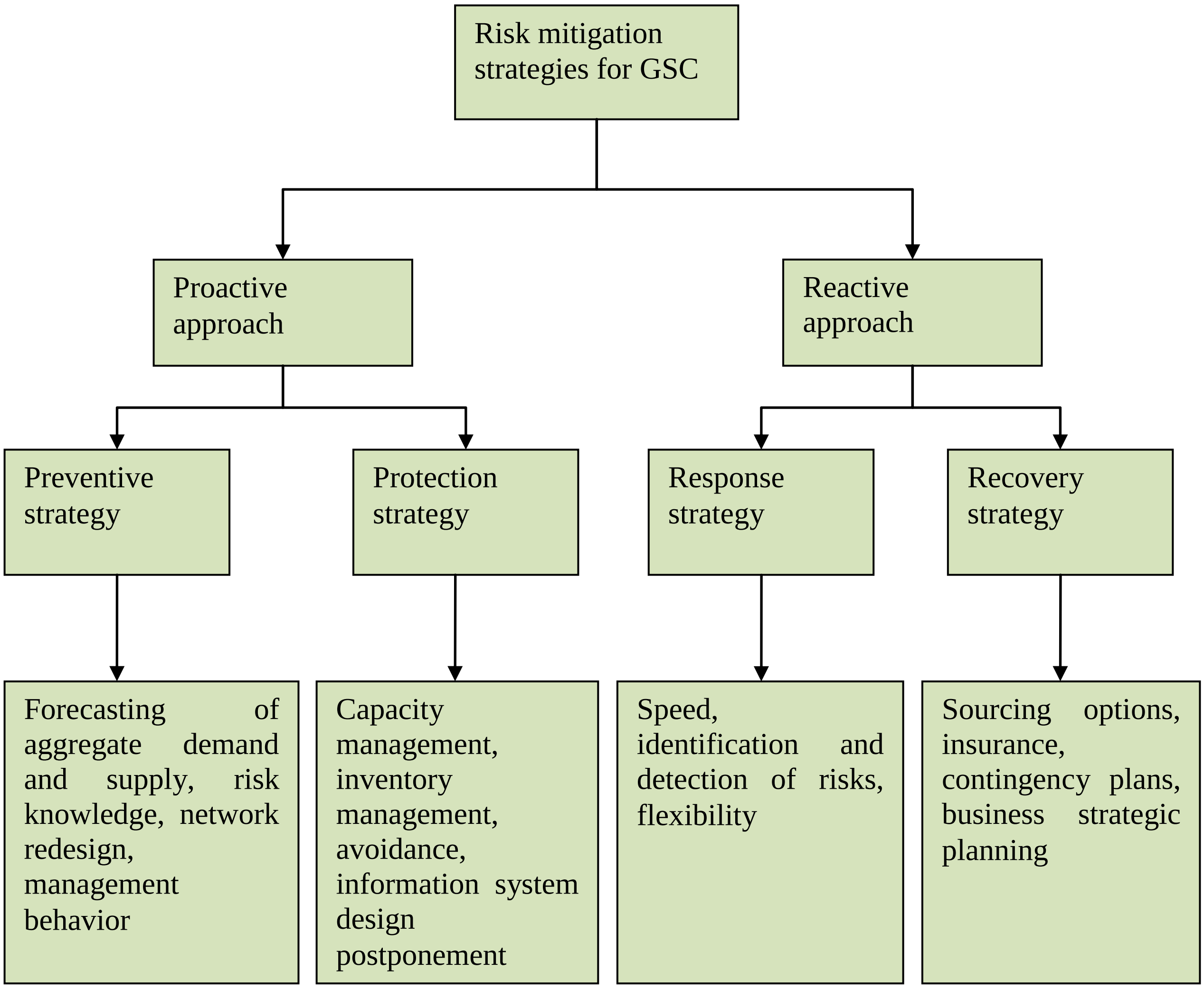


Figure 7.2 Schematization of Risk Mitigation Strategies for GSC

Proactive approach includes actions in advance to deal with risks and uncertainties. This approach involves controlling a state of unexpected events by causing something to happen, instead of waiting for a response after it happens. It can further be sorted into a preventive strategy and a protection strategy. The preventive strategy concerns preventing a risk and finding a solution that can totally eliminate the risk. It can be viewed as increasing the Mean time to failure (MTTF) of a supply node (Gurnani et al., 2012). Since severe disturbances in supply are rare, MTTF is not used as a measure in general. As a result, it would be better to focus on the probability of the occurrence of risk in any given period, and work in a direction that reduces the chance of occurrence of a risk that covers the objectives. The probability of occurrence of risks in terms of their preference weights have already been computed in Chapter

4. With this perception, the preventive strategies are further expanded into several risk mitigation measures for GSC a shown in Figure 7.2.

There should be visibility in decisions and transparency among all partners for greening the supply chain. In addition, to prepare for disturbances in supply and demand risks in GSC business activities, forecasting of aggregate demand and supply should also be performed in GSC as in traditional supply chain practices. However, for accurate forecasts, a manager and planner should have comprehensive knowledge on risks related to GSC. Moreover, having human expertise in terms of knowledge on risk and their sources in GSC can help organizations to take early preventive measures to achieve risk reduction. The GSC may also be redesigned to incorporate effective measures to reduce the probability of the occurrence of the risks and the negative effects (Shuhong, 2009). Finally, the approach and behaviour of management (i.e. commitment) in this strategy is important (Mangla et al., 2012).

Protection strategy deals with measures on protecting a GSC network. This strategy is unable to entirely isolate risks, but is helpful in shortening the user interval. The protection strategy measures for GSC, such as capacity management, inventory management, avoidance, information sharing and postponement etc., are summarized in Figure 7.2. Decisions on capacity planning are easy and simple to employ in static-conditions. However, in a dynamic environment, where customer and market behaviour are unpredictable, a planned capacity policy is required (De Castro et al., 1997). Effective decision analysis can improve performance by confirming product return quantity and quality (Georgiadis et al., 2006). The approach of keeping sufficient inventory can also mitigate the consequences of related risk in GSC. The use of inventory as a protective mechanism varies and depends on different conditions and environments (Liu et al., 2010). This measure aids in managing inventory related decisions during manufacturing and the recovery of products within an organization, or at external reprocessing stations. It also aids in prevention of unacceptable risks while working in a given product market or geographical region (Miller, 1992). If mitigation of a particular risk is difficult, it would be better to avoid that situation for a while. For instance, an organization could drop specific geographical markets, products, process, technology, to mitigate the particular risk and disturbance.

Advancements in information technology have become increasingly important for business operations and organizational green focused supply chain design. At the same time, organizations are having higher risks of interruption in their information systems. For example, the incidence like 9/11 almost disrupted the entire local information technology network. To mitigate this issue, some measures and backup information systems can be included in the GSCM plan. For example, tracking the products information via radio-frequency identification (RFID), enterprise resource planning (ERP), and bar code etc. would be useful to enhance the effectiveness of the recovery process (Madaan et al., 2012). When planning for complex uncertain situations in GSC network design, if good reactions cannot be made, it would then be better to postpone the decision for a while (Srivastava, 2008).

Thereafter, a taxonomy that is useful when an organization identifies a risk, after it is struck into the supply chain (reactive approach) is discussed. This approach can be understood as acting in response to a situation instead of controlling it. Additionally, this approach is sorted into various strategies such as response, recovery, and contingency plan for risk mitigation in GSC as shown in Figure 7.2. The response strategies can be viewed as decreasing the mean time to repair (MTTR). It means the sooner a firm starts resolving a problem, the quicker it will be able to recover (Gurnani et al., 2012). Besides, adoption and usage of the response strategy varies with organizations and the surrounding environments. Some measures of the response strategy, such as speed, detection & identification, agility, and flexibility in network design of GSC, are discussed for clear illustration. Under highly uncertain conditions and long-term market share implications, the speed an organization responds to the risk is essential. Once a risk is detected, the consequences depend on how quickly the firm can react (Juttner et al., 2003; Sheffi, 2005). Ability in identifying the risks is also very important, as nothing can be done to mitigate the disruption if the existence of risk is not identified. Another important response strategy measure is agility and flexibility of network design of GSC in handling the risky unforeseeable events (Madaan et al., 2012; Bai and Sarkis, 2013).

Concerning the recovery strategies on risk mitigation, the vast majority of research on operations management has focused on decisions prior to the happening of the risk. However, preparedness for risks is also essential, and organizations should not overlook the opportunities for mitigating the consequences of risks in GSC. More importantly, customer concerns and loyalty are also associated with the consequences of a supply disturbance. It can persist long after the disruption event has ended. For instance, Ericsson suffered a fall in market share well beyond the resolution of the supply problem caused by a fire at a Philips plant (Sheffi, 2005). Likewise, the supply decision on virgin-secondary material is significant in the GSC perspective in satisfying customers’ demand. For the traditional forward supply chain organizations’ point of view to insure a risk, it has to be identifiable, quantifiable, and manageable (Martha and Subbakrishna, 2002). Similarly, in the GSC perspective, insuring is a good option in recovering the consequences of risk. Insuring has no effect on preventing a disturbance, but it can mitigate cash flow problems that plague a firm in the wake of a serious disturbance. Another mechanism to mitigate risks in GSC is multiple sourcing i.e. having multiple suppliers to reduce the chance or mitigate the consequences of disturbances in the supply of raw virgin-reused materials. For instance, in the traditional supply chain, the multiple-sourcing strategy adopted by Nokia helped it to recover quickly in the case of the fire at the Philips plant.

Finally, construction of contingency plans is a significant approach under the recovery strategy in covering the consequences of post disturbances of a network. Effective business strategies and planning at an operational, tactical, and strategic level also helps in contributing preparedness for risks and good execution of plans, both within and beyond the organization.

7.2.3.2 Procedure for Mitigating Risks in GSC

After understanding the impact of risks on organizations in terms of reduced brand image, customer satisfaction, economic and ecological performance, the mitigation of risks has become essential in GSC. In addition, managers should outline well documented mitigation procedures or step series in dealing with risks. Therefore, on consulting with experts the following steps are suggested to apply:

- Identify the risks relevant to an organizational GSC that would provide an understanding on unexpected events on its surrounding.
- The risk assessment includes assignment of probability values to various risks in the GSC system and estimation of the impacts of the risk in GSC.
- The actions to mitigate a particular GSC risk should be implied. Various response measures may be used to manage the risk consequences. Further, from an organizational perspective, the approach used for risk mitigation actions depends on their capability and the surrounding environment. The risk mitigation actions act either directly on the pre-identified risks (i.e. proactive actions), or for instance on the backup scenario after the occurrence of risks (i.e. reactive actions).
- Monitoring of risk issues, which involves continuous supervision of the system on detecting and recognizing risks in the GSC network.

7.2.4 Learning

7.2.4.1 Issues in Building Risk Mitigation Strategies for GSC

In this study, the key issue related to the situation is mapping of the internal and external environment, technology, and global changes in operations of GSC network. In fact, GSCM has been acknowledged as a great differentiator to the ecological success for a variety of firms competing in the era of turbulent business environments (Srivastava, 2007; Testa and Iraldo, 2010; Singh et al., 2012). However, this changing and turbulent environment would increase the occurrence of unexpected events resulting in complex GSC networks, which becomes increasingly uncontrollable, and susceptible to disturbances (Ma et al., 2012). Thus, to stay competitive in the global marketplace, organizations require an understanding on the risks to develop mitigation strategies for management. As a result, risk mitigation strategies need to be appropriately built to make provisions for GSC networks to react and respond in real-time under a changing global business environment.

7.2.4.2 Issues Related to Actors

Effective collaborative actions between suppliers, customers, supply chain managers, and top management, along with identification on the domains of freedom of choice for possible collaboration are the key issues allied to the actors in GSC (Simpson and Sampson 2008). In addition, the expertise of managers and planners on the awareness of uncertain and unpredictable events and their chance of occurrence is also an imperative issue. Managers need to uphold a growing edge in understanding of business uncertain conditions and technological process changes and their impacts on environment. Besides, attentiveness is required for the existing risk mitigation strategies to assess the capabilities of the supplier's decision at ecological perspective. Furthermore, for better outcomes, the various ways of responding is essential for top management and managers to fulfill global consumer ecological requirements. It requires a careful outlook on the customer and suppliers when building strategies to mitigate risks in GSC. Top level management should also make provisions to manage the issues in occurrence of risk in GSC (Qianlei, 2012).

7.2.4.3 Issues Related to Process of Building Risk Mitigation Strategies in GSC

To build risk mitigation strategies in GSC, organizational, social, technological and global changes are needed to be addressed (Simpson and Sampson, 2008). Two key issues related to the process of building risk mitigation strategies for GSC are examination of present scenarios on risk management or mitigation approach, and the approach on implementation, along with building the cluster of risk mitigation strategy, for an organization. Furthermore, the collaboration of business strategies with risk mitigation strategies, foreseeing of the current and future processes, governmental intervention for enforcement of environmental regulations and information flow within and among each member of GSC network, and a robust organizational and business culture are some of the key issues linked to the process of managing risks (Qianlei, 2012; Ma et al., 2012).

7.2.5 Action

7.2.5.1 Actions Ought to Be Done to Change the Situation

A business may hold low overall costs under a stable environment, but the situation could be different under an uncertain environment. Thus, risk mitigation is crucial. This part proposes some characteristics to change and improve the situation of building risk mitigation strategies in GSC. Initially, managers should understand the risk and risk driving factors. After that, formulation of strategies and accomplishment is required to manage the issues. The formulation of strategies varies between organizations, and is important in deciding a suitable approach towards mitigation of risk. As demanded by organizations to manage risks, mapping the adaption and responsiveness would give a chance to fill the gap for developing risk mitigation framework for inclusion in GSCM.

7.2.5.2 Action Can Be Done to Change the Actors

An organization should understand the importance of the actors in establishing their business plans and risk management environment for GSC. Top level management should arrange special workshops and training programs to update the managers' knowledge on understanding of technological, environmental, and global changes (Simpson and Sampson, 2008; Govindan et al., 2014). In addition, they should be responsive on the consequences of risks along with importance of risk mitigation in GSC. Besides, managers should have comprehensive idea about the possible threats and risk issues related to sourcing, production, distribution, end users, and reverse logistics operations for closing the GSC loop (Mangla et al., 2013). Effective communication between managers and top level management could help to understand and improve the existing situation. Additionally, to cope with the various requirements, supplier and consumers should also be involved in decisions on risk mitigation strategies design. Similarly, suppliers and ultimate users have ample expectations from the organization in terms of green product performance, cost, and service. Coherency between the requirements of consumers and suppliers, and the planning of managers is therefore necessary in building risk related decisions in GSC.

7.2.5.3 Action Ought to Be Done to Change the Process

The choices and adoption of risk mitigation strategies in GSC are different among organizations. Thus, for effective implementation of strategies, organizations should formulate their potentials and deficits in terms of various dimensions of GSCM, such as sourcing, processes, demand, supply, and information system requirements (Simpson and Sampson 2008). Managers of GSCs need to address these issues by building more capabilities on these dimensions. For instance, a well developed relationship between organizations and their suppliers, a robust environment, and a transparency of decisions among network partners can strengthen the risk mitigation approach. The risk mitigation strategies process can also be strengthened by considering the effect of revolutions in technology, and customers taste and expectation. Finally, the initiative, understanding, and the level of implementing risk mitigation strategies in GSC are also vital for an organization to manage its network successfully.

7.2.6 Performance

7.2.6.1 Impact on the Situation

After having a comprehensive understanding, the preparedness for risks by outlining the strategies of risk mitigation in GSC will be helpful in improving the overall performance. The initiation of risk understanding would provide managers with a basis to deal with current and required strategies for risks mitigation. This will further result in a situation of perfect ongoing dialogue between ecological changes and risk mitigation strategies.

7.2.6.2 Impact on the Actor(S) Performance

From the actor’s point of view, building a risk mitigation strategies framework in GSC could increase the loyalty level of the customer and suppliers. By feeling safeguards against disturbances and risks, their level of satisfaction will also increase. Furthermore, by involving users meaningfully, supply chain managers and planners can design effective risk mitigation approaches to manage risks. Top level management will therefore be able to achieve GSC business success in terms of definite objective.

7.2.6.3 Impact on the Process Performance

Once a risk mitigation strategies framework is built and implemented, effective performance of organizational GSCs can be attained. This could be linked with the business strategies to achieve desired goals. Consequently, there will be a free and smooth flow of information and resources in all functional areas of the GSC. The organization environment would become robust and less prone to uncertain and unplanned events. When a risk occurs, with adoption of risk mitigation strategies, organizations can easily manage its consequences.

The SAP-LAP based decision framework relatively lacks in interpreting the interactions among the identified variables. IRP technique is used for interpreting of the interactions among the variables. It enables to analyze the interactions among the SAP-LAP based framework variables.

7.3 Interpreting the Interactions among SAP-LAP Based Framework Variables: IRP Application

Interpretive Ranking Process (IRP) is introduced and used as a flexible decision approach by Sushil (2009a). It uses the strength of both the intuitive process and the rational choice process of decision making. This approach builds on the strengths of the paired comparison approach (Warfield, 1974; Saaty, 1980) which minimizes the cognitive overload. It uses interpretative matrix as a basic tool and paired comparison of interpretation in the matrix (Haleem et al., 2012). The intuitive process of decision making such as SAP-LAP drawback that the interpretation of judgments of the experts remains opaque to the implementer is overcome in this method. Besdies, IRP also makes an internal validity check via the vector logic of the dominance relationships in the form of a dominance system graph. The details of the application of IRP (Sushil, 2009a) process applied in this research are discussed as follows:

- Step 1: Establish two sets of variables - one to be ranked with reference to the other: In this work, based on SAP-LAP model, the role of actor’s w.r.t. the processes and the influence of actions on the performance are studied. The various variables identified in the SAP-LAP based framework are given in the Table 7.1 and 7.2. In the present work, the ranking of ‘Actors’ w.r.t. ‘Processes’ is discussed while explaining the remaining steps of the IRP.

Table 7.1 Variables of SAP-LAP in Building Risks Mitigation Strategy in GSC

Components	**Variables**	
Situation	S1: Customer requirements	
	S2: Governmental rules and legislatives pressures	
	S3: Globalization and competitiveness	
	S4: Increasing environmental deterioration	
Actor	A1: Suppliers	
	A2: Customers	
	A3: Supply chain managers	
	A4: Top management	
Process	Proactive approach	P1: Preventive strategy
		P2: Protection strategy
	Reactive approach	P3: Response strategy
		P4: Recovery strategy

Table 7.2 Variables of SAP-LAP in Building Risks Mitigation Strategy in GSC

Components	**Variables**
Learning	L1: Technology change (its development & absorption)
	L2: Global changes
	L3: Mapping of organizational internal and external surroundings
	L4: Information flow and sharing
Action	A1*: Training and education of supplier's
	A2*: Building technology management
	A3*: Support and involvement of supply chain managers
	A4*: Building commitment of top management
	A5*: Formulating organizational plans and contingencies
Performance	P1*: Ecological
	P2*: Economic
	P3*: Customer satisfaction
	P4*: Enhanced competitive gains

- Step 2: Derive a cross-interaction matrix between the two sets of variables: A cross-interaction matrix between the two sets of variables is constructed. The two sets of variables identified in this study are actor's v/s processes and actions v/s performances cross-interaction matrix represents the relationship between the actor's v/s processes and actions v/s performances. In this matrix, '1' represents a presence of relationship between the pair of variables and '0' represents its absence. Expert's inputs were used for this purpose. Further, the cross-interaction binary matrix of variables (i.e., actor's v/s processes and actions v/s performances) to achieve build risk mitigation strategy and culture in the GSC is developed and presented in Table 7.3 and Table 7.4.

- Step 3: Convert the cross-interaction matrix into an interpretive matrix: The cross-interaction binary matrix is converted into a cross-interpretive matrix (Sushil, 2009a, b) by interpreting all the interactions with entry '1' in terms of contextual relationship. For instance, (Actor A1, Process P2) is interpreted as 'Supplier knowledge and commitment will be crucial form protection strategy point of view'. A complete cross-interpretive matrix (i.e., actors v/s processes and actions v/s performances) to build risk mitigation strategy and culture in the GSC is presented in Table 7.3 and Table 7.4.

Table 7.3 Cross Interaction Matrix for Actor v/s Process

Contextual Relationship: Roles of actors in various processes

a) Binary matrix

	P1	**P2**	**P3**	**P4**
A1	-	1	1	-
A2	-	1	1	-
A3	1	1	1	-
A4	1	1	1	1

Note: A1, A2, A3, A4 represents the Actor. P1, P2, P3, P4 represents the Process.

b) Interpretive matrix

	P1	**P2**	**P3**	P4
A1		Supplier knowledge and commitment	Organizational requirements	-
A2	-	Customer requirements and awareness	Understanding customer needs	-
A3	Expertise and level of understanding the present	Involvement and support	Formulating the plans and understanding the consequences of risks	-
A4	Proactive vision	Global vision	Waiting for market response	Provision of contingency and funds

Note: A1, A2, A3, A4 represents the Actor. P1, P2, P3, P4 represents the Process.

Table 7.4 Cross Interaction Matrix for Action v/s Performance

Contextual Relationship: Influence of actions on various performance

a) Binary matrix

	P1*	**P2***	**P3***	**P4***
A1*	1	1	-	1
A2*	1	1	1	1
A3*	1	1	1	1
A4*	1	1	1	1
A5*	1	1	-	-

Note: A1*, A2*, A3*, A4*, A5* represents the Action. P1*, P2*, P3*, P4*, P5* represents the Performance.

b) Interpretive matrix

	P1*	**P2***	**P3***	**P4***
A1*	Adoption of green practices at supplier end	Improved quality in material supply	-	Improves image in market
A2*	Adoption of latest green technology	Improves green manufacturing and hence performance	Introduction of best green products	Improves company brand image
A3*	Facilitates green adoption and implementation	Promotes an effective use of green practices	Producing best green products	Better understand the competitor's strategies
A4*	Better planning of ecological concern	Strategic view planning	Customer requirement understanding	Benchmark the performance
A5*	Consideration of ecological benefits	Helps in gaining economic advantages in long run	-	-

Note: A1*, A2*, A3*, A4*, A5* represents the Action. P1*, P2*, P3*, P4*, P5* represents the Performance.

