

CHAPTER 1

INTRODUCTION

1.1. Introduction

A supply chain (SC) is the network of organizations and facilities connected to fulfill customer demand through the flow of material, information, and finance (Papapostolou et al., 2011). While the interconnectedness of the organizations has inherent benefits, however, its actual strength and vulnerabilities is defined by the weakest link present in the chain (Juttner et al., 2003; Stone and Rahimifard, 2018). The present business environment is highly uncertain and vulnerable and is subjected to many non-business-related events along with the businesses such as socio-political disturbances, natural disasters, fast-changing technology, terrorist attacks, etc., that lead to a partial or complete breakdown of the business. Since the growth of industrialization and the global business market, the organizations are not working in isolation; instead, they work in a network of organizations connected through the flow of material, information, capital, etc., called supply chain (SC). These SCs bring huge capabilities. However, due to inter-connectedness, they also make the businesses more uncertain and vulnerable to disruptions. The disruptions result from the many unexpected and undesirable events, called risks, uncertainties, catastrophes, crises, etc. (Duchek, 2020). One of the most recent events that shook the global business is COVID-19. It has been found that COVID-19 has abruptly disturbed the financial position of almost all the countries, solely for India it accounts for declining GDP growth by -7.3% in the financial year 2020-21 (IMF report- Policy responses to COVID-19). It obstructed the businesses and made the decision-makers think about the way of doing business.

Some of the earlier events that partially or fully disrupted businesses in the last two decades are the Tsunami (2004), Earthquake (2011), terrorist attack (9/11, 26/11), fire at Phillips (2000), Suez Canal obstruction (2021), Tianjin port explosion (2015), etc. Even most businesses had some risk mitigation plan. Still, they failed to respond to these uncertain events, which led the researchers to think beyond the classical risk management approach. Thus, a new concept, ‘resilient supply chain (RSC)’, has evolved (Christopher and Peck, 2004; Agarwal and Seth, 2021). Christopher and Peck (2005) and Sheffi (2005) were among the first to discuss the concept of resilience in the SC. Since then, it has evolved humongous and applied to almost all kinds of businesses to minimize the risk, vulnerability, and disruption impacts (Pettit et al., 2019). RSC is the ability of the SC to mitigate disruptions and regain its initial or even better position post disruptions (Christopher and Peck, 2004). The RSC is attributed to many capabilities considering its definitions and the resilience characteristics from various fields. Such as the ability to anticipate, resist and absorb the adversities along with the capabilities like adaptive, learning, and springing back lead to the recovery of the SC to its initial or more demanding position (Duchek, 2020; Ruiz-Benítez et al., 2018).

Further, to enable these resilient capabilities in the SC, researchers have identified several resilient practices or enablers such as flexibility, agility, visibility, collaboration, real-time information sharing, strategic stocking, postponement, silent product rollover, redundancy, etc. (Rajesh, 2020; Hohenstein et al., 2016; Ali et al., 2017; Jain et al., 2017; Soni et al., 2014). These practices enable the SCs to prepare against expected and unexpected events and develop the ability to quickly recover to their initial or even better position (Ponomarov and Holcomb, 2009). Ever since the development of the RSC and its practical implementation into the SCs, many time, it has been observed that the SCs are unable to resist, absorbs, or recover from the disturbances, and they tumble

down, causing huge business and social losses (Agarwal and Seth, 2021a; Ali et al., 2017; Rajesh, 2018). This inability of the RSC indicates the presence of some inhibiting factors, which act as barriers to the successful implementation and execution of resilient practices. These inhibiting factors are named the barriers of the RSC (Ali et al., 2017). Further, considering the force field theory, for the survival, adaptation, and growth of the SCs, the magnitude and impact of the driving force (RSC practices) should be more than that of the inhibiting factors (Agarwal and Seth, 2021b). Thus, identifying and analyzing the resilient practice (driving forces) and the inhibiting factors (resisting forces) help the SCs overcome vulnerabilities and the disruption impacts, thus gaining competitive success both before and after the disruptive events.

Moreover, it has often been observed that the practitioner faces problems in planning, implementing, and controlling the resilient behavior of the SC solely based on the resilient practices and their causal dependence relationships. Thus identifying the attributes of the resilient practices will aid the realization of the resilient behavior of a SC through proper implementation of practices. And also, quantifying the resilience score of the SC considering these practices and the attributes will lead to identifying the performing and non-performing sections of the SC (Rajesh, 2019).

1.1.1. Supply chain (SC)

A supply chain (SC) is a network of organizations working to fulfill customer demand. It links the suppliers, sub-suppliers, manufacturers, logistics, retailers, and customers through the flow of finance, material, and information. It transforms the raw material into a customer-ready product while interacting with all the entities of the SC in terms of sourcing of material and information, production and value addition, distribution of the product and services to the ultimate customers, and flow of funds. The participants

of the SC are also called SC members or SC entities, such that specific tasks and responsibilities bind each one. The flow of material, information, and funds often takes place in both directions, i.e., supplier to customer and vice-versa, and is controlled by single or multiple SC entities. According to Manish (2002), along with the complementary companies, the competitor is also an entity to the SC that questions the success of one's business, thus indirectly motivating improvement. Carvalho et al. (2012) divide SC into entities (typology, available alternatives, geographic locations, etc.), relational links (collaboration, supplier-manufacturer relations, retailer-buyer relationships, etc.), material flow (quantity, frequency, mode of transport, etc.), information flow (technology, used, frequency, etc.), management policies (procurement strategy, in-house operations, order capacity, lot size, etc.), and lead times (transit time, order procurement time, etc.).

SC has been defined by many researchers such that Manish (2002) considers the SC network-wide characteristics and describes it as “the network of an organization that collaborates to improve the flow of material and information among the supplier, producer, and customer at minimal cost and time.” It is the interconnectedness among the organizations governed by the common objective of fulfilling customer demand. Hohenstein et al. (2015) consider SC as a whole a unique entity with a unique strategy and goal, such that each participant benefits equally and gets equal opportunities to grow. In simple words, SC can be defined as “the network of organizations having a common goal, connected through the flow of material, information, and finance.” *Network configuration* refers to the geographical positioning and connectivity of the SC entities that promote the level of contact, resource exchanges, accessibility, and flexibility in the SC.

The SC depends mostly upon its design, planning, and implementation, which ultimately defines its overall profitability and success. Among these, design plays the most significant role in the entire network, providing the desired SC configuration, space for resource allocation, and implementing tactical strategies. Some of the most important strategic decisions are- make or buy, location of production facilities, location of the warehouse units; mode of transportation; use of information sharing tools, etc. According to Amish (2002), cooperative and inter-dependent decision-making by the SC members leads to a win-win strategy which improves the overall SC capability as well as the efficiency of the SC. At the beginning of the SC concept, it was assumed that information moves from downstream to upstream, while material/products move from upstream to downstream; however, the competitiveness as well as environmental awareness program breaks this barrier and promotes the real-time information available to all the participants of the SC along with the re-use and recycling of the waste generated at the customer end. Thus, the present SCM procedure promotes coordination among the SC activities.

1.1.2. Supply chain management (SCM)

Further, to manage the activities involved in SC, Oliver and Weber (1982) coined the term supply chain management (SCM), which is defined as “the design and management of seamless value-added process across organizational boundaries to meet the real needs of the end customer” (Institute of SCM). It focuses on controlling and optimizing SC activities; over time and has become a vital part of business management. The terms material management, integrated logistics, virtual enterprising, etc., has assumed to be stimulated by the development of SCM. SCM comprises supply management, strategic purchasing, network coordination, and logistics integration, and

it aims to improve market sensitivity, enhance product quality, minimize the cost of production, control the SC exposure to uncertainty, improve data accuracy, and integrate the processes (Rajesh, 2017a).

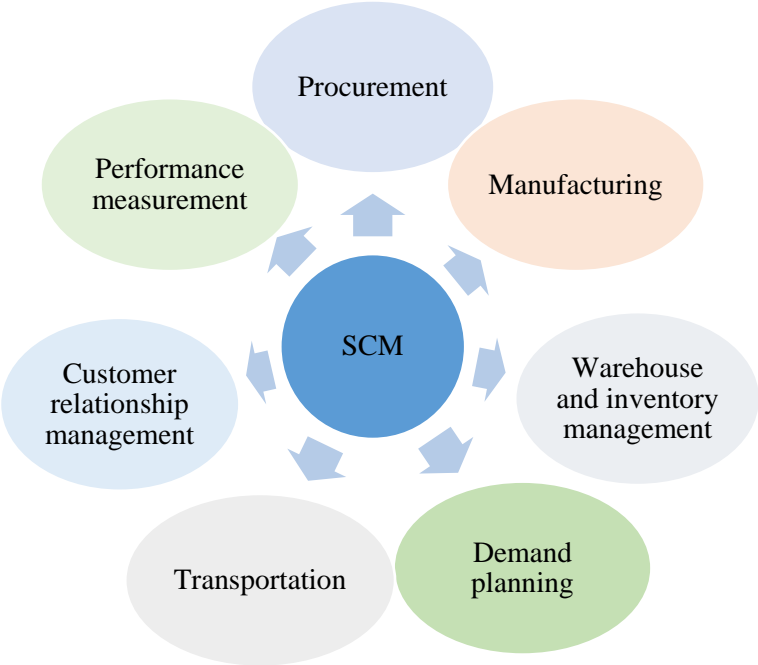


Figure 1.1: Functions of the SCM

According to Li et al. (2005) and Machado et al. (2009), SCM comprises strategic supplier partnership, information sharing, information quality, internal lean practices, and postponement. Christopher (1992) defines the SCM as the management of the relationship between the upstream and downstream SC members to create value for the customer at the least possible cost. Thus, it is a cross-organizational boundary phenomenon with multiple entities and business domains aiming to plan and manage the different business practices, e.g., procurement, production, logistics, etc. The fulfillment of the customer demand requires valued addition to the product in various stages and at different organizations. These interdependencies of the activities suggest that the actual competition lies between the SCs, not between the firms (Christopher and

Peck, 2004). And also, continuously changing customer demand, shortening of the product lifecycle, globalization of the supply network, increased competitiveness, etc., coupled with a complex and turbulent business environment, have made the management of the SC a tedious job. Thus, efficient and effective management of the SC operations has become the priority among the management groups for business success. The various function of the SC is pictorially represented in Figure 1.1.

1.1.3. Supply chain risk, vulnerability, and disruptions (SVDs)

Moreover, the SC practices and related activities have been observed to be associated with some of the inherent risks and vulnerabilities, e.g., transportation failure, cultural differences, and exchange rate risks, whose realization leads to disruption to business continuity and sometimes complete loss of the businesses. Zsidisin and Ritchie (2008) and Zsidisin and Wagner (2010) represent a broader picture of the SC risk and consider it as a multidimensional construct and define it as “the probability of an incident associated with the SC members, whose outcomes not only inhibit the delivery of the customer demands but also can be fatal to consumer and the Society.” Tang and Nurmaya (2010) define SC risk as an undesired event that derails the flow of finance, information, and material, thus hampering the SC outcomes. SC risks are broadly classified as an internal and environmental risks, where internal risk represents all the activities and events internal to the SC, such as supply failure, demand variability, production failure, poor quality, delay, etc., and external risk includes socio-political disturbances, cross-border conflicts, advancement in technology, ecological adversities, change in regulations and standards, etc. (Peck, 2005; Barlas and Gunduz, 2011). These risks result from excessive outsourcing, globalization, centralization, lean process, and poor information.

Moreover, SC vulnerability and uncertainty is another term that is widely used with risks to the SC. It is assumed to be the SC risks with the anticipated outcomes (Christopher and Peck, 2004; Wagner and Bode, 2008). It is assumed to be the state of insufficient SC capability against the risks, thus representing the possible outcomes in the event of internal or external hazards. Gondard (2004) defines three characteristics of the vulnerable SC: the ability to anticipate the risks; second, the ability to withstand the shock; and the ability to develop and improve the capability. Laville (2006) considers the SC vulnerability as the result of its malfunctioning and thus avoidable. Pettit et al. (2010) classifies the SC vulnerabilities in terms of financial strength, organizations, network dispersion, post disruption recovery, efficiency, competitive position, adaptation to change, collaboration, visibility, flexibility, anticipation, and security. According to the Normal Accident Theory (NAT) proposed by Perrow (1984), the more complex and tightly coupled SCs are more vulnerable. Their vulnerability is derived from the excessive focus on revenue creation, outsourcing solely based on cost parameters, and increased interdependency among SC members. Christopher and Peck (2004) define SC vulnerability as “an exposure to serious disturbance, arising from risks within the SC as well as risks external to the SC.”

Moreover, the uncertainty to the SCs is because of the organizational inability to anticipate the risk, inadequate information sharing and its inappropriate interpretation, and poor estimation of future events and the probability parameters. These uncertainties are further classified into human resource uncertainty, supply uncertainty, demand uncertainty, production uncertainty, and environmental uncertainty (Rao and Goldsby, 2009). Wagner and Bode (2008) differentiated the term uncertainty and risk based on the directionality of the outcomes, i.e., the risk is always associated with adverse effects while uncertainty may result in positive or negative consequences.

SC disruption is another term that is most widely used in the business field and can be stated as the realization of the risks, vulnerabilities, and uncertainties associated with the SCs. According to Craighead et al. (2007) and Blackhurts et al. (2011), a SC disruption is an unanticipated event that hinders the flow of materials, thus causing potential negative consequences to the SC members. The impacts of the disruptions depend widely upon the rate and intensity of its propagation to the various sections of the SC, also called the risk diffusion and ripple effect (Sokolov et al., 2016). In the present complex and dynamic business scenario, SC disruption is evitable and is among the most horrifying to the practitioner, and a continuous attempt is made to prevent and manage it through identification, prediction, and estimation (Scheibe and Blackhurts, 2018; Ivanov et al., 2016; Manuj and Mentzer 2008). Further, according to the study conducted by Computer Science Corporation in 2004, about 60% of global businesses are vulnerable to disruptions; similarly, Cap Gemini Research Institute stated in its report – rethinking SC resilience for a post-COVID-19 world that more than 80% of the organizations failed to manage their business activities during COVID-19 and faced huge losses. Thus, operating SC activities in these challenging and unabsorbable situations have become a tedious job; hence identifying, evaluating, and mitigating these unwanted conditions of the SCs has become the prerequisite for business success. Scheibe and Blackhurts (2018) and Sawik (2019) consider the portfolio approach to counter the SC disruptions, such as developing the primary as well as the recovery suppliers and dispersing the purchases. These strategies are able to counter specific entity-oriented disruptions. However, most of the time, these strategies are found to be insufficient and lead to the complete failure of the SC and thus suggest the need for the network-wide risk management approach (Gupta et al., 2017). In the literature, the abstract notion of the unexpected is specified using different concepts: some authors

talk about ‘rare events’ (Marcus and Nichols 1999; Lampel et al. 2009), while others call them ‘surprises’ (Lampel and Shapira 2001; Bechky and Okhuysen 2011), ‘catastrophes’ (Weick and Roberts 1993; Majchrzak et al. 2007; Duchek, 2020), or ‘crises’ (Duchek, 2020; Rerup 2009).

