

RESEARCH PAPER

Role of supply chain resilience in mitigating sustainable risks

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Highlights

- Elaborates the concept and importance of supply chain resilience in manufacturing.
- Identifies sustainable risks causing disruptions in supply chains.
- Highlights the role of supply chain resilience in mitigating sustainable risks in manufacturing for enhanced productivity and competitive advantage.
- Offers future recommendations for the application of supply chain resilience.

Graphical Abstract



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Abstract

Supply chains have become more lean and efficient while expanding across the globe. The need for sustainability and prevention against climate change is being enforced by regulatory bodies through maintaining laws, rules and regulations. The supply chain is subject to numerous risks and disruptions of varying nature. The sustainable risks can be both minor (low impact - high frequency) or major (high impact - low frequency) causing disruptions and breakdown in logistics in the supply chain network. It is an interesting phenomenon to investigate how such risks and disruptions will be alleviated in supply chains, especially with modernized, efficient technology and management mechanisms. The role of supply chain resilience to build monetary surplus, enhanced productivity and competitive advantage is enabled through this research. The summarized findings of supply chain resilience frameworks along with definitions, components, theories and concepts have been synthesized for understanding of the phenomenon in manufacturing industry. The sustainability of processes, organization and resources is focused upon by building a unique strategic response from the combination of nodes, resources and structure in the face of disruptions. The study is useful for industry professionals, environmentalists, strategic planners, managers and policy makers to undertake resilience practices and strategies for alleviating sustainable supply chain risks across manufacturing.



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1. Introduction

Supply Chains are evolving at a global level and are having an increasingly large share in the world economy. The latest Information and communication technologies enable intercompany scope and management across the globe. These supply chains are subjected to unique sustainable risks depending upon geography, players, processes and resources. The sustainable risks are environmental, economic, institutional, social, technical, supply side and demand side. Some risks are internal to the firm, some internal to supply chain and there are the external PESTEL risks (Gouda and Saranga, 2018). It is increasingly focused upon to practice risk management in the supply chain. The mitigation, response, recovery and renewal against supply chain risks has increasingly being focused upon. The reactive and proactive response to supply chain risks has been well documented. The sustainable risks and disruptions in the supply chain to enable continued operations and flow of logistics involves building Supply Chain Resilience. How resilience capabilities are built and used across unique and varying geographical supply chains for alleviating sustainable risks is an area to explore. A number of studies, including conceptual, literature review and empirical, have been conducted to investigate the issue (Macdonald et al., 2018; Shekarian and Mellat Parast, 2021). The concept of resilience evolves from the resource based view which highlights that important resources join together to form bundles of capabilities which counter the disruptions generated by risk factors. The resilience factors could be developed through hard and soft resources in combination with each other. These resilience capabilities are especially useful to alleviate high impact low occurrence disruptions within built capabilities.

The studies have evolved from lean management to agile practices moving towards the greening of processes and products. The technologies and innovations of the 4th industrial revolution are further shaping the way in which resilience capabilities can be built and used (Ivanov and Dolgui, 2021). Through the course of management history in supply chain, the focus initially was on lean and efficient practices followed by the flexible or agile aspect of supply chain. This generated the concept of leagile supply chains. The sustainability, green and conservation of resources gave rise to green supply chains. The COVID – 19 pandemic focused on the existence or viability of supply chains. The factors, risks and situations occurring in the environment, technology and performance indicate increased importance and relevance of the Supply Chain resilience concept. The article focuses on identification of supply chain risks which are impacting supply chains and suggests how resilience factors are developed and used to counteract the effect of supply chain risks which build into disruptions. The next section gives an overview of the materials and methods, Section 3 gives the results and discussion with the study concluded through summarization of important findings in Section 4.

2. Materials and Methods

A literature review has been conducted on Supply Chain Resilience for understanding and conceptualization of the concept. The study was initiated with the selection of topic. Key issues affecting the globe and the latest research streams were integrated to arrive at a novel and impactful topic. The key areas of Supply Chain, Resilience, Risk Management and Sustainability were combined and investigated to understand their complementary roles with each other. The key individual areas were investigated through identification and study of high relevant and cited articles. More than 100 articles on Sustainable Risks, Supply Chain Management, Supply Chain Resilience and Supply Chain Performance were studied. The development of a structure for presenting summarized findings of select articles explaining the definition, components, framework and mechanism of Supply Chain Resilience was conducted. Select key articles were summarized and their findings presented in Table 1. The selection of the articles was done on the basis of coherence, relevance, originality and link with the study. The summarized table in complement with the discussion on the triangular phenomenon comprising of sustainable risks, resilience and performance have been investigated. The research focuses on supply chain affected by disruptions and sustainable risks. The resilience phenomenon and its components are presented with emphasis on how they are important for mitigating, alleviating sustainable risks. The aim is to highlight the research stream to environmentalists, practitioners and researchers towards

use of resilience theory, elements and practices. The way forward and directions for enhancing resilience capabilities with the advent of technologies of the 4th Industrial revolution are also highlighted.

