2.1 INTRODUCTION TO SUPPLY CHAIN

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

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

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

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

2.2.1 Traditional Supply Chain (TSC)

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

2.2.2 Agile Supply Chain (ASC)

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

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

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

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

### 2.2.3 Green Supply Chain (GSC)

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

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

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

Adding the ‘green’ component to supply chain management involves addressing the influence and relationship between supply chain management and natural environment (Srivastava, 2007). GSCM, also known as Sustainable Supply Chain Management (SSCM), combines green purchasing, green manufacturing/material management, green distribution/marketing and reverse logistics (Hervani et al., 2005).
The aim of organisations adopting GSCM practices is to enhance their environmental and financial performance, investment recovery and eco-design or design for environmental practices (Zhu and Sarkis, 2004). Also, there is pressure from both business and the public who as customers want products and services that support their efforts to be sustainable (Tuttle and Heap, 2008). Thus, environmental sustainability has emerged as one of the biggest challenges for the global community to confront with. Organizations are conducting business within complex legal structures, while stakeholders’ demands are increasing and environmental performance expectations are becoming more demanding. To operate effectively in this environment, organisations are now required to demonstrate proactive management of the environmental impacts of their business activities and adopt environmentally responsible practices, i.e., green business practices into everyday business processes. There is a definite relation between environmental concerns and economic growth. The economic growth is linked to the environment through extraction, production and consumption of natural resources. The excessive economic growth creates not only resource scarcity but also pollutants that might exceed the assimilative capacity of natural environments, thereby degrading essential life-supporting systems. Zhou (2009) have defined green supply chain management as a sort of modern management mode which could comprehensively consider the environmental influence and resource utilization efficiency in the whole supply chain and how to implement the green supply chain management in special industrial operation at present has become into one of hotspot problems. But, this is not an easy task, business managers in manufacturing organizations now required to identify, analyse and manage these barriers in their ‘supply chains’ such that the business practices can turn out to be effective and efficient in addressing environmental concerns.

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

### 2.3 DIFFERENT ISSUES CONCERNED WITH SUPPLY CHAINS

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

#### 2.3.1 Role of Information Technology (IT) in SC

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

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

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

2.3.3 Just in Time (JIT)

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

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

2.3.4 Flexibility in SC

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

2.3.5 Logistics

In today competitive global economy, companies face the challenge of evolving strategies and capabilities to compete effectively. The increasing trend of economic globalisation has made efficient logistics management critical to the success of every business organisation. Logistics, however, is human-centric relying, to a great extent, on the capabilities of the individuals managing the logistics processes. A good logistics system requires a skilled workforce. A major concern of most researchers and practitioners is the nature and role of employee skills on logistics performance (Dadzie, 1998). The Council of Supply Chain Management Professionals (CSCMP) (2007) defines logistics as that part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption to meet customers’ requirements. Logistics is critical to the success of every organisation as customers’ demand for quality products, quality service and increasing value, has increased the importance of the logistics function (Tompkins, 1997; Sohal and D’Netto, 2004).

There are many issues in logistics like improper man machine management, increase lead time, customer satisfaction etc. One major concern of logistics is the determination of the right kind of skills required to function effectively. Logistics is very broad and requires a diverse set of skills; from people to process to information skills. Previous researches have tried to identify the skills required for logistics profession. These skills include team orientation, people, technology, cross-functional and supply chain skills (Cooke, 2000; Gammelgaard and Larson, 2001). Many studies have highlighted the shortage of suitably qualified logistics talents to fill vacant positions (Sarana, 2006).