1.1.4. Supply chain risk management (SCRM)

Considering the importance of the successful execution of the SC activities for fulfilling the customer demand in the vivid of the SC risks, vulnerabilities, and disruptions, researchers have coined the term SC risk management (SCRM), which is a network-wide concept and involves the upstream and downstream SC members for its effective implementation (Christopher and Peck, 2004). SCRM is “*the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain risk members, to reduce supply chain vulnerability*” (Juttner and Maklan., 2011). SCRM is becoming a concern for SC managers worldwide. Sodhi et al. (2011) and Scheibe and Blackhursts (2018) suggests that SCRM should be beyond the organizational boundary of the focal company and must include at least three entity of the SC for risk handling. Stonbraker et al. (2009) and Neiger et al. (2009) consider the SCRM as a strategic choice and a tool to improve SC performance through risk capturing, SC collaboration, and integrating risk management strategies with the other SC strategies. It has evolved in four phases of the SC, i.e., risk management, business risk management, enterprise risk management, and SCRM. According to Wu and Blackhurst (2007), SCRM is a proactive approach to risk management that requires the active participation of each member. It comprises the following activities, (i) Identification of the risks, (ii) Analysis and assessment of the risk impact, (iii) Managing the risks and their impact, (iv) Risk monitoring and evaluation, and (v)

Learning and capability improvement. Pfohl et al. (2010) consider the SCRM as a network-wide integrated practice. Each member actively mitigates the risks and disruptions impact, irrespective of its source and victims. The essential functions of the SCRM is depicted in Figure 1.2. Some of the most widely used risk mitigation tools include buffer creation, information sharing to strategic members, insurance, portfolio selection, and contracting, which are founds to be adequate only to tackle the high probability and low impact risks and ignore the low probability disastrous risk. However, Rajesh (2015) divides risk management into three strategies, i.e., avoidance, mitigation, and contingency planning, and considers it as an approach to low combat probability and high impact risk. And suggests real-time information sharing among every node as the key to improving flexibility and responsiveness, thus enabling the SC to withstand major disruptions.

SCRM is a process of identifying and choosing the appropriate strategies and actions to mitigate the SC risks and vulnerabilities through a coordinated approach among the SC members. Jüttner and Maklan (2011) define the SCRM as the combination of four SC aspects applicable to its three stages, i.e., planning, operations management, and change management. These stages include identifying the risk sources, estimating the risks' consequences, specifying agents driving the risks, and postulating the strategies that can be implemented to mitigate the risks and their impacts. SCRM is a system of action plan to address the SC risks by identifying their mutual interactions, the echelons of its impact, and the tools to mitigate it (Shi, 2013). It can be further stated as the process of understanding the SC risks and the corresponding mitigating strategies while involving the SC partners in eradicating or reducing the probability and impact of the SC disruption, limiting its propagation, and preparing to avoid its reoccurrence (Rajesh, 2015). Chopra and Sodhi (2004) focus on identifying the variety and interconnectedness

among the risks as a tool to choose the risk mitigation strategies for low probability and high impact risks. Some important practices followed in the SCRM include diversification, determining and strengthening the weakest link, focusing on preventive strategies, and adequate balance between efficiency and robustness. Shi (2013) has stated the three steps of the SCRM, i.e., risk identification, risk categorization, and risk management program.

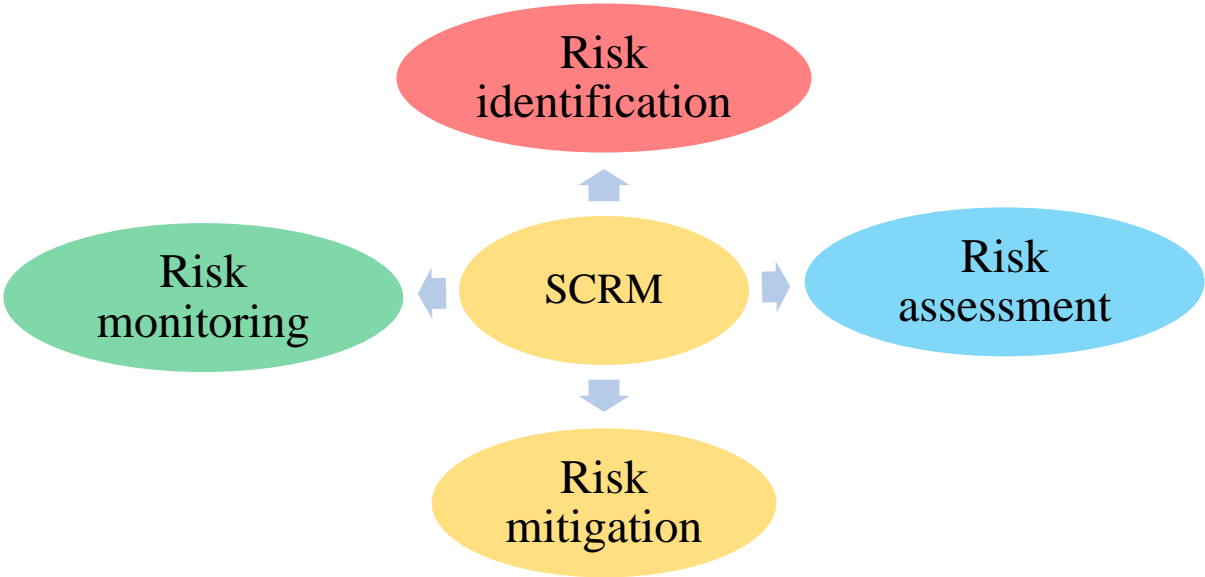


Figure 1.2: Functions of the SCRM

Similarly, Rajesh and Ravi (2015) considered the risk description, risk assessment, and risk mitigation as the path to SCRM. A similar approach is stated by Sodhi et al. (2012), where the first step is identifying the risks and related uncertainties. The second step comprises the risk assessment, including the likelihood of its occurrence and the impacts. The third step deals with the identification of the mitigation process. The final step is the implication of the mitigation strategies against the actual disruptions, thus minimizing its impact and accelerating the recovery. Considering the cross-boundary and network-wide phenomenon of the SCRM, Christopher and Ryals (2014) suggest the

development of the risk management culture as an essential tool for mitigating the SC risks.

According to March and Shapira (1987), the cut-throat competition, shorter product life, changing customer demand, and technological advancement coupled with the other ecological and social hindrances have made the SC risk an integrated and inevitable part of SC management. Thus managing the SC risks and disruption is among the essential practice for the success of the business. SCRM practices or strategies are developed based on the risk and its possible negative consequences. However, most of the time, the organization focuses widely on those risks that are frequently occurring irrespective of their intensity and widely underestimates the consequences of the low probability events. These low probability events may have a devastating impact. The initial step involved in SCRM is identifying and estimating the risks, followed by implementing strategic approaches to minimize their occurrence and consequences. Researchers have explored many approaches for enabling the SCRM, such as Rajesh (2015), giving importance to developing multiple suppliers, strategic stocking, transportation flexibility, redundancies, and product postponement strategy along with the probabilistic measure of adverse events and their impacts. At the same time, Scheibe and Blackhurts (2018) focus on mitigating the upstream vulnerabilities through the development of multiple suppliers and the associated order quantity.

Similarly, Tang and Tomlin (2008) emphasize the postponement strategy and flexibility in product customization and pricing. Tang (2006) and Manuj and Mentzer (2008) emphasize the coordination and collaboration among the SC members. Tang and Musa (2011) and Tang (2006) consider upstream flexibility, early warning systems, SC configuration, postponement, contingency planning, collaboration, incentive alignment,

and environmental protection investing as the main SCRM strategies. Developing the culture of risk management, which includes the use of modern tools for risk estimation and reporting, enabling real-time information sharing, aligning the SC practices and resources for minimizing the risk, and also developing the contingent resources to minimize the disruption impact, will be a very effective tool for the risk management.

Further, the effectiveness of the SCRM strategies over specific risks depends upon a number of factors, like SC complexity, adoption of the strategy by SC members, preparedness, and propagation and intensity of the risks. Thus, focusing on implementing the SCRM practices alone will not be sufficient to mitigate the SC risks and requires adopting the risk management culture at every node of the SC. In addition, developing flexibility at the SC level and decentralizing decision-making may help practitioners deal with unanticipated events. Some other issues that affect the successful implementation of the SCRM include inter-firm rivalry (Park and Ungson, 2001), poor risk and reward sharing (Faisal et al., 2005), inadequate collaboration (Agarwal and Shankar, 2003), and inadequate technological capability (Kwan, 1999). While the interconnectedness of the organizations has inherent benefits, the weakest link makes the chain more vulnerable to disruption (Juttner et al., 2003; Stone and Rahimifard, 2018). According to Taleb et al. (2009) and Sabauhi et al. (2018), the traditional risk management approach is insufficient to deal with the current competitive business environment as it is associated with many black swan-type human-made and ecological disruptions (Taleb et al., 2009). Considering the limitations of the SCRM and its impact on business performance, experts have coined the term “resilient supply chain (RSC) or “supply chain resilience (SCR),” which can eradicate or minimize the occurrence and the adverse impact of the SC uncertainties, vulnerabilities, risks, and disruptions (Christopher and Peck, 2004; Xiao et al., 2012; Ambulkar et al., 2015).

According to Ponomarov and Holcomb (2009) and Pettit et al. (2010), the RSC concept is evolved from the SCRM concept; however, Colicchia et al. (2010) and Thun and Hoenig (2011) suggest that the SCRM acts as the enablers to the RSC. No matter what relationship exists between the SCRM and the RSC, the objective of these two phenomenon is to develop a SC that maintains business continuity during the presence of uncertainties and vulnerabilities and recover quickly post disruption with minimum loss and in minimum time (Ambulkar et al., 2015). Further, to reduce the SC risk, SC must be designed to incorporate event readiness, provide an efficient and effective response, and be capable of recovering to their original state or even better post the disruptive event. This is the essence of supply chain resiliency.

1.2. The concept of the resilience in SC

1.2.1. Resilience

The word ‘resilience’ is a Latin word ‘resilio’ which means springing back, rebounding, or recoiling (Ponis and Koronis, 2012). Holing (1973) was among the first few who considered resilience and stability as the two basic requirements for the existence of an ecological system and defined resilience as the ability of the system to absorb the changes and stability as the ability of a system to return to its initial position post disturbances. Westman (1986) further explores the ecological perspective of resilience and provides its five essential components, i.e., elasticity, amplitude, hysteresis, malleability, and Damping. According to Carpenter et al. (2001), resilience has three fundamental properties (i) the amount of change that system can absorb without changing its characteristics, (ii) the degree to which the system is able to reorganize itself without any external aid, and (iii) degree to which system response to the disturbances by learning and adaptation.

Similar to Holing (1973), Timmerman (1981) is among the first few who explores the resilience concept considering the social science paradigm, i.e., social, psychological, and economic

perspectives, and defines resilience as the ability to absorb and recover from the disruptive events (Ponomarov and Holcomb, 2009). The United Nations International Strategy for Disaster Reduction focuses on strengthening the robustness of the structure and function of a system and considers learning and adaptation as the basic characteristics of resilience (United Nations, 2005). The societal view of resilience focuses on learning from the past, reorganizing to develop and improve capability, and adapting to changing conditions. Thus enabling the absorption and recovery from the major disruptions. The psychological perspective of resilience considers it as a developmental capability and is achieved by three principles, i.e., control, connectedness, and coherence of the system objectives (Ponomarov and Holcomb, 2009). It is a system-wide concept that requires the involvement of each level in reducing the risk, learning from the past, and developing the capability.

Considering the economic perspective of resilience, Holling (1993) considers it as a static capability, which enables the system to resist and/or absorb the undesired event, while Ponomarov and Holcomb (2009) consider it a dynamic competency that allows the system to recover from the shock or disruptions. Ross (2004) classifies these two characteristics as inherent, i.e., able to mitigate the disruptions by substituting the distorted elements, and adaptive, i.e., learning and developing quickly to mitigate the disruptions. Considering the societal, psychological, and economic paradigms, Hamel and Valikangas (2003) and Hohenstein et al. (2015) state that resilience is the preparedness against undesired events and represents it as a continuous approach for improvement through realigning resources and learning. Further, to get the benefits of the resilience capabilities in business, experts have derived the organizational perspectives of resilience. In this, researchers focus on improving organizational capabilities through rearranging the available capacities to deal with uncertainties and disruptions. It considers static as well as the dynamic characteristics of resilience altogether to maintain business continuity during the adverse condition, adapt and learn

to bounce back quickly from disruptions, and the developing a culture of learning and adaptability to grow and develop over time (Sutcliffe and Vogus, 2003). Thus organizational resilience comprises flexibility, adaptability, continuity, learning, and recovery ability.

Moreover, Stoltz (2004) considers resilience as the organization's capability to grow in the myriads of uncertainties and have a sustainable competitive advantage compared to other organizations. Resilience also has an engineering perspective, which defines it as the ability of the material to absorb strain energy while deformation when the external force is applied, and release this accumulated energy and return to the initial equilibrium position when force is released. However, the attainment of the equilibrium position is subjected to the condition that deformation occurs within the elastic limit.

Considering the multi-disciplinary nature of resilience, Sheffi (2001) defines it as the capability to store energy and return to its equilibrium position after disruption, while Carpenter et al. (2001) consider resilience as the disturbance-absorbing ability of a system before it achieves any new position or set of controls. Similarly, Walker et al. (2004) define resilience as the adapting and reorganizing capability of the system to cope with the situation. Folke (2006) focuses on the positive reaction against the disruptions, while Garmezy (1973) focuses on the continuous improvement characteristics of the system. Lindell et al. (2007) focus on implementing the resilience concept for emergency management and sustainable growth and provide the different stages of it, which include hazard mitigation, disaster readiness, learning, adequate response, and disaster recovery. Zsidsin and Ritchie (2008) consider it the mitigation strategy that allows the system to keep functioning at the desired level during disturbances and recover quickly after major disruptions. Further, it can be stated that

resilience enables the persistent behavior in a system to absorb the disturbances and maintain the desired level of connectedness among the system entities, thus developing the capability to withstand and adapt the turbulences and discontinuities. In simple terms, resilience can be defined as managing system risk and disruptions to gain a competitive advantage over competitors (Rajesh, 2017). The development of the resilience capacity will help the organizations deal effectively with undesired and unexpected events during highly volatile and uncertain situations and enable them to quickly recover from crises and gain future success (Duchek, 2020).