- Step 4: Change the interpretive matrix into an interpretive logic (Knowledge Base) of pair-wise comparisons and dominating interactions matrix: It has been done by interpreting the dominance of one interaction over the other. The inputs of experts' were used for this purpose. The interpretive logic of Knowledge Base of the variables (i.e., actor's v/s processes and actions v/s performances) to achieve build risk mitigation strategy and culture in the GSC is developed and presented in Appendix F. Further, the variables in interpretive matrix were compared with respect to the reference variables in a pair-wise manner. For example, the actor A1 is compared with actor A2 with respect to various processes P1, P2, P3 and P4, respectively and the interpretive logic of dominating interaction between A1 and A2, with respect to their reference variables is recorded. On the basis of which, dominating interaction of the variables (i.e., actor's v/s processes and actions v/s performances) to build risk mitigation strategy and culture in the GSC is developed and presented in Table 7.5 and Table 7.6.

Table 7.5 Dominating Interactions Matrix – Ranking of Actors w.r.t. Processes

	Dominating	**A1**	**A2**	**A3**	**A4**
	A1	-	P3	P2	-
Being	A2	P2	-	-	P1
Dominated	A3	P1, P2, P3	P1, P2, P4	-	P2, P3
	A4	P1, P2, P3, P4	P2, P3, P4	P1, P2, P3, P4	-

Note: A1, A2, A3, A4 represents the Actor. P1, P2, P3, P4 represents the Process.

Table 7.6 Dominating Interactions Matrix – Ranking of Actions w.r.t. Performances

	Dominating	A1*	A2*	A3*	A4*	A5*
	A1*	-	P1*,P2*,P4*	P1*,P4*	P1	P1*,P2*
Being	A2*	P1*,P2*, P4*	-	P2*, P4*	P2*, P4*	P1*,P2*
Dominated	A3*	P1*,P2*,P4*	P1*	-	P2*	P1*,P2*,P3*
	A4*	P1*,P2*,P3*,P4*	P1*,P2*,P3*,P4*	P1*,P2*,P3*,P4*	-	P1*,P2*,P3*,P4*
	A5*	P3*,P4*	P3*,P4*	P4*	P4*	-

Note: A1*, A2*, A3*, A4*, A5* represents the Action. P1*, P2*, P3*, P4*, P5* represents the Performance**.**

- Step 5: Obtain ranking and interpret the ranks in terms of dominance of number of interactions: The dominating interactions are shown through dominance matrix. It gives the number of cases in which one ranking variables dominates or being dominated by other ranking variable. The net dominance for a ranking variable i.e. action is computed as (D – B), where D shows the total no. of cases where these ranking variable (s) dominate all other ranking variables and B shows the total number of cases in which a particular ranking variable has been dominated by all other ranking variables. The highest net positive dominance of a ranking variable has been ranked '1' and followed by next lower and so on. The variable (s) with highest negative net dominance will be ranked lower because these are being dominated more by other variable(s). Like, actor A4 (Top management) receives the highest positive net dominance, and hence it is ranked I. In that way, the ranking of the variables (i.e., actor's v/s processes and actions v/s performances) to build risk mitigation strategy and culture in the GSC is developed and presented in Table 7.7 and Table 7.8. If, two variables posses equal negative net dominance score or value, then, the ranking is decided on the basis of number of cases being dominated (Luthra et al., 2014a). The variables with higher number of cases being dominated will be ranked higher in that case. For instance, the action A2* (Building technology management) and A3* (Support and involvement of supply chain managers) receives the equal negative net dominance, but action A2* occupy higher no. of cases being dominated than action A3*, and therefore, action A2* is ranked II. The details are given in Table 7.8.

Table 7.7 Dominance Matrix – Ranking of Actors w.r.t. Processes

Dominating → Being dominated ↓	**A1**	**A2**	**A3**	**A4**	**Number of cases dominating (D)**	**Net dominance (D-B)**	**Rank dominating**
A1	-	1	1	-	2	-6	IV
A2	1	-	-	1	2	-5	III
A3	3	3	-	2	8	3	II
A4	4	3	4	-	11	8	I
(B)[a]	8	7	5	3	23/23		

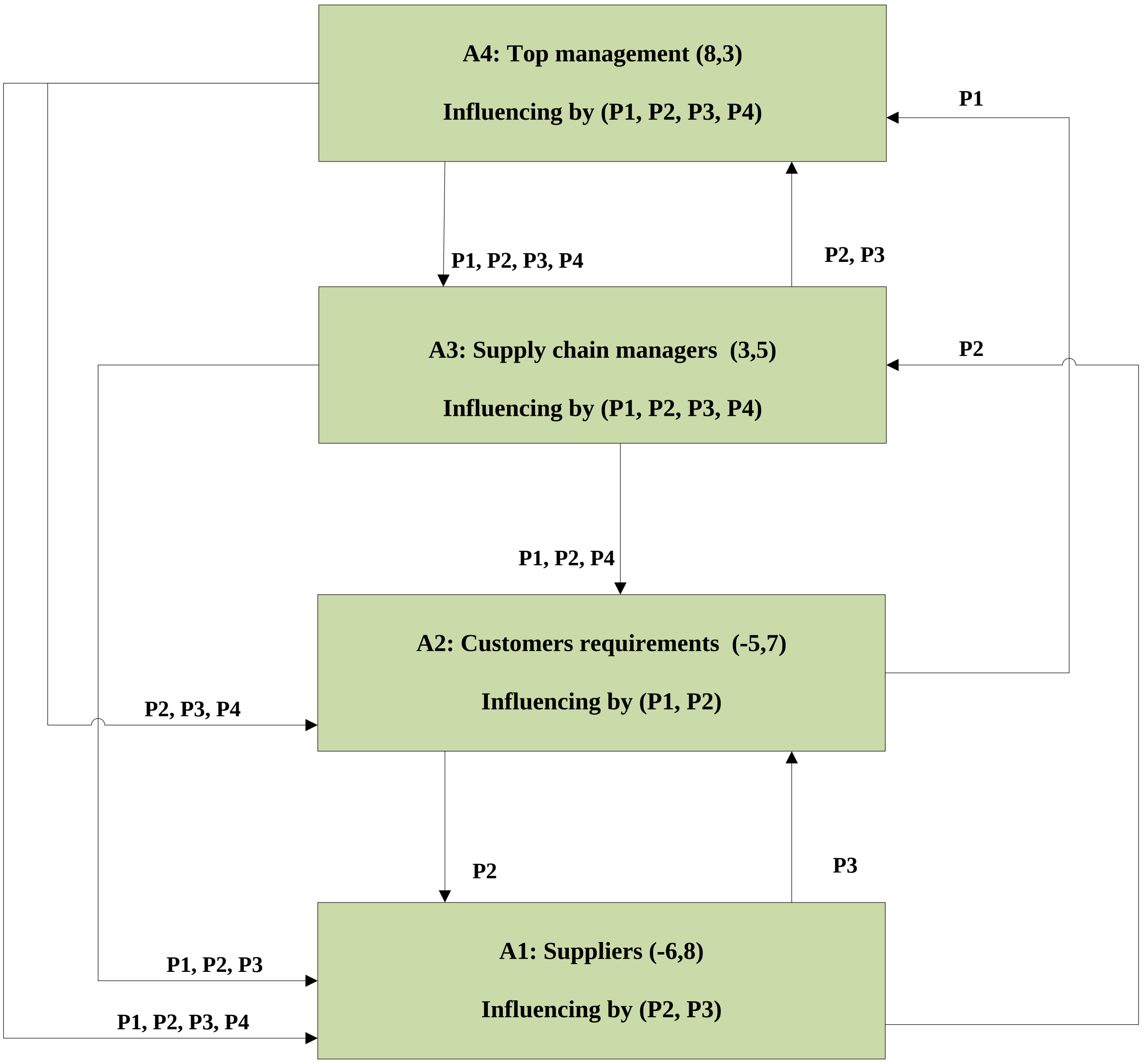
Note: 1) [a] Number of cases being dominated.
2) A1, A2, A3, A4, represents the Actor. P1, P2, P3, P4 represents the Process.

Table 7.8 Dominance Matrix – Ranking of Actions w.r.t. Performances

Dominating → **Being ↓ dominated**	A1*	A2*	A3*	A4*	A5*	**Number of cases dominating (D)**	**Net dominance (D-B)**	**Rank dominating**
A1*	-	3	2	1	2	8	-4	IV
A2*	3	-	2	2	2	9	-1	II
A3*	3	1	-	1	3	8	-1	III
A4*	4	4	4	-	4	16	11	I
A5*	2	2	1	1	-	6	-5	V
(B)[a]	12	10	9	5	11	47/47		

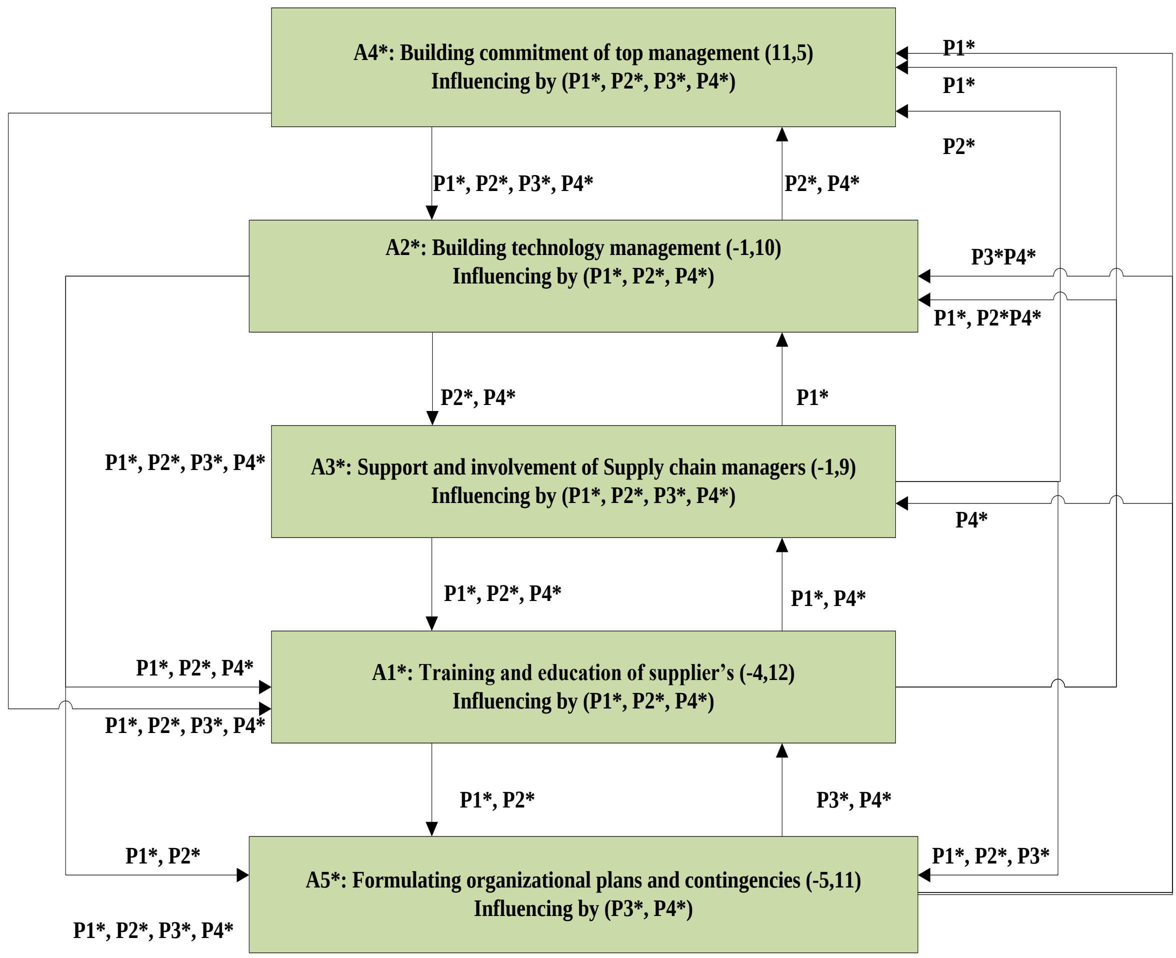
Note: 1) [a] Number of cases being dominated.
2) A1*, A2*, A3*, A4*, A5* represents the Action. P1*, P2*, P3*, P4*, P5* represents the Performance.

- Step 6: Confirm the ranks thus derived: The ranks so obtained by the dominance matrix are validated. The cross-validation analysis of the Dominance matrix is performed for this purpose.
- Step 7: Represent the obtained ranking diagrammatically in the form of an interpretive ranking model: To illustrate final ranks of the ranking variables, an interpretive ranking model is used. The arrow in this diagram represent the reference variable (s) in which cases a particular ranking variable is dominating the other ranking variables. Also, the numbers dominating and number being dominated are displayed in brackets for all variables. This will help to interpret how each Actor and Action is influencing various Processes and Performances. The IRP model shown in Figure 7.3 suggests that actor A4 (Top management) has got highest rank. This clearly indicates that for any business organization wishing to improve GSC processes and performances, the commitment of top management is crucial. The ranking order of the remaining Actors is as follows: A3 (Supply chain managers) > A2 (Customers requirements) > A1 (Suppliers). Here, the arrow from A4 to A1 demonstrates that A4 is dominating A1 for processes P1, P2 P3 and P4. For all the actor's and actions, the numbers dominating and numbers being dominated are summarized within brackets. For example, for actor A4, the numbers dominating and dominated are shown as (8, 3). The interactive ranking model of the variables (i.e., actors v/s processes and actions v/s performances) to build risk mitigation strategy and culture in the GSC is shown in Figure 7.3 and Figure 7.4.
- Step 8: Interpret the ranking order and use it as the base for recommending action: The ranking model of Actor's v/s Processes interprets the roles of different actors in the strategic processes. It also clarifies the dominating roles played by various actors, which will be useful for organizations in developing an actor centered approach for improving the effectiveness of these processes. Similarly, the ranking model of Actions v/s Performances interprets the influence of key strategic actions on the performance. It will be helpful in setting strategic priorities in enhancing the performance in key areas of building risk mitigation strategies in GSC.



A1, A2, A3, A4 represents the Actor.
P1, P2, P3, P4 represents the Process.

Figure 7.3 Interpretive Ranking Model of Actor's v/s Processes to Build Risk Mitigation Strategy in GSC



A1*, A2*, A3*, A4*, A5* represents the Action.
P1*, P2*, P3*, P4*, P5* represents the Performance

Figure 7.4 Interpretive Ranking Model of Actions v/s Performances to Build Risk Mitigation Strategy in GSC

7.4 Managerial Implications

The suggested conceptual framework helps to address risk mitigation strategies for GSC over situation, actors, process, learning, actions and performance aspects. The risk mitigation strategies framework provides measures to manage transient environments while greening the supply chain network (Simpson and Sampson, 2008). The SAP-LAP based framework is developed to evaluate the Actors and Actions w.r.t. Processes and Performances respectively. The managers and planners have an imperative role in managing the GSC. The work in this chapter provides several implications for the managers as follows:

- This study proposes a conceptual SAP-LAP framework for risk mitigation strategies to help managers to build understandings on managing GSC risks.
- Based on developed SAP-LAP framework to mitigate risks in GSC, two approaches, proactive and reactive, have further been proposed. No organization can afford to adopt all of these strategies. Managers must make good understanding on both the values and shortcomings of the strategies, as well as their appropriateness for an organization.
- Managers should consider the importance and involvement of suppliers, stakeholders, consumers, and top-level management while framing risk mitigation strategies in GSC.
- The ranks of Actors and Actions are identified by using the IRP methodology. It would clarify the dominating roles played by various actors, which will be useful for organizations in developing an actor centered approach for improving the effectiveness of these processes. Also, it would be helpful in setting strategic priorities in enhancing the performance in key areas.
- The application of IRP enables mangers to better understand the interactions among the variables of the SAP-LAP based decision framework.
- Managers must consider the finance and costing issues associated with initiating and implementing the risk mitigation strategies for a GSC.

7.5. Suggestive Risk Mitigation Strategies Processes to Manage the Recognized GSC Risks

The present work develops a conceptual SAP-LAP framework for risk mitigation strategies to help managers to build understandings on managing GSC risks. The prime purpose of risk mitigation is to manage and control the occurrence of any problematic situation. It plays a crucial role in mitigating of the risks. At the same time, an in-depth understanding and correct implication of strategies will be crucial to mitigate risk in GSC. To mitigate risks in GSC, two approaches, proactive and reactive, are discussed. It is difficult for business organizations to adopt all of these strategies, due to involvement of various constraints in their adoption and execution. Thus, to help business organizations, these approaches are further expanded; other details have already been mentioned in Section 7.4.3.1.

The developed decision framework is used to suggest some mitigating strategies to manage the GSC risks identified in this work. As already mentioned, this research work has identified twenty five risks linked to GSC in Indian plastic sector. The details for managing and mitigating the identified risks in relation to the developed risk mitigation strategies are given in Table 7.9.

Table 7.9 Summary for Suggestive Risk Mitigating Strategies for Managing the Identified Risks in GSC

GSC risks	**Suggested risk mitigating strategies**	**Explanation for accomplishment of suggested risk mitigating strategies**
Machine, equipment or facility failure (O1)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Design risks (O2)	Proactive	Preventive in terms of network redesign like adaptation in processing methods
Scarcity of skilled labor (O3)	Reactive	Response in terms of human expertise
Green technology level (O4)	Reactive	Response in terms of speed and flexibility
Procurement costs risks (S1)	Preventive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Key supplier failures (S2)	Reactive -	Response and recovery in terms of flexibility and multiple suppliers
Supplier quality issues (S3)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Green raw-material supply disruptions (S4)	Reactive	Response in terms of flexibility
Inventory and capacity design risks at reprocessing centers (PR1)	Proactive	Protection in terms of inventory and capacity management
Gate keeping design failures (PR2)	Proactive	Protection in terms of avoidance
Reverse logistics design risks (PR3)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)

Table 7.9 Contd...

GSC risks	Suggested risk mitigating strategies	Explanation for accomplishment of suggested risk mitigating strategies
Take-back obligations risks (PR4)	Reactive	Response in terms of detection and identification
Sourcing of funds (F1)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Inflation and currency exchange rates (F2)	Response	Recovery in terms of speed and detection
Financial restrictions (F3)	Proactive	Protection in terms of speed and detection
Bullwhip effect risks (D1)	Proactive	Preventive in terms of forecasting of aggregate demand and supply
Market dynamics (D2)	Reactive	Response in terms of speed and detection
Key customer failures (D3)	Reactive	Response and recovery in terms of flexibility and contingency plans
Competing risks (D4)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Management policy failures (GO1)	Proactive	Preventive in terms of the approach and behaviour of management (i.e. commitment)
Government policy risks (GO2)	Reactive	Response in terms of detection and identification
Information asymmetry risk across GSC members in hierarchy (GO3)	Proactive	Protection in terms of information sharing system design
Lack in enterprise strategic goals (GO4)	Reactive	Recovery in terms of business strategic planning

Table 7.9 Contd...

GSC risks	Suggested risk mitigating strategies	Explanation for accomplishment of suggested risk mitigating strategies
Legal risks (GO5)	Reactive	Recovery in terms of insuring and contingency plans
Partnership risks (GO6)	Reactive	Recovery in terms of insuring and contingency plans

7.6 Conclusions

The SAP-LAP and IRP based decision framework is developed in this chapter to manage and reduce the consequence of risks in GSC. It would be helpful for organizations in improving the GSC robustness and result in enhanced ecological-economic performance, customer satisfaction etc. According to developed SAP-LAP framework, the standpoint of the actors including ultimate users, supply chain managers, suppliers, and top management are crucial in building a GSC risk mitigation strategy decision framework. Further, to capture the interactions among the variables of SAP-LAP based framework, i.e., Actors v/s Processes and Actions v/s Performances, an interactive process of decision making is used. The application of IRP enables the managers to overcome the limitations of the SAP-LAP, which is an intuitive type of decision making approach. According to the findings of IRP methodology, the role of top management as an Actor and the commitment of top management as an Action come out be most important in building the risk mitigation strategies in GSC. The decision on selection and implementation of the discussed risk mitigation strategies depends on the situation and choice of the supply chain managers and top-level management. Further, the developed framework can help in reviewing current risk mitigation strategies in GSC by supply chain experts and managers to make them more comprehensive and robust. At the end, the developed decision framework is applied to analyze various mitigating strategies to manage the GSC risks.

CHAPTER 8

RESEARCH SUMMARY AND CONCLUSIONS

This chapter provides a comprehensive overview of the research work conducted and the major findings along with the contribution of the present study in the existing set of literature. Besides, this chapter also provides the managerial implications of the present work. The last section of this chapter provides the limitation of the study. This chapter concludes by highlighting the suggestions related to scope of future work.

8.1 Introduction

The present work attempts to contribute in the literature by illustrating the understanding, analysis and management of risks related to GSC for increasing its effectiveness on strategic level in a business. The current research work focus on identifying and understanding of GSC risk management agenda from Indian plastic sector perspectives. Based on critical review of literature and inputs received from the experts, various significant risks related to GSC were selected. The identified risks were subjected to an analysis procedure to determine their priority and to know the interpretive logic of dominance of one risk over the other using fuzzy AHP and IRP methods. Further, the risks identified in this study were evaluated to assess their impacts on GSC using Monte Carlo Simulation. The use of this methodical approach helps in understanding of the probable risks and consequences to emerge in GSC. The research work also suggests an integrated fuzzy AHP – TOPSIS based model to propose responses to manage risks in GSC. Also, this work develops a decision framework to suggest strategies to mitigate risks in GSC. SAP-LAP based methodology is used for this purpose. The variables involved in the developed SAP-LAP based risk mitigation strategies framework were evaluated to distinguish their interpretive logic using IRP technique. The findings of this research would be useful for organizations to become more capable in analyzing the GSC risks and reducing pessimistic consequences. It will help in managing the risks and risk driving factors relevant to a successful implementation of GSC initiatives, and hence enhancement in ecological-economic gains of the business organizations.