2.3.6 Uncertainty and Risk

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

2.4 RISK IDENTIFICATION IN SUPPLY CHAINS

Uncertainty and risk identification is an important part of supply chains. Uncertainty is the deviation from actual demand on other hand risk is the probability of the occurrence. Uncertainty and risk in the supply chain can be classified in three ways deviation, disruption and disaster (Gaonkar and Viswanadham, 2004). A deviation is occurred when one or more parameters, such as cost, quality, delivery, etc., within the supply chain system occurs from their expected or mean value, without any changes to the underlying supply chain structure. Deviation in supply chain is responsible for affecting cost, quality and delivery. A disruption occurs when the structure of the supply chain system is radically transformed, through the non-availability of certain production, warehousing and distribution facilities or transportation options due to unexpected events caused by human or natural factors. Disruptions may be influenced by the distinctive supply related characteristics of each entity, including environment, infrastructure, service delivery, inter organisational linkages and relationships, or a combination of these factors (Peck, 2005). Disaster means a temporary irrecoverable shut-down of the supply chain network due to unforeseen catastrophic system-wide disruptions. Disasters like terrorist attacks, earthquake, heavy rain etc are responsible for the complete shutdown of supply chain (Tang, 2006). Different types of uncertainty and risks associated with supply chains are discussed in the following sections:
2.4.1 Plan and Control Risks
Strategic planning can reduces the plan and control risks in supply chains. This is the one most important risk, which start at the planning stage at supply chain. Improper planning can give the invitation to other type of risks. It involves the issues related to production, material management and information technology etc. Plan and control risks are characterised by different measures such as IT planning and control (ITPC), material planning and control (MPC), production planning and control (PPC), sales marketing plan and control (SMPC) (Moeinzadeh and Hajfathaliha, 2009).

2.4.2 Procurement Risks
A procurement risk is the potential deviations in the inbound supply in terms of time, quality and quantity that may result in uncompleted orders (Kumar et al., 2010). Inconsistency in the suppliers’ performance will make their performance unpredictable and thus increase procurement risks. There are many factors that can affect suppliers’ performance such as production capacity constraints, lack of quality control, congestion in the production, or even a machine break down (Zsidisin and Ellram, 2003). All these can interrupt supply in terms of supply lead time, quantity and quality.
Due to the practice of outsourcing, the capability of the suppliers to assure supply is critical for the buying companies. Inconsistent supply lead-time makes it unpredictable and thus increases the forecast error (Zsidisin 2003). Problems also occur when suppliers cannot satisfy volume or mix requirements in the order. Since the buying company relies on its suppliers to maintain capable production processes, the inability of suppliers to deliver the required material, components or products will have detrimental effects on the supply chain’s ability to serve its customers. Success of an organization depends upon the seamless linkages between different activities within the chain such as inbound logistics and outbound logistics. Supply risk will have detrimental effects on outbound logistics, which will ultimately impact on the performance of the supply chain.
2.4.3 Process Risk

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

2.4.4 Demand Risks

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

**2.4.5 Natural and Social Risks**

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

**2.4.6 Transportation Risks**

Transportation risks occur due to delay in transportation mode chosen. Due to transportation risk overall production system can be stopped. To outcome this type of risks suitable mode of transportation should be chosen. Diabat et al. (2012) have analysed that transportation risks affect the firm’s internal ability to produce goods and services, ultimately affecting the profitability of the company, and may result from a breakdown in manufacturing or processing capability and/or changes in technology.

**2.4.7 Market-Related Risks**

Market related risks reside in the movement of goods from the firm to the customers, and include the risk of obsolescence, stock-outs, and over-inventory (Samvedi et al., 2013). Market related risks are related to the excess and less demand of customer or
depend on the seasonality. Shimizu et al. (2013) have investigated the customer claims to improve organizational processes in supply chain risk management.

### 2.4.8 Supplier-Related Risks

Supplier related risks reside in the course of movement of materials from suppliers to the firm and include the reliability of suppliers, and considerations such as single versus multiple sourcing and centralised versus decentralised sourcing (Chen et al., 2013). Sawik (2013) have described decision maker needs to select and protect suppliers against disruptions and to allocate order quantity among the selected suppliers and the inventory among the protected suppliers to minimise total cost of supplier protection, inventory holding, ordering, purchasing and shortage of parts and to mitigate the impact of disruption risks.