1.2.2. Resilient Supply Chain (RSC)

The 21st-century global business has been very competitive and derived from the complex set of SC organizations. These SCs are subjected to various risks, uncertainties, and sometimes disastrous disruptions. The impacts of these disruptions are very pronounced and lead to huge financial losses and sometimes complete loss of the business if not addressed at the right time (Chowdhury and Quaddus, 2017). And for the survival and growth of the business in the propensity of adversities, the SC needs to be incorporated with the capabilities that enable them to counter the adversities and capitalize on the events that could potentially harm the firm survival (Duchek, 2020; Lengnick-Hall et al. 2011). Further, the effective mitigation of these hindrances to the SC is found to be insufficient with the traditional risk management approach, thus requiring the development of resilient capabilities in the SC (Chowdhury and Quaddus, 2017; Juttner and Maklan, 2011). The resilience concept in the SC was coined by Christopher and Peck (2004) in their work “Building the resilience supply chain” since then, this concept has been explored widely. According to Christopher and Peck (2004) and Melnyk et al. (2014), RSCs can deal with unanticipated events and disruptions. And

also, in the case of outages, it helps the SCs to return to their initial operational position or a more desirable position. Ponomarov and Holcomb (2009) elaborated the concept of RSC by adding adaptiveness to it and defined RSC as the ability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function. The resilient concept of the SC has gained its characteristic from various fields, such as ecology, psychology, social, etc., (Figure 1.3.)

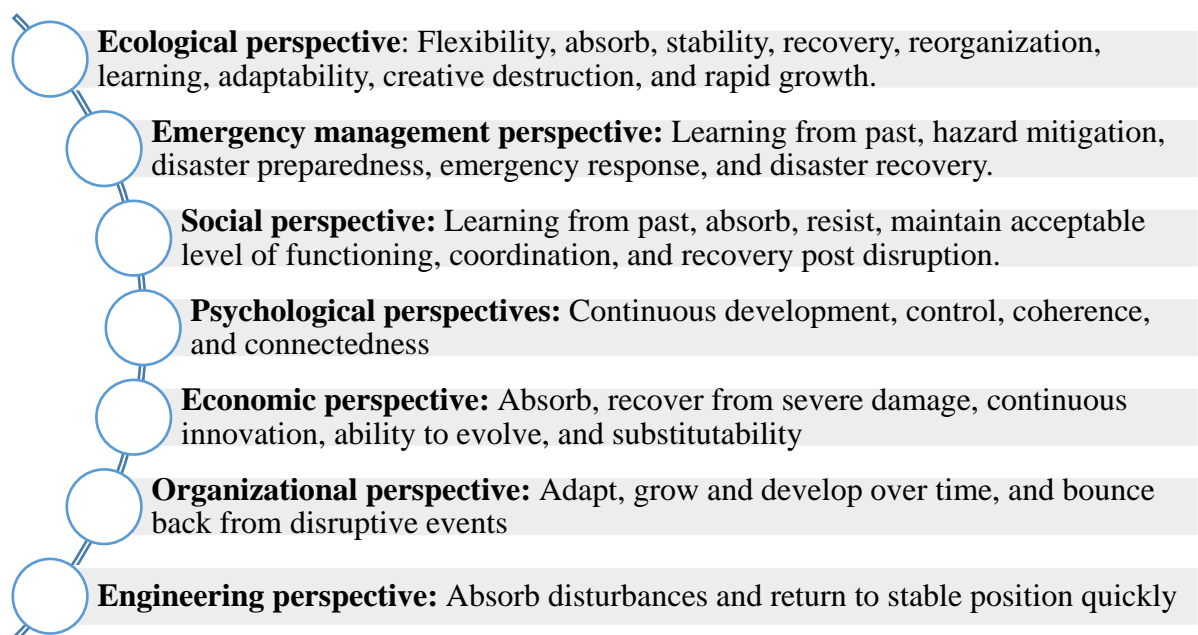


Figure 1.3: Perspectives defining the behavior of the RSC

Building RSC has become the need of the present dynamic and vulnerable business environment, which enables the anticipation and curtailing of the negative effects of the disruption-causing events while minimizing the time required to attain normal business operations (Al-Hakimi et al., 2021). Scholten et al. (2020) consider it as the competitive ability that enables business growth while competitors struggle to recover from the disruptions. Tukamuhabwa et al. (2015) and Sabahi and Parast (2020) consider RSC as the adaptive capability that minimizes the probability, spread, and impact of the

disturbances while maintaining the functionality and control over SC structures. According to Golan et al. (2020), a RSC can adapt the future uncertainty and recover from unknown disruptions. While the National academy of science (NAS) emphasizes the SC's preparedness to absorb, adapt, and recover from undesirable events. The RSC definition given by Christopher and Peck (2004) and Pettit et al. (2010) aligns with the definition given by the NAS. And defines it as the SC's preparedness, responsiveness, and recovery ability that maintains the business continuity. Mancheri et al. (2018) focus on improving the upstream capability to maintain business continuity and give importance to developing alternative suppliers as resilient behavior. Ponomarov and Holcomb (2009) emphasize the SC's ability to absorb and learn from the disruption and grow and gain competitive advantage post disruption.

Supply chain resilience is the capability of the SC to return to its initial state or move to a new and more desirable state after being disturbed (Christopher and Peck, 2004). Sheffi and Rice (2005) consider the adaptive and bouncing back characteristics and define supply chain resilience as the ability to manage the risk while learning from the disturbances/disruptions to be in a better position than the competitor. Svensson (2002) describes supply chain resilience as the vulnerability reduction ability, whereas Jüttner et al. (2003) viewed the SCR as the approach for risk management.

Later on, Jüttner and Maklan (2011) developed an empirical relationship that showed that resilience acquires vulnerability as well as risk management. Some authors have related views for supply chain resilience, such as Rice and Caniato (2003) considered the reaction and restoration properties; Peck (2006) highlighted the disturbance absorbing capability, whereas Datta et al. (2007) considered absorbing, adapting, and responding behavior of the SC. RSC has the ability to be prepared for unexpected

events, responding to and recovering quickly from potential disruptions to return to its original situation or grow by moving to a new, more desirable state to increase customer service, market share, and financial performance” (Hohenstein et al., 2015). Thus taking a cue from above definitions, SCR is defined as “the ability of SC to work efficiently in normal working conditions while learning from the disturbance and adapting to the situation to restore its initial or move to a better position.”

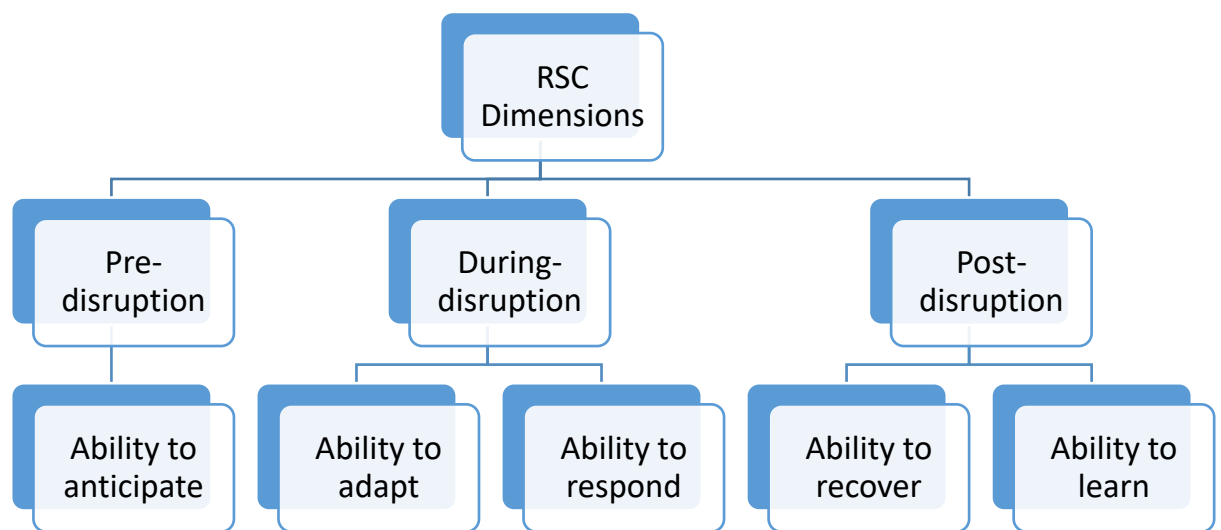


Figure 1.4: RSC and its attribute (Ali et al., 2017)

Further, to reduce the risks and disruption impacts, the SC event readiness needs to be incorporated, which also supports an effective and efficient response against the potential disruptions. It also mitigates the adversities of SC reconfiguration and the implication of other strategies during disruptive events. Ali et al., (2017) had provided a broader view of the RSC and classified the RSC into three phases, i.e., the pre-disruption phase, during-disruption phase, and post-disruption phase. And also subsequently provided the capabilities needed by the SC to evolve during these phases (Figure 1.4). The various definition of RSC available in the literature is provided in Table 1.1. Moreover, considering the various characteristics and capabilities of the

RSC, it can be defined as “the SC which performs efficiently in normal working condition, anticipates and reduce the probability of disruptions, and learn and innovate during disruptions to minimize the disruption impact and to restore its initial position or sometimes to move to a new desirable position.”

1.2.3. RSC capabilities

From the above discussion, it is evident that the characteristics of the RSC are derived from many disciplines, which accounts for its different capabilities. Rajesh (2015) focuses on the three critical areas of the RSC, i.e., the discovery of disruption, recovery from the disruption, and redesigning the SC to enable resilient capabilities. It includes the identification of the SC nodes or extent of SC which is affected by the disruptions and also estimation of the disruption impacts. This further helps in the selection and implication of the resilient strategies, thus enabling quick recovery from the disruption. It also helps in understanding the source of the disruption, factors responsible for the disruptions, and the preventive strategies that can be imparted into the SC to avoid and/or minimize the repetition of disruptions and their impact.

Disruption recovery follows the implication of strategies that tends to minimize the disruption impact, enable the business continuity at desired performance level, and develop the newer capability to gain competitive advantage. Resilience capability is an intrinsic attribute of the SC systems and is nurtured by developing a relevant organizational culture.

Table 1.1: RSC definitions

Authors	RSC Definitions
Barroso et al. (2010)	It is the SC's ability to react to the negative effects caused by disturbances that occur at a given moment to maintain the SC's objectives (Reactive).
Brandon-Jones et al. (2014)	It is defined as the ability of a system to return to its original state, within an acceptable period of time, after being disturbed (Reactive).
Carvalho, Duarte, and Cruz Machado (2011)	It is concerned with the system's ability to return to its original state or to a new more desirable one after experiencing a disturbance and avoiding the occurrence of failure modes (Reactive).
Carvalho et al. (2012)	It is the ability of the SC to cope with unexpected disturbances (Proactive).
Christopher and Peck (2004)	It is the ability of the SC to return to its original state or move to a new, more desirable state after being disturbed (Reactive).
Christopher and Rutherford (2004)	It is the ability of a system to return to its original (or desired) state after being disturbed (Reactive).
Closs and McGarrell (2004)	It is the SC's ability to withstand and recover from an incident (Proactive and reactive).
Datta et al., (2007)	It is not only the ability to maintain control over performance variability in the face of disturbance but also a property of being adaptive and capable of sustained response to sudden and significant shifts in the environment in the form of uncertain demands (Proactive and reactive).
Datta, Christopher, and Allen (2007)	It is the ability of the production–distribution system to meet each customer's demand in terms of time and quantity (Proactive and reactive).
Erol, Sauser, and Mansouri (2010)	It is the responsiveness of the SC to unexpected or unforeseen changes and disturbances and an ability to adapt and respond to such changes (Reactive).
Falasca, Zobel, and Cook (2008)	It is the ability of a SC to reduce the probabilities of a disruption, to reduce the consequences of those disruptions when they occur, and to reduce the time to recover normal performance (Proactive and reactive).
Gaonkar and Viswanadham (2007)	It is the ability of a SC to maintain, resume and restore operations after a disruption (Reactive).

Authors	RSC Definitions
Guoping and Xinqiu (2010)	It is the ability of the SC to return to its original or ideal status under emergency risk environment (Reactive).
Longo and Oren (2008)	It allows the SC to react to internal/external risks and vulnerabilities, quickly recovering an equilibrium state capable of guaranteeing high performance and efficiency levels (Reactive).
Pettit, et al., (2010)	It is the ability to survive, adapt and grow in the face of turbulent change (Reactive).
Ponis and Koronis (2012)	It is the ability to proactively plan and design the SC network for anticipating unexpected disruptive (negative events), respond adaptively to disruptions while maintaining control over structure and function, and transcend to a post-robust state of operations, if possible, a more favorable one than that before the event, thus gaining a competitive advantage (Proactive and Reactive).
Ponomarov and Holcomb (2009)	It is the adaptive capability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function (Proactive and Reactive).
Ponomarov (2012)	It is an adaptive capability of an SC to prepare for and respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than before the disruption (Proactive and Reactive).
Rice and Caniato (2003)	Resilience in the supply network environment is the ability to react to unexpected disruption and restore normal supply network operations (Reactive).
Sheffi (2005)	It is the ability of the company to bounce back from a large disruption, including the speed with which it returns to a normal level of performance (Reactive).
Shuai, Wang, and Zhao (2011)	It is defined as the rapid recovery ability to equilibrium after the SC is attacked by a disturbance (recovery).
Xiao, Yu, and Gong (2012)	It is the SC's ability to return to the original or ideal status after external disruption and includes both the abilities of adaptability to the environment and recovery from the disruption (Reactive).
Yao and Meuriern (2012)	It is the ability of the SC to bounce back from disruptions and to permanently deal with and respond to the changing environment (Reactive)

Authors	RSC Definitions
Ambulkar et al. (2015)	It is the capability of the firm to be alert to, adapt to, and quickly respond to changes brought by a SC Disruption (Reactive).
Tukamuhabwa et al. (2015)	It is the adaptive capability of a SC to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations ideally, a better state than prior to the disruption (Proactive and Reactive).
Hohenstein et al. (2015)	It is the SC's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance (Proactive and Reactive).
Kamalahmadi and Parast (2016)	It is the SC to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plans to transcend the disturbance and restore the SC to a robust state of operations (Proactive and Reactive).
Chowdhury and Quaddus (2016)	It is the SC to prevent disruptions and reduce the impact of disruptions through developing the required level of readiness, quick response and recovery ability (Proactive and reactive).
Liu et al. (2017)	It is the enterprise's ability to identify bottlenecks and potential risks in managing an SC, which allows it to adopt effective measures before an SC is disconnected (Reactive).
Birkie et al. (2017)	It is the adaptive capability of the SC to prepare for unexpected events, and respond and recover from disruptions while sustaining operations (Proactive and Reactive).
Li et al. (2017)	It is the SC's capability to cope with changes, which is formed through being prepared to endure future changes, being alert to changes and being agile in response to changes (Proactive and Reactive).
Rajesh (2017)	It is the Sc capacity to handle impending vulnerabilities and potential disruptions (Reactive).
Datta et al. (2017)	It is a dynamic process of steering the actions so that the organization always stays out of the danger zone, and if a disruptive/uncertain event occurs, resilience implies initiating a very rapid and efficient response to minimize the consequences and maintaining or regaining a dynamically stable state, which allows it to adapt operations to the requirements of the changed environment before the competitors and succeed in the long run (Proactive and Reactive).