The main purpose of this study is to provide a better understanding of developing and managing of GSC in a most effective way. Besides, this work touched on various problematic issues of Indian plastic business organizations that may be helpful in developing strategies and will be useful in improving GSC effectiveness. The present work is useful to both theoretical and practical domains in the field of GSCM. Finally, this research work may help managers and practitioners to manage the GSC efficiently, while achieving sustainability in business.

8.2 Summary and Contributions

The aim of this research is to develop a framework to analyze and manage the risks in GSC. Based on the research gaps highlighted above, this work aims in achieving the two objectives. A brief summary and contributions made in this work in accordance with the research objectives is given as follows:

Objective 1: The first objective of this work was - Identifying, understanding, and analyzing risks in green supply chain from industrial perspective. To achieve this objective, the present work analyzes the risks relevant to adoption and effective implementation of GSC initiatives. These risks and their respective sources have a tendency to disturb the GSC functioning, and thereby, decline in the ecological-economic performance. Therefore, identification of risks and their subsequent analysis in the GSC are very important to understand. Twenty five specific risks, associated with the GSC, were identified. The basis of identification of the risks was literature and inputs received from the experts. Experts' opinion has been collected from the officials and managers of Indian plastic manufacturing business organizations. Further, these identified risks were grouped into six categories of risks, namely, Operational risks (O), Supply risks (S), Product recovery risks (PR), Financial risks (F), Demand risks (D), and Government and Organizational related risks (GO). These categories of risks were finalized through an interactive discussion with the experts of decision-making team. The fuzzy AHP, a qualitative and quantitative analysis was used to analyze the identified risks for determining of their priority. The used fuzzy AHP approach is also useful in dealing with the human subjectivity and ambiguity involved in the risk analysis. The weight vectors for the categories of risks (i.e., 0.2507, 0.1863, 0.1449, 0.2236, 0.0607 and 0.1338) were established. The order of priority of categories of risks is as, O > F > S > PR > GO > D, whereas, the priority for the specific risks within their respective category was also determined, and is as given as- O4 > O2 > O3 > O1 for risk category O; S4 > S3 > S2 > S1 for risk category S; PR4 > PR3 > PR1 > PR2 for risk category PR; F3 > F1 > F2 for risk category F; D4 > D1 > D3 > D2 for risk category D; and GO1 > GO4 > GO2 > GO3 > GO5 > GO6 for risk category GO.

To confirm the fuzzy AHP based ranking, the methodology of IRP was used. This method present interpretive logic for dominance of one risk over the other for each paired comparison developed, and thus, overcome the shortcomings of the AHP - fuzzy AHP method (Sushil, 2009). Six categories of risks (O, S, PR, F, D, and GO) relevant to GSC and four expected performance (Environmental performances (P1), Economic performances (P2), Operational performances (P3), and Competitiveness performance (P4)) measures by implementing efficient GSCM concept were identified. Interpretive ranking model of the derived final ranks of the risks was drawn. This will help to interpret how each risk is influencing various performances. The IRP based model suggests that risk Operational risk has obtained the highest rank. This clearly indicates that for any of the business organization under consideration wishing to improve GSC processes and performances, the management of operational risks is crucial. The results obtained from the fuzzy AHP and IRP analysis in terms of their importance order is given as O > F > S > PR > GO > D. It corresponds to a reasonable consistency in the findings of the present research work. Human judgment input is utilized to calculate the weights for the listed categories of risks and specific risks. Thereby, it is recommended to test the final ranking by varying the weights of all the categories of risks. To illustrate the sensitivity analysis the effect of an incremental change in value from 0.1 to 0.9, to the operational category risk (O), was determined. According to the sensitivity analysis, priority (rank) of the specific risks varies with respect to the change in operational category risk. Thus, it may be concluded that operational category risk is very important in adopting an effective and robust GSC concept. If the managers are able to reduce and or manage the operational risks and its related concerns in implementing the GSCM concept, it will be quite useful in managing and reducing the consequences of the other risks relevant to GSCM adoption, which may further lead to gain in economic-ecological performance of the related business organizations. The sensitivity analysis thus may provide a further insight to the causes of risks in adoption and effective implementation of GSC initiatives.

The present work also analyzes the performance of GSC from risks management viewpoint. To analyze the performance from risks management viewpoint, impacts of the GSC risks specifically in terms of delay were assessed. The risks identified in this work were evaluated to access their effects in terms of Time, Brand image, Economic, Health and Safety, and Quality. The maximum impacts were seen in time based effects and that was measured in terms of time delays and disruptions. In time based dimension, time delay/disturbance is the significant impact of GSC risks. The human based assessment unable to give extreme scenario.

Thus, simulation approach was used. Monte Carlo Simulation approach is used to analyze the drivers of risk and their impact on GSC performance. In addition, it also helps to capture the uncertainties in the inputs. A sensitivity analysis test (Sensitivity Tornado) was performed to capture the effects of risks on the delay profile mean. The proposed model will provide analytic means to analyze the risks more efficiently towards effective implementation of GSCM.

Objective 2: The second objective of this work was - Effective management of green supply chain risks. According to this objective, after listing the potential risks and their impacts, it is needed to understand how to manage the risks and its consequences. For managing the GSC risks, various mitigation strategies and response measures need to be proposed. Therefore, this research work proposes a model by using an integrated approach based on the fuzzy AHP and the fuzzy TOPSIS methods to prioritize the responses in GSC to manage its risks under the fuzzy environment. As stated above, six categories of risks and twenty-five specific risks in GSC were finalized. In order to manage these risks, seventeen responses were identified. These responses were selected through literature and inputs received from the experts of the decision-making team. In this way, twenty-five risks and seventeen responses, to manage these risks, were decided, and a decision hierarchy was constructed to address the problem. It consists of four levels, which are given as, Prioritizing responses of the risks in effective adoption and implementation of GSC initiatives (the goal of research) at Level 1; Risks (the main criteria used in this research) at Level 2; Risks (sub-criteria used in this research) at Level 3; Responses (proposed alternatives) represented at Level 4. It will help in managing the risks relevant to a successful implementation of GSC business initiatives. The fuzzy AHP is useful in deciding the importance weights of the GSC risks. Among all categories of risks, the operational risk category receives the highest priority. While, the priority of the responses in a successful accomplishment of GSC business initiatives is determined using the fuzzy TOPSIS. According to the values of closeness coefficient, the priority of concern of the responses of the risks in GSC is given as, R12-R15-R10-R7-R17-R16-R8-R6-R14-R11-R13-R5-R4-R9-R3-R1-R2. To develop and upgrade on technology being used in the specific sectors for implementation of green (R12) obtains the highest rank. Thus, it needs to focus this response at priority in managing the risks in GSC. The commitment of top management and support of lower and middle level managers (R15) comes next to R12 in priority in adopting an efficient GSCM thought. Flexibility in design to process and operational level (R10) and Incorporation of environmental practices in company policies and mission at strategically (R7) occupies the third and fourth place of priority, and so on up to Use of information technology in tracking the returning of products to foster the product recovery (R2), which obtains the last rank. The model proposed would offer a scientific decision means to the managers/business professionals/practitioners for systematic implementation of the responses of risks relevant to adoption and effective implementation of GSC initiatives in business. A sensitivity analysis test was also performed to monitor the robustness of the proposed model. In sensitivity analysis, the ranking of the responses of risks were monitored with respect to the changes in the importance weights of the risks.

With regard to the second objective of this work, a framework is developed to evaluate the strategies to mitigate risk in GSC, which would be helpful for business organizations in improving the GSC robustness. This framework is developed on the basis of SAP-LAP and IRP approaches. According to the SAP-LAP approach, the standpoint of the actors including ultimate users, supply chain managers, suppliers, and top management should be considered in building a GSC risk mitigation strategy framework. To mitigate risks in GSC, two approaches, proactive and reactive, were discussed. No organization can afford to adopt all of these strategies. Managers must make good understanding on both the values and shortcomings of the strategies, as well as their appropriateness for an organization.

To capture the interactions among the variables of SAP-LAP based model, i.e., Actors v/s Processes and Actions v/s Performances, an interactive process of decision making is used. The methodology of IRP enables the managers to limit the limitations of the SAP-LAP. According to the findings of IRP approach, the role of top management as an Actor and the commitment of top management as an Action come out be most important in building and implementation of GSC risk mitigation strategies. The decision on selection and implementation of the discussed risk mitigation strategies depends on the situation and choice of the supply chain managers and top-level management. The developed framework can help in reviewing current risk mitigation strategies in GSC by supply chain experts and managers to plan for further improvements to make them more comprehensive and robust. Furthermore, the developed SAP-LAP and IRP based framework would help organizations to address risk mitigation strategies for GSC with concerns over situation, actors, process, learning, actions and performance aspects, together with to interpret the of role and influence of actors and actions in accordance with process and performance, that will increase the GSC effectiveness. At the end, the developed decision framework is applied to analyze the suggested mitigating strategies to manage the GSC risks listed in this work.

8.3 Implications of the Research

The outcomes of the present research may add to the extent theory and practice in GSCM context. The main purpose of this study was to provide a better understanding of developing and managing of GSC in a most effective way. The findings of the study will help managers and practitioners to manage the GSC risks and pessimistic consequences based on proposed guidelines in the present research. The key implications of the present research are as follows:

- A bibliographic record is revealed in the literature survey may work as a guideline for future research on this subject of research.
- Advantages and disadvantages of qualitative and quantitative techniques may serve as a source of learning in the selection of a suitable technique by the researcher.
- The present research work efforts to propose how the risks to implement GSCM can be listed, analyzed and managed. It is important as generally manager's focuses on certain GSC risks, which they think are important without considering the impacts of other risks, which might be significant risks for initiating green trends in the business.
- It is important to fully understand the possible risks in GSC. This study has identified six categories of risks and twenty five specific risks, which is believed to be supportive for managers in planning and making significant decisions under unplanned situations in greening the supply chains.
- The work carried out in this research is an attempt to analyze and manage the risks in GSC. The network research model suggested in the study is based on various intuitive and interpretive decision making, and MCDM techniques, such as, fuzzy AHP, fuzzy TOPSIS, SAP-LAP, IRP, and Monte Carlo Simulation. The application of these decision making methods will provide sufficient choice to managers of Indian plastic manufacturing business organizations to adopt the proposed network research models in improving their GSCs.
- This work provides a linkage between fuzzy AHP and IRP methodologies. It assists to confirm the risks and to help managers and practitioners in understanding the appropriate and viable rational for dominance when evaluating two risks relevant to an effective GSCM adoption and implementation.
- Interpretive rankin*g* model that shows a diagrammatical representation of the derived final ranks of the risks is developed in this study. This will help to interpret how each risk is influencing various Performances. The ranking model of risks v/s performances

interprets the roles of different risks in the strategic decision processes and interprets the influence of key strategic actions on the performance. It also clarifies the dominating roles played by various risks, which will be useful for managers in developing a logical approach for improving the effectiveness of the processes in implementing GSC initiatives. It will be helpful in setting strategic priorities in enhancing the performance in key areas of managing risks in GSC context.

- Various risk responses and risk mitigation strategies are proposed to manage the GSC risks identified in this work. It is difficult to declare, which response to adopting effective green initiatives in business to manage its risks is more significant. Also, in real world situations, it is very difficult for organizations to implement all the response measures simultaneously because of various constraints and curbs. The prioritizing of these responses could be more effective from the point of view of business organizations under consideration in this situation. By implementing appropriate response measures, organizations would become more capable in managing GSC risk and reducing pessimistic consequences.
- This study proposes a conceptual framework for risk mitigation strategies to help managers to build understandings on managing GSC risks. The ranks of Actors and Actions were identified. It would clarify the dominating roles played by various actors, which will be useful for organizations in developing an actor centered approach for improving the effectiveness of these processes. It would be helpful in setting strategic priorities in enhancing the performance in key areas.
- This research work is conducted for the plastic sector. However, the proposed networks are quite relevant for the related business organizations in this sector.
- The research work may provide a benchmarking framework with a focus on GSCM adoption and implementation to formulate the decisive suggestive measures in managing the GSC risks in a most effective way.
- Finally, the present research work provides an analytic mean to document and apply various risk mitigation strategies to manage risks and uncertainties in GSC.

8.4 Limitations of the Present Research Work

The work carried out in this research has its own limitations, mentioned as below:

- The finding of this work is primarily depends upon the knowledge and experience of expert, which may distort the process of decision-making due to human bias. Therefore, evaluation procedure needs to be carried out carefully.
- Due to unavailability of sufficient data and research literature on GSC in Indian context, case study based approach is used. The data and its analysis are typically based on the plastic product manufacturing business organizations operational in the northern region of India. Hence, the generalization of findings may not be extended in the context of organizations of different types, regions, sizes, etc.
- In this research, a fuzzy AHP based framework has been developed with twenty-five risks to analyze the risks in implementing the efficient GSC practices in business. More risks have not been recognized and classified.
- Seventeen responses have been identified to manage the risks in the context of GSC. More responses to manage these risks have not been recognized and classified.
- The aspects of risks related to Quality, Human health and safety and the Brand image are not analyzed in the present study.
- IRP model is based on interpretive and judgmental processes. It usually treats all the criteria equally ignoring their relative importance. However, this limitation can be overcome by assigning ordinal weights to various criteria and carrying out sensitivity analysis. But this may complicate the process to some extent and would require justification for the weights assigned.
- In IRP technique, it is difficult to be validated in terms of objective validation tests. It is difficult to interpret a matrix of size beyond 10x10 as the number of paired comparisons would exponentially increase, and thus only modest sized problems can be effectively implemented with this process (Sushil, 2009).
- There are several limitations of case study research need to be taken care off. It includes, time consumption, difficulty in data collection, incorrect interpretation of the facts, etc. (Collins and Hussey, 2003). Thus, secondary data have been used in this research wherever required.

8.5 Future Scope for Research

As mentioned in previous section that the work has its own limitations. These limitations may be considered as research opportunities for the future. The research work is based on the literature survey, fuzzy AHP framework, IRP technique, Fuzzy AHP-TOPSIS framework, MCS, and SAP-LAP analysis. The following are some research directions suggested for future research based on this work:

- Complexity in the selection of risk might be the challenge for the perspective of future research.
- All business organization considered for this work is based on single-country perspective, and so, future research may be conducted in the context of other developing/developed countries to compare the findings with this study.
- The projected network models might be extended to various sectors of industry, for example, the automobile, service etc. that seeks to determine the performance ratings of the responses of the risks in implementing an effective GSCM concept. However, the expert's judgment may vary with industry type and its priorities. In addition, the proposed network models may be applied to other developing countries with marginal modifications.
- The aspects of risks related to Quality, Human health and safety and the Brand image may also be analyzed in future perspective in the GSC context.
- Developing IRP models for decision-making under fuzzy environment can be another direction for further research.
- Some other techniques like SWOT analysis may be one option to analyze the strategies to mitigate risks in GSC and the comparisons among the results can be made in future.
- Future work may be conducted by using any of other risk analysis techniques, such as, Failure Mode Effect Analysis (FMEA) (Yadav et al., 2003, 2006), Quality Function Deployment (QFD), etc.
- The fuzzy AHP method is used to prioritize risks in GSC. Future research can be conducted using the analytic network process (ANP) method, which also considers the interrelationships between the considered risks (Agarwal et al., 2006).
- The work could be further extended by analyzing some more qualitative and quantitative environmental data, and other MCDM techniques like Interpretive Structural Modelling (ISM), Decision Making Trial and Evaluation Laboratory (DEMATEL), may also be applied to capture the interaction and causality among identified risks and to analyze the responses to manage the risks in GSC.
- Due to case study approach, the study findings may lack in terms of generalizability. Thus, empirical research may be conducted in future studies to better explore the problem and analyze the results to improve the overall performance in the GSC context.

- The present work could also be extended by considering societal issues along with the economical and environmental issues from a GSC context.

With regard to the work conducted in this research, various researchers and practitioners all around the world may consider the above mentioned future research agendas to manage green and sustainability problematic issues and risks in supply chain. Certainly, the findings obtained in this work sets foundation for broadening research in area of GSC to manage its risks as well as to improve environmental and economic gains in GSCM especially in India and other developing nations.

REFERENCES

[1]. Abdallah, T., Farhat, A., Diabat, A., & Kennedy, S. (2012). Green supply chains with carbon trading and environmental sourcing: Formulation and life cycle assessment. *Applied Mathematical Modelling*, *36*(9), 4271-4285.

[2]. Action for Planet (2012), "Top ten polluting countries", Electronic copy available at: www.actionforourplanet.com/top-10-polluting-countries/4541684868 (Accessed: 2 November, 2012).

[3]. Adler, J. (2006). *Going Green*. Newsweek, July 17, pp. 42-52, online at www.msnbc.msn.com.

[4]. Afshar, A., Mariño, M. A., Saadatpour, M., & Afshar, A. (2011). Fuzzy TOPSIS multi-criteria decision analysis applied to Karun reservoirs system. *Water resources management*, *25*(2), 545-563.

[5]. Agami, N., Saleh, M., & Rasmy, M. (2012). A hybrid dynamic framework for supply chain performance improvement. *Systems Journal, IEEE*, *6*(3), 469-478.

[6]. Agarwal, A., **Shankar, R.,** & Tiwari, M.K. (2006). Modeling the metrics of lean, agile and leagile supply chain: an ANP based approach. *European Journal of Operational Research*, *173*(1), 211-225.

[7]. Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of Cleaner Production*, *52*, 329-341.

[8]. AlKhidir, T., & Zailani, S. (2009). Going green in supply chain towards environmental sustainability. *Global Journal of Environmental Research*, *3*(3), 246-251.

[9]. Amiri, M. P. (2010). Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods. *Expert Systems with Applications*, *37*(9), 6218-6224.

[10]. Anand, K. R., & Parthiban, P. (2014, September). Evaluation of Green Supply Chain Factors Using DEMATEL. In *Applied Mechanics and Materials*, *592*, 2619-2627.

[11]. Andiç, E., Yurt, Ö., & Baltacıoğlu, T. (2012). Green supply chains: Efforts and potential applications for the Turkish market. *Resources, Conservation and Recycling*, *58*, 50-68.

[12]. Arshinder, Kanda, A., & **Deshmukh, S. G.** (2007). Supply chain coordination issues: an SAP-LAP framework. *Asia Pacific Journal of Marketing and Logistics*, *19*(3), 240-264.

[13]. Arshinder, Kanda, A., & **Deshmukh**, S.G. (2008). Supply chain coordination: perspectives, empirical studies and research directions. *International Journal of Production Economics*, *115*(2)**,** 316-335.

[14]. Aydogan, E. K. (2011). Performance measurement model for Turkish aviation firms using the rough-AHP and TOPSIS methods under fuzzy environment.*Expert Systems with Applications*, *38*(4), 3992-3998.

[15]. Azevedo, S. G., Carvalho, H., & Machado, V. C. (2011). The influence of green practices on supply chain performance: a case study approach. *Transportation research part E: logistics and transportation review*, *47*(6), 850-871.

[16]. Bai, C., & Sarkis, J. (2010). Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics*, *124*(1), 252-264.

[17]. Bai, C., & Sarkis, J. (2013). Flexibility in reverse logistics: a framework and evaluation approach. *Journal of Cleaner Production*, *47*, 306-318.

[18]. Balasubramanian, S. (2012). A hierarchical framework of barriers to green supply chain management in the construction sector. *Journal of Sustainable Development*, *5*(10), 15-27.

[19]. Barve, A., & Muduli, K. (2011, September). Challenges to environmental management practices in Indian mining industries. In *International Conference on Innovation, Management and Service IPEDR* (Vol. 14).

[20]. Beamon, B. M. (1999). Designing the green supply chain. *Logistics information management*, *12*(4), 332-342.

[21]. Bernstein, P. (1996). *Against the Gods*. John Wiley & Sons Inc.

[22]. Bhattacharya, A., Mohapatra, P., Kumar, V., Dey, P. K., Brady, M., Tiwari, M. K., & Nudurupati, S. S. (2014). Green supply chain performance measurement using fuzzy ANP-based balanced scorecard: a collaborative decision-making approach. *Production Planning & Control*, *25*(8), 698-714.

[23]. Büyüközkan, G., & Çifçi, G. (2012a). A combined fuzzy AHP and fuzzy TOPSIS based strategic analysis of electronic service quality in healthcare industry. *Expert Systems with Applications*, *39*(3), 2341-2354.

[24]. Büyüközkan, G., & Çifçi, G. (2012b). A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Systems with Applications*, *39*(3), 3000-3011.

[25]. Büyüközkan, G., Feyzioğlu, O., & Nebol, E. (2008). Selection of the strategic alliance partner in logistics value chain. *International Journal of Production Economics*, *113*(1), 148-158.

[26]. Caniato, F., Golini, R., & Kalchschmidt, M. (2013). The effect of global supply chain configuration on the relationship between supply chain improvement programs and performance. *International Journal of Production Economics*, *143*(2), 285-293.

[27]. Chan, F. T., Kumar, N., Tiwari, M. K., Lau, H. C. W., & Choy, K. L. (2008). Global supplier selection: a fuzzy-AHP approach. *International Journal of Production Research*, *46*(14), 3825-3857.

[28]. Chandrashekaran, A., & **Gopalakrishnan, B.** (2008). Maintenance risk reduction for effective facilities management. *Journal of Facilities Management*, *6*(1), 52-68.