### 2.4.9 Financial Risks

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

### 2.4.10 Operations Risks

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

2.4.11 Performance Measurement Risks

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

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

2.5.1 Poor Quality

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

2.5.2 Utility Failure

In operations management, however, the expected profit maximization assumption started coming into question only recently. Some authors, for example, Lim and Ho (2007) and Ho and Zhang (2008) have studied considerable rejections through the lens of the random utility theory. The theory postulates that when faced with several options people do not select the highest utility option with certainty, but instead select it only with some probability, depending on the relative utility of the option and the precision parameter.
2.5.3 Human Resource (HR) Problems
As companies reorganize to gain competitive edge, human resources play a key role in helping companies to deal with a fast-changing competitive environment and the greater demand for quality employees. New approaches are applied to work process design, succession planning, career development and inter-organizational mobility. One major concern of logistics practitioners is the determination of the right kind of skills required to function effectively. Logistics is very broad and requires a diverse set of skills; from people to process to information skills. Many researchers have identified the skills required for logistics profession. These skills include: team orientation, people, technology development, cross-functional and supply chain skills (Cooke, 2000; Gammelgaard and Larson, 2001). Additional skills identified by other researchers include: functional, managerial and interfacing, customer service, strategic management, communications, leadership, computer, collaborative, problem solving and financial skills (Bowersox et al., 2000; Sohal and D’Netto, 2004).

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

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

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

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

2.5.6 Theft of Information

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

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

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

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

2.6.1 Vendor Selection Problems in Supply of High Tech Equipment

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

2.6.2 Lack of Supply Chain Planning and Coordination

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

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

2.6.4 Lack of Knowledge

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

2.6.5 Inadequate IT Infrastructure Resources

Information Technology (IT) and its use in organizations and across the supply chain has become a determinant of competitive advantage for many corporations. It also highlights the contribution of IT in helping to restructure the entire distribution set up to achieve higher service levels and lower inventory and lower supply chain costs.
Recent development in technologies enables the organization to avail information easily in their premises. These technologies are helpful to coordinates the activities to manage the supply chain. The cost of information is decreased due to the increasing rate of technologies. According to Macleod (1994) supply chain managers increasingly want to automate all of the supply chain, from forecasting to distribution, and to link every element of the chain. More and more companies want an integrated solution to enable them to see the entire supply chain at once. Unfortunately for many midsize companies in these times of economic recession, such clarity in global distribution remains largely restricted to major multinationals with deep pockets and volumes large enough to justify the hefty initial investment in IT that can run into millions of dollars.

2.6.6 Lack of Purchase Management

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

2.6.7 High Costs of Implementation

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

### 2.6.8 Lack of Sharing and Accurate Information

It is crucial for information to be shared where there is decreasing information visibility so that there is less risk including that of catalogue non-availability that includes up to date and standardized profiles of organizations. However, the availability of more information sharing can cause loss of IPR. In order for knowledge sharing to be accepted, a organization must have established values relating to sharing and collaboration as part of their fundamental ethos. Some may feel that they have an advantage because they possess knowledge that others do not and this causes a refusal to share knowledge with others out of a desire to protect their own interests. Networks must share information because where it is lacking the result may be panic, confused behaviour and increased costs (Childerhouse et al., 2003). It is agreed currently by models for SCM that sharing business information is vital, connecting SC completely together (Zhenxin et al., 2001; Yu et al., 2001). It has been felt that there is a risk involved in sharing with other members such sensitive information as inventory levels and production schedules. Information sharing should be subject to choosing those with whom the information will be shared, what type of information it will be and of what quality. Efficient network coordination depends upon information sharing, with a number of studies finding that it impacts significantly on network performance and, in particular, is able to reduce the bullwhip effect. Information sharing leads to better operational decision making within enterprises which leads to more efficient use of resources and lower costs (Lee et al., 1997; Yu et al., 2001). A bond made between two independent members in supply channels is called a supply chain partnership. It is formed by increasing the levels of information sharing in order to lower the total costs and inventories.