Authors	RSC Definitions
Kochan and Nowicki (2018)	It is the ability of the SC to identify, monitor and reduce SC risks and disruptions, but also react quickly and cost-effectively (Proactive and Reactive).
Adobor and McMullen (2018)	It is the capacity of a system to adapt to change and deal with surprise while retaining the system's basic function and structure (Reactive).
Dubey et al. (2019)	It is the property that enables the disrupted SC to recover its normal operating performance, within an acceptable period, after the disrupting forces are withdrawn or disappear (Reactive)
Petit et al. (2019)	It is the capability of a SC to develop the required level of readiness, response, and recovery capability to manage (Reactive).
Chowdhury et al. (2019)	It is the capability of a SC to develop the required level of readiness, response, and recovery capability to manage disruptions risks and get back to the original state or even a better state after disruption (Reactive).
Kaviani et al. (2020)	It is the adapting ability of the system to simultaneously face unpredictable events, address disorders, and solve them, ensuring operational continuity (Reactive).
Mandal (2020)	It is the capability of a SC to withstand the negative consequences of disruptions, adjust and develop in disturbed situations (Reactive).
Rajesh (2020)	It is the ability of a SC system to reduce (i) probabilities of disruptions, (ii) consequences of disruptions if they occur, and (iii) time to recover normal performances (Proactive and Reactive).
Wong et al. (2020)	It is the dynamic capability that enables the SC to adapt effectively, respond, and recover from disruptions and which in turn increases the firm's competitive advantage (Reactive).
Li and Zobel (2020)	It is the capability of a SC to prepare for, respond to and recover from a disruption (Proactive and Reactive).
Agarwal et al. (2020)	It is the ability of two or more SC entities to sustain collectively by co-adapting efforts against possible disruptions (Reactive).
Behzadi et al. (2020)	A resilient SC can quickly return to its original state or even move to a new and more desirable state after being disrupted (Reactive).
Kumar and Anbanandam (2020)	It is the ability of SC "to anticipate, adapt, respond, recover and learn" from disruption events (Proactive and Reactive).

Authors	RSC Definitions
Agarwal and Seth (2021b)	The ability of a SC to resist an upcoming disruption by avoidance, respond to it by decreasing the time between the onset of disruption and the start of the recovery from that disruption and recover till when there is continuity of operations at the desired level of connectedness and control over structure and function (Proactive and Reactive).

Moreover, Rajesh (2020) explores the SCRM tools developed by Faisal et al. (2015) for enabling RSC, i.e., risk identification, risk assessment, risk treatment, and risk monitoring, while Ali et al. (2017) consider anticipation, adaptiveness, responsiveness, recovery, and learning as the five phases of the RSC. This concept is further incorporated by Li et al. (2020) in RSC. It considers the vulnerability and disruption impact estimation as the first step towards RSC development, followed by preparedness and responsiveness. Chowdhury and Quaddus (2016) focus on the SC performance parameters to identify the RSC's dimensions and antecedents. According to Weick and Sutcliffe (2007), anticipation ability enables the SC members to foresee their potential vulnerabilities, undesired and uncontrolled impacts of the disruptions, and the possible resource availability to combat the vulnerabilities and the disturbances. DuHadway et al. (2017) and Radhakrishnan et al. (2018) claim the identification and evaluation of the risk and vulnerability as an initial phase of the RSC and provide a theoretical basis for the selection of the strategies for different stages of the RSC, whereas Rajesh (2020) focuses on prioritization of the SC strategy concerning their ability to mitigate the risk. Teece (2007) focuses on building, developing, integrating, and reconfiguring the firms' internal and external resources and capabilities for adapting to uncertain business environments and the quick restoration/reconfiguration of SC operations. For enabling resilient capabilities, Gligor and Holcomb (2014) focus on integrating and unifying the individual firm's capacity to improve and efficiently and effectively execute the SC activities.

Sheffi and Rice (2005) gave the concept of the 3R, i.e., readiness, responsiveness, and recovery capability. Where readiness signifies the proactive measures that the decision-maker takes against the disruption-causing events and their impacts, it includes minimizing the risk sources, developing alternatives for the critical resources, such as multiple suppliers, make and buy strategy, and strengthening the financial position, etc. Responsiveness is assumed to be an SC reaction against the disturbances, e.g., the quick arrangement of resources to satisfy market demand. The recovery stage enables the SC to achieve its initial or sometimes better working position post disruptive events in the minimum possible time and with minimal cost. Similarly, to understand the responsiveness of the SC, Manuj and Mentzer (2008) and Jüttner and Maklan (2011) used the term velocity as the speed by which SC responds and recovers from disruptions and also advocate its applicability in all three phases of the disruption management, i.e., before, during and after the SC disruption. In recent studies, for e.g., Mancheri et al. (2018) use the term rapidity that focuses on improving the responsiveness of the SC that quickly counter the undesired impact of the uncertain events. It signifies how quickly SC can fulfill market demand during normal and disrupted conditions by developing new capabilities, minimizing the lead time, quickness in decision making and its implementation, and quickness in adaptation and recovery. It is assumed that the higher the rapidity, the higher the resilience capability of the SC (Singh and Singh., 2019; Mandal et al., 2016). Bruneau et al. (2003) explain the RSC's four dimensions, i.e., resourcefulness, robustness, redundancy, and rapidity. Where resourcefulness enables the disturbance absorbing ability in the SC through mobilizing the available resources; robustness empowers the SC to withstand a certain level of SC stress to maintain performance and/or function; redundancy refers to the availability of the alternatives in

the SC; while rapidity focus on quick response to the opportunities and the undesired events to evolve and contain the losses.

Furthermore, Hossieni *et al.* (2019) explores the resilient capabilities of the SCs and define RSC in terms of three resilience capacities, i.e., (i) absorptive capacity, which includes segregating the suppliers, multiple sourcing strategies, and inventory positioning, (ii) adaptive capacity, which comprises freight rerouting, developing backup supplier, and strengthening the communication system (iii) restorative capacity that enables the quick recovery from the major disruptions, it consists of the facility restoration, technological restoration, and the human resource restoration. Hence, based on the above discussion, the RSC can be further characterized by anticipating, preparing, surviving, absorbing, adapting, recovering, growing, and responding quickly to abnormalities. Christopher and Peck (2004) and Aslam *et al.* (2020) focus on the recovery and growing ability of the SC post disruptions. At the same time, Hohenstein *et al.* (2015) and Kumar and Anbanandam (2020) consider the preparedness, responsiveness, and recovery ability to absorb unexpected disturbances and gain competitive advantages post disruptions. Similarly, Sangari and Dashtpeyma (2019) give importance to the responsiveness of the SC, whereas Parast *et al.* (2019) focuses on the SC's reactive and recovery ability against vulnerabilities. However, Tukamuhabwa *et al.* (2015) focus on improving the SC's adaptiveness, quickness, and cost-management ability to achieve better position post disruptions.

Pettit *et al.* (2019) focus on capability improvement as the tool to get rid of vulnerability, while Christopher and Peck (2004) and Ponomarov and Holcomb (2009) highlight the importance of learning new capabilities to combat adversities. Similarly, Rajesh (2020) promotes preparedness to mitigate the risks and the disruption impacts,

whereas, Sheffi and Rice (2005) emphasize the disruption absorbing and recovery capability. Development of the anticipation and the preparedness ability to respond and adapt to unexpected events is a better resilience tool to make RSC (Ponis and Koronis, 2012), while Ivanov and Sokolov (2013) give importance to the continuity capability to maintain or achieve the planned position during and after the disruption. Govindan et al. (2016) focus on controlling the structure and functionality during and post-disruption to transcend the disturbances and restore the SC to a robust state of operations. Ivanov and Dolgui (2020b) explain the intertwined supply networks' that combine present advanced technology with the classical risk management approach to deal with the SC's RVDs. According to Golan et al. (2020), achieving a RSC requires significant improvement in the planning, absorbing, recovery, and adaptive capability of the SC is needed. At the same time, Rowen and Laffey (2020) emphasize contingency planning to fight against the non-availability and delay in SC. Similarly, Singh and Singh (2019) focus on improving the information technology infrastructure capabilities (ITICs). Ivanov and Dolgui (2020a) consider the adaptation and recovery ability as the two main capabilities of the RSC to attain desired performance level post disruption. However, Fiksel (2013) names adaptability, efficiency, cohesion, and adversity as the characteristics of the RSC. Adaptive capability of the system refers to the ability to respond to changes in the external environment and to recover from the damage to internal structures within the system affecting the capability to achieve its purpose (Wu et al., 2013).

Considering the similarity among the RSC characteristics, the researcher classifies them into different capabilities. Such as Biringer et al. (2013) and Hosseini et al. (2019) classify them into absorptive, restorative, and adaptive capability based on their applicability before, after, and during the disruption, respectively, and business

performance; Chowdhury and Quaddus (2016) and Radhakrishnan et al. (2018) classify them into readiness, robustness, and recovery. Chen et al. (2019) consider disruption discovery and disruption recovery as the facet of the RSC. Disruption discovery includes improved visibility, information analysis, initial decision, etc., whereas disruption recovery includes technical recovery, capacity recovery, operations recovery, learning, and SC redesign (Ruiz-Benítez et al., 2018). Further, Ribeiro and Barbosa-Povoa (2018) classify the RSC into readiness, responsiveness, recovery, and growth capabilities. Sheffi and Rice (2005) consider quickness as an antecedent to responsiveness and recovery, whereas Longo and Oren (2008) consider quickness as a different capability of the RSC. Annarelli et al. (2020) derive four capabilities of the RSC – robustness, redundancy, resourcefulness, and rapidity. Belhadi (2021) segregates the RSC capabilities as proactive and reactive, such that SC that are able to plan and develop the capability to counter any possible uncertainty or disruptions are called proactive capability of the SC. Similarly, the ability of the SC to develop the capability to minimize the disruption impact and recover quickly post disruption is called reactive capability. Further, based on the characteristics, the researchers define the RSC into different capabilities and phases. Such as Biringer et al. (2013) categorize RSC capability into absorptive, adaptive, and restorative capacity; Kamalahmadi and Parast (2015) divide them into anticipative, resistive, and recovery ability; Ali et al. (2017) divide them into disruption (prepare, resist, avoid, alert), during disruption (respond, cope, and adapt) and post-disruption (recover, survive, restore and return) phases, respectively. Accordingly, Hohenstein et al. (2015) elaborated on the concept given by Juttner and Maklan (2011), Datta et al. (2007); Sheffi and Rice (2005), etc. and characterized the RSC into four phases, i.e., readiness, response, recovery and growth and classify the capabilities into proactive and reactive strategies. Considering the

above discussion the RSC can be proposed as the combination of four resilient capabilities, i.e., readiness, robustness, recovery and growth, and rapidity.

1.2.4. RSC practices

To enable these capabilities to the SC, the researchers provided several strategies and managerial practices. However, these strategies and the practices are given different names by the researchers, such as dimensions (Aigbogun et al., 2014), enablers (Jain et al., 2017; Patel et al., 2021b), enhancers (Blackhurst et al., 2011), capabilities (Craighead et al., 2007), factors (Hosseini et al., 2019), elements (Ali et al., 2017), antecedents (Scholten et al. 2014), principles (Christopher and Peck, 2004), competencies (Wieland, 2013), strategy (Rajesh, 2020), etc. However, to have the consistency of the terminology and also consider the commonality of these enabling entities, it is expressed as the practices of the RSC, such that implementation of these practices enables the resilient capabilities of the SC. Further, past research suggests that the implementation of these resilient practices leads to business continuity during disruptive events and also improves the business performance and competitive gain during normal as well as disruptions. However, some of the recent findings suggest that whatsoever resilient practices are implemented, the SCs tumbled down unexpectedly during adversities, thus suggesting the presence of the factors inhibiting the implementation of the resilient practices (Agarwal and Seth, 2021b; Ali et al., 2017; Rajesh, 2018). These inhibiting factors are called barriers to the RSC.

Apart from its large number of capabilities, the proactive and business continuity approach followed by the RSC is observed to complement the traditional risk management approach. To enable the resilience ability, Geary et al. (2002) give importance to the SC integration extending to the customer to mitigate the uncertainties

associated with the SC process, customer demand, and supply. In comparison, Christopher and Lee (2001) give importance to transparency and the common SC goal, with equal opportunity and accessibility of the information related to inventory position, market demand, capacities, backlogs, etc. RSC focuses on improving the SC's responsiveness against turbulence and discontinuities and develops the capabilities to withstand the disruptions and adapt with varying business conditions. Flexibility in the SC adjusts to the changing working conditions and the stakeholders with the minimum effort and time (Hosseini et al., 2019; Lahyani et al., 2021). Christopher and Holweg (2011) describe flexibility as the rapid adaptability to handle unexpected SC and related events within and outside the business environment. It comprises labor flexibility, sourcing flexibility, production flexibility, logistics flexibility, multi-skilled human resources, etc. (Neubauer, 2018; Hosseini et al., 2019). The flexibility of the SC enables the absorption of the Short term disruptions and is achieved by building trust among the members of the SC. Trust enables the smooth flow of information, thus improving collaboration. Chowdhury and Quaddus (2016) focus on enhancing the information available across the SC, thus promoting the information and generation and sharing as the essential practice. It plays an important role in curtaining the RVDs, improving the SC competency to minimize the disruption impact, and quick recovery post disruptions. The availability of information improves the SC preparedness against risk and uncertainties and enables quick recovery from failures. Information sharing is considered to be the pre-requisite for visibility, collaboration, risk and reward sharing, product postponement, etc.