[29]. Chang, C. W., Wu, C. R., Lin, C. T., & Chen, H. C. (2007). An application of AHP and sensitivity analysis for selecting the best slicing machine. *Computers & Industrial Engineering*, *52*(2), 296-307.

[30]. Chang, D. Y. (1992). Extent analysis and synthetic decision. *Optimization Techniques and Applications*, *1*(1), 352–355.

[31]. Charan, P., **Shankar, R.,** & Baisya, R.K. (2008). Analysis of interactions among the variables of supply chain performance measurement system implementation. *Business Process Management Journal*, *14*(4), 512-529.

[32]. Chen, J., Sohal, A. S., & Prajogo, D. I. (2013). Supply chain operational risk mitigation: a collaborative approach. *International Journal of Production Research*, *51*(7), 2186-2199.

[33]. Chien, M. K., & Shih, L. H. (2007). An empirical study of the implementation of green supply chain management practices in the electrical and electronic industry and their relation to organizational performances *International Journal of Science and Technology*, *4*(3), 383-394.

[34]. Chopra, S., & Meindl, P. (2007). *Supply chain management. Strategy, planning & operation* (pp. 265-275). Gabler.

[35]. Chopra, S., & Sodhi, M. (2004). Managing risk to avoid supply chain breakdown. *Sloan Management Review*, *46*(1), 53-62.

[36]. Chopra, S., & Sodhi, M. S. (2012). Managing risk to avoid supply-chain breakdown. *MIT Sloan Management Review (Fall 2004).*

[37]. Chopra, S., Meindl, P. (2001). *Supply Chain Management – Strategy, Planning, and Operation*. Prentice-Hall. New Jersey.

[38]. Choudhary, D., & **Shankar, R.** (2012). An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India. *Energy, 42*(1), 510–521.

[39]. Choudhary, M., & Seth, N. (2011). Integration of Green Practices in Supply Chain Environment: The practices of Inbound, Operational, Outbound and Reverse logistics. *International Journal of Engineering Science & Technology*, *3*(6), 4995-4993.

[40]. Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management*, *15*(2), 1-14.

[41]. Closs, D. J., Speier, C., & Meacham, N. (2010). Sustainability to support end-to-end value chains: the role of supply chain management. *Journal of Academy of Marketing Science, 39*, 101-116.

[42]. Collins, J., & Hussey, R. (2003). *Business Research: A practical guide for undergraduate and postgraduate students. New York: Paigrave Macmillan*.

[43]. **Creese, R.C.** (2001). Cost management in lean manufacturing enterprises and the effects upon small and medium enterprises. *Proceedings of the fourth SME International Conference, Aoborg, Denmark, 14-16 March*, 144-150.

[44]. **Creese, R.C.,** & Nandeshwar, A. (2003). Improvement curve and revenue cost models. AACE International Annual Meeting, Orlando, Florida.

[45]. Dağdeviren, M., Yavuz, S., & Kılınç, N. (2009). Weapon selection using the AHP and TOPSIS methods under fuzzy environment. *Expert Systems with Applications*, *36*(4), 8143-8151.

[46]. Dan-li, D., Ju, Q., & Hong-yan, Z. (2011, November). Risk assessment study of manufacturing green supply chain based on grey theory. In *International Conference on Information Systems for Crisis Response and Management (ISCRAM), 2011*, 234-240.

[47]. Das, P. 2012. *Sustainable Supply Chains: Eco-Friendly Packaging and the Indian Challenges*. Accessed February 14, 2013. http://www.managementcanvas.iimindore.in/icanvas/index.php.

[48]. Davies, J., & Hochman, S. (2007). The greening of the supply chain. *Supply Chain Management Review, 11*(5), 13-14.

[49]. De Castro, E.L., **Tabucanon, M.T.,** & **Nagarur, N.** (1997). A Production Order Quantity Model with Stochastic Demand for a Chocolate Milk Manufacturer. *International Journal of Production Economics*, *49*(2), 145-156.

[50]. De Giovanni, P., & Vinzi, V. E. (2012). Covariance versus component-based estimations of performance in green supply chain management. *International Journal of Production Economics*, *135*(2), 907-916.

[51]. de Sousa Jabbour, A. B. L. (2015). Understanding the genesis of green supply chain management: lessons from leading Brazilian companies. *Journal of Cleaner Production*, *87*, 385-390.

[52]. de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Latan, H., Teixeira, A. A., & de Oliveira, J. H. C. (2015). Reprint of "Quality management, environmental management maturity, green supply chain practices and green performance of Brazilian companies with ISO 14001 certification: Direct and indirect effects". *Transportation Research Part E: Logistics and Transportation Review (In Press).*

[53]. Deleris, L. A., & Erhun, F. (2005, December). Risk management in supply networks using monte-carlo simulation. In *Simulation Conference, 2005 Proceedings of the Winter*, IEEE, p. 7.

[54]. Dey, P.K, Ogunlana S.O., **Tabucanon, M.T.,** & Gupta, S.S. (2001). Multiple attribute decision making approach to petroleum pipelineroute selection. *International Journal of Services Technology & Management*, *2*(3), 347-362.

[55]. Diabat, A., & Govindan, K. (2011). An analysis of the drivers affecting the implementation of green supply chain management. *Resources, Conservation and Recycling*, *55*(6), 659-667.

[56]. Diabat, A., Kannan, D., & Mathiyazhagan, K. (2014). Analysis of enablers for implementation of sustainable supply chain management–A textile case. *Journal of Cleaner Production*, *83*, 391-403.

[57]. Diabat, A., Khodaverdi, R., & Olfat, L. (2013). An exploration of green supply chain practices and performances in an automotive industry. *The International Journal of Advanced Manufacturing Technology*, *68*(1-4), 949-961.

[58]. Dubey, R., Gunasekaran, A., & Ali, S. S. (2015). Exploring the relationship between leadership, operational practices, institutional pressures and environmental performance: A framework for green supply chain. *International Journal of Production Economics*, *160*, 120-132.

[59]. Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532-550.

[60]. Eltayeb, T. K., Zailani, S., & Ramayah, T. (2011). Green supply chain initiatives among certified companies in Malaysia and environmental sustainability: Investigating the outcomes. *Resources, conservation and recycling*, *55*(5), 495-506.

[61]. Fahimnia B, Sarkis J, Davarzani H. (2015). Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics*, Online at (http://dx.doi.org/10.1016/j.ijpe.2015.01.003).

[62]. Faisal, M. N., **Banwet, D. K., & Shankar, R.** (2007a). Information risks management in supply chains: an assessment and mitigation framework. *Journal of Enterprise Information Management*, *20*(6), 677-699

[63]. Faisal, M. N. (2010). Sustainable supply chains: a study of interaction among the enablers. *Business Process Management Journal*, *16*(3), 508-529.

[64]. Faisal, M. N., **Banwet, D. K., & Shankar, R.** (2007b). Quantification of risk mitigation environment of supply chains using graph theory and matrix methods. *European Journal of Industrial Engineering*, *1*(1), 22-39.

[65]. Faisal, M. N., **Banwet, D. K., & Shankar, R.** (2007c). Supply chain risk management in SMEs: analysing the barriers. *International Journal of Management and Enterprise Development*, *4*(5), 588-607.

[66]. Fink, A. (2013). *Conducting research literature reviews: from the Internet to paper*. Sage Publications.

[67]. Frosdick, S. (1997). The techniques of risk analysis are insufficient in themselves. *Disaster Prevention and Management: An International Journal*, *6*(3), 165-177.

[68]. Georgiadis, P., Vlachos, D., & Tagaras, G. (2006). The Impact of Product Lifecycle on Capacity Planning of Closed-Loop Supply Chains with Remanufacturing. *Production and Operations Management*, *15*(4), 514-527.

[69]. Ghosh, S. K., Pal, S., & Ray, S. (2013). Study of microbes having potentiality for biodegradation of plastics. *Environmental Science and Pollution Research*, *20*(7), 4339-4355.

[70]. Gilbert, S. (2001). Greening supply chain: enhancing competitiveness through green productivity. *Tapei, Taiwan*, *16*.

[71]. Giovanni, P. D., & Vinzi, V. E. (2012). Covariance versus component-based estimations of performance in green supply chain management. *International Journal of Production Economics*, *135*(2), 907-916.

[72]. Global Plastics Industry. Published on Business Vibes http://www.businessvibes.com; 2013.

[73]. Godfrey, R. (1998). Ethical purchasing: developing the supply chain beyond the environment. *Greener purchasing: Opportunities and innovations*, 244-251.

[74]. Golmohammadi, D., **Creese, R. C.,** Valian, H., & Kolassa, J. (2009). Supplier selection based on a neural network model using genetic algorithm. *Neural Networks, IEEE Transactions on*, *20*(9), 1504-1519.

[75]. **Gopalakrishnan,** B., Banta, L., & Bhave, G. (2007a). Modeling steam based energy supply chain in an integrated steel manufacturing facility: A simulation based approach. International Journal of Industrial & System Engineering, 2(1), 1-29.

[76]. **Gopalakrishnan,** B., Gupta, D.P., Mardikar, Y., & Chaudhari, S. (2007b). Industrial Energy Efficiency (reviewed by Editor), *Handbook of Environmentally Conscious Manufacturing*, John Wiley & Sons, Inc.

[77]. Govindan, K., Kaliyan, M., Kannan, D., & Haq, A. N. (2014). Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *International Journal of Production Economics*, *147*, 555-568.

[78]. Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A. B. L. D. S., & Jabbour, C. J. C. (2013). Analysing green supply chain management practices in Brazil's electrical/electronics industry using interpretive structural modelling. *International Journal of Environmental Studies*, *70*(4), 477-493.

[79]. Green Jr, K. W., Zelbst, P. J., Meacham, J., & Bhadauria, V. S. (2012). Green supply chain management practices: impact on performance. *Supply Chain Management: An International Journal*, *17*(3), 290-305.

[80]. Green, K., Morton, B., & New, S. (1996). Purchasing and environmental management: interactions, policies and opportunities. *Business Strategy and the Environment*, *5*(3), 188-197.

[81]. Green, K., Morton, B., & New, S. (1998). Green purchasing and supply policies: do they improve companies' environmental performance?. *Supply Chain Management: An International Journal*, *3*(2), 89-95.

[82]. Green, K., Morton, B., & New, S. (2000). Greening Organizations Purchasing, Consumption, and Innovation. *Organization & Environment*, *13*(2), 206-225.

[83]. Guide Jr, V. D. R., & Van Wassenhove, L. N. (2009). OR FORUM-the evolution of closed-loop supply chain research. *Operations research*, *57*(1), 10-18.

[84]. Gunasekaran, A., & Gallear, D. (2012). Special Issue on Sustainable development of manufacturing and services. *International Journal of Production Economics*, *140*(1), 1-6.

[85]. Gunasekaran, A., & Spalanzani, A. (2012). Sustainability of manufacturing and services: Investigations for research and applications. *International Journal of Production Economics*, *140*(1), 35-47.

[86]. Gungor, A., & Gupta, S. M. (1999). Issues in environmentally conscious manufacturing and product recovery: a survey. *Computers & Industrial Engineering*, *36*(4), 811-853.

[87]. Gupta, S., & Palsule-Desai, O. D. (2011). Sustainable supply chain management: Review and research opportunities. *IIMB Management Review*, *23*(4), 234-245.

[88]. Gurnani, H., Mehrotra, A., & Ray, S. (2012). *Supply chain disruptions: Theory and practice of managing risk*. London: Springer.

[89]. Haleem, A., & Sushil, Q. MA and Kumar, S. (2012). Analysis of critical success factors of world class manufacturing practices: an application of interpretive structural modeling and interpretative ranking process. *Production Planning and Control: The Management of Operations*, *23*(10-11), 722-34.

[90]. Hall, J. (2000). Environmental supply chain dynamics. *Journal of cleaner production*, *8*(6), 455-471.

[91]. Hall, J. (2001). Environmental supply-chain innovation. *Greener Management International*, *35*, 105-119.

[92]. Handfield, R., Sroufe, R., & Walton, S. (2005). Integrating environmental management and supply chain strategies. *Business Strategy and the Environment*, *14*(1), 1-19.

[93]. Handfield, R.B. and Nichols, E.L. (1999). *Introduction to supply chain management.* Prentice-Hall, New Jersey, 1999, 1-183.

[94]. Handfield, R.B., Walton, S.V., Seegers, L.K., and Melnyk, S.A. (1997). Green' value chain practices in the furniture industry. *Journal of Operations Management*, *15*(4), 293-315.

[95]. Harland, C., Brenchley, R., & Walker, H. (2003). Risk in supply networks. *Journal of Purchasing and Supply management*, *9*(2), 51-62.

[96]. Harputlugil, T., Prins, M., Tanju Gültekin, A., & Ilker Topçu, Y. (2011, June). Conceptual framework for potential implementations of multi criteria decision making (MCDM) methods for design quality assessment. In *CIB International Conference on Management and Innovation for a Sustainable Built Environment; MISBE 2011,(June 20-23), Amsterdam*. Delft University of Technology.

[97]. Hervani, A. A., Helms, M. M., & Sarkis, J. (2005). Performance measurement for green supply chain management. *Benchmarking: An International Journal*, *12*(4), 330-353.

[98]. Hill, J. D., & Warfield, J. N. (1972). Unified program planning. *Systems, Man and Cybernetics, IEEE Transactions on*, *5*, 610-621.

[99]. Hillary, R. (Ed.). (2000). *Small and medium-sized enterprises and the environment: business imperatives*. Greenleaf Publishing.

[100]. Ho, J. C., Shalishali, M. K., Tseng, T., & Ang, D. S. (2009). Opportunities in green supply chain management. *The Coastal Business Journal*, *8*(1), 18-31**.**

[101]. Hoejmose, S., Brammer, S., & Millington, A. (2012). “Green” supply chain management: The role of trust and top management in B2B and B2C markets. *Industrial Marketing Management*, *41*(4), 609-620.

[102]. Holt, D., & Ghobadian, A. (2009). An empirical study of green supply chain management practices amongst UK manufacturers. *Journal of Manufacturing Technology Management*, *20*(7), 933-956.

[103]. Hong, P., Kwon, H., & Roh, J. J. (2009). Implementation of strategic green orientation in supply chain: An empirical study of manufacturing firms. *European Journal of Innovation Management*, *12*(4), 512-532.

[104]. Hora, M., & Klassen, R. D. (2013). Learning from others’ misfortune: factors influencing knowledge acquisition to reduce operational risk. *Journal of Operations Management*, *31*(1), 52-61.

[105]. Hsu, C. W., & Hu, A. H. (2008). Green supply chain management in the electronic industry. *International Journal of Environmental Science & Technology*, *5*(2), 205-216.

[106]. Hsu, C. W., Hu, A. H., & Wu, W. C. (2008, May). Using FMEA and FAHP to risk evaluation of green components. In *International Symposium on Electronics and the Environment, 2008. ISEE 2008. IEEE*, 1-6.

[107]. Hu, A. H., & Hsu, C. W. (2010). Critical factors for implementing green supply chain management practice: an empirical study of electrical and electronics industries in Taiwan. *Management Research Review*, *33*(6), 586-608**.**

[108]. Hu, A. H., Hsu, C. W., Kuo, T. C., & Wu, W. C. (2009). Risk evaluation of green components to hazardous substance using FMEA and FAHP. *Expert Systems with Applications*, *36*(3), 7142-7147.

[109]. Hussain, M. (2011). *Modelling the enablers and alternatives for sustainable supply chain management* (Doctoral dissertation, Concordia University).

[110]. Hwang, C. L., & Yoon, K. (1981). Basic Concepts and Foundations. In *Multiple Attribute Decision Making* (pp. 16-57). Springer Berlin Heidelberg.

[111]. Ilgin, M. A., & Gupta, S. M. (2010). Environmentally conscious manufacturing and product recovery (ECMPRO): a review of the state of the art. *Journal of environmental management*, *91*(3), 563-591.

[112]. Ishaswini and S. K., Datta. (2011). Pro-Environmental Concern Influencing Green Buying: A Study On Indian Consumers. *International Journal of Business and Management, 6*(6), 124–133.

[113]. Ishizaka, A., & Labib, A. (2009). Analytic hierarchy process and expert choice: Benefits and limitations. *OR Insight*, *22*(4), 201-220.

[114]. Jabbour, A. B., Jabbour, C., Govindan, K., Kannan, D., & Arantes, A. F. (2014). Mixed methodology to analyze the relationship between maturity of environmental management and the adoption of green supply chain management in Brazil. *Resources, Conservation and Recycling*, *92*, 255-267.

[115]. Jain, V., Wadhwa, S., & **Deshmukh,** S.G. (2009). Select supplier-related issues in modeling a dynamic supply chain: Potential, challenges and direction for future research. *International Journal of Production Research*, *47*(11), 3013-3039.

[116]. Jakhar, S. K., & Barua, M. K. (2014). An integrated model of supply chain performance evaluation and decision-making using structural equation modelling and fuzzy AHP. *Production Planning & Control*, *25*(11), 938-957.

[117]. Jellouli, O., & Chatelet, E. (2001). Monte Carlo simulation and genetic algorithm for optimising supply chain management in a stochastic environment. In *IEEE International Conference on Systems, Man, and Cybernetics, 3*, 1835-1839.

[118]. Jharkharia, S., & **Shankar, R.** (2006). Supply chain management: some sectoral dissimilarities in the Indian manufacturing industry. *Supply Chain Management: An International Journal*, *11*(4), 345-352.

[119]. Jha, J. K., & **Shanker, K.** (2009). Two-echelon supply chain inventory model with controllable lead time and service level constraint. Computers & Industrial Engineering, *57*(3), 1096-1104.

[120]. Joshi, R., **Banwet, D. K., & Shankar, R.** (2011). A Delphi-AHP-TOPSIS based benchmarking framework for performance improvement of a cold chain. *Expert Systems with Applications*, *38*(8), 10170-10182.

[121]. Jung, (2011). A bibliometric analysis on green supply chain management:a pre-liminary result. *In Commerce and Enterprise Computing, IEEE 13th Conference,* pp.418–420. (http://dx.doi.org/10.1109/CEC.2011.68).

[122]. Jung, J. Y., Blau, G., Pekny, J. F., Reklaitis, G. V., & Eversdyk, D. (2004). A simulation based optimization approach to supply chain management under demand uncertainty. *Computers & chemical engineering*, *28*(10), 2087-2106.

[123]. Jüttner, U., Peck, H., & Christopher, M. (2003). Supply chain risk management: outlining an agenda for future research. *International Journal of Logistics: Research and Applications*, *6*(4), 197-210.

[124]. Jyoti, **Banwet, D. K.,** & **Deshmukh, S. G.** (2008). Evaluating performance of national R&D organizations using integrated DEA-AHP technique. *International journal of productivity and performance management*, *57*(5), 370-388

[125]. Kannan, D., de Sousa Jabbour, A. B. L., & Jabbour, C. J. C. (2014). Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. *European Journal of Operational Research*, *233*(2), 432-447.

[126]. Kannan, D., Khodaverdi, R., Olfat, L., Jafarian, A., & Diabat, A. (2013). Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain. *Journal of Cleaner Production*, *47*, 355-367.

[127]. Kaya, T., & Kahraman, C. (2010). Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul. *Energy*,*35*(6), 2517-2527.

[128]. Kelle, P., & Silver, E. A. (1989). Forecasting the returns of reusable containers.*Journal of Operations Management*, *8*(1), 17-35.

[129]. Khurana, M. K., Mishra, P. K., Jain, R., & Singh, A. R. (2010). Modeling of information sharing enablers for building trust in Indian manufacturing industry: an integrated ISM and fuzzy MICMAC approach. *International Journal of Engineering Science and Technology*, *2*(6), 1651-1669.

[130]. Kim, J. H., Youn, S., & Roh, J. J. (2011). Green supply chain management orientation and firm performance: evidence from South Korea. *International Journal of Services and Operations Management*, *8*(3), 283-304.

[131]. Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management*, *14*(1), 53-68.

[132]. Kleindorfer, P. R., Singhal, K., & Wassenhove, L. N. (2005). Sustainable operations management. *Production and operations management*, *14*(4), 482-492.

[133]. Koushal, V., Sharma, R., Sharma, M., Sharma, R., & Sharma, V. (2014). Plastics: Issues Challenges and Remediation. *International Journal of Waste Resources, 4*(1), 1-6.

[134]. Kumar, R., & Chandrakar, R. (2012). Overview of green supply chain management: operation and environmental impact at different stages of the supply chain. *International Journal of Engineering and Advanced Technology*, *1*(3), 1-6.

[135]. Kumar, R., Singh, R. K., & **Shankar, R.** (2013). Study on coordination issues for flexibility in supply chain of SMEs: a case study. *Global Journal of Flexible Systems Management*, *14*(2), 81-92.

[136]. Kumar, S., Teichman, S., & Timpernagel, T. (2012). A green supply chain is a requirement for profitability. *International Journal of Production Research*, *50*(5), 1278-1296.

[137]. Kuo, M. S., Tzeng, G. H., & Huang, W. C. (2007). Group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment. *Mathematical and Computer Modelling*, *45*(3), 324-339.

[138]. Kushwaha, G. S. (2011). Sustainable development through strategic green supply chain management. *International Journal of Engineering and Management Sciences*, *1*(1), 7-11.

[139]. Lai, K. H., Bao, Y., & Li, X. (2008). Channel relationship and business uncertainty: Evidence from the Hong Kong market. *Industrial Marketing Management*, *37*(6), 713-724.

[140]. Lai, K. H., Cheng, T. C. E., & Tang, A. K. (2010). Green retailing: factors for success. *California Management Review*, *52*(2), 6-31.

[141]. Lamming, R., & Hampson, J. (1996). The environment as a supply chain management issue. *British journal of Management*, *7*(s1), S45-S62.

[142]. Li, B. (2011, May). Research on evaluation of knowledge transfer risk based on green supply chain. In IEEE *International Conference on Business Management and Electronic Information (BMEI), 2*, 237-240.