### 2.6.9 Lack of Time and Decision Making

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

2.7 CRITICAL SUCCESS FACTORS IN SUPPLY CHAIN
The success of supply chain is a joint effort made by every member in supply chain. Some of the critical success factors in supply chains are discussed as below:

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

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

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

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

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

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

2.7.5 Forecasting of Demand on Point of Sale (POS)

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

2.7.6 Trust Development in SC Partners

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

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

2.7.7 Developing JIT Capabilities in System

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

2.7.8 Development of Reliable Suppliers

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

2.7.9 Higher Flexibility in Production System

Flexibility is the most important part of production system and helpful for the success of SC. Higher flexibility helps the organizations to fulfill the customer need timely. Kogut (1985) writes that MNEs can utilize an international activity network to provide operational flexibility. MNEs need not only operating and product abilities, but also flexibility in order to achieve the maximum profit and minimum risk. Buckley and Casson (1998) have defined flexibility as the ability to reallocate resources quickly and smoothly in response to changes. Flexibility is the response of an organization to uncertainty in the business environment. Flexibility can also be described as the agility of a manufacturing firm. It reflects change and spontaneity. Flexibility is the organizational ability to meet an increasing variety of customer expectations without excessive cost, time, disruption or loss hence increasing the range of products available and improving performance and response. Jack and Raturi (2002) have identified the key issues in the definition of volume flexibility are the effectiveness of the flexible response not just the ability. This demonstrates the fact that flexibility is a capability of an organization. If the purchasing function of an organization can manage supplier capabilities effectively, the result could be an increase in manufacturing flexibility. The volume flexibility capability of potential suppliers is a requirement for the improvement of coordination at each level of the SC, especially with increasing demand.

2.7.10 Focus on Core Strengths

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

2.7.11 Improvement in Product Quality

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

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

2.7.12 Supply Chain Benchmarking

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

2.7.13 Timely Delivery

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

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

### 2.8 METHODOLOGIES USED FOR RISK ANALYSIS

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

#### 2.8.1 Weighted Interpretive Structural Modeling Technique (W-ISM)

W-ISM is the combination of interpretive structural modeling (ISM) and effectiveness index (EI). ISM is one of the interactive management methods which assist research groups in dealing with complex issues (Warnfield, 1974; 1987). ISM transforms unclear, poorly articulated mental models of a system into visible well defined, hierarchal models. It is a well known methodology for identifying and summarizing relationships among specific elements, which define an issue or a problem, and provide a means by which order can be imposed on the complexity of such elements (Mandal and Deshmukh, 1994). Thus, a set of different and directly related elements are structured into a comprehensive systematic model. ISM is primarily intended as a group learning process, but individuals may also apply it (Ravi and Shankar, 2005; Faisal et al., 2007). Any methodology for dealing with complex issues, must, therefore, be able to break complexity down into manageable chunks of information so that the human mind can deal with it. ISM tries to do this, by enabling an individual or a group to focus on the interrelations between two elements in an issue at a time, without losing sight of the properties of the whole.
From the risk sources which have been identified earlier and the potential impact of failure to meet delivery time, cost and quality targets or total failure for the collaboration, a questionnaire was developed using ISM methodology to determine underlying relations among these sources. ISM is a process that helps people to structure their collective knowledge and to model interrelationships in a way that enhances our ability to understand.

Various steps involved in ISM methodology are as follows:

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

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

Different applications of ISM available in the literature are shown in Table 2.1
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Author(s)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Saxena et al. (1990)</td>
<td>Identified the key variables using direct and indirect interrelationships amongst the variables a case for ‘Energy conservation in the Indian cement industry’.</td>
</tr>
<tr>
<td>2.</td>
<td>Saxena et al. (1992)</td>
<td>Used this technique to identify the key actors, objectives and activities for energy conservation in the Indian cement industry.</td>
</tr>
<tr>
<td>3.</td>
<td>Mandal and Deshmukh (1994)</td>
<td>Shows the inter-relationships of criteria and their different levels in vendor selection</td>
</tr>
<tr>
<td>5.</td>
<td>Singh et al. (2003)</td>
<td>Use this technique for the implementation of knowledge management in engineering industries.</td>
</tr>
<tr>
<td>7.</td>
<td>Ravi et al. (2005b)</td>
<td>Productivity improvement in supply chain</td>
</tr>
<tr>
<td>8.</td>
<td>Jharkharia and Shankar (2005)</td>
<td>IT enablement of supply chains: understanding the barriers</td>
</tr>
<tr>
<td>9.</td>
<td>Bolanos et al. (2005)</td>
<td>Use in Strategic decision making</td>
</tr>
<tr>
<td>10.</td>
<td>Faisal et al. (2006)</td>
<td>Risk mitigation in supply chain</td>
</tr>
<tr>
<td></td>
<td>Author(s) (Year)</td>
<td>Title or Description</td>
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<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>15.</td>
<td>Mudgil et al. (2010)</td>
<td>Modelling the barriers of greening the supply chain practices</td>
</tr>
<tr>
<td>17.</td>
<td>Chidambaranathan et al. (2010)</td>
<td>Analyzing the buyer supplier relationship factors: an integrated modeling approach</td>
</tr>
<tr>
<td>20.</td>
<td>Attrj et al. (2012)</td>
<td>Modeling the enablers in the implementation of Total Productive Maintenance (TPM).</td>
</tr>
<tr>
<td>22.</td>
<td>Nagar and Raj (2012b)</td>
<td>Analysis of critical success factors for implementation of humanised flexible manufacturing system in industries</td>
</tr>
<tr>
<td>23.</td>
<td>Mishra et al. (2012)</td>
<td>Interrelationship of drivers for agile manufacturing: an Indian experience</td>
</tr>
<tr>
<td>25.</td>
<td>Panahifar et al. (2014)</td>
<td>Analysis of CPFR implementation barriers</td>
</tr>
</tbody>
</table>

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

\[ W_i = \begin{cases} 
+1 & \text{(Strength), when percentage score} > 60\% \ (\text{Mean value} > 3). \\
0 & \text{(Neutral), when percentage score is between 40-60\% Mean value between 2 and 3).} 
\end{cases} \]
-1 (Weakness), when percentage score < 40% (Mean value < 2). This framework was given by Cleveland et al. (1989) is Cj = Sum [Wi Log Ki]. Chand and Singh (2010) have also used this model for study the select issues of supply chain management. Competitiveness analysis of a medium scale organisation in India: a case (Singh et al. 2006).

### 2.8.2 Analytical Network Process (ANP)

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

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

- ANP is built on the widely used on the basis of AHP technique,
- ANP allows for interdependency among the elements
- ANP technique deals with dependence within a set of elements (inner dependence) and among different sets of elements (outer dependence),
The ANP networks make possible, the representation of any decision problem without concern for what criteria comes first and what comes next as in a hierarchy.

The ANP is a non-linear structure that deals with sources, cycles and sinks having a hierarchy of linear form with goals in the top level and the alternatives in the bottom level.

ANP portrays a real world representation of the problem under consideration by prioritizing not only just the elements but also groups or clusters of elements as is often necessary.

The ANP utilizes the idea of a control hierarchy or a control network in dealing with different criteria, eventually leading to the analysis of benefits, opportunities, costs and risks.

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

**Table-2.2: Brief review of ANP applications**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Author(s)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Chung et al. (2005)</td>
<td>Product mix for efficient manufacturing in a semiconductor fabricator</td>
</tr>
<tr>
<td>4.</td>
<td>Aggarwal et al. (2005)</td>
<td>Modelling the matrices of lean, agile and leagile supply chain</td>
</tr>
<tr>
<td>No.</td>
<td>Authors</td>
<td>Title</td>
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<tr>
<td>11.</td>
<td>Aragones-Beltran et al. (2008)</td>
<td>Valuation of urban industrial land</td>
</tr>
<tr>
<td>13.</td>
<td>Chen et al. (2009)</td>
<td>To identify the committee who intend the pattern of tourism</td>
</tr>
<tr>
<td>17.</td>
<td>Hemmati and Rabbani (2010)</td>
<td>To determine the appropriate product delivery strategy for different products in manufacturing systems</td>
</tr>
<tr>
<td>18.</td>
<td>Alptekin (2010)</td>
<td>To predict the market share in white goods sectors</td>
</tr>
<tr>
<td>20.</td>
<td>Anand et al. (2011)</td>
<td>Selection of material handling systems in the design of flexible manufacturing systems</td>
</tr>
<tr>
<td>22.</td>
<td>Shahin et al. (2012)</td>
<td>Selecting optimum maintenance strategy with a case study in the mining industry</td>
</tr>
<tr>
<td>23.</td>
<td>Goyal and Grover (2013)</td>
<td>Manufacturing system’s effectiveness measurement</td>
</tr>
</tbody>
</table>
2.8.3 Multi-Objective Optimization by Ratio Analysis (MOORA)