Developing the redundant resources and capacities across the SC has been among the traditional risk mitigation approach, which is still relevant and feasible in the present business scenario filled with cut-throat competition and uncertainty in business

operations. It is defined as the development of the excess capacity in the SC that tackles and absorbs the variability and disruption impact (Hosseini et al., 2019; Neubauer et al., 2018; Wu et al., 2013; Ali et al., 2017). It enables the SC continuity during uncertainties and improves competency in the normal business environment. It includes safety stock, multiple suppliers, capacity buffer, energy backups, etc. Sá et al. (2019) argue that redundancy is the idle capacity usable during disruptions and thus improves the robustness of the SC.

Further, information sharing and collaboration among the SC seem complementary and are supported by trust-based relationships. The presence of trust-based relationships, collaboration, information sharing, etc., improves the flexibility of the SC. Agility, also known as the SC's response capability, leads to a quick reaction against opportunities and disruptions (Wieland, 2013; Patel et al., 2020a). It minimizes the uncertainty, moderates the impact of the disruptions, gains the advantage from the available opportunities, and develops the ability to respond the adversities. It enables the mitigation strategy's effective implementation during the risk event or potential disruptions (Carvalho et al., 2012). Dubey et al. (2019) and Hosseini et al. (2019) consider the SC network structure as an enabler to agility and consider it as the ability to fulfill the dynamic customer requirement. Wu et al. (2013) claim the importance of SC visibility during adversities and advocates that it minimizes over-reaction, ineffective decision, and unnecessary interventions during uncertain events. It acts as the warning signal before any major disturbances. It thus provides valuable time to align the available resources and capabilities to avoid or minimize the impact of the disruption (Ali et al., 2017). It realizes the inventories, supply and demand position, technological advancement, competitor performance, purchase schedules, etc., across the SC (Ambulkar et al., 2015; Radhakrishnan et al., 2018; Jain et al., 2017). Francis

(2008) explains visibility in terms of – the identity, location, schedule, and status of entities transiting the SC. It ensures effective decision-making and serves as the warning signal, ultimately informing firms to align their capabilities to minimize the disruption impacts through proactive steps (Stecke and Kumar, 2009; Ali et al., 2017).

Collaboration has proven to be the ability of the SC to plan and execute the SC operations together through sharing capabilities and resources (Scholten and Schilder, 2015; Hosseini et al., 2019). It reduces the probability of disruption and prevents and minimizes the propagation of the disruptions' negative impact. Moreover, collaborative decision-making improves the risk and reward sharing and minimizes the opportunistic behavior of the SC members. Collaboration among the SC members has been enhanced by the voluntary inter-industry commerce standards (VICS) through collaborative planning, forecasting, and replenishment (CPFR). Rajesh (2019) explains a number of the cooperative schemes of the SC, such as vendor-managed inventory (VMI) and co-managed inventory (CMI), efficient consumer response (ECR), quick response (QR), just in time (JIT), collaborative planning, forecasting and replenishment (*CPFR*) and *collaborative transportation management (CTM)*. Practicing the strategic outsourcing approach allows the SC to absorb the supply deviation, variability in demand, and the production process. It enables flexibility in the SC and supports the timely fulfillment of customer demand during uncertainty. SC re-engineering is an important resilient practice post disruption of the SC. It is the prime responsibility of the planning team to re-align the SC structure to resume operations at the desired level of connectedness and control. It focuses on developing new suppliers, entering the new market, practicing the new product development approach, etc. Giunipero and Eltantawy (2004) give importance to improving efficiency and consider it an essential trait of the RSC.

To enable the absorption of the downstream uncertainty, researchers, e.g., Barroso et al. (2011) and Rajesh (2020), has considered the silent product rollover strategy. It fulfills two specific purposes. First, it substitutes the existing product whose production process has been disrupted, and second, it enables competitive gain by developing the new product. It manages the stock-outs without harming the firm goodwill in the customers and the stakeholders' eyes and provides a competitive advantage (Ye et al., 2020). Further, it improves the SC adaptability to mitigate vulnerability and disruptions. Improving the firm's operational and financial performance. Dubey et al. (2015) consider adaptability as the tool to deal with stochastic events, whereas Eckstein et al. (2015) consider it the tool to improve the firm's operational and financial performance. Adaptability is defined as the SC's ability to modify the facilities, capacities, and operations to adapt to challenges and opportunities. The success of adaptability depends upon the decisions made during normal and stressful situations (Neubauer, 2018; Radhakrishnan et al., 2018).

According to Chowdhury and Quaddus (2017) and Hosseini et al. (2019), developing the financial reserves improves the SC's dynamic capability that acts as a cushion against cash flow variability. It is the ability of the firm to hold sufficient financial reserves and liquidity to mitigate and absorb the disruption events (Radhakrishnan et al., 2017; Neubauer, 2018). Further, Randall and Farris (2009) focus on implementing financial techniques to minimize the cost incurred in the SC. To improve the resilience capability of the SC, Blome et al. (2014) and Tang (2008) focus on the voluntarily sharing capacities and the benefits with the SC members. It improves the risk mitigation and disruption recovery capability of the SC. Jain et al. (2017) and Soni et al. (2014) consider it as the prerequisite for the risk-sharing among the SC members, while Narayan and Raman (2004) consider it as the SC capacity improvement tool and

Pakdeechoho and Sukhotu (2018) consider it as the first step towards the sustainability into the SC.

Moreover, intentionally delaying the SC activities will lead to the absorption of supply and demand uncertainty and provide space for the reorganization of the SC against disruptions. This SC process is known as the postponement strategy (Yang et al., 2004). It also enables to cope with the variability in frequency and magnitude of the quantity and the timing of the shipment along with the capacity management through strategic positioning of the decoupling point of the customer's order (Ashayeri and Selen, 2005). It allows mass customization through modular designing, standardization, and real-time information sharing (Yeung et al., 2007). The continuous approach of identifying the potential RVDs and their corresponding mitigating strategies are also proven practices that enable the SC's robustness. It promotes every member of the SC to embrace the risk minimization approach and starts with the commitment of the SC firm's top management (Christopher and Peck, 2004; Kamalahmadi and Parast, 2016). It includes the employee's training for risk-sensitive culture and mindset, crisis management team, risk and reward sharing, etc. (Hohenstein et al., 2015; Williams et al., 2009). This combined proactive approach to risk discovery and minimization is called the SC risk management culture.

Blackburn and Scudder (2003) target the demand-based pricing strategy for a specified period to maximize the profit, manage the demand variability, and gain a competitive advantage. It mitigates the vulnerability associated with the product demand depending on time and price and has varying product development and holding cost. In the presence of other resilient strategies, this dynamic pricing strategy serves as the superior strategy in case of uncertainty and fierce competition (Jia and Hu, 2011; Zhang et al.,

2020). Offering the optimal set of products to the customers at different times will enable the SC managers to control the uncertainty of supply and demand. Mantrala et al. (2009) define it as the assortment planning at the storage level and provide the three aspects of it, i.e., variety of products, depth of the products, and the service level or inventory position to be allocated. Further, Tang (2006) and Tukamuhabwa et al. (2015) argue that it absorbs disruptions and helps firms gain market share and brand loyalty. It also improves inventory management through substitution and influencing customer preferences (Mahajan and Van Ryzin, 2001).

Developing the inventories at the strategic locations for the critical items will enable the SC to absorb the short-term supply disruptions and thus lead to business continuity (Jain et al., 2017). The strategic locations can be the shared distribution centers, logistic hubs, and third-party warehouses. It is often used as a strategy to absorb the demand and supply fluctuations, reduce the inventory cost, and improve customer service (Puga et al., 2009; Kumar et al., 2015). Funaki (2012) considers strategic stocking a tool to mitigate uncertainty in demand quantity as well as the due date, while Kumar and Aouam (2019) consider it to optimize production capacity and absorb the variability in service or lead time. Moreover, Efficient and effective warehouse and inventory management empower the SC to absorb the variability in supply and demand and gain a competitive advantage (Ambulkar et al., 2015; Alawneh and Zhang, 2018; Razavian et al., 2021). It is achieved by developing the infrastructure that facilitates information sharing and control over the lead time and other facilities. Further, it absorbs the uncertainty in supply, demand, price, and production, thus improving customer service (Sheffi and Rice, 2005). Taking a cue from nature that change is inevitable, SC needs to be upgraded in anticipation of gaining opportunities and developing new capabilities. It includes redesigning the business processes, adopting the new technology, choosing the

new supplier, distribution centers, logistics, etc. Ponomarov and Holcomb (2009) consider it as the proactive and capability development approach, whereas Monostori (2020) considers it a tool for creating sustainability. It is among the most widely used post-disruption strategies that enable quick recovery and gaining market cover.

The ability to perceive better and quickly the customer's preferences and the market trends are proven to be an effective tool to improve SC responsiveness (Abimbola and Khan, 2019). It is broadly known as market sensitivity. This approach work with the actual demand rather than forecasting based on past sales. It promotes quick decision deployment, minimizes product development cycle time, and enables product postponement based on customer demand. The success of the new product, sales, and profitability is highly dependent on market sensitivity governed by collaboration, information sharing, risk and revenue sharing, agility, etc. (Ateke et al., 2017; Patel et al., 2017; Faisal, 2005). The SC having scope for aligning the new members with specific capacity improves the overall resilience capability. Moreover, the short-term goal-oriented virtual integration of the organizations having different capabilities enhances the SC's desired capability or overall resilience capability (Huang et al., 2013; Samdantsoodol et al., 2017). It is the retailers, manufacturers, suppliers, and other service providers' strategic alliance to optimize and brings competency to the SC (Matsuda et al., 2019). It also enables goal-oriented short-term collaboration.

Ponomarov and Holcomb (2009) mentioned that firms could adopt a combination of SC practices differently and dynamically to ensure resilience in uncertain and complex circumstances. From the literature, it is evident that many researchers are focused on analyzing the set of resilient practices rather than an individual for enabling the RSC. Christopher and Peck (2004) are among the first few who explain the practices enabling

the resilient characteristics of the SC and consider a group of practices that need to be followed by the SC members to enable resilient capabilities in the SC. It includes understanding the SC structure, adequate number of suppliers, collaboration among the SC members, agility in SC operations, flexibility in crucial components of the SC, and the culture of risk management across the SC. Further, Ponis and Koronis (2012) explore the RSC concept and suggest that agility, collaboration, velocity, flexibility, resource availability, visibility, redundancy, and knowledge of SC structure are the primary antecedents of the RSC. Tukamuhabwa et al. (2015) emphasize increased flexibility, developing redundancy, enabling collaborative SC relationships, and enhancing agility as the tool to enhance the resilience of a SC. Rajesh (2017a) focuses on improving the dynamic integration of the SC as a strategy for RSC and considers it an enabler for control, coherence, and connectedness of the SC during major disruptions. Moreover, the author also emphasizes perseverance, motivation, optimism, and flexibility as essential characteristics of the RSC. In the view of Ponomarov and Holcomb (2009), risk sharing among the SC members is obtained to be having a positive influence on the resilience capability, and also it promotes intuitive participation in risk reduction and disruption recovery. Rajesh (2020) explains the importance of risk sharing for SC flexibility, collaborative capabilities, and visibility. Lavastre et al. (2012) give preference to the built-to-order, centralization of the inventory management, product standardization, and postponement as the primary strategies of the RSC. The practices explored by the researcher over time are provided in Table (1.2).

1.2.5. Barriers to the RSC

Ever since the development of the RSC and its practical implementation into the SCs, many time, it has been observed that the SCs are unable to resist, absorbs, or recover from the disturbances, and they tumble down, causing huge business and social losses (Agarwal and Seth, 2021a; Ali et al., 2017; Rajesh, 2018). This inability of the RSC indicates the presence of some inhibiting factors, which act as barriers to the successful implementation and execution of resilient practices. These inhibiting factors are named as the barriers of the RSC (Ali et al., 2017). Further, considering the force field theory, for the survival, adaptation, and growth of the SCs, the magnitude and impact of the driving force (RSC practices) should be more than that of the inhibiting factors (Agarwal and Seth, 2021a). Thus, identifying and analyzing the resilient practice (driving forces) and the inhibiting factors (resisting forces) help the SCs overcome vulnerabilities and the disruption impacts, thus gaining competitive success both before and after the disruptive events. Further, from the literature, it is evident that these inhibiting factors are inherited in the SCs in the form of poor network, lack of organizational commitment, poor cooperation among members, etc., which need to be identified and evaluated.

Further, from the earlier research, it has been evident that how stressful implications is adopted to develop a RSC, the businesses get affected in the midst of the adversities (e.g., COVID-19, Suez Canal obstruction, etc.). The failures of the RSC amid the adversities suggest the presence of some inhibiting factors called barriers (Ali et al., 2017; Agarwal and Seth, 2021a).