[143]. Lin, R. J. (2011). Moderating effects of total quality environmental management on environmental performance. *African Journal of Business Management*, *5*(20), 8088-8099.

[144]. Lin, R. J. (2013). Using fuzzy DEMATEL to evaluate the green supply chain management practices. *Journal of Cleaner Production*, *40*, 32-39.

[145]. Linton, J. D., Klassen, R., & Jayaraman, V. (2007). Sustainable supply chains: An introduction. *Journal of Operations Management*, *25*(6), 1075-1082.

[146]. Lippmann, S. (1999). Supply chain environmental management: elements for success. *Corporate Environmental Strategy*, *6*(2), 175-182.

[147]. Liu, H. T., & Tsai, Y. L. (2012). A fuzzy risk assessment approach for occupational hazards in the construction industry. *Safety science*, *50*(4), 1067-1078.

[148]. Liu, S., So, K. C., & Zhang, F. (2010). Effect of supply reliability in a retail setting with joint marketing and inventory decisions. *Manufacturing & Service Operations Management*, *12*(1), 19-32.

[149]. Luthra, S., Garg, D., & Haleem, A. (2013). Identifying and ranking of strategies to implement green supply chain management in Indian manufacturing industry using Analytical Hierarchy Process. *Journal of Industrial Engineering and Management*, *6*(4), 930-962.

[150]. Luthra, S., Garg, D., & Haleem, A. (2014a). Critical success factors of green supply chain management for achieving sustainability in Indian automobile industry. *Production Planning & Control*, (ahead-of-print), 1-24.

[151]. Luthra, S., Garg, D., & Haleem, A. (2014c). Greening the supply chain using SAP-LAP analysis: a case study of an auto ancillary company in India. *International Journal of Business Excellence*, *7*(6), 724-746.

[152]. Luthra, S., Garg, D., & Haleem, A. (2014d). Empirical analysis of green supply chain management practices in Indian automobile industry. *Journal of The Institution of Engineers (India): Series C*, *95*(2), 119-126.

[153]. Luthra, S., Garg, D., & Haleem, A. (2015). An analysis of interactions among critical success factors to implement green supply chain management towards sustainability: An Indian perspective. *Resources Policy (In Press)*.

[154]. Luthra, S., Kumar, V., Kumar, S., & Haleem, A. (2010). Green supply chain management issues: A literature review approach. *Journal of Information, Knowledge and Research in Mechanical Engineering*, *1*(1), 12-20.

[155]. Luthra, S., Kumar, V., Kumar, S., & Haleem, A. (2011). Barriers to implement green supply chain management in automobile industry using interpretive structural modeling technique: an Indian perspective. *Journal of Industrial Engineering and Management*, *4*(2), 231-257.

[156]. Luthra, S., Qadri, M. A., Garg, D., & Haleem, A. (2014b). Identification of critical success factors to achieve high green supply chain management performances in Indian automobile industry. *International Journal of Logistics Systems and Management*, *18*(2), 170-199.

[157]. Ma, R. M., Yao, L. F., & Huang, R. (2012). The green supply chain management risk analysis. *Advanced Materials Research*, *573*, 734-739.

[158]. MacDonald, B., & Walker, R. (1975). Case-study and the social philosophy of educational research. *Cambridge journal of Education*, *5*(1), 2-11.

[159]. Madaan, J., Kumar, P., & Chan, F. T. S. (2012). Decision and information interoperability for improving performance of product recovery systems. *Decision Support Systems*, *53*(3), 448-457.

[160]. Mahajan, R., Garg, S., & Sharma, P. B. (2013). Frozen corn manufacturing and its supply chain: Case study using SAP–LAP approach. *Global Journal of Flexible Systems Management*, *14*(3), 167-177.

[161]. Mahapatra, S.C., & Shekhar, B.R. (2013). Enlisting the airline services using fuzzy evaluation approach in Indian context. *International Journal of Innovative Research and Development*, *2*(12), 281-284.

[162]. Majumdar, S. K., & Gupta, M. P. (2001). E-business strategy of car industry: SAP–LAP analysis of select case studies. *Global Journal of Flexible Systems Management*, *2*(3), 13-28.

[163]. Malhotra, N. K. (2008). *Marketing research: An applied orientation, 5/e*. Pearson Education India.

[164]. Malviya, R. K., & Kant, R. (2014, September). Predicting the success possibility for Green Supply chain management implementation. In *IEEE International Conference on Management of Innovation and Technology (ICMIT)*, 520-525.

[165]. Mandal, A., & **Deshmukh**, S.G. (1994). Vendor selection using interpretive structural modeling (ISM). *International Journal of Operations & Production Management*, *14*(6), 52-59.

[166]. Mangla, S., Madaan, J., & Chan, F. T. (2012). Analysis of performance focused variables for multi-objective flexible decision modeling approach of product recovery systems. *Global Journal of Flexible Systems Management*, *13*(2), 77-86.

[167]. Mangla, S., Madaan, J., & Chan, F. T. (2013). Analysis of flexible decision strategies for sustainability-focused green product recovery system. *International Journal of Production Research*, *51*(11), 3428-3442.

[168]. Mangla, S., Madaan, J., Sarma, P. R. S., & Gupta, M. P. (2014). Multi-objective decision modelling using interpretive structural modelling for green supply chains. *International Journal of Logistics Systems and Management*, *17*(2), 125-142.

[169]. Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management*, *38*(3), 192-223.

[170]. Marsillac EL. (2008). Environmental impacts on reverse logistics and green supply chains: similarities and integration. *International Journal of Logistics Systems and Management*, *4*(4), 411-422.

[171]. Martha, J., & Subbakrishna, S. (2002). Targeting a just-in-case supply chain for the inevitable next disaster. *Supply Chain Management Review*, *6*(5), 18–23.

[172]. Massoud, M. A., Al-Abady, A., Jurdi, M., & Nuwayhid, I. (2010). The challenges of sustainable access to safe drinking water in rural areas of developing countries: case of Zawtar El-Charkieh, Southern Lebanon. *Journal of Environmental Health*, *72*(10), 24-30.

[173]. Mathiyazhagan, K., Govindan, K., & Noorul Haq, A. (2014). Pressure analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *International Journal of Production Research*, *52*(1), 188-202.

[174]. Mathiyazhagan, K., Govindan, K., NoorulHaq, A., & Geng, Y. (2013). An ISM approach for the barrier analysis in implementing green supply chain management. *Journal of Cleaner Production*, *47*, 283-297.

[175]. Meacham, J., Toms, L., Green Jr, K. W., & Bhadauria, V. S. (2013). Impact of information sharing and green information systems. *Management Research Review*, *36*(5), 478-494.

[176]. Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. & Zacharia, Z.G. (2001). *What is supply chain management. in Mentzer, J.T. (Ed.), Supply Chain Management*, Sage, Thousand Oaks, CA, pp. 1-25.

[177]. Merriam, S. B. (2014). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

[178]. Michelsen, O. (2007). Investigation of relationships in a supply chain in order to improve environmental performance. *Clean Technologies and Environmental Policy*, *9*(2), 115-123.

[179]. Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*. SAGE Publications, Incorporated.

[180]. Miller, K. D. (1992). A framework for integrated risk management in international business. *Journal of International Business Studies*, 311-331.

[181]. Min, H., & Galle, W. P. (2001). Green purchasing practices of US firms. *International Journal of Operations & Production Management*, *21*(9), 1222-1238.

[182]. Min, H., & Kim, I. (2012). Green supply chain research: past, present, and future. *Logistics Research*, *4*(1/2), 39-47.

[183]. Mirhedayatian, S. M., Azadi, M., & Saen, R. F. (2014). A novel network data envelopment analysis model for evaluating green supply chain management. *International Journal of Production Economics*, *147*, 544-554.

[184]. Mishra, S., & Suar, D. (2010). Does corporate social responsibility influence firm performance of Indian companies?. *Journal of Business Ethics*, *95*(4), 571-601.

[185]. Mitchell, V. W. (1995). Organizational risk perception and reduction: a literature review. *British Journal of Management*, *6*(2), 115-133.

[186]. Mitra, S., & Datta, P. P. (2014). Adoption of green supply chain management practices and their impact on performance: an exploratory study of Indian manufacturing firms. *International Journal of Production Research*, *52*(7), 2085-2107.

[187]. Mohanty, P.D. and Deshmukh, P.D. (2005). *Supply Chain Management: Theories & Practices.* Dreamtech Press, Biztantra, Delhi.

[188]. Mohanty, R. P., & Prakash, A. (2014). Green supply chain management practices in India: an empirical study. *Production Planning & Control*, *25*(16), 1322-1337.

[189]. Mollenkopf, D., Stolze, H., Tate, W. L., & Ueltschy, M. (2010). Green, lean, and global supply chains. *International Journal of Physical Distribution & Logistics Management*, *40*(1/2), 14-41.

[190]. Mudgal, R. K., **Shankar, R.,** Talib, P., & Raj, T. (2009). Greening the supply chain practices: an Indian perspective of enablers' relationships. *International Journal of Advanced Operations Management*, *1*(2), 151-176.

[191]. Mudgal, R. K., **Shankar, R.,** Talib, P., & Raj, T. (2010). Modelling the barriers of green supply chain practices: an Indian perspective. *International Journal of Logistics Systems and Management*, *7*(1), 81-107.

[192]. Muduli, K., & Barve, A. (2013). Sustainable development practices in mining sector: a GSCM approach. *International Journal of Environment and Sustainable Development*, *12*(3), 222-243.

[193]. Muduli, K., Govindan, K., Barve, A., & Geng, Y. (2013). Barriers to green supply chain management in Indian mining industries: a graph theoretic approach. *Journal of Cleaner Production*, *47*, 335-344.

[194]. Muralidhar, P., Ravindranath, K., & Srihari, V. (2012). Application of Fuzzy AHP for Evaluation of Green Supply Chain Management Strategies. *IOSR Journal of Engineering*, *2*(3), 461-467.

[195]. Muralidhar, P., Ravindranath, K., & Srihari, V. (2013). The influence of GRA and TOPSIS for assortment of green supply chain management strategies in Cement industry. *International Journal of Supply Chain Management*, *2*(1), 49-54.

[196]. Mutha, N. H., Patel, M., & Premnath, V. (2006). Plastics materials flow analysis for India. *Resources, Conservation and Recycling*, *47*(3), 222-244.

[197]. **Nagarur,** N. (1992). Some Performance Measures of Flexible Manufacturing Systems. *International Journal of Production Research*, *30*(4), 799-809.

[198]. **Nagarur,** N., & Rajbhandari, B. (2001). Data Envelopment Analysis for the Performance Evaluation of Air Conditioning and Refrigeration Companies in Thailand. *International Journal of Business Performance Management*, *3*(2/3/4), 276-300.

[199]. Naini, S. G. J., Aliahmadi, A. R., & Jafari-Eskandari, M. (2011). Designing a mixed performance measurement system for environmental supply chain management using evolutionary game theory and balanced scorecard: A case study of an auto industry supply chain. *Resources, Conservation and Recycling*, *55*(6), 593-603.

[200]. Narasimhan, R., & Carter, J.R. (1998). *Environmental Supply Chain Management.* The Center for Advanced Purchasing Studies, Arizona State University, Tempe, AZ.

[201]. Nelson, D., Marsillac, E., & Rao, S. (2012). Antecedents and evolution of the green supply chain. *Journal of Operations and Supply Chain Management*, *1*(1), 29-43.

[202]. Nemuth, I. T. (2008). Practical Use of Monte Carlo Simulation for Risk Management within the International Construction Industry. In *Grauber, Schmidt & Proske: Proceedings of the 6th International Probabilistic Workshop, Darmstadt*.

[203]. Nimawat, D., & Namdev, V. (2012). An overview of green supply chain management in India. *Research Journal of Recent Sciences*, *1*(6), 77-82.

[204]. Faisal, M. N., **Banwet, D. K., & Shankar, R.** (2006). Supply chain risk mitigation: modeling the enablers. *Business Process Management Journal*, *12*(4), 535-552.

[205]. Odeyale, S. O., Oguntola, A. J., & Odeyale, E. O. (2013). Evaluation and selection of an effective green supply chain management strategy: A case study. *International Journal of Research Studies in Management*, *3*(1), 27-39.

[206]. Oliver, R. K., & Webber, M. D. (1982). Supply-chain management: logistics catches up with strategy. *Outlook*, *5*(1), 42-47.

[207]. Olugu, E. U., Wong, K. Y., & Shaharoun, A. M. (2011). Development of key performance measures for the automobile green supply chain. *Resources, Conservation and Recycling*, *55*(6), 567-579.

[208]. Oluwafemi, O. J., & Oyatoye, E. O. (2012). Corporate social responsibility: are firms in Nigeria actually giving back or giving away?. *International Journal of Business Excellence*, *5*(1), 116-129.

[209]. Online available at: http://www.indianmirror.com/indian-industries/plastic.html.

[210]. Orsato, R. J. (2006). When does it pay to be green?. *California Management Review*, *48*(2), 128.

[211]. Pal, O., Gupta, A. K., & **Garg, R. K.** (2013). Supplier Selection Criteria and Methods in Supply Chains: A Review. International Journal of Social, Management, *Economics and Business Engineering*, *7*(10), 1403-1409.

[212]. Palanisamy, R. (2012). Building information systems flexibility in SAP–LAP framework: A case study evidence from SME sector. *Global Journal of Flexible Systems Management*, *13*(1), 57-74.

[213]. Parmigiani, A., Klassen, R. D., & Russo, M. V. (2011). Efficiency meets accountability: Performance implications of supply chain configuration, control, and capabilities. *Journal of Operations Management*, *29*(3), 212-223.

[214]. Patil, S. K., & Kant, R. (2014). A hybrid approach based on fuzzy DEMATEL and FMCDM to predict success of knowledge management adoption in supply chain. *Applied Soft Computing*, *18*, 126-135.

[215]. Patton, E., & Appelbaum, S. H. (2003). The case for case studies in management research. *Management Research News*, *26*(5), 60-71.

[216]. Paulraj, A. (2009). Environmental motivations: a classification scheme and its impact on environmental strategies and practices. *Business Strategy and the Environment*, *18*(7), 453-468.

[217]. Perera, H.S.C., **Nagarur,** N., & **Tabucanon, M.T.** (1999). Component Part Standardization: A Way to Reduce Life-Cycle Costs of Products. *International Journal of Production Economics*, *60-61*, 109-116.

[218]. Perron, G. M. (2005). Barriers to environmental performance improvements in Canadian SMEs. *Dalhousie University, Canada*.

[219]. Pishvaee, M. S., & Razmi, J. (2012). Environmental supply chain network design using multi-objective fuzzy mathematical programming. *Applied Mathematical Modelling*, *36*(8), 3433-3446.

[220]. Plastic Europe (2009). The compelling facts about plastics 2009, an analysis of European plastics production, demand and recovery for 2008, *Plastic Europe* [online] http://www.plasticseurope.org (accessed August 2013).

[221]. Plastic News. (2013). *SAY YES TO PLASTIC,* May issue 2013. *66*(5), 1-66.

[222]. Porter, M., & Van der Linde, C. (1996). Green and competitive: ending the stalemate. *Business and the Environment, Earth scan Publications Ltd, London*, 61-77.

[223]. Prakash, G., & **Shanker, K.** (2008, September). Achieving competitive advantage and organisational performance through service quality initiatives in the supply chain. In *Management of Innovation and Technology, 2008. ICMIT 2008. 4th IEEE International Conference on* (pp. 1104-1109). IEEE.

[224]. Qadri, M.A., Haleem, A., & Arif, M. (2011). Identification of drivers for greening of supply chain in India. *International Journal of Construction Project Management*, *3*(3), 1-17.

[225]. Qianlei, L. (2012, October). The study on the risk management of agricultural products green supply chain based on systematic analysis. In *Second International Conference* of *Business Computing and Global Informatization (BCGIN)*, 250-253.

[226]. Qureshi, M. N., Kumar, P., & Kumar, D. (2009). Selection of 3PL service providers: a combined approach of AHP and graph theory. *International Journal of Services Technology and Management*, *12*(1), 35-60.

[227]. Ramanathan, U., & Gunasekaran, A. (2014). Supply chain collaboration: Impact of success in long-term partnerships. *International Journal of Production Economics*, *147*, 252-259.

[228]. Ramesh, A., **Banwet, D. K., & Shankar, R.** (2010). Modeling the barriers of supply chain collaboration. *Journal of Modelling in Management*, *5*(2), 176-193.

[229]. Rao, P. (2002). Greening the supply chain: a new initiative in South East Asia. *International Journal of Operations & Production Management*, *22*(6), 632-655.

[230]. Rao, P., & Holt, D. (2005). Do green supply chains lead to competitiveness and economic performance? *International Journal of Operations & Production Management*, *25*(9), 898-916.

[231]. Ravi, V., & **Shankar, R.** (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, *72*(8), 1011-1029.

[232]. Rettab, B., & Ben Brik, A. (2008). Green supply chain in Dubai. UAE: Dubai Chamber Centre for Responsible Business, 2008. Electronic copy available at: http://www.dubaichamber.com/wp-content/uploads/2009/07/GREEN-SUPPLY-CHAIN-IN-DUBAI.pdf / (Accessed: 12 April, 2012).

[233]. Roarty, M. (1997). Greening business in a market economy. *European Business Review*, *97*(5), 244-254.

[234]. Rostamy, A. A. A., Shaverdi, M., & Ramezani, I. (2013). Green Supply Chain Management Evaluation in Publishing Industry Based on Fuzzy AHP Approach. *Journal of Logistics Management*, *2*(1), 9-14.

[235]. Rostamzadeh, R., Govindan, K., Esmaeili, A., & Sabaghi, M. (2015). Application of fuzzy VIKOR for evaluation of green supply chain management practices. *Ecological Indicators*, *49*, 188-203.

[236]. Saaty, T. L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill Book Co., New York.

[237]. Sabri, E. H., & Beamon, B. M. (2000). A multi-objective approach to simultaneous strategic and operational planning in supply chain design. *Omega*, *28*(5), 581-598.

[238]. Samvedi, A., & Jain, V. (2013). A study on the interactions between supply chain risk management criteria using fuzzy DEMATEL method. *International Journal of Operational Research*, *18*(3), 255-271.

[239]. Sarkis, J. (1998). Evaluating environmentally conscious business practices. *European Journal of Operational Research*, *107*(1), 159-174.

[240]. Sarkis, J. (2003). A strategic decision framework for green supply chain management. *Journal of Cleaner Production*, *11*(4), 397-409.

[241]. Sarkis, J. (2006). *Greening the Supply Chain (Book Review).* Springer, New York, 407 pages.

[242]. Sarkis, J., Zhu, Q., & Lai, K. H. (2011). An organizational theoretic review of green supply chain management literature. *International Journal of Production Economics*, *130*(1), 1-15.

[243]. Sarmiento, R., & Thomas, A. (2010). Identifying improvement areas when implementing green initiatives using a multitier AHP approach. *Benchmarking: An International Journal*, *17*(3), 452-463.

[244]. Schmitt, A. J., & Singh, M. (2009, December). Quantifying supply chain disruption risk using Monte Carlo and discrete-event simulation. In *Winter Simulation Conference*, 1237-1248.

[245]. Şengül, Ü., Eren, M., Shiraz, S. E., Gezder, V., & Şengül, A. B. (2015). Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey. *Renewable Energy*, *75*, 617-625.

[246]. Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, *16*(15), 1699-1710.

[247]. Shang, K. C., Lu, C. S., & Li, S. (2010). A taxonomy of green supply chain management capability among electronics-related manufacturing firms in Taiwan. *Journal of environmental management*, *91*(5), 1218-1226.

[248]. Sheffi, Y. (2005). *The resilient enterprise: overcoming vulnerability for competitive advantage*. MIT Press Books, Cambridge, MA.

[249]. Shen, L., Muduli, K., & Barve, A. (2013a). Developing a sustainable development framework in the context of mining industries: AHP approach. *Resources Policy*. Online at: http://dx.doi.org/10.1016/j.resourpol.2013.10.006i.

[250]. Shen, L., Olfat, L., Govindan, K., Khodaverdi, R., & Diabat, A. (2013b). A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. *Resources, Conservation and Recycling*, *74*, 170-179.

[251]. Sheu, J. B., & Chen, Y. J. (2012). Impact of government financial intervention on competition among green supply chains. *International Journal of Production Economics*, *138*(1), 201-213.

[252]. Shipley, M. F., de Korvin, A., & Obid, R. (1991). A decision making model for multi-attribute problems incorporating uncertainty and bias measures. *Computers & operations research*, *18*(4), 335-342.

[253]. Shuhong, Z. (2009, December). Research on the Readiness Evaluation Index System of Green Supply Chain Management Based on RBV. In IEEE *1st International Conference on Information Science and Engineering (ICISE),* 4480-4484.

[254]. Shukla, R. K., Garg, D., & Agarwal, A. (2011). Study of Select Issues Related to Supply Chain Coordination: Using SAP-LAP Analysis Framework. *Global Journal of Enterprise Information System*, *3*(2), 56-69.

[255]. Siaminwe, L., Chinsembu, K. C., & Syakalima, M. (2005). Policy and operational constraints for the implementation of cleaner production in Zambia. *Journal of Cleaner Production*, *13*(10), 1037-1047.

[256]. Siddiqui, F., Haleem, A., & Sharma, C. (2012). Strategic planning of service supply chain using dynamic SAP-LAP model: a case study of a leading gas organisation in India. *International Journal of Services, Economics and Management*, *4*(3), 169-185.

[257]. Siegel, D. S. (2010). Green management matters only if it yields more green: An economic/strategic perspective. *Strategic Direction*, *26*(2), 5–16.

[258]. Simpson, D., & Samson, D. (2008). Developing strategies for green supply chain management. *Decision line*, *39*(4), 12-15.

[259]. Simpson, D., Power, D., & Samson, D. (2007). Greening the automotive supply chain: a relationship perspective. *International Journal of Operations & Production Management*, *27*(1), 28-48.