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

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

**Step 2:** The next step is to represent all the information available for the criterias in the form of a decision matrix. The data given in eq. (1) are represented where $Ai$ represents the alternatives, $i = 1, 2, \ldots, m$; $Cj$ represents $j$th criterion, $j = 1, 2, \ldots, n$, related to $i$th alternative. The SC of the $j$th attribute is denoted by $Wj$ and $xij$ indicates the performance of each alternative $Ai$ with respect to each criterion $Cj$. Then a ratio system is developed in which each performance of an alternative on an attribute is compared to a denominator which is a representative for all the alternatives concerning that criterion.
Step 3: Brauers et al. (2008) concluded that for this denominator, the best choice is the square root of the sum of squares of each alternative per criteria. This ratio can be expressed as below:

\[ X^*_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}} \]  

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

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

\[ y^*_i = \sum_{j=1}^{g} w_j X^*_{ij} - \sum_{j=g+1}^{n} w_j X^*_{ij} \]  

Where \( w_j \) is the weight of \( j \)th criteria, which can be determined applying analytic network process (ANP).

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

**Table-2.3: Brief review of MOORA applications**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Author(s)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Lootsma (1999)</td>
<td>Decision matrix showing the performance of different alternatives with respect to various criteria (objectives).</td>
</tr>
<tr>
<td>2.</td>
<td>Brauers (2004)</td>
<td>Multi objective optimization technique that can be successfully applied to solve various types of complex decision making problems in the manufacturing.</td>
</tr>
<tr>
<td>6.</td>
<td>Karande and Chakraborty (2012)</td>
<td>Normalization by comparing the performance of an alternative on a criterion to a denominator which is a representative for all the alternatives concerning that criterion.</td>
</tr>
<tr>
<td>7.</td>
<td>Das et al. (2012)</td>
<td>Comparative evaluation of Indian technical institutions.</td>
</tr>
<tr>
<td>8.</td>
<td>Attri and Grover (2013)</td>
<td>Decision making over the production system life cycle</td>
</tr>
</tbody>
</table>
2.8.4 Graph Theoretical Approach (GTA)

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

- Digraph representation
- Matrix representation
- Permanent function representation.

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

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

Different applications of GTA available in the literature are shown in Table 2.4
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Author(s)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Gandhi and Agrawal (1994)</td>
<td>Failure Mode Effect Analysis</td>
</tr>
<tr>
<td>5.</td>
<td>Grover et al. (2004)</td>
<td>Quantifying TQM environment</td>
</tr>
<tr>
<td>11.</td>
<td>Raj et al. (2010)</td>
<td>To evaluate the intensity of barriers in the implementation of FMSs</td>
</tr>
<tr>
<td>13.</td>
<td>Dev et al. (2014)</td>
<td>Combined cycle power plant efficiency analysis</td>
</tr>
</tbody>
</table>
2.8 CONCLUSION
From this chapter it is concluded, there are different types of uncertainty and risks associated with the different types of supply chains i.e. traditional supply chain, lean supply chain, agile supply chain, green supply chain. For a successful supply chain management and to cope with the uncertainty and risks, there is a need of deep understanding of different concerned issues with the supply chain partners. The various issues related to the uncertainty and risks in the context of supply chain have been reviewed. The various directions for risk mitigations and their benefits have been found for a successful supply chain management. From the literature, it is found that the main focused issues which affect the whole supply chain are information technology, performance measurement, just in time, flexibility and logistics. Among these issues some of the important uncertainty and risk measures have been identified so that they can be analyzed for a successful supply chain management. At last it is concluded that industries should focus on the important uncertainty and risk measures, and try to improve these areas by removing the barriers in the way of successful developed supply chain management. So the strategies should be developed to tackle the uncertainty and risk measures, and to identify the key areas by utilizing the different methodologies tools and techniques. The identified uncertainty and risk issues, measures should be further analysed for mitigating the risks in supply chains.