Table 1.2: Resilient practices of the SC

Author(s)	Resilient practices	Research method	Industry and country setting
Christopher and Peck (2004)	SC re-engineering, SC understanding, supply base strategy, SC design principles, SC collaboration, collaborative planning, SC intelligence, Agility, visibility, velocity, Risk mitigation culture- top management commitment, and SC continuity teams.	Conceptual framework	General SC (UK)
Tang (2006)	Postponement, strategic stock, Flexible supply base, make and buy strategy, economic supply incentives, flexible transportation, revenue management, dynamic assortment planning, silent product rollover.	Theoretical framework	General SC
Juttner and Maklan (2011)	Flexibility, velocity, visibility, collaboration, sharing risk, redundant resources, knowledge management	SEM	General SC
Fakoor et al. (2013)	Adaptability, effectiveness, recovery, supply flexibility, flexibility in order fulfillment, production technology development, collaboration, human resources, dispersion, security	Fuzzy logic approach	Automobile (Iran)
Pettit et al. (2013)	Flexibility, efficiency, capacity, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security, financial strength	Theoretical framework	General SC
Kumar et al. (2013)	Supplier audit, strategic stock, postponement, location hedging, multisource, make and buy, transportation management, assortment planning, and price and promotion planning.	Conceptual framework	Pet product (Canada)

Author(s)	Resilient practices	Research method	Industry and country setting
Soni et al. (2014)	Sustainability, risk and revenue sharing, trust, visibility, risk management culture, Adaptive capability, SC structure	ISM and Graph theory	General SC (India)
Scholten et al. (2014)	Mitigation: collaboration, SC re-engineering, risk awareness, knowledge management; Preparedness: collaboration, knowledge management; Response: collaboration, agility, information sharing; Recovery: risk awareness, post-disruption knowledge management, and collaboration	Conceptual framework	General SC
Sahu et al. (2017)	SC re-engineering, SC collaboration, risk management culture, agility	Fuzzy based approach	Automotive (India)
Mandal et al. (2016)	Integrated logistics capabilities, collaboration, visibility, flexibility, and velocity	SEM	General SC (India)
Kamlahmadi and Parast (2016)	Agility, visibility, velocity, visibility, SCRM culture, innovation, flexibility, redundancy, trust, information sharing, visibility, leadership	Literature review	General SC
Chowdhury and Quaddus (2016)	SC orientation, SC risk management culture, learning and development, disaster preparation, flexibility, redundancy, visibility, collaboration	SEM	Apparel (Bangladesh)
Hosseini and Khaled (2016)	Backup supplier, surplus inventory, reliability of supplier, rerouting, raw material replacement.	Hybrid ensemble and AHP	Agriculture (Korea)

Author(s)	Resilient practices	Research method	Industry and country setting
Jain et al. (2017)	Adaptive capability, collaboration, trust, sustainability, risk and revenue sharing, information sharing, SC structure, market sensitiveness, agility, visibility, culture, technology capability, minimizing uncertainty	SEM	General SC (India)
Pramanik et al. (2017)	Surplus capacity and responsiveness	AHP, TOPSIS, QFD	Automobile (Iran)
Ali et al. (2017)	Proactive-anticipate-situation awareness, robustness, increasing visibility, building security, pre disruption knowledge management; Concurrent-adapt-flexibility, redundancy, concurrent respond, collaboration, agility; Reactive: recovery, contingency planning, market position, reactive-learn- social capital, and post disruption knowledge management	Systematic literature review	General SC (India)
Li et al. (2017)	Reconfigure SC, adaptability, adjust SC process, streamline SC process	SEM	General SC
Rajesh (2017 a)	SC redesign, supply flexibility, collaboration, postponement, standardization, capacity improvement, inventory, product rollover, pricing, and planning capabilities,	TISM	Electronics manufacturing (India)
Rajesh (2017 b)	Quality, cost, flexibility, velocity, visibility, vulnerability, collaboration, awareness, continuity management, technological capability, research and development, safety, and environmental concern	Grey analysis approach	Electronics SC (India)

Author(s)	Resilient practices	Research method	Industry and country setting
Jain et al. (2017)	Adaptive capability, Collaboration, Trust, Sustainability, Risk and revenue sharing, Information sharing, SC structure, Market sensitiveness, SC agility, SC visibility, Risk management culture, Minimising uncertainty, Technological capability among partners	ISM and SEM	General SC
Birkie et al. (2017)	Quality; cost; return on asset; cost on re-work; speed; flexibility and dependability	SEM	General SC
Ali et al. (2017)	Situation awareness, robustness, visibility, security, knowledge management, flexibility, redundancy, collaboration, contingency, agility, market position, building social capital	Theoretical framework	General SC
Ivanov et al. (2017)	Risk mitigation inventory, capacity flexibility, backup facilities and the channels, stability, visibility, resource allocation priorities, SC reconfiguration, and inventory	Literature review	General SC
Brusset and Teller (2017)	Flexibility, external and integration capabilities	SEM	General SC (France)
Radhakrishnan et al. (2018)	Flexibility, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security, financial strength	Literature review	General SC
Adobor and McMullen (2018)	Readiness- contingency planning, control-oriented approaches, efficiency; Response-adaptation, flexibility, redundancy, self-organization; Recovery, growth and renewal-collaboration, social capital, inter-firm trust, leadership, system learning	Conceptual framework	General SC (North America)

Author(s)	Resilient practices	Research method	Industry and country setting
Namdar et al. (2018)	Single and multiple sourcing, backup supplier contracts, spot purchasing, collaboration, and visibility.	Mathematical modeling	Hypothetical SC
Macdonald et al. (2018)	Inter arrival time, buffer stock, SC connectivity	Simulation Study	General SC
Margolis et al. (2018)	SC network, cost, SC connectivity	Mathematical modeling	General SC
Ramezankhani et al. (2018)	Operational cost, ordering cost, transportation cost, defective rate, energy consumption, water usage, green technology, training, injury, job security, customer satisfaction, research and development.	QFD, DEMATEL and DEA	Automotive (Iran)
Rajesh (2019)	Flexibility, risk management culture, agility, responsiveness, collaboration and control, and risk assessment	Fuzzy logic approach	Electronics manufacturing (India)
Sangari and Dashtpeyma (2019)	Flexibility, velocity, visibility, information sharing, adaptability, robustness, adaptability, commitment, leadership, innovation, integration, collaboration	ISM and ANP	General SC (Iran)
Ali and Golgeci (2019)	Preparedness: flexibility, collaboration, redundancy, culture, information sharing, innovation, top management support, co-opetition, industry 4.0; Resistance: visibility, robustness, agility, velocity; Rebound: resource configuration/mobilization, adaptation, disruption mitigation, SC re-design, additive manufacturing	Systematic literature review	General SC

Author(s)	Resilient practices	Research method	Industry and country setting
Dubey et al. (2019)	Data analytics capability and organizational flexibility	SEM	General manufacturing (India)
Mackay et al. (2019)	Insurance, redundancy, flexibility, expediting, reconfiguration, and strategic adaptive capability	Theoretical framework	General SC
Chen et al. (2019)	Visibility, initial information analysis, initial decision, preventive plans and stabilization	Theoretical framework	ICT industry (China)
Chen et al. (2019)	Disruption discovery: Improved visibility, initial information analysis, initial decision; Recovery from disruptions: preventive plans, information management tools, pilot production and stabilization, collaboration, coordination, crisis team, standard of procedure, learning and SC-redesign.	Conceptual framework	Information and communication technology (Taiwan)
Kaviani et al. (2020)	Flexibility in order fulfillment, capacity, efficiency, visibility, adaptability, recovery, dispersion, market position	Conceptual framework	Automotive (Iran)
Agarwal and Seth (2020)	Collaboration, information sharing, backup supplier, business intelligence system, information tracking, reserve capacity of machinery, logistics flexibility, contract flexibility, production flexibility, sourcing flexibility, multi-skilled workforce, and quick action.	Graph theoretic approach	Indian automobile

Author(s)	Resilient practices	Research method	Industry and country setting
Piprani et al. (2020)	Readiness: situational awareness, visibility, robustness, security, SC risk management, pre-disruption knowledge management; Responsiveness: flexibility, redundancy, collaboration, agility; Recovery: contingency planning, market position, social capital, post-disruption knowledge management	AHP	Textile (Pakistan)
Giancotti and Mauro (2020)	Resistance: coordination, building partnership, knowledge management, business continuity planning, resource availability, absorption; Continuity: flexibility, organizational ambidexterity, employee involvement, visibility, tolerance; Restoration: knowledge management, adaptation; Recovery: organizational change capabilities, development of new norms, values and practices	Systematic literature review	General SC
Fattahi et al. (2020)	Recovery time, performance loss, the capacity of the distribution center, inventory decisions, allocations decision	Mathematical modeling	General SC (Iran)
Wong et al. (2020)	Quickness, ability to maintain the desired level of connectedness, ability to maintain the desired level of control, knowledge to recover from disruptions and unexpected events	SEM	General SC
Piprani et al. (2020)	Situational awareness, visibility, robustness, security, SC risk management, pre-disruption knowledge management, flexibility, redundancy, collaboration, agility, contingency planning, market position, building social capital, post disruption knowledge management	Multi-criteria decision making	Textile (Pakistan)

Author(s)	Resilient practices	Research method	Industry and country setting
Gölgeci and Kuivalainen (2020)	Social capital, absorptive capacity, and marketing-SCM alignment	SEM	General SC (Turkey)
Aslam et al. (2020)	Agility, adaptability, and alignment	SEM	Manufacturing SC (Pakistan)
Mackay et al. (2020)	Insurance, expedited, redundancy, strategic capability, flexibility, adaptive	Theoretical framework	General SC
Kumar and Anbanandam (2020)	Risk management culture, collaborative capabilities, flexible contracts, risk awareness, security, and information sharing	SAP-LAP analysis	Automobile (India)
Asghar et al. (2021)	Knowledge sharing, corporate training, managerial competence, IT competency, Managers resilience	SEM	General SC (Pakistan)
Khurana et al. (2021)	Economic, trade and commerce, IT preparedness, roles of governance, SC and logistics, industry protocol, environmental issues, capacity building, and organizational culture	Multi-criteria decision making	Micro, Small and Medium-scale Enterprise
El-Baz and Ruel (2021)	Risk identification, risk assessment, risk mitigation, and risk control	SEM	General SC (France)
Sharma et al. (2021)	Collaboration, flexibility, visibility, governance structure, adoption of digital technology, emergency stock, information sharing, reducing product complexity, product delivery flexibility, SC redesigning, operational and dynamic capability, and external sources.	Best worst method (BWM)	Retail (India)

Author(s)	Resilient practices	Research method	Industry and country setting
Hsu et al. (2021)	Management: resource reconfiguration, leadership, risk emergency mechanism, multiple supplier source; Relationship: risk monitoring and responsibility sharing, communication and cooperation with customers and suppliers; Enterprise culture: non-hierarchical communication, trust and accountability, self-discipline; System information system integration, cross-functional training, information sharing; Logistics: adequate buffer stock, optimize transportation modes and routes	QFD	Fashion SC (China)

These barriers inhibit the success of the RSC by mitigating the successful implementation of the resilient strategies. Further, according to the force field theory, the system's existence is possible only when the forces driving it are more than the forces resisting it. Thus, the identification and the analysis of the barriers of the RSCs are equally as important as the identification and the implementation of the enablers which obstructs and absorb the disruptions (Rajesh, 2018).

Pareira et al. (2014) are among the first few researchers who consider the identification of the barriers as a key to the success of RSC and identifies the key barriers, i.e., poor financial strength, inadequate capacity, poor collaboration, lack of flexibility, poor visibility, inadequate knowledge, poor information sharing, lack of trust, inadequate coordination and control, longer lead time, etc. Moreover, Ali et al. (2017) classify the RSC barrier into internal and external barriers and precisely explain the significance and consequences of the organizational financial constraints, poor information sharing, and

poor managerial commitment. A similar study is also carried out by Halkos et al. (2018) in the context of small and medium enterprises in Greece and explains the importance of resource availability, organizational culture, market vulnerability, support among the SC members, etc. Rajesh (2018) has brought about the most elaborated research and explains the thirty possible barriers to the RSCs in the electronic manufacturing SC.

Further, the author has classified these barriers into four clusters: barriers related to humans and their judgment, barriers related to the assets and system, barriers related to the operations, and the barriers related to the sourcing. In continuation to the above discussion, Agarwal and Seth (2021a) focused on identifying and analyzing the most influencing barriers inhibiting the successful implementation of resilient characteristics to the automobile manufacturing SC. Here, the author has briefly discussed the causal dependence relationships among the barriers, which include lack of managerial commitment, poor relations with suppliers, inadequate forecasting, poor information sharing, lack of flexibility, inability to change and innovation, infrastructural inadequacy, inadequate trading partner's capabilities, and un-availability of the multitasking workforce. Moreover, Gorane and Kant (2014), Khullar et al. (2020), etc. have considered the poor financial health of the SC members as the impactful barrier, whereas Rajesh (2019) and Yinan *et al.* (2014) have considered the centralization of the assets as the critical barrier. Giunipero and Eltantawy (2004) focus on improving the response of the SC members during and after the disruptions, while Blackhurst et al. (2005) and Eriksson and McConnell (2011) focused on improving the contingent resources to minimize the disruption impacts. Moreover, according to Yinan *et al.* (2014) and Govindan *et al.* (2013), centralization of the SC activities also acts as a barrier to the RSC, e.g., centralized planning and decision making, single production and distribution facilities, centralized quality control process, etc., is causing to the

delay and sometime breakdown of the SC. Further, the continuous approach for the lean SC caused the eradication of all those resources and capabilities that guard the SC against uncertainties and disruptions, e.g., minimizing redundant capabilities and lead time, single sourcing and dedicated freight service, etc., will act as the inhibitors for the RSC (Pettit et al., 2013). Analyzing the cause and effect relationships among the barriers will enable the SC practitioners to understand the most influencing barriers, which further helps in selecting the strategies to minimize their ill effects. Rajesh (2018) suggests that identifying, analyzing, and evaluating the barriers of the RSC will reduce the vulnerability, thus enabling the robustness of the SC. Understanding the causal dependence relationships between the RSC barriers will help to improve the successful implementation of resilient practices.

Thus, from the above discussion, it is apparent that the RSC is a network-wide concept whose success depends upon the three parameters, i.e., understanding of resilient capabilities, identifying the resilient practices leading to the resilient capabilities, and the identification and analysis of the barriers that inhibit the successful implementation of the resilient practices. And also, the literature suggests that there exists enormous research regarding the development of resilient capabilities and their allied practices. However, very little research focuses on identifying and evaluating the inhibiting factors of the RSC. Further, in the literature survey, very few studies are focused on quantifying the causal dependence relation among the barriers of the RSC. Implementing the fuzzy logic to minimize the expert's perception ambiguities will add value to our research. Moreover, identification and analysis of the RSC barrier in the context of the iron and steel industry post the first phase of the COVID-19 pandemic is the need of a developing nation like India. Because, in the present economic condition, the Indian manufacturing sector has proved its presence in the global market and is

among the most trustable partner to many developing and developed nations. According to a report published by the Ministry of Steel (Government of India) in 2020, India is the world's second-largest steel producer next to china. As per the report published by the Ministry of Steel, Government of India, "development of Indian steel sector since 2010-11", the production and consumption of steel is continuously increasing post-economic liberalization. E.g., in the financial year 2010-11, total finished steel production was 68.621 MT, and in 2017-18 it reached 126.855 MT. Since 2018-19, though this production evaluation methodology is changed, this rising trend of steel production continues except during the explosion of the COVID-19 scenario. E.g., month on month basis, the total domestic production and consumption were 23% and 26%, respectively, during April 2021 (The Hindu business line). However, as soon as COVID-19 restrictions get released the steel production rebounded with much higher capacity, i.e., the year-wise finished steel production was found to be 101.287 MT, 102,621 MT, 96.204 MT, and 113.596 MT in the financial year 2018-19, 2019-20, 2020-21, and 2021-22 respectively. Moreover, since 2018-19 India has become a net exporter of the total finished steel, with a total export capacity of 8.355 MT, 10.784 MT, and 13.494 MT in the year 2018-19, 2019-20, and 2020-21, respectively.