[260]. Singh, A., Singh, B., & Dhingra, A. K. (2012). Drivers and barriers of green manufacturing practices: a survey of Indian industries. *International Journal of Engineering Sciences*, *1*(1), 5-19.

[261]. Singh, R. K., & Sharma, M. K. (2014). Prioritising the alternatives for flexibility in supply chains. *Production Planning & Control*, *25*(2), 176-192.

[262]. Singh, R.K., Garg, S.K., & **Deshmukh**, **S.G.** (2008). Challenges and strategies for competitiveness of SMES: A case study in the Indian context. *International Journal of Services & Operations Management*, *4*(2), 181-200.

[263]. Singh, R.K., Garg, S.K., **Deshmukh**, **S.G.,** & Kumar, M. (2007). Modelling of critical success factors for implementation of AMTs. *Journal of Modelling in Management*, *2*(3), 232-250.

[264]. Snider, H. W. (1991). Risk management: A retrospective view. *Risk Management*, *91*, 47-54.

[265]. Somsuk, N. (2014). Prioritizing Drivers of Sustainable Competitive Advantages in Green Supply Chain Management Based on Fuzzy AHP. *Journal of Medical and Bioengineering*, *3*(4), 259-266.

[266]. Srivastava, S. K. (2007). Green supply-chain management: a state-of-the-art literature review. *International Journal of Management Reviews*, *9*(1), 53-80.

[267]. Srivastava, S. K. (2008). Network design for reverse logistics. *Omega*, *36*(4), 535-548.

[268]. Stake, R. E. (1995). *The Art of Case Study Research*. Sage.

[269]. Stevens, G. C. (1989). Integrating the supply chain. *International Journal of Physical Distribution & Materials Management*, *19*(8), 3-8.

[270]. Stevens, G.C. (1990). Successful Supply-Chain Management. *Management Decision*, *28*(8), 25-30

[271]. Subramanian, R., Talbot, B., & Gupta, S. (2010). An approach to integrating environmental considerations within managerial decision-making. *Journal of Industrial Ecology*, *14*(3), 378-398.

[272]. Sun CC. (2010). A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert Systems with Applications*, *37*(12), 7745-7754.

[273]. Sunil, A., Sengupta, R.N., & **Shanker, K**. (2009). Impact of information sharing and lead time on bullwhip effect and on-hand inventory. *European Journal of Operational Research*, *192*(2), 576-593.

[274]. Suri, P. K. (2008). Towards a strategy for implementing e-governance applications: a case study of integrated fertilisers management information system based on SAP-LAP framework. *Electronic Government, An International Journal*, *5*(4), 420-444.

[275]. Sushil, (2005). Interpretive matrix: A tool to aid interpretation of management and social research. *Global Journal of Flexible Systems Management*, *6*(2), 27–30.

[276]. Sushil, (2009b). SAP-LAP linkages—a generic interpretive framework for analyzing managerial contexts. *Global Journal of Flexible Systems Management*, *10*(2), 11-20.

[277]. Sushil, X. (1997). Flexible systems management: An evolving paradigm. *Systems research and behavioral science*, *14*(4), 259-275.

[278]. Sushil. (2000). SAP-LAP models of inquiry. *Management Decision*, *38*(5), 347-353.

[279]. Sushil. (2001a). SAP-LAP framework. *Global Journal of Flexible Systems Management*, *2*(1), 51-59.

[280]. Sushil. (2001b). SAP-LAP models. *Global Journal of Flexible Systems Management*, *2*(2), 55-61.

[281]. Sushil. (2009a). Interpretive Ranking Process. *Global Journal of Flexible Systems Management*, *10*(4), 1-10.

[282]. Tabucanon, M.T. (1988). *Multiple criteria decision making in industry*. Amsterdam [The Netherlands], New York : Elsevier.

[283]. Tang, C. S. (2006). Perspectives in supply chain risk management. *International Journal of Production Economics, 103*(2), 451-488.

[284]. Tejpal, G., **Garg, R. K.,** & Sachdeva, A. (2013a). Trust among supply chain partners: a review. *Measuring Business Excellence*, *17*(1), 51-71.

[285]. Tejpal, G., **Garg, R. K.,** & Sachdeva, A. (2013b, December). Factor analysis of rational trust among supply chain partners in Indian industries. In *Industrial Engineering and Engineering Management (IEEM), 2013 IEEE International Conference on* (pp. 915-918). IEEE.

[286]. Testa, F., & Iraldo, F. (2010). Shadows and lights of GSCM (Green Supply Chain Management): determinants and effects of these practices based on a multi-national study. *Journal of Cleaner Production*, *18*(10), 953-962.

[287]. Thakkar, J., **Deshmukh, S.G.,** Gupta, A.D., **& Shankar, R. (2007).** Development of a balanced scorecard: an integrated approach of interpretive structural modeling (ISM) and analytic network process (ANP). *International Journal of Productivity & Performance Management*, *56*(1), 25-59.

[288]. Thakkar, J., Kanda, A., & **Deshmukh, S. G.** (2008). A conceptual role interaction model for supply chain management in SMEs. *Journal of Small Business and Enterprise Development*, *15*(1), 74-95.

[289]. The Economic Times (2012). India ranks 125th in environment performance index: report in The Economic Times, January 29, 2012, Electronic copy available at: http://articles.economictimes.indiatimes.com/2012-01-29/news/30675964_1_india-ranks-pollution-control-management (Accessed: 4 November, 2012).

[290]. Thompson, D. (Ed.). (2002). *Tools for environmental management: A practical introduction and guide*. New Society Pub.

[291]. Toke, L. K. (2012). An empirical study of green supply chain management in Indian perspective. *International Journal of Applied Science and Engineering Research*, *1*(2), 372-383.

[292]. Toke, L. K., Gupta, R. C., & Dandekar, M. (2010, January). Green supply chain management; critical research and practices. In *Proceedings of the 2010 International*

Conference on Industrial Engineering and Operations Management Dhaka, Bangladesh.

[293]. Tsiakis, P., Shah, N., & Pantelides, C. C. (2001). Design of multi-echelon supply chain networks under demand uncertainty. *Industrial & Engineering Chemistry Research*, *40*(16), 3585-3604.

[294]. Vachon, S., & Klassen, R. D. (2006). Green project partnership in the supply chain: the case of the package printing industry. *Journal of Cleaner Production*, *14*(6), 661-671.

[295]. Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of operational research*, *169*(1), 1-29.

[296]. Vilko, J. P., & Hallikas, J. M. (2012). Risk assessment in multimodal supply chains. *International Journal of Production Economics*, *140*(2), 586-595.

[297]. Viswanadham, N., & Samvedi, A. (2013). Supplier selection based on supply chain ecosystem, performance and risk criteria. *International Journal of Production Research*, *51*(21), 6484-6498.

[298]. Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International journal of operations & production management*, *22*(2), 195-219.

[299]. Walker, H., & Jones, N. (2012). Sustainable supply chain management across the UK private sector. *Supply Chain Management: An International Journal*, *17*(1), 15-28.

[300]. Walker, H., Di Sisto, L., & McBain, D. (2008). Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors. *Journal of purchasing and supply management*, *14*(1), 69-85.

[301]. Walton, S. V., Handfield, R. B., & Melnyk, S. A. (1998). The green supply chain: integrating suppliers into environmental management processes. *International Journal of Purchasing and Materials Management*, *34*(1), 2-11.

[302]. Wang, L., Chu, J., & Wu, J. (2007). Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process. *International Journal of Production Economics*, *107*(1), 151-163.

[303]. Wang, X., & Chan, H. K. (2013). A hierarchical fuzzy TOPSIS approach to assess improvement areas when implementing green supply chain initiatives. *International Journal of Production Research*, *51*(10), 3117-3130.

[304]. Wang, X., Chan, H. K., Yee, R. W., & Diaz-Rainey, I. (2012). A two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain. *International Journal of Production Economics*, *135*(2), 595-606.

[305]. Wang, Y. M., & Elhag, T. M. (2006). Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert systems with applications*, *31*(2), 309-319.

[306]. Ware, N. R., Singh, S. P., & Banwet, D. K. (2014). Modeling flexible supplier selection framework. *Global Journal of Flexible Systems Management*, *15*(3), 261-274.

[307]. Warfield, J. N. (1974). Developing interconnection matrices in structural modeling. *IEEE Transcript on Systems, Men and Cybernetics*, *4*(1), 51-81.

[308]. Waters, D. (2007). *Supply chain risk management: Vulnerability and resilience in logistics*. London: Kogan page.

[309]. Wee, H. M., Lee, M. C., Jonas, C. P., & Wang, C. E. (2011). Optimal replenishment policy for a deteriorating green product: Life cycle costing analysis. *International Journal of Production Economics*, *133*(2), 603-611.

[310]. Wong, W. P., Jaruphongsa, W., & Lee, L. H. (2008). Supply chain performance measurement system: a Monte Carlo DEA-based approach. *International Journal of Industrial and Systems Engineering*, *3*(2), 162-188.

[311]. Wu, H. H., & Tsai, Y. N. (2012). An integrated approach of AHP and DEMATEL methods in evaluating the criteria of auto spare parts industry. *International Journal of Systems Science*, *43*(11), 2114-2124.

[312]. Wu, K. J., Liao, C. J., Tseng, M. L., & Chiu, A. S. (2015). Exploring decisive factors in green supply chain practices under uncertainty. *International Journal of Production Economics*, *159*, 147-157.

[313]. Wu, W. W. (2008). Choosing knowledge management strategies by using a combined ANP and DEMATEL approach. *Expert Systems with Applications*, *35*(3), 828-835.

[314]. Xu, L., Mathiyazhagan, K., Govindan, K., Haq, A. N., Ramachandran, N. V., & Ashokkumar, A. (2013). Multiple comparative studies of green supply chain management: pressures analysis. *Resources, Conservation and Recycling*, *78*, 26-35.

[315]. Yadav, O. P., & **Goel, P. S.** (2008). Customer satisfaction driven quality improvement target planning for product development in automotive industry. *International Journal of Production Economics*, *113*(2), 997-1011.

[316]. Yadav, O. P., Nepal, B., **Goel, P. S.,** & Jain, R. (2010). Insights and learning's from lean manufacturing implementation practices. *International Journal of Services and Operations Management*, *6*(4), 398-422.

[317]. Yadav, O.P., Singh, N., & **Goel, P.S.** (2006). Reliability demonstration test planning: A three dimensional consideration. *Reliability Engineering & System Safety*, 91(8), 882-893.

[318]. Yadav, O.P., Singh, N., Chinnam, R.B., & **Goel, P.S.** (2003). A fuzzy logic based approach to reliability improvement estimation during product development. *Reliability Engineering & System Safety*, *80*(1), 63-74.

[319]. Yang, M. G. M., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics*, *129*(2), 251-261.

[320]. Yang, Z. K., & Li, J. (2010, October). Assessment of green supply chain risk based on circular economy. In *17th IEEE International Conference on Industrial Engineering and Engineering Management (IE&EM)*, 1276-1280.

[321]. Yen, B. C., & Zeng, B. (2010, December). A hierarchical assessment method using Bayesian network for material risk detection on green supply chain. In *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 1184-1188.

[322]. Yin, R. (1994). *Case study research: Design and methods*. Beverly Hills.

[323]. Yin, R. K. (2003). *Case study research, design and methods.* 3rd ed. Newbury Park: Sage Publications.

[324]. Yin, R. K. (2009*). Case Study Research*. Fourth ed. Sage, Thousand Oaks.

[325]. Yusuf, Y. Y., Gunasekaran, A., Musa, A., El-Berishy, N. M., Abubakar, T., & Ambursa, H. M. (2013). The UK oil and gas supply chains: An empirical analysis of adoption of sustainable measures and performance outcomes. *International Journal of Production Economics*, *146*(2), 501-514.

[326]. Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, *8*(3), 338-353.

[327]. Zayed, T., Amer, M., & Pan, J. (2008). Assessing risk and uncertainty inherent in Chinese highway projects using AHP. *International Journal of Project Management*, *26*(4), 408-419.

[328]. Zhang, X., & Zhiwei, Z. (2009, May). Study of Green Supply Chain and its Performance Based on Fuzzy AHP and Measurement System. In *IEEE International Conference on E-Business and Information System Security, 2009. EBISS'09*, 1-5.

[329]. Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management*, *22*(3), 265-289.

[330]. Zhu, Q., & Sarkis, J. (2006). An inter-sectoral comparison of green supply chain management in China: drivers and practices. *Journal of Cleaner Production*, *14*(5), 472-486.

[331]. Zhu, Q., & Sarkis, J. (2007). The moderating effects of institutional pressures on emergent green supply chain practices and performance. *International Journal of Production Research*, *45*(18-19), 4333-4355.

[332]. Zhu, Q., Geng, Y., Fujita, T., & Hashimoto, S. (2010). Green supply chain management in leading manufacturers: case studies in Japanese large companies. *Management Research Review*, *33*(4), 380-392.

[333]. Zhu, Q., Geng, Y., Sarkis, J., & Lai, K. H. (2011). Evaluating green supply chain management among Chinese manufacturers from the ecological modernization perspective. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 808-821.

[334]. Zhu, Q., Sarkis, J., & Geng, Y. (2005). Green supply chain management in China: pressures, practices and performance. *International Journal of Operations & Production Management*, *25*(5), 449-468.

[335]. Zhu, Q., Sarkis, J., & Lai, K. H. (2007a). Green supply chain management: pressures, practices and performance within the Chinese automobile industry. *Journal of Cleaner Production*, *15*(11), 1041-1052.

[336]. Zhu, Q., Sarkis, J., & Lai, K. H. (2007b). Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers. *Journal of Environmental Management*, *85*(1), 179-189.

[337]. Zhu, Q., Sarkis, J., & Lai, K. H. (2008a). Green supply chain management implications for closing the loop. *Transportation Research Part E: Logistics and Transportation Review*, *44*(1), 1-18.

[338]. Zhu, Q., Sarkis, J., & Lai, K. H. (2008b). Confirmation of a measurement model for green supply chain management practices implementation. *International Journal of Production Economics*, *111*(2), 261-273.

[339]. Zhu, Q., Tian, Y., & Sarkis, J. (2012). Diffusion of selected green supply chain management practices: an assessment of Chinese enterprises. *Production Planning & Control*, *23*(10/11), 837-850.

[340]. Zimmerman, H. J. (1996). *Fuzzy sets theory and its applications*. Kluwer Academic Publishers, Boston.

[341]. Zou, P. X., & Couani, P. (2012). Managing risks in green building supply chain. *Architectural Engineering and Design Management*, *8*(2), 143-158.

[342]. Zsidisin, G. A., & Siferd, S. P. (2001). Environmental purchasing: a framework for theory development. *European Journal of Purchasing & Supply Management*, *7*(1), 61-73.

APPENDICES

Appendix A

	Department of Mechanical and Industrial Engineering Indian Institute of Technology Roorkee, Roorkee Phone: +91-1332-285678, Fax: +91-1332-273560

Letter from Supervisor,

February, 2013

Dear Participants,

We wish to introduce *Mr. Sachin Kumar*. He is a research scholar in the Department of Mechanical and Industrial Engineering and is enrolled for Ph.D. program under our supervision at the Indian Institute of Technology Roorkee (IITR), Uttrakhand, India. His doctoral thesis is a study on “Analysis and Management of Risks in Green Supply Chain”. To carry out his research work and to make it more fruitful, we seek your kind cooperation. All information/data collected during the study will be used only for academic research work and strict confidentiality will be maintained. We would like to repeat how grateful we would be if you could assist Mr. Sachin Kumar. Thank you for your valuable time.

Thanking you in anticipation,

Yours Sincerely,

Dr. Pradeep Kumar
MIED, IIT Roorkee

Dr. Mukesh Kumar Barua
DoMS, IITRoorkee

APPENDIX B

Greetings!!!!!

This study has been conducted for analysing the risks in managing the green supply chain (GSC) effectively. An effort has been made to know the most important risk in GSC context. There are five categories of risk and thirteen specific risks have been mentioned in the Response sheet based on relevant literature. However, there may be several other types of risks involved in accomplishing the GSC business activities effectively and efficiently. Thus, please put your response in the response sheet by mentioning other kinds of risks (risk categories and specific risks), if any, which according to you (experts) would be important in implementing the effective GSC practices w.r.t. the specific industry where you work.

Phase 1: *Identifying the most common risk relevant to effective adoption and implementation of GSC practices at industrial context.*

Table B4.1 Response sheet

S.No.	**Specific risks**
Operational risks	
1.	Machine, equipment or facility failure
2.	Design risks
3.	Scarcity of skilled labor
(please mention any other risk in this category)	
(please mention any other risk in this category)	
Supply risks	

4.	Procurement costs risks
5.	Key supplier failures
6.	Supplier quality issues
(please mention any other risk in this category)	
(please mention any other risk in this category)	
Product recovery risks	
7.	Reverse logistics design risks
8.	Gate keeping design failures
(please mention any other risk in this category)	
S.No.	**Specific risks**
Financial risks	
9.	Sourcing of funds
10.	Inflation and currency exchange rates
(please mention any other risk in this category)	
(please mention any other risk in this category)	
(please mention any other risk in this category)	
Demand risks	
11.	Bullwhip effect risks
12.	Market dynamics
13.	Key customer failures
(please mention any other risk in this category)	
(please mention any other category of risk and specific risks in that category)	
(please mention any other category of risk and specific risks in that category)	

Phase 2: *Analyzing final common risks for determining of their priority of concern*

After listing the categories of risk and specific risks, it is needed to analyze them. For this, it needs to determine their respective priority of concern. In view of this, please put your response in the pair wise evaluation matrices for risk categories and specific risks. Please use the given fuzzy linguistic scale for entering your responses.

Table B4.2 Fuzzy Linguistic Scale for Forming Pair-Wise Evaluation Matrix

Uncertain judgment	**Fuzzy score**
Approximately equal	1/2,1,2
Approximately x times more significant	x-1, x, x+1
Approximately x times less significant	1/x+1, 1/x, 1/x-1
Between y and z times more significant	y, (y + z)/2, z
Between y and z times less significant	1/z, 2/(y + z), 1/y
Note: The value of x ranges from 2, 3...9; whereas the values of y and z can be 1, 2......9, and y<z.	

Table B4.3 Pair-Wise Evaluation Matrix for Risk Categories

	O	S	PR	F	D	GO
O	(1,1,1)					
S		(1,1,1)				
PR			(1,1,1)			
F				(1,1,1)		
D					(1,1,1)	
GO						(1,1,1)

APPENDIX C

Table C4.1: Interpretive Logic – Knowledge Base - Ranking of Actors w.r.t. Processes

Paired Comparison	Interaction with Performance	Interpretive Logic
O Dominating S	P2/P3/P4	O will support more than S
O Dominating PR	P1/P2/P3	O will support more than PR
O Dominating F	P1/P3/P4	O will support more than F
O Dominating D	P1/P2/P3	O will support more than D
O Dominating GO	P2/P3/P4	O will support more than GO
S Dominating O	P1	S will support more than O
S Dominating PR	P1/P2/P3	S will support more than PR
S Dominating F	P1	S will support more than F
S Dominating D	P1/P2/P3	S will support more than D
S Dominating GO	P1/P2/P3	S will support more than GO
PR Dominating O	P4	PR will support more than O
PR Dominating S	P4	PR will support more than S
PR Dominating F	P1/P2	PR will support more than F
PR Dominating D	P1/P4	PR will support more than D
PR Dominating GO	P1/P2	PR will support more than GO
F Dominating O	P2	F will support more than O
F Dominating S	P2/P3/P4	F will support more than S
F Dominating PR	P3/P4	F will support more than PR
F Dominating D	P2/P3/P4	F will support more than D
F Dominating GO	P2/P3	F will support more than GO

Paired Comparison	**Interaction with Performance**	**Interpretive Logic**
D Dominating O	P4	D will support more than O
D Dominating O	P4	D will support more than O
D Dominating S	P4	D will support more than S
D Dominating PR	P2/P4	D will support more than PR
D Dominating F	P4	D will support more than F
D Dominating GO	P2	D will support more than GO
GO Dominating O	P1	GO will support more than O
GO Dominating S	P1/P2	GO will support more than S
GO Dominating PR	P1/P2	GO will support more than PR
	P3/P4	GO not having any direct influence
GO Dominating F	P1/P2	GO will support more than F
GO Dominating D	P1	GO will support more than D

Table D5.1 Advanced Sensitivity Analysis Test Results of Operational Risks

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
O1	B4	Perc%: 1%	0.2933	0.0500	0.0178	0.0904	0.0464	0.0490	0.0130	0.0002	2.5005	0.2737	0.0301	0.0730
O1	B4	Perc%: 5%	0.3468	0.0502	0.0179	0.0905	0.0465	0.0491	0.0130	0.0002	2.5005	0.2737	0.0302	0.0732
O1	B4	Perc%: 25%	0.4665	0.0505	0.0182	0.0908	0.0468	0.0494	0.0130	0.0002	2.5005	0.2737	0.0305	0.0735
O1	B4	Perc%: 50%	0.5670	0.0507	0.0184	0.0910	0.0471	0.0497	0.0130	0.0002	2.5005	0.2737	0.0307	0.0737
O1	B4	Perc%: 75%	0.6938	0.0510	0.0188	0.0914	0.0474	0.0500	0.0130	0.0002	2.5005	0.2737	0.0311	0.0740
O1	B4	Perc%: 95%	0.8631	0.0514	0.0192	0.0918	0.0478	0.0504	0.0130	0.0002	2.5005	0.2737	0.0315	0.0745
O1	B4	Perc%: 99%	0.9388	0.0516	0.0194	0.0920	0.0480	0.0506	0.0130	0.0002	2.5005	0.2737	0.0317	0.0746
O2	B5	Perc%: 1%	0.0354	0.0502	0.0183	0.0913	0.0431	0.0492	0.0130	0.0002	2.5008	0.2741	0.0303	0.0732
O2	B5	Perc%: 5%	0.0791	0.0503	0.0184	0.0914	0.0432	0.0493	0.0130	0.0002	2.5008	0.2741	0.0304	0.0733
O2	B5	Perc%: 25%	0.1768	0.0506	0.0187	0.0916	0.0434	0.0495	0.0130	0.0002	2.5008	0.2741	0.0307	0.0735
O2	B5	Perc%: 50%	0.2500	0.0507	0.0188	0.0918	0.0436	0.0497	0.0130	0.0002	2.5008	0.2741	0.0309	0.0737
O2	B5	Perc%: 75%	0.3232	0.0509	0.0190	0.0920	0.0438	0.0499	0.0130	0.0002	2.5008	0.2741	0.0310	0.0739
O2	B5	Perc%: 95%	0.4209	0.0512	0.0193	0.0923	0.0441	0.0501	0.0130	0.0002	2.5008	0.2741	0.0313	0.0741
O2	B5	Perc%: 99%	0.4646	0.0513	0.0194	0.0924	0.0442	0.0502	0.0130	0.0002	2.5008	0.2741	0.0314	0.0743
O3	B6	Perc%: 1%	1.2000	0.0441	0.0172	0.0779	0.0397	0.0429	0.0125	0.0002	2.4015	0.3042	0.0252	0.0665
O3	B6	Perc%: 5%	1.4472	0.0453	0.0183	0.0790	0.0408	0.0440	0.0125	0.0002	2.4015	0.3042	0.0263	0.0676
O3	B6	Perc%: 25%	2.0000	0.0477	0.0208	0.0815	0.0433	0.0465	0.0125	0.0002	2.4015	0.3042	0.0288	0.0701

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
O3	B6	Perc%: 50%	2.5505	0.0502	0.0232	0.0840	0.0458	0.0490	0.0125	0.0002	2.4015	0.3042	0.0313	0.0726
O3	B6	Perc%: 75%	3.2679	0.0535	0.0265	0.0872	0.0490	0.0522	0.0125	0.0002	2.4015	0.3042	0.0345	0.0758
O3	B6	Perc%: 95%	4.2254	0.0578	0.0308	0.0915	0.0533	0.0565	0.0125	0.0002	2.4015	0.3042	0.0388	0.0801
O3	B6	Perc%: 99%	4.6536	0.0597	0.0327	0.0935	0.0552	0.0584	0.0125	0.0002	2.4015	0.3042	0.0408	0.0821
O4	B7	Perc%: 1%	1.3464	0.0275	0.0196	0.0385	0.0253	0.0270	0.0038	0.0000	2.4110	0.4106	0.0220	0.0346
O4	B7	Perc%: 5%	1.7746	0.0318	0.0239	0.0428	0.0296	0.0313	0.0038	0.0000	2.4110	0.4106	0.0263	0.0388
O4	B7	Perc%: 25%	2.7321	0.0414	0.0335	0.0523	0.0392	0.0409	0.0038	0.0000	2.4110	0.4106	0.0358	0.0484
O4	B7	Perc%: 50%	3.5359	0.0494	0.0415	0.0604	0.0472	0.0489	0.0038	0.0000	2.4110	0.4106	0.0439	0.0565
O4	B7	Perc%: 75%	4.5505	0.0596	0.0517	0.0705	0.0574	0.0591	0.0038	0.0000	2.4110	0.4106	0.0540	0.0666
O4	B7	Perc%: 95%	5.9046	0.0731	0.0652	0.0841	0.0709	0.0726	0.0038	0.0000	2.4110	0.4106	0.0676	0.0801
O4	B7	Perc%: 99%	6.5101	0.0792	0.0713	0.0901	0.0770	0.0787	0.0038	0.0000	2.4110	0.4106	0.0736	0.0862

Table D5.2 Advanced Sensitivity Analysis Test Results of Supply Risks

Input					Output: Delay/disturbance profile									
Name	Cell	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skewness	5%	95%
S1	B4	Perc%: 1%	7.070E-02	1.298E-01	1.588E-02	2.548E-01	1.120E-01	1.280E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.598E-02	2.083E-01
S1	B4	Perc%: 5%	1.581E-01	1.298E-01	1.589E-02	2.548E-01	1.120E-01	1.280E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.599E-02	2.083E-01
S1	B4	Perc%: 25%	3.536E-01	1.298E-01	1.591E-02	2.549E-01	1.120E-01	1.280E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.601E-02	2.083E-01
S1	B4	Perc%: 50%	5.000E-01	1.298E-01	1.592E-02	2.549E-01	1.121E-01	1.280E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.602E-02	2.084E-01
S1	B4	Perc%: 75%	6.464E-01	1.299E-01	1.593E-02	2.549E-01	1.121E-01	1.280E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.604E-02	2.084E-01
S1	B4	Perc%: 95%	8.419E-01	1.299E-01	1.595E-02	2.549E-01	1.121E-01	1.281E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.606E-02	2.084E-01
S1	B4	Perc%: 99%	9.293E-01	1.299E-01	1.596E-02	2.549E-01	1.121E-01	1.281E-01	4.584E-02	2.102E-03	2.421E+00	1.150E-01	5.607E-02	2.084E-01
S2	B5	Perc%: 1%	1.424E+00	1.183E-01	1.202E-02	2.336E-01	1.098E-01	1.163E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	4.439E-02	1.969E-01
S2	B5	Perc%: 5%	1.949E+00	1.206E-01	1.438E-02	2.359E-01	1.121E-01	1.186E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	4.675E-02	1.992E-01
S2	B5	Perc%: 25%	3.121E+00	1.259E-01	1.965E-02	2.412E-01	1.174E-01	1.239E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	5.203E-02	2.045E-01
S2	B5	Perc%: 50%	4.000E+00	1.298E-01	2.361E-02	2.452E-01	1.214E-01	1.278E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	5.598E-02	2.085E-01
S2	B5	Perc%: 75%	4.879E+00	1.338E-01	2.756E-02	2.491E-01	1.253E-01	1.318E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	5.994E-02	2.124E-01
S2	B5	Perc%: 95%	6.051E+00	1.391E-01	3.284E-02	2.544E-01	1.306E-01	1.371E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	6.521E-02	2.177E-01
S2	B5	Perc%: 99%	6.576E+00	1.414E-01	3.520E-02	2.567E-01	1.329E-01	1.394E-01	4.554E-02	2.074E-03	2.401E+00	1.197E-01	6.757E-02	2.201E-01

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
S3	B6	Perc%: 1%	6.892E+00	3.790E-02	2.395E-02	5.259E-02	3.754E-02	3.789E-02	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	2.862E-02	4.716E-02
S3	B6	Perc%: 5%	1.417E+01	5.611E-02	4.215E-02	7.080E-02	5.574E-02	5.610E-02	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	4.683E-02	6.537E-02
S3	B6	Perc%: 25%	3.046E+01	9.682E-02	8.286E-02	1.115E-01	9.645E-02	9.681E-02	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	8.754E-02	1.061E-01
S3	B6	Perc%: 50%	4.283E+01	1.278E-01	1.138E-01	1.424E-01	1.274E-01	1.277E-01	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	1.185E-01	1.370E-01
S3	B6	Perc%: 75%	5.665E+01	1.623E-01	1.483E-01	1.770E-01	1.619E-01	1.623E-01	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	1.530E-01	1.715E-01
S3	B6	Perc%: 95%	7.508E+01	2.084E-01	1.944E-01	2.231E-01	2.080E-01	2.084E-01	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	1.991E-01	2.176E-01
S3	B6	Perc%: 99%	8.333E+01	2.290E-01	2.150E-01	2.437E-01	2.286E-01	2.290E-01	5.556E-03	3.087E-05	2.415E+00	-8.566E-04	2.197E-01	2.383E-01
S4	B7	Perc%: 1%	2.933E-01	1.285E-01	1.508E-02	2.534E-01	1.178E-01	1.267E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.464E-02	2.070E-01
S4	B7	Perc%: 5%	3.468E-01	1.288E-01	1.532E-02	2.537E-01	1.180E-01	1.269E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.488E-02	2.072E-01
S4	B7	Perc%: 25%	4.665E-01	1.293E-01	1.586E-02	2.542E-01	1.185E-01	1.274E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.541E-02	2.078E-01
S4	B7	Perc%: 50%	5.670E-01	1.298E-01	1.632E-02	2.547E-01	1.190E-01	1.279E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.587E-02	2.082E-01
S4	B7	Perc%: 75%	6.938E-01	1.303E-01	1.689E-02	2.552E-01	1.196E-01	1.285E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.644E-02	2.088E-01
S4	B7	Perc%: 95%	8.631E-01	1.311E-01	1.765E-02	2.560E-01	1.203E-01	1.292E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.720E-02	2.096E-01
S4	B7	Perc%: 99%	9.388E-01	1.314E-01	1.799E-02	2.563E-01	1.207E-01	1.296E-01	4.584E-02	2.101E-03	2.420E+00	1.154E-01	5.754E-02	2.099E-01

Table D5.3 Advanced Sensitivity Analysis Test Results of Product Recovery Risks

Input					Output: Delay/disturbance profile									
Name	Cell	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skew ness	5%	95%
PR1	B4	Perc%: 1%	1.1414	0.0866	0.0298	0.1477	0.0836	0.0860	0.0179	0.0003	2.7871	0.1262	0.0579	0.1170
PR1	B4	Perc%: 5%	1.3162	0.0866	0.0298	0.1478	0.0836	0.0860	0.0179	0.0003	2.7871	0.1262	0.0579	0.1170
PR1	B4	Perc%: 25%	1.7071	0.0867	0.0298	0.1478	0.0837	0.0861	0.0179	0.0003	2.7871	0.1262	0.0580	0.1170
PR1	B4	Perc%: 50%	2.0000	0.0867	0.0299	0.1478	0.0837	0.0861	0.0179	0.0003	2.7871	0.1262	0.0580	0.1170
PR1	B4	Perc%: 75%	2.2929	0.0867	0.0299	0.1479	0.0837	0.0861	0.0179	0.0003	2.7871	0.1262	0.0580	0.1171
PR1	B4	Perc%: 95%	2.6838	0.0868	0.0299	0.1479	0.0838	0.0862	0.0179	0.0003	2.7871	0.1262	0.0581	0.1171
PR1	B4	Perc%: 99%	2.8586	0.0868	0.0299	0.1479	0.0838	0.0862	0.0179	0.0003	2.7871	0.1262	0.0581	0.1171
PR2	B5	Perc%: 1%	1.6000	0.0699	0.0238	0.1243	0.0616	0.0694	0.0158	0.0002	2.7101	0.1610	0.0447	0.0968
PR2	B5	Perc%: 5%	2.3416	0.0732	0.0271	0.1276	0.0649	0.0727	0.0158	0.0002	2.7101	0.1610	0.0481	0.1002
PR2	B5	Perc%: 25%	4.0000	0.0807	0.0346	0.1351	0.0724	0.0802	0.0158	0.0002	2.7101	0.1610	0.0555	0.1076
PR2	B5	Perc%: 50%	5.2566	0.0864	0.0402	0.1407	0.0780	0.0858	0.0158	0.0002	2.7101	0.1610	0.0612	0.1133
PR2	B5	Perc%: 75%	6.6459	0.0926	0.0465	0.1470	0.0843	0.0921	0.0158	0.0002	2.7101	0.1610	0.0674	0.1195
PR2	B5	Perc%: 95%	8.5000	0.1010	0.0548	0.1553	0.0926	0.1004	0.0158	0.0002	2.7101	0.1610	0.0758	0.1279
PR2	B5	Perc%: 99%	9.3292	0.1047	0.0585	0.1591	0.0963	0.1041	0.0158	0.0002	2.7101	0.1610	0.0795	0.1316
PR3	B6	Perc%: 1%	2.3077	0.0666	0.0240	0.1157	0.0594	0.0659	0.0151	0.0002	2.6346	0.1982	0.0431	0.0925
PR3	B6	Perc%: 5%	3.9240	0.0707	0.0280	0.1198	0.0634	0.0699	0.0151	0.0002	2.6346	0.1982	0.0472	0.0966
PR3	B6	Perc%: 25%	7.5383	0.0797	0.0371	0.1288	0.0725	0.0790	0.0151	0.0002	2.6346	0.1982	0.0562	0.1056

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
PR3	B6	Perc%: 5%	3.9240	0.0707	0.0280	0.1198	0.0634	0.0699	0.0151	0.0002	2.6346	0.1982	0.0472	0.0966
PR3	B6	Perc%: 25%	7.5383	0.0797	0.0371	0.1288	0.0725	0.0790	0.0151	0.0002	2.6346	0.1982	0.0562	0.1056
PR3	B6	Perc%: 50%	10.2532	0.0865	0.0439	0.1356	0.0792	0.0857	0.0151	0.0002	2.6346	0.1982	0.0630	0.1124
PR3	B6	Perc%: 75%	13.1080	0.0936	0.0510	0.1427	0.0864	0.0929	0.0151	0.0002	2.6346	0.1982	0.0701	0.1195
PR3	B6	Perc%: 95%	16.9178	0.1032	0.0605	0.1522	0.0959	0.1024	0.0151	0.0002	2.6346	0.1982	0.0797	0.1291
PR3	B6	Perc%: 99%	18.6216	0.1074	0.0648	0.1565	0.1002	0.1067	0.0151	0.0002	2.6346	0.1982	0.0839	0.1333
PR4	B7	Perc%: 1%	1.3464	0.0635	0.0255	0.1069	0.0613	0.0634	0.0127	0.0002	2.7053	0.0313	0.0426	0.0848
PR4	B7	Perc%: 5%	1.7746	0.0678	0.0298	0.1112	0.0656	0.0677	0.0127	0.0002	2.7053	0.0313	0.0469	0.0891
PR4	B7	Perc%: 25%	2.7321	0.0774	0.0394	0.1208	0.0751	0.0773	0.0127	0.0002	2.7053	0.0313	0.0565	0.0987
PR4	B7	Perc%: 50%	3.5359	0.0854	0.0474	0.1288	0.0832	0.0853	0.0127	0.0002	2.7053	0.0313	0.0645	0.1067
PR4	B7	Perc%: 75%	4.5505	0.0955	0.0575	0.1389	0.0933	0.0955	0.0127	0.0002	2.7053	0.0313	0.0746	0.1169

Table D5.4 Advanced Sensitivity Analysis Test Results of Financial Risks

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
F1	B4	Perc%: 1%	1.6000	0.1697	0.0253	0.3180	0.1514	0.1689	0.0593	0.0035	2.4028	0.0341	0.0714	0.2695
F1	B4	Perc%: 5%	2.3416	0.1730	0.0287	0.3213	0.1547	0.1723	0.0593	0.0035	2.4028	0.0341	0.0747	0.2729
F1	B4	Perc%: 25%	4.0000	0.1805	0.0361	0.3288	0.1622	0.1797	0.0593	0.0035	2.4028	0.0341	0.0822	0.2803
F1	B4	Perc%: 50%	5.2566	0.1862	0.0418	0.3344	0.1678	0.1854	0.0593	0.0035	2.4028	0.0341	0.0878	0.2860
F1	B4	Perc%: 75%	6.6459	0.1924	0.0480	0.3407	0.1741	0.1916	0.0593	0.0035	2.4028	0.0341	0.0941	0.2922
F1	B4	Perc%: 95%	8.5000	0.2007	0.0564	0.3490	0.1824	0.2000	0.0593	0.0035	2.4028	0.0341	0.1024	0.3006
F1	B4	Perc%: 99%	9.3292	0.2045	0.0601	0.3527	0.1862	0.2037	0.0593	0.0035	2.4028	0.0341	0.1061	0.3043
F2	B5	Perc%: 1%	1.3464	0.1807	0.0218	0.3411	0.1747	0.1801	0.0598	0.0036	2.4245	0.0327	0.0819	0.2814
F2	B5	Perc%: 5%	1.7746	0.1818	0.0229	0.3422	0.1758	0.1812	0.0598	0.0036	2.4245	0.0327	0.0830	0.2824
F2	B5	Perc%: 25%	2.7321	0.1842	0.0253	0.3446	0.1782	0.1836	0.0598	0.0036	2.4245	0.0327	0.0854	0.2848
F2	B5	Perc%: 50%	3.5359	0.1862	0.0273	0.3466	0.1802	0.1856	0.0598	0.0036	2.4245	0.0327	0.0874	0.2868
F2	B5	Perc%: 75%	4.5505	0.1887	0.0298	0.3491	0.1827	0.1881	0.0598	0.0036	2.4245	0.0327	0.0899	0.2894
F2	B5	Perc%: 95%	5.9046	0.1921	0.0332	0.3525	0.1861	0.1915	0.0598	0.0036	2.4245	0.0327	0.0933	0.2928

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skew ness**	**5%**	**95%**
F2	B5	Perc%: 99%	6.5101	0.1936	0.0347	0.3540	0.1876	0.1930	0.0598	0.0036	2.4245	0.0327	0.0948	0.2943
F3	B6	Perc%: 1%	3.0149	0.0633	0.0394	0.0899	0.0632	0.0631	0.0089	0.0001	2.5228	0.0901	0.0487	0.0785
F3	B6	Perc%: 5%	5.5056	0.0882	0.0643	0.1148	0.0881	0.0880	0.0089	0.0001	2.5228	0.0901	0.0736	0.1034
F3	B6	Perc%: 25%	11.0747	0.1439	0.1200	0.1705	0.1438	0.1437	0.0089	0.0001	2.5228	0.0901	0.1293	0.1591
F3	B6	Perc%: 50%	15.2521	0.1857	0.1617	0.2123	0.1856	0.1855	0.0089	0.0001	2.5228	0.0901	0.1711	0.2008
F3	B6	Perc%: 75%	19.5717	0.2289	0.2049	0.2555	0.2288	0.2287	0.0089	0.0001	2.5228	0.0901	0.2143	0.2440
F3	B6	Perc%: 95%	25.3363	0.2865	0.2626	0.3132	0.2864	0.2863	0.0089	0.0001	2.5228	0.0901	0.2719	0.3017
F3	B6	Perc%: 99%	27.9143	0.3123	0.2884	0.3389	0.3122	0.3121	0.0089	0.0001	2.5228	0.0901	0.2977	0.3274

Table D5.5 Advanced Sensitivity Analysis Test Results of Demand Risks

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
D1	B4	Perc%: 1%	6.8915	0.0719	0.0348	0.1161	0.0687	0.0711	0.0136	0.0002	2.5348	0.2258	0.0510	0.0956
D1	B4	Perc%: 5%	14.1738	0.0901	0.0530	0.1343	0.0869	0.0893	0.0136	0.0002	2.5348	0.2258	0.0692	0.1138
D1	B4	Perc%: 25%	30.4576	0.1308	0.0937	0.1750	0.1277	0.1300	0.0136	0.0002	2.5348	0.2258	0.1099	0.1545
D1	B4	Perc%: 50%	42.8301	0.1618	0.1247	0.2059	0.1586	0.1609	0.0136	0.0002	2.5348	0.2258	0.1408	0.1854
D1	B4	Perc%: 75%	56.6458	0.1963	0.1592	0.2404	0.1931	0.1955	0.0136	0.0002	2.5348	0.2258	0.1753	0.2200
D1	B4	Perc%: 95%	75.0836	0.2424	0.2053	0.2865	0.2392	0.2416	0.0136	0.0002	2.5348	0.2258	0.2214	0.2661
D1	B4	Perc%: 99%	83.3292	0.2630	0.2259	0.3071	0.2598	0.2622	0.0136	0.0002	2.5348	0.2258	0.2421	0.2867
D2	B5	Perc%: 1%	1.4243	0.1523	0.0248	0.2838	0.1552	0.1508	0.0471	0.0022	2.4732	0.1019	0.0761	0.2321
D2	B5	Perc%: 5%	1.9487	0.1546	0.0272	0.2862	0.1576	0.1532	0.0471	0.0022	2.4732	0.1019	0.0785	0.2345
D2	B5	Perc%: 25%	3.1213	0.1599	0.0325	0.2914	0.1629	0.1585	0.0471	0.0022	2.4732	0.1019	0.0838	0.2397
D2	B5	Perc%: 50%	4.0000	0.1639	0.0364	0.2954	0.1668	0.1624	0.0471	0.0022	2.4732	0.1019	0.0877	0.2437
D2	B5	Perc%: 75%	4.8787	0.1678	0.0404	0.2994	0.1708	0.1664	0.0471	0.0022	2.4732	0.1019	0.0917	0.2476
D2	B5	Perc%: 95%	6.0513	0.1731	0.0457	0.3046	0.1761	0.1717	0.0471	0.0022	2.4732	0.1019	0.0970	0.2529
D2	B5	Perc%: 99%	6.5757	0.1755	0.0480	0.3070	0.1784	0.1740	0.0471	0.0022	2.4732	0.1019	0.0993	0.2553
D3	B6	Perc%: 1%	0.0050	0.1638	0.0347	0.3043	0.1451	0.1624	0.0474	0.0023	2.4841	0.1022	0.0871	0.2445
D3	B6	Perc%: 5%	0.0253	0.1638	0.0347	0.3043	0.1451	0.1624	0.0474	0.0023	2.4841	0.1022	0.0871	0.2445
D3	B6	Perc%: 25%	0.1340	0.1638	0.0347	0.3043	0.1451	0.1624	0.0474	0.0023	2.4841	0.1022	0.0872	0.2445
D3	B6	Perc%: 50%	0.2929	0.1639	0.0347	0.3043	0.1451	0.1624	0.0474	0.0023	2.4841	0.1022	0.0872	0.2445