Further, the steel industry's success is crucial to any nation's economic and social development. Moreover, the steel produced in India not only fulfills its own needs but also supplies its product to many countries, including the United States, United Arab Emirates, China, Singapore, Canada, Pakistan, etc. Thus, proving its importance at the global level. In addition, the extent of the market to which the Indian steel industry is spread out further establishes its importance for industrial growth across the globe. In addition, the recent development in the steel sector is twofold. On one side industry is facing rapid change from a labor-intensive to a more capital-intensive industry; on the

another, the merger and acquisitions of the big manufacturers. These two developments are coupled with serious concerns regarding energy consumption, environmental regulation, standards, and end-market requirements. All these advancements and challenges associated with iron and steel manufacturing make its SC more vulnerable. Moreover, the continuous, effective, and efficient operation of the Indian iron and steel SC had a global impact. Thus, developing a RSC seems to be the only solution to mitigate the vulnerability associated with the Indian Iron and steel manufacturing sector and enable a sustainable business environment. Therefore, analyzing the practices and the barriers to the RSC in the view of the steel manufacturing sector of Indian origin is of prime importance. And, thus this research would be of great utility to Indian business and the world market.

1.3. Modeling practices and the barriers of the RSC

The resilience concept of the SC was initially focused on identifying and analyzing the factors (practices and barriers) imparting the resilience characteristics into it. However, due to the complexity involved in SC management and the presence of causal dependence relationships among the resilient factors, the applicability of these studies was under scrutiny. Further, with the development of the resilient concept in the SC, modern tools have gained much importance and are used to assess the significance of the RSC enablers and the barriers, such as mathematical modeling (Sabouhi et al., 2018; Bottani et al., 2019; Lohmer et al., 2020), simulation (Carvalho et al., 2012; Ivanov, 2019), multi-criteria decision-making tools (Magableh and Mistarihi, 2022; Mohammed et al., 2019), statistical modeling (Pettit et al., 2010; Jain et al., 2017), etc.

Further, the sequence in which factors need to be controlled is missing in most of the available research because the sequence or priority provided in the existing literature is

based on the SC tier or disruption phases. And therefore, implementation or controlling of these factors is very difficult (Ali et al., 2017; Ivanov et al., 2017).

Table 1.3: Barriers to the RSC

Authors	Barriers	Method used	Industry and country setting
Pettit et al. (2013)	Turbulence, deliberate threats, external pressures, resource limits, sensitivity, connectivity, supplier/customer disruption	Survey-based assessment tool	General SC
Pereira et al. (2014)	Complexity, financial weakness, lack of capacity, collaboration, coordination and control, information, integration, flexibility, knowledge, visibility and trust, long lead times and long distances.	Systematic literature review	General SC
Chaple et al. (2017)	Problems associated with internal funding, poor supervisory skills, time management, employee attitude/resistance to change, poor external funding, poor senior management skills, cultural issues, etc.	TISM	Manufacturing industry (India)
Rajesh (2018)	Centralization of assets, operations and operational barriers, dispersed and unclear ownerships, lack of insurance for the risky assets, and extensive networking.	Grey clustering and VIKOR approaches	Electronics manufacturing (India)
Halkos et al. (2018)	Internal-resources, understanding and perception, implementation, attitude and culture, external consulting services, economics, institutional conditions, support and guidance.	Empirical study using PLS-SEM	SMEs of European union
Ali et al. (2017)	Lack of managerial autonomy, inadequate investments, lack of IT integration, transportation risk, financial risk, climatic risk, and supply-demand mismatch.	Semi-structured interviews	SMEs (Australia)

Authors	Barriers	Method used	Industry and country setting
Kochan and Nowicki (2018)	External–turbulence, regulatory, legal and bureaucratic, financial, Internal–resource limits, supplier, customer, infrastructure, deliberate threats, structural-supply chain structure, supplier chain design characteristics, SC complexity.	Systematic literature review	General SC
Ali and Golgeci (2019)	Resource scarcity and asset problems, lack of collaboration, lack of visibility, lack of trust, financial weakness, lack of IT integration, research and development and autonomy of control.	Systematic literature review	General SC
Gupta et al. (2020)	Technological barriers, economic and financial barriers, regulatory and institutional barriers, social and cultural barriers, and organizational barriers,	BWM	Indian Manufacturing industry
Agarwal and Seth (2021a)	Non-commitment of top management, poor relations with vendors, forecasting issues, poor information sharing, mistrust amongst partners, lack of flexibility, opposition to change and innovation, lack of infrastructural facility, incomparable trading partners’ capabilities, and lack of financial resources.	TISM	Automotive industry (India)

The various approach followed by the researchers for analyzing the resilience factors is provided in Table 1.3. Though many approaches are available to study the resilience behavior of the SC, its capabilities, and the factors influencing it, the presentation of these factors in a systematic structure has proven to be extremely important. Because systematic hierarchical structure not only provides the information about the factors, but also suggests their significance for improving the resilience capability of the SC. It explains their causal dependence relations and the hierarchy of their implementation.

The tools used in this research are total interpretative structural modeling (TISM), quality function deployment (QFD), and the Fuzzy- Decision-making trial and evaluation laboratory (Fuzzy-DEMATEL).

Since the evolution of the TISM, it has become the most widely accepted qualitative modeling technique in SC management because of its ability to model the qualitative parameters in terms of hierarchical dependence relationships. This approach was developed by Sushil (2012) and is used to identify and understand the relationships between the essential components of the SC. It is derived from interpretative structural modeling (ISM) and is advantageous over its base approach in terms of its ability to interpret the nodes and links of the hierarchical structure while considering all the obscurities and vagueness associated with the nodes (Sushil, 2012; Jayalakshmi and Pramod, 2015; Rajesh, 2017). It is among the most widely used approaches for analyzing the causal dependence relationships between system factors. For example, Dubey et al. (2015) and Jayalakshmi and Pramod (2015) model the factors of the green SC; Shibin et al. (2017) model the enablers of the sustainable SC; Vaishnavi et al. (2019) model the readiness factors of the SC to improve the agility of the SC; Irfan et al. (2020) propose the model for improving the SC performance, etc. TISM, along with MICMAC analysis, has been proven to be a prevailing tool in modeling the factors of the RSC even in most of the most complex situations of the SCM (Jena et al., 2017). However, very few researchers have attempted to analyze the resilient factors of the SC using the TISM approach, e.g., Rajesh (2017) investigated the technological factors of the RSC for electronics SC; Agarwal and Seth (2021) focus on analyzing the barriers to the RSC of an automotive SC, etc. However, there exist several case study that focuses on exploring the resilient factors of the SC using ISM, e.g., Soni et al. (2014); Jain et al. (2017), Rajesh (2017); Can Saglam et al. (2020), etc.

QFD was developed in the 1960s to customize the products based on customer demand. Though the QFD was developed for product development and customer needs analysis, it also received significant acceptance from the SC field (Chan and Wu, 2002). Considering its usability and ease of use, at present, organizations are successfully using QFD as a powerful tool to address the strategic, tactical and operational decisions of the SCs (Chowdhury et al., 2012). Bottani and Rizzi (2006) used the QFD to improve logistics facilities to improve customer satisfaction, while Bevilacqua et al. (2009) used the QFD to select the most efficient supplier for the SC. Akkawuttiwanich and Yenradee (2018) utilize the QFD concept for supply chain operations reference indicators. The recent research trends show that QFD is equally applicable in mitigating the SC RVDs, e.g., Chowdhury et al. (2012) utilize the QFD approach to make the SC resilient. The author identified the SC's vulnerabilities and the corresponding mitigating resilient capabilities. Similarly, Chowdhury and Quaddus (2016) use this approach to develop an efficient portfolio of the resilient strategies of the SC that minimizes the SC vulnerability and enables quick recovery post disruptions. Lam and Bai (2016) capitalize the QFD concept in improving the resilience of the maritime SC.

DEMATEL technique was first developed by the Geneva Research Centre of the Battelle Memorial Institute (Gabus and Fontela, 1972). It is among the preferred tool to identify and quantify the relationships between the different factors of the system. It provides the essence of a structural model and quantifies causal dependence relationships between the factors. Chang et al. (2011) follow the DEMATEL approach for selecting the suppliers based on the key criteria to improve the SC performance. Dubey and Tanksale (2022) carried out the DEMATEL approach to study the barriers to the adoption and growth of food banks. Falatoonitoosi et al. (2013) focus on selecting an adequate supplier to achieve their green SC goals. Moreover, Goel et al. (2021) used

the fuzzy DEMATEL approach to explore the causal dependence relationships between the barriers to the development of electric vehicles. Similarly, Feldmann et al. (2022) used the Fuzzy DEMATEL approach to explore and analyze the barriers inhibiting the success of modular construction, which aims to improve productivity and shorten the environmental burden on the construction industry.

1.4. Assessment of the resilient score of the SC

To postulate the role of resilient practices in enabling the resilient capability of the SC, it is essential to evaluate the resilience score of the SC. The resilience score provides the preparedness of the SC to minimize the disruptions and their impact by quick rebounding to an initial or more desirable position. It also suggests the degree of improvement required in the existing state of the SC for becoming truly resilient. Despite the importance of the resilience score of the SC, it has been given the least importance in the field of building SC resilience. From the above discussions, it pertains that the concept of the RSC is among the most evolving concept in the 21st century. Its importance has been undoubtedly proven during the COVID-19. Though a huge number of research has been carried out since the evolvement of the resilience concept in SC, and also its number is exponentially increasing day by day; however, the research focus specifically on quantification of resilience score is minimally addressed.

In this section, the RSC literature specifically focusing on the quantification of the resilience score is reviewed. Ponomarov and Holcomb (2009) suggest that the quantification of the resilience capability of a SC signifies its ability to mitigate the disruption-causing events and their corresponding impacts, which further helps in the restoration of the SC post disruptions. Moreover, quantifying the resilience score of the SC enables the practitioners to benchmark and compare the resilience capabilities with

other SCs (Jain et al., 2017; Agarwal and Seth, 2020). Carvalho and Cruz Machado (2007) is among the first few who discuss the SC's quantification of the resilience score. However, the author explores only the adaptability and cohesion while omitting the proactive and preparedness characteristics of the SC. Falasca et al. (2008) focus on quantifying the resilience level while considering the SC density, SC complexity, and the SC node criticality; however, the author didn't consider the practices/strategies that can be followed to mitigate these criticalities. Murino et al. (2007) focus on evaluating the resilience level of a SC based on its dynamic behavior, i.e., inventory position, upstream flexibility, and the production cycle. Cabral et al. (2012) have provided an elaborated study for the SC and mention the importance of the redundancy of the capacities, collaboration, transportation lead times, and replenishment frequency in achieving a high service level and minimizing the lead time and cost. Research carried out by Soni et al. (2014) provided an elaborated concept of the RSC, its capabilities of the RSC, and the practices enabling the RSC. Moreover, the author has provided the most influencing resilient practice based on the causal dependence relationships between the resilient practices of the SC. Further, using the graph theory approach author quantified the resilience score of the SC as a single numerical index. Rajesh (2019) has provided a fuzzy logic approach for the quantification of the resilience score of a SC while considering the practices and the corresponding attributes. Here, the author has suggested a three-layered strategy, i.e., goal, practices leading the goal, and the attributes of the resilient practices. Following the approach discussed by Soni et al. (2014), Agarwal and Seth (2021) provided a more elaborated aspect of the RSC. In this, the author has considered fourteen resilient practices of the RSC and clustered them into three groups, i.e., strategic enablers, tactical enablers, and operative enablers. Further,

using the graph theory approach, the author has coined a resilience score for the automotive SC.

Munoz and Dunbar (2015) consider the resilience ability of the SC as a network-wide concept and presented a regression model for SC delivery performance while considering the SC tier, disruption magnitude, and disruption frequency. In this study, the author lags the consideration of the attributes of the RSC. And also, the practices required for the development of the RSC remain unexplored. Moreover, quantifying the resilience score of a SC based on the practices and attributes will enable the SC experts to proactively prepare for uncertain events by developing redundant and flexible SC capacities. Further, it also provides information about the non-performing links. Therefore, evaluating the SC resilience capacity while considering the practices and its attributes provides a clearer picture of the actual capability of the SC. Hence, employing the practices and the attributes-based approach for evaluating the resilience score of the SC will be very helpful for the decision-makers and the practitioners. Among the available resilience quantification approach, the study provided by Rajesh (2019) agglomerates the wider concept of the RSC and provides a step-by-step procedure for enabling the resilience capability of the SC. Moreover, this approach also identifies the attributes against which SC is least performing or the attributes hindering the SC in attaining the desired resilience score.

1.5. Background and motivation of the topic

In the present competitive business environment, the success of the business depends upon the strength of its SC, which is vulnerable to its weakest link (Stone and Rahimifard, 2018). These SCs are subjected to many business-related risks, such as changing customer demand, technological development, supply and demand failure,

etc., and also compounded with many ecological and man-made disruptive events whose impact sometimes is devastating. Thus, it is now a common saying in the business that “individual companies do not compete rather their SC compete” (Tukamuhabwa et al., 2015). Moreover, with the passage of time and business development, a number of approaches have evolved, such as Enterprise risk management, SC business continuity management, SC risk management, SC robustness, SC agility, etc. (Pettit et al., 2019; Patel et al., 2018; Tukamuhabwa et al., 2015). However, the traditional risk management approach is insufficient to deal with the current competitive business environment coupled with many black swan-type human-made and ecological disruptions (Taleb et al., 2009; Sabauhi et al., 2018; Pettit et al., 2019). Thus, the term resilience approach of risk management appears to not only reduce the vulnerability of the SCs but also help in overcoming the disruptions quickly with minimum possible losses (Tang, 2006; Sa et al., 2019). The resilience ability enables business continuity by quickly absorbing unexpected events, adapting to the changes, and recovering from the disruptions (Ponomarov and Holcomb, 2009; Christopher and Peck, 2004; van der Vegt et al., 2015).

Some of the 21st century disruptive events that shook’s global businesses are the fire in the semiconductor plant of Koninklijke Philips (2000), Tsunami (2004), SARS (2004), terrorist attack (26/11 Indian; 9/11 USA), Tianjin port blast (2011), Japan Earthquake (2011), COVID-19 (2019), Suez Canal blockage (2021), etc. (Christopher and Peck, 2004; Heidari et al., 2018; Sazvar et al., 2021). Cap Gemini Research Institute stated in its report – rethinking SC resilience for a post-COVID-19 world that more than 80% of the organizations failed to manage their business activities (planning, sourcing, production, warehousing, distribution, and sales) during the pandemic COVID-19. Considering the capabilities and practices of the RSC and its proven applicability in the

myriads of disturbances and uncertainties, the RSC has appeared to be one of the essential tools for the global SC to survive, compete and grow (Bevilacqua et al., 2019). In addition, more than 80% of the world's companies have accepted the importance of the RSC and are serious about making their SC resilient (Hohenstein et al., 2015).