Input					Output: Delay/disturbance profile									
Name	Cell	Analysis	Value	Mean	Min	Max	Mode	Median	StdDev	Var	Kurtosis	Skewness	5%	95%
D3	B6	Perc%: 75%	0.5000	0.1639	0.0347	0.3043	0.1451	0.1624	0.0474	0.0023	2.4841	0.1022	0.0872	0.2445
D3	B6	Perc%: 95%	0.7764	0.1639	0.0348	0.3044	0.1451	0.1625	0.0474	0.0023	2.4841	0.1022	0.0872	0.2446
D3	B6	Perc%: 99%	0.9000	0.1639	0.0348	0.3044	0.1452	0.1625	0.0474	0.0023	2.4841	0.1022	0.0872	0.2446
D4	B7	Perc%: 1%	1.3464	0.1407	0.0232	0.2645	0.1382	0.1387	0.0459	0.0021	2.4123	0.1193	0.0665	0.2197
D4	B7	Perc%: 5%	1.7746	0.1449	0.0275	0.2687	0.1424	0.1430	0.0459	0.0021	2.4123	0.1193	0.0708	0.2240
D4	B7	Perc%: 25%	2.7321	0.1545	0.0371	0.2783	0.1520	0.1526	0.0459	0.0021	2.4123	0.1193	0.0803	0.2335
D4	B7	Perc%: 50%	3.5359	0.1626	0.0451	0.2864	0.1601	0.1606	0.0459	0.0021	2.4123	0.1193	0.0884	0.2416
D4	B7	Perc%: 75%	4.5505	0.1727	0.0553	0.2965	0.1702	0.1707	0.0459	0.0021	2.4123	0.1193	0.0985	0.2517
D4	B7	Perc%: 95%	5.9046	0.1862	0.0688	0.3100	0.1837	0.1843	0.0459	0.0021	2.4123	0.1193	0.1121	0.2653
D4	B7	Perc%: 99%	6.5101	0.1923	0.0749	0.3161	0.1898	0.1903	0.0459	0.0021	2.4123	0.1193	0.1181	0.2713

Table D5.6 Advanced Sensitivity Analysis Test Results of Governmental and Organizational Related Risks

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
GO1	B4	Perc%: 1%	1.6000	0.0372	0.0251	0.0514	0.0365	0.0369	0.0040	0.0000	2.6974	0.2315	0.0309	0.0441
GO1	B4	Perc%: 5%	2.3416	0.0446	0.0326	0.0588	0.0440	0.0443	0.0040	0.0000	2.6974	0.2315	0.0383	0.0515
GO1	B4	Perc%: 25%	4.0000	0.0612	0.0491	0.0754	0.0605	0.0609	0.0040	0.0000	2.6974	0.2315	0.0549	0.0681
GO1	B4	Perc%: 50%	5.2566	0.0737	0.0617	0.0879	0.0731	0.0735	0.0040	0.0000	2.6974	0.2315	0.0675	0.0807
GO1	B4	Perc%: 75%	6.6459	0.0876	0.0756	0.1018	0.0870	0.0874	0.0040	0.0000	2.6974	0.2315	0.0814	0.0946
GO1	B4	Perc%: 95%	8.5000	0.1062	0.0941	0.1204	0.1055	0.1059	0.0040	0.0000	2.6974	0.2315	0.0999	0.1131
GO1	B4	Perc%: 99%	9.3292	0.1145	0.1024	0.1287	0.1138	0.1142	0.0040	0.0000	2.6974	0.2315	0.1082	0.1214
GO2	B5	Perc%: 1%	0.5866	0.0719	0.0234	0.1262	0.0766	0.0713	0.0188	0.0004	2.4477	0.1101	0.0415	0.1039
GO2	B5	Perc%: 5%	0.6936	0.0724	0.0239	0.1267	0.0771	0.0717	0.0188	0.0004	2.4477	0.1101	0.0419	0.1044
GO2	B5	Perc%: 25%	0.9330	0.0734	0.0250	0.1277	0.0782	0.0728	0.0188	0.0004	2.4477	0.1101	0.0430	0.1055
GO2	B5	Perc%: 50%	1.1340	0.0743	0.0259	0.1286	0.0791	0.0737	0.0188	0.0004	2.4477	0.1101	0.0439	0.1064
GO2	B5	Perc%: 75%	1.3876	0.0755	0.0270	0.1298	0.0802	0.0749	0.0188	0.0004	2.4477	0.1101	0.0451	0.1075
GO2	B5	Perc%: 95%	1.7261	0.0770	0.0285	0.1313	0.0818	0.0764	0.0188	0.0004	2.4477	0.1101	0.0466	0.1090
GO2	B5	Perc%: 99%	1.8775	0.0777	0.0292	0.1320	0.0824	0.0771	0.0188	0.0004	2.4477	0.1101	0.0473	0.1097
GO3	B6	Perc%: 1%	1.2000	0.0708	0.0230	0.1220	0.0728	0.0702	0.0187	0.0004	2.4400	0.1027	0.0405	0.1027
GO3	B6	Perc%: 5%	1.4472	0.0714	0.0236	0.1227	0.0734	0.0708	0.0187	0.0004	2.4400	0.1027	0.0411	0.1033
GO3	B6	Perc%: 25%	2.0000	0.0728	0.0250	0.1240	0.0748	0.0722	0.0187	0.0004	2.4400	0.1027	0.0425	0.1047

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
GO3	B6	Perc%: 50%	2.5505	0.0742	0.0264	0.1254	0.0762	0.0736	0.0187	0.0004	2.4400	0.1027	0.0439	0.1061
GO3	B6	Perc%: 75%	3.2679	0.0760	0.0282	0.1272	0.0780	0.0754	0.0187	0.0004	2.4400	0.1027	0.0457	0.1079
GO3	B6	Perc%: 95%	4.2254	0.0784	0.0306	0.1296	0.0804	0.0778	0.0187	0.0004	2.4400	0.1027	0.0481	0.1103
GO3	B6	Perc%: 99%	4.6536	0.0795	0.0316	0.1307	0.0814	0.0788	0.0187	0.0004	2.4400	0.1027	0.0491	0.1114
GO4	B7	Perc%: 1%	1.3464	0.0687	0.0205	0.1186	0.0658	0.0679	0.0186	0.0003	2.4260	0.1094	0.0386	0.1003
GO4	B7	Perc%: 5%	1.7746	0.0698	0.0215	0.1197	0.0669	0.0690	0.0186	0.0003	2.4260	0.1094	0.0397	0.1014
GO4	B7	Perc%: 25%	2.7321	0.0722	0.0239	0.1221	0.0693	0.0714	0.0186	0.0003	2.4260	0.1094	0.0421	0.1038
GO4	B7	Perc%: 50%	3.5359	0.0742	0.0259	0.1241	0.0713	0.0734	0.0186	0.0003	2.4260	0.1094	0.0441	0.1058
GO4	B7	Perc%: 75%	4.5505	0.0767	0.0285	0.1266	0.0738	0.0759	0.0186	0.0003	2.4260	0.1094	0.0466	0.1083
GO4	B7	Perc%: 95%	5.9046	0.0801	0.0319	0.1300	0.0772	0.0793	0.0186	0.0003	2.4260	0.1094	0.0500	0.1117
GO4	B7	Perc%: 99%	6.5101	0.0816	0.0334	0.1315	0.0787	0.0808	0.0186	0.0003	2.4260	0.1094	0.0515	0.1132
GO5	B8	Perc%: 1%	0.0707	0.0744	0.0248	0.1290	0.0781	0.0737	0.0188	0.0004	2.4563	0.1076	0.0440	0.1065
GO5	B8	Perc%: 5%	0.1581	0.0745	0.0248	0.1290	0.0781	0.0737	0.0188	0.0004	2.4563	0.1076	0.0440	0.1065
GO5	B8	Perc%: 25%	0.3536	0.0745	0.0248	0.1290	0.0781	0.0738	0.0188	0.0004	2.4563	0.1076	0.0441	0.1065
GO5	B8	Perc%: 50%	0.5000	0.0745	0.0248	0.1290	0.0781	0.0738	0.0188	0.0004	2.4563	0.1076	0.0441	0.1065
GO5	B8	Perc%: 75%	0.6464	0.0745	0.0248	0.1290	0.0782	0.0738	0.0188	0.0004	2.4563	0.1076	0.0441	0.1065

Input					Output: Delay/disturbance profile									
Name	**Cell**	**Analysis**	**Value**	**Mean**	**Min**	**Max**	**Mode**	**Median**	**StdDev**	**Var**	**Kurtosis**	**Skewness**	**5%**	**95%**
GO5	B8	Perc%: 99%	0.9293	0.0745	0.0248	0.1291	0.0782	0.0738	0.0188	0.0004	2.4563	0.1076	0.0441	0.1066
GO6	B9	Perc%: 1%	0.0354	0.0745	0.0248	0.1290	0.0716	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 5%	0.0791	0.0745	0.0248	0.1290	0.0716	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 25%	0.1768	0.0745	0.0248	0.1290	0.0717	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 50%	0.2500	0.0745	0.0248	0.1290	0.0717	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 75%	0.3232	0.0745	0.0248	0.1290	0.0717	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 95%	0.4209	0.0745	0.0249	0.1290	0.0717	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1065
GO6	B9	Perc%: 99%	0.4646	0.0745	0.0249	0.1290	0.0717	0.0738	0.0188	0.0004	2.4562	0.1076	0.0441	0.1066
GO4	B7	Perc%: 50%	3.5359	0.0742	0.0259	0.1241	0.0713	0.0734	0.0186	0.0003	2.4260	0.1094	0.0441	0.1058
GO4	B7	Perc%: 75%	4.5505	0.0767	0.0285	0.1266	0.0738	0.0759	0.0186	0.0003	2.4260	0.1094	0.0466	0.1083

APPENDIX E

Greetings!!!!!

After identifying and analyzing the risks by determining of their priority of concern, it is important to manage the GSC risks. For this, the responses of risks to manage the GSC effectively need to be evaluated and priortized. In view of this, please put your response in the pair wise evaluation matrices for risks and responses to manage the risks. Please use the given fuzzy linguistic scale for entering your responses.

Table E6.1 Linguistic Scale Used for Responses Rat**ing** (Wang et al. (2007))

Linguistic variables	**Fuzzy score**
Important	1/2,1,2
Approximately x times more important	x-1, x, x+1
Approximately x times less important	1/x+1, 1/x, 1/x-1
Between y and z times more important	y, (y + z)/2, z
Between y and z times less important	1/z, 2/(y + z), 1/y

Note: The value of x ranges from 2, 3...9, whereas the values of y and z can be 1, 2......9, and y<z.

Table E6.2 Aggregate Fuzzy Performance Matrix for the Responses of Risks in GSC

	O1	**O2**	**O3**	**…**	**…**	**GO4**	**GO5**	**GO6**
R1	(0.7,1.2,2)	(1,2,3.4)	(0.5,0.5,1.2)	…	…	(1,1.78,2)	(1/2,0.66,0.9)	(0.89,1.9,3)
R2	(2.78,3.5,3.91)	(2,2.91,3)	(1.9,3,3.82)	…	…	(3.1,3.5,4.2)	(2.1,2.71,3.5)	(0.5,1.1,2)
R3	(1.1,2,3.2)	(0.5,1.2,2)	(0.45,0.66,1.64)	…	…	(2.12,2.5,3.56)	(0.5,1.1,2.89)	(1.1,2,3.5)
…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
R15	(2.67,4,5.34)	(1.9,3,4.21)	(2,2.5,3.1)	…	…	(3.2,4,5.45)	(2.6,4,5.67)	(2.1,2.5,3.4)
R16	(0.92,2.1,3.2)	(1,2.21,3)	(0.6,1,1.95)	…	…	(1.9,3,4.4)	(2,2.7,3.23)	(1.9,3,4.50)
R17	(0.45,1,2.12)	(1.12,1.93,3)	(2.1,3.41,4.3)	…	…	(2.2,3,4.56)	(2.8,4.3,5.5)	(4.4,5,6.32)

Sources: *fuzzy-TOPSIS analysis*

APPENDIX F

Table F7.1: Interpretive Logic – Knowledge Base - Ranking of Actors w.r.t. Processes

Paired Comparison	Interaction with Performance	Interpretive Logic
A1 Dominating A2	P2	A2 will have more influence than A1
	P3	A1 will have more influence than A2
A1 Dominating A3	P2	A1 will have more influence than A3
	P3	A3 will have more influence than A1
A1 Dominating A4	P2/P3	A4 will have more influence than A1
A2 Dominating A1	P1	A1 not having any direct role
	P2	A2 will have more influence than A1
A2 Dominating A3	P1/P2	A3 will have more influence than A2
A2 Dominating A4	P1	A2 will have more influence than A4
	P2	A4 will have more influence than A2
A3 Dominating A1	P1/P4	A1 not having any direct role
	P2	A1 will have more influence than A3
	P3	A3 will have more influence than A1
A3 Dominating A2	P1/P2	A3 will have more influence than A2
	P3/P4	A2 not having any direct influence
A3 Dominating A4	P1/P4	A4 will have more influence on than A3
	P2/P3	A3 will have more influence than A4
A4 Dominating A1	P1/P4	A1 not having any direct role
	P2/P3	A4 will have more influence on than A1
A4 Dominating A2	P3/P4	A2 not having any direct role
	P1	A2 will have more influence than A4
	P2	A4 will have more influence than A2
A4 Dominating A3	P1/P2/P3/P4	A4 will have more influence than A3

Table F7.2: Interpretive Logic – Knowledge Base – Influence of Actions on Various Performances

Paired Comparison	**Interaction with Performance**	**Interpretive Logic**
A1* Dominating A2*	P1*/P2*/P4*	A1* will support more than A2*
A1* Dominating A3*	P1*	A1*will support more than A3*
	P2*	A3* will have more influence than A1*
	P4*	A1* will support more than A3*
A1* Dominating A4*	P1*	A1* will support more than A4*
	P2*/P4*	A4* will support more than A1*
A1* Dominating A5*	P1*/P2*	A1*will support more than A5*
	P4*	A5* will have more influence than A1*
A2* Dominating A1*	P1*/P2*/P4*	A1* will support more than A2*
A2* Dominating A3*	P1*/P4*	A3* will have more influence than A2*
	P2*	A2* will have more influence than A3*
A2* Dominating A4*	P1*	A4* will have more influence than A2*
	P2*/P4*	A2* will have more influence than A4*
A2* Dominating A5*	P1*/P2*	A2* will have more influence than A5*
	P4*	A5* will have more influence than A2*
A3* Dominating A1*	P2*/P4*	A1* will have more influence than A3*
	P3*	A3* will have more influence than A1*
A3* Dominating A2*	P1*/P3*	A3* will have more influence than A2*
	P2*/P4*	A2* will have more influence than A3*
A3* Dominating A4*	P2*	A3* will have more influence than A4*
	P1*/P3*/P4*	A4* will have more influence than A3*
A3* Dominating C5	P1*/P2*/P3*	A3* will have more influence than A4*
	P4*	A3* will have more influence than A4*
A4* Dominating A1*	P1*	A1* will have more influence than A4*
	P2*/P4*	A4* will have more influence than A1*
	P3*	A1* not having any direct influence
A4* Dominating A2*	P2*/P4*	A2* will support more than A4*
	P1*	A4* will support more than A2*
	P3*	A2* not having any direct influence

Paired Comparison	**Interaction with Performance**	**Interpretive Logic**
A4* Dominating A3*	P1*/P2*	A3* will support more than A4*
	P3*/P4*	A4* will support more than A3*
A4* Dominating A5*	P1*/P2*/P3*/P4*	A4* will support more than A5*
A5* Dominating A1*	P3*	A1* not having any direct influence
	P4*	A5* will support more than A1*
A5* Dominating A2*	P3*	A2* not having any direct influence
	P4*	A2* will have more influence than A5*
A5* Dominating A3*	P3*	A3* will have more influence than A5*
	P4*	A5* will have more influence than A3*
A5* Dominating A4*	P3*	A3* will have more influence than A5*
	P4*	A5* will have more influence than A3*

LIST OF PUBLICATIONS FROM PRESENT RESEARCH

Publication Accepted/Published in Refereed International Journals

1) **Mangla S.K.,** Kumar P., & Barua M.K. (2015). Prioritizing the Responses to Manage Risks in Green Supply Chain: an Indian Plastic Manufacturer Perspective**,** Sustainable Production and Consumption- Official Journal of the European Federation of Chemical Engineering Part E, *1 (1)*, 67- 86.
2) **Mangla S.K.,** Kumar P., & Barua M.K. **(**2015). Risk Analysis in Green Supply Chain Using Fuzzy AHP Approach: a Case Study, Recycling Resources and Conservation, Online at: (http://dx.doi.org/10.1016/j.resconrec.2015.01.001). (**SCI Indexed Impact factor 2.692**).
3) **Mangla S.K.,** Kumar P., & Barua M.K. (2015). Flexible Decision Modeling for Evaluating the Risks in Green Supply Chain Using Fuzzy AHP and IRP Methodologies. *Global Journal of Flexible Systems Management*, *16*(1), 19-35.
4) **Mangla S.K.,** Kumar P., & Barua M.K. **(**2014). Monte Carlo Simulation Based Approach to Manage Risks in Operational Networks in Green Supply Chain, *Procedia Engineering*, *97*, 2186-2194.
5) **Mangla S.K.,** Kumar P., & Barua M.K. (2014). An integrated methodology of FTA and fuzzy AHP for risk assessment in green supply chain. International Journal of Operational Research (**forthcoming**).
6) **Mangla S.K.,** Kumar P., & Barua M.K. (2014). A flexible Decision Framework for Building Risk Mitigation Strategies in Green Supply Chain using SAP-LAP and IRP Approaches. *Global Journal of Flexible Systems Management, 15*(3), 203-218.

Papers: Presented/Accepted/Published in International Conferences

1) **Mangla S.K.,** Kumar P., & Barua M.K. (December, 2014). Managing the Supply Risks in Green Supply Chain using Monte Carlo Simulation, NITIE-POMS International Conference, NITIE, Mumbai, India, pp. 172-177. ISBN: 978-93-84869-01-4
2) **Mangla S.K.,** Kumar P., & Barua M.K. (December, 2014). Using Monte Carlo Simulation to Manage the Product Recovery Risks in Green Supply Chain, Society of Operations Management (SOM). Indian Institute of Technology Roorkee, India. ISBN: 978-93-84935-02-3.
3) **Mangla S.K.,** Kumar P., & Barua M.K. (December, 2014). Monte Carlo Simulation Based Approach to Manage Risks in Operational Networks in Green Supply Chain, Global Congress on Manufacturing Management (GCMM-2014) VIT University, Vellore, Tamil Nadu, India. **(Scopus Indexed)**.
4) **Mangla S.K.,** Kumar P., & Barua M.K. (December, 2013). Flexible Decision Modeling for Evaluating Green Supply Chain Risks using Fuzzy AHP Methodology. In: Proceedings of GLOGIFT 13, IIT Delhi, India, pp. 575-583. ISBN 978-93-83893-00-3.
5) **Mangla S.K., &** Kumar P. Fuzzy DEMATEL (November, 2013). Approach for Analysing Risks in Green Supply Chain, 2nd international conference on industrial engineering (ICIE), ISBN: 978-93-83083-37-4, NIT Surat, India, pp. 151-155. ISBN: 978-93-83083-37-4.
6) **Mangla S.K.,** Kumar P., & Madaan, J. (May, 2013). Decision Modeling for Risk Bearing in Green Concern Sustainable Supply Chain. World Congress on Business, Finance, Marketing and Industrial Management for Sustainable Development (BFMIMSD). Jawaharlal Nehru University, New Delhi, India.

AUTHOR BRIEF PROFILE

Sachin Kumar

Permanent Address: H.No. 216, VPO- Marwa Kalan, Tehsile- Bilaspur, Distt.- Yamunangar, Haryana – 135102, INDIA
Mobile: +91-9458354826/9416824761
E-mail: sachinmangl@gmail.com
Date of Birth: 13.02.1987
Sex (Status): Male (Married)

Educational Profile

Qualification/ Degree	University / Board	Marks (%) or CGPA	Year Of Passing	Remark
Ph.D.	Indian Institute of Technology Roorkee	-	(Pursuing, 2012 onwards)	Result awaited
M-Tech. (Production and Industrial Engg.)	Indian Institute of Technology Roorkee	CGPA 8.91, or (89%)	2011	Branch topper
B.Tech. (Mechanical Engineering)	Jai Mukand Lal Institute of Technology & Management (JMIT), Radaur affiliated to Kurukshetra University.	73.80%	2008	Degree awarded (Honors)
12th Std	C.B.S.E. Board	75.6%	2004	Merit
10th Std	B.S.E.H. Board	70%	2002	First division

Software Packages

@RISK ; ARENA; SPSS; Fuzzy Logic Toolbox in MATLAB.

Subscription of Society and memberships

Associate member Institution of Engineers (India); Member- GLOGIFT; Member-SOMS.

International visit

Attended and presented a research paper entitled **"Flexible Decision Modeling for Analyzing the Enablers to Enhance the Sustainable Supply Chain Performance"** in twin conference: The 14th Global Conference on Flexible Systems Management, GLOGIFT 14 & 7th

International Conference on Contemporary Business 2014, 7th ICCB being hosted by the Curtin University, Singapore, during October 15 – 17, 2014.

Research impacts

Google scholar citations = 80 (till date)

h-index = 6

i10-index =4

Research gate Score = 12.27 (till date).

Awards/Prize/Certificates

- Won best paper award for the paper: **Mangla, S.,** Madaan J, Karveker R. Lean Focused approach for improving performance of a Shop floor, XVI Annual international conference of Society of Operations Management, IIT Delhi, India, December 21-23, 2012.
- GATE Qualified with AIR 863.
- Recipient of the MHRD fellowship for PhD at IIT Roorkee (July 2012 – Current).
- Branch Topper in M. Tech.
- B. Tech degree with Honors.
- Participation in NATIONAL MEMORY CONTEST, 2003 Organized Under The Aegis of LIMCA BOOK OF RECORDS.

Areas of interests

- Supply Chain Management
- Operations Research/Quantitative Techniques
- Quality Management
- Operations Management
- Simulation