Further, a large number of studies exist regarding the identification and analysis of the RSC capabilities and the practices; however, very few studies consider these characteristics to identify and understand the dependence relationship between the RSC practices. Further, most of the available research is exploratory (Manning and Soon, 2016; Ponis, 2012) and requires empirical validation to prove the relationships between the RSC practices. Together, there exist very few studies that attempt to model the RSC factors based on their interdependence relationships, such as Soni et al. (2014); Layek (2015); Jain et al. (2017), Rajesh (2017); Can Saglam et al. (2020), etc., and provide the empirical evidence for their priority ranking. However, these empirical studies lag the holistic view of the RSC in terms of RSC capabilities and practices. Also, the developed structural model provides only the hierarchical structure and does not explain their linkages. And also, the available research lags the quantitative measure for estimating resilient practice's usefulness for enabling the RSC.

However, it has often been observed that the practitioner faces problems in planning, implementing, and controlling the resilient behavior of the SC solely based on the resilient practices and their causal dependence relationships. Thus identifying the attributes of the resilient practices will aid the realization of the resilient behavior of a SC through proper implementation of practices. Moreover, there exist very few studies that aim to quantify the resilience score of the SC considering the resilient practices and their attributes, such as Soni et al. (2014), Rajesh (2019), Agarwal and Seth (2020),

Behzadi et al. (2020), etc. However, most of them lag the holistic view of the RSC and also consider attributes for the resilient practices are

Ever since the development of the RSC and its practical implementation into the SCs, many times, it has been observed that the SCs are unable to resist absorbing or recover from the disturbances, and they tumble down, causing huge business and social losses (Agarwal and Seth, 2021; Ali et al., 2017; Rajesh, 2018). This inability of the RSC indicates the presence of some inhibiting factors, which act as barriers to the successful implementation and execution of resilient practices. These inhibiting factors are named the barriers of the RSC (Ali et al., 2017). Further, considering the force field theory, for the survival, adaptation, and growth of the SCs, the magnitude and impact of the driving force (RSC practices) should be more than that of the inhibiting factors (Agarwal and Seth, 2021a). Thus, identifying and analyzing the resilient practice (driving forces) and the inhibiting factors (resisting forces) help the SCs overcome vulnerabilities and the disruption impacts, thus gaining competitive success both before and after the disruptive events. Further, from the literature, it is evident that these inhibiting factors are inherited in the SCs in the form of a poor network, lack of organizational commitment, poor cooperation among members, etc., which need to be identified and evaluated. However, despite the resistance offered by the RSC barriers in the success of the RSC, it has been given the least importance by the researchers (Agarwal and Seth, 2021). Thus there exists a considerable research gap regarding the identification and analysis of the RSC barriers.

Further, the literature suggests that most of the empirical studies carried out for the development of the RSC take place only in the developed nation, with minimal involvement of the SCs operational in developing nations (Hohenstein et al., 2015;

Scholten and Schilder, 2015). Thus, leaving the developing countries severely under-represented at the global SC level. And also, the developing nation account for about 70% of the world population and more than 50% of the world economy and estimated that they will account for about 60% of the world economy by 2030 (Perspective of Global Development 2010). Though lesser research has been carried out with respect to developing nations' SC, however, they are also subjected to similar kind of SC failure as the case in a developed country. And also the disruption that takes place also shows its impact on the developed economy of the world. For example, India and China are the two big homes for Australian coal, and mishappening to the SCs will adversely affect the Australian economy. This effect was seen during COVID-19 when China tried to cut down coal imports from Australia, then Australia created India as their new sustainable customer. Similarly, the Tianjin port blast (2010) badly affected the Japanese automobile manufacturing company and caused it to stop production for many weeks. In addition, developing nations are also competing among themselves on a large scale, e.g., Bangladesh surpasses India in terms of textile export and has become the hub for the textile industry. Further, COVID-19 has equally hurt global businesses irrespective of their economy; however, the developed economy recovers more quickly compared to developing and underdeveloped countries. Further, the developing nations are the source of many basic manufactured goods and raw materials for the developed nations, and any disruptions to the SCs may have a global impact. And also, to have a safe and sustainable world, it is required to develop the RSC at the global level.

1.6. Objectives of the research work

From the above discussion, it is evident that the 21st-century business environment is full of vulnerabilities, uncertainties, and opportunities, which is also coupled with many

man-made and ecological disruptions. However, the concept of RSC has proven to be a better safeguard as well as a strategic tool to combat all these hindrances and gain competitive advantages. Since its evolution and capabilities, the RSC concept has gained much more attention and has become a greater interest for researchers and practitioners. Though the RSC concept is about two decades old, the RSC's capabilities, practices, and barriers require more in-depth analysis. It has been observed that the resilient practices are closely related to each other, and often their success depends upon the success of the other resilient practices. Thus it is required to estimate and identify their causal dependence relationships, which may further lead to the successful implementation of the resilient capabilities of the SCs.

Additionally, to make the SC truly resilient, apart from implementing the resilient practices and the attributes, it is required to understand the actual resilience score of the SC, which may further help in identifying and understanding the barriers inhibiting the attainment of the desired resilience level. Though a few studies attempt to estimate the resilience score, most of them lag the multidimensionality and holistic view of the RSC. Hence, there is a need for developing a resilience assessment model that can accommodate a wider part of the RSC and provides information regarding the actual resilience level along with the attributes against which SC is not performing. Moreover, the implication of the RSC practices and attributes alone finds to be insufficient; thus, identification and estimation of the RSC barriers based on their causal dependence are also of enormous importance in delivering a truly resilient SC. Therefore considering the above research gaps in the available literature, the following objectives have been carried out this thesis work.

1. To identify the resilient practices of the SC and estimate and interpret their causal dependence relationships.
2. To quantify the applicability of the resilient practices for enabling the resilient capabilities to the SCs.
3. To estimate the resilience level of the case organization SC and identify the attributes against which SC is not performing.
4. To identify the hindrances to the successful implementation of the resilient practices to the SC and also prioritize them based on their causal dependence relationships.

To carry out above four objectives, this study collects the response from the experts of an Indian iron and steel manufacturing firm of global importance having the global SC network. This company has eight manufacturing units, among which five are integrated plants, and three are special steel plants. The location of each unit is primarily focused on the eastern and central part of India, rich in iron ore, coal, etc. It has divided its main distributor into four regions, i.e., the Eastern region, Northern region, southern region, and western region, with 35 distributors. And these four regions of distributor account for about 2300 dealers in India. However, their units directly govern the import of raw materials, export of the products, and big contracts of government and other private organizations. It is famous for its quality product, and its products are in massive demand for infrastructural development and other household and industrial equipment, like railway tracks, bridges, engineering structures, shipbuilding, roofing, industrial sheeting, automobile structures, etc.

1.7. Scope of the work

This research work aims to explore the concept of the RSC by identifying the practices, attributes, and barriers inhibiting the attainment of a truly RSC. For this, thorough literature has been carried out, considering the research article published between 2000 and 2021. Further, to develop in-depth knowledge about the resilience concept, its origin, and its implementation in SC, some articles have been considered beyond the mentioned time frame. Though in the previously published research article, several resilient characteristics, capabilities, practices, attributes, factors, enablers, barriers, hindrances, etc., have been identified and explained. However, there is no consensus regarding their terminology, and most of these terms are used interchangeably. Thus, in this research, this issue is clarified and provides four resilient capabilities, 19 resilient practices, 76 attributes of the resilient practices, and 14 barriers inhibiting the successful implementation of the resilient practices in the SC.

To judge the significance and applicability of the resilient practices, the total interpretive structural modeling (TISM) and quality function deployment (QFD) approach is used. Where TISM justified the applicability of the practices for enabling the RSC, as the practices are interdependent over each other and thus represent the component of the RSC. And, QFD justified the applicability of the practices for enabling the resilient capabilities to the SC and its usability for the case organization SC, as the weight for each of the practices is significantly high for all the practices. The resilience score calculated for the case organization SC is basically based on the implementation level and the practitioners' satisfaction level regarding the RSC's attributes. A fuzzy logic approach is used for this purpose, which not only quantifies the expert's response but also mitigates any possible ambiguities present in their response.

It enables the practitioners to understand the importance of each practice and its attributes and helps them to create a RSC. Moreover, the barriers identified in this study will help the practitioners prepare in advance to mitigate these barriers. The Fuzzy-DEMATEL quantifies their significance, which further helps the practitioners make the SC truly resilient.

Further, in this research study, the focus is on creating the RSC through the development of the four resilient capabilities to the SC through the implementation of the resilient practices and the attributes and mitigating the corresponding barriers. The organization is considered solely because of its importance at the national as well as global level, with the assumption that practitioners have sound knowledge of the RSC concept. The experts involved in this research study belonged to an individual company and had experience of more than ten years in SC and operations management-related activities. Though the input to this research study is subjective, however considering the experience level of the experts, the responsibilities they handle, and the performance of the organization, the response provided by them is trustable and can be assumed to be better than any quantitative data.

Though the research is carried out with respect to an organization operative in eastern and central parts of India, however, the findings are equally applicable to the manufacturing firms operating in other parts of India, as the considered firm has a global SC network. The implications of this research to the manufacturing firms of the other part of the world might require some assumptions because changes in socio-political, economic, and ecological conditions may lead to different types of risks, vulnerabilities, uncertainties, and disruptive events.

1.8. Organization of the thesis

This thesis is organized into six chapters, with the introduction (present chapter) as the first chapter, followed by chapters 2 to chapter 5 corresponding to the four research objectives of the thesis. The last chapter, i.e., chapter 6, summarises the thesis study and discusses the future scope of the work. The thesis overview is briefly provided below and pictorially presented in Figure (1.5).

Chapter 1 presents the introduction of the thesis study. It explores the concepts like SC, SCM, SC risks, SC uncertainty, SC vulnerability, SC disruptions, SCRM, resilience, and RSC. It presents a comprehensive review of the RSC literature, including the various approaches to risk management, characteristics and capabilities of the RSC, practices, attributes, and barriers of the RSC. It also provides the definitions of SCRM and RSC provided by the researchers for mitigating the SC risks, vulnerability, uncertainty, and disruptions in different business scenarios. Further, to position the findings of the thesis study in the context of the available research, the previous research is reviewed and provided systematically regarding the approach and tools used. Further, it provides the brief background and motivation for this research study and the research gap that needs to be addressed in the present business management scenario. It also provides a brief introduction to the various research objectives carried out in this research study, the approaches used and the implications of the findings.

Chapter 2 focuses on analyzing the causal dependence relationships among the chosen resilient practices. The tool used for this purpose is TISM, which is advantageous over classical interpretive structural modeling (ISM) in terms of its ability to interpret the linkage between the practices.

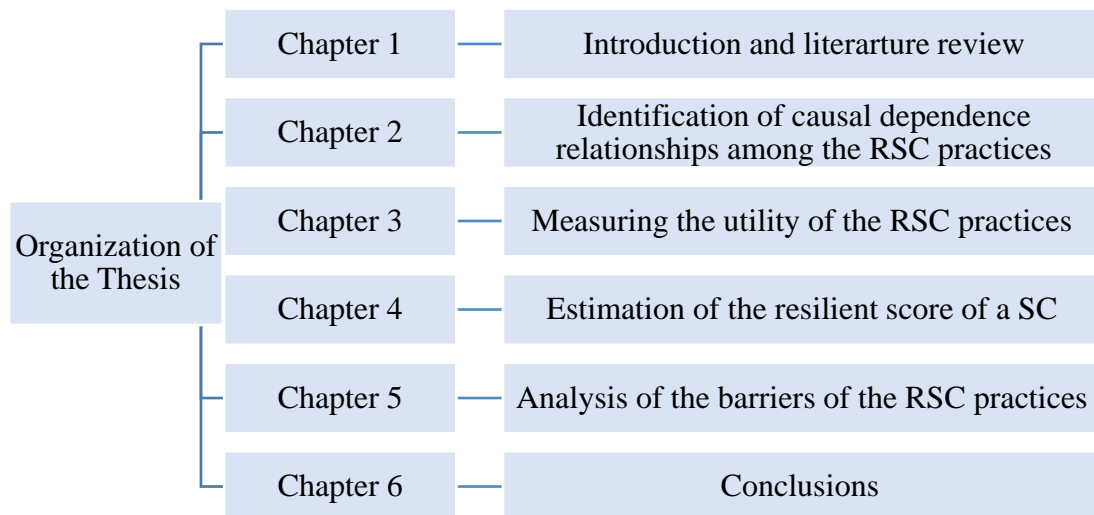


Figure 1.5: Organization of the thesis

Based on the expert response, no practice belongs to the independent cluster of Matrice d'Impacts Croisés Multiplication Appliquée a un Classement (MICMAC) analysis; thus, all the practices are interlinked (direct or indirect), thus supporting their applicability for enabling the RSC.

Chapter 3 focuses on estimating the applicability of resilient practices for enabling the resilient capabilities of the SC. Considering the expert's response and the applicability for enabling the resilient behavior to the SC, market sensitivity and virtual enterprising are also considered, along with the seventeen resilient practices discussed in chapter 1. In this chapter, a QFD approach is used, which considers the expert's response as input and evaluates the importance of each practice while considering their correlation as well as their individual importance for enabling resilient capabilities. The weights obtained for each of the practices are very close to each other, thus justifying the importance of the practices for enabling the resilience capabilities to SC and their applicability for making the case organization SC resilient.

Chapter 4 attempts to develop a novel approach for estimating the resilience score of SC based on the implementation and performance of the case organization SC with respect to the resilient practices and their corresponding attributes. In total, this thesis discusses the nineteen practices and seventy-six attributes for enabling the RSC. This approach scales the SC's resilience level from 'not at all resilient' to 'definitely resilient' and provides information regarding the attributes for which SC is not performing. This study provides information regarding the margin by which case SC lags behind a truly resilient position. The resilience score for the case organization is found to be intensely resilient and lags the position of definitely resilient, hence requiring some more effort.

Chapter 5 deals with identifying the factors inhibiting the SC in attaining truly resilient behavior. These factors are named barriers to the RSC. These barriers prohibit the successful implementation of the RSC practices and attributes and thus making the SC more prone to disruptions. In this chapter, fourteen barriers have been identified and using the fuzzy-DEMATEL, their causal dependence relationships are estimated. Further, a priority ranking for these barriers will help the practitioners strategize their available resources and capacities in mitigating these barriers, thus making the SC genuinely resilient.

Chapter 6 provides the conclusion and discussion of the thesis study, which includes contributions, managerial implications, theoretical implications, limitations of the study, and future scope. It also discusses how this thesis will be a proven resource for academicians and practitioners in understanding the various paradigm of the RSC and deciding the focus area for improving the overall resilience level of the SC.