3. Results and Discussion

The Globalized economy is moving towards sustainability and circularity through establishment of intercompany Supply Chains (Lahane et al., 2020). The concept of Focused Factory emphasizes that no single factory can produce any engineering product completely under one roof. Outsourcing of carefully selected components and parts has to be done involving Supplier relationships and procurement (Quinn and Hilmer, 1994). The Manufacturing business has to focus on a few value adding activities which are the strength of the concern (Ketokivi and Jokinen 2006). With increased technology and progress in Information Technology, Internet and ERP systems the companies have evolved from an internal focus towards a supply chain perspective. All entities in a chain are now joined together to move from a Focused Factory to a cohesive, flexible and resilient Supply Chain (Azevedo et al., 2011). The value stream mapping of manufacturing process is now extended to mapping of the supply chain. The inputs, transformation process adding value and outputs used for flow of logistics across the stations and entities can be mapped by value stream analysis and improved (Ma et al., 2021).

These supply chains attain configurations which are varied through geographical, technological or management factors. The location, density, criticality and structure of each node is important. These nodes are aligned and reconfigured to best suit the economics and profit surplus of the whole Supply Chain. No Supply Chain can exist with weak or ineffective nodes as disruption and breakdown of any single node can have a ripple effect across the whole Supply Chain. This disruption and the inability of the Supply Chain to address it can damage the flow of Logistics across the whole network (Akkermans and Van Wassenhove, 2018; Saenz and Revilla, 2014). The China Pakistan Economic Corridor (CPEC) is a logistics enabling supply chain infrastructure development project which can connect the geographical regions of Central Asia, Western territories of China and within Pakistan itself. How the structure will be planned and resilience integrated into the future Supply Chains is an emerging and interesting area to explore (Bugvia et al., 2021).

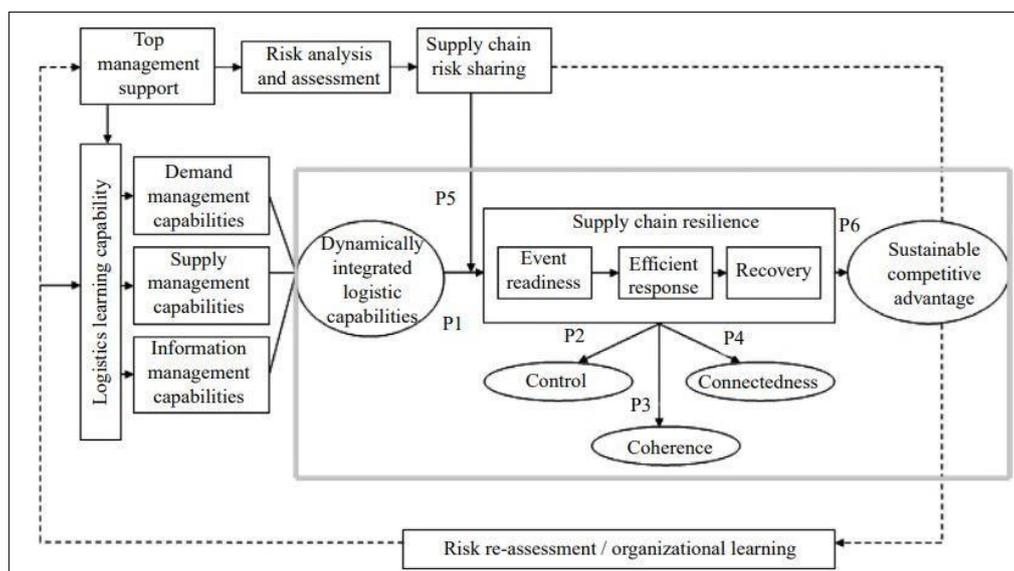


Fig. 1. Logistics Supply Chain Resilience Conceptual Framework (Ponomarov and Holcomb, 2009).

Disruptions and Breakdown can be both major or minor in nature. The minor fluctuations across the globalized Supply Chain are due to multifarious risks which range from poor forecasting, fluctuations in demand and supply, political conditions, technical issues, inventory problems, manpower shortage etc. With the need, requirement and increased regulations to protect the environment focus has shifted towards Sustainable Risks (Chowdhury and Quaddus, 2021). Industries concerned with agricultural produce as well as

manufacturing are emitting hazardous material and waste impacting the environment at an increasingly large scale (Ali et al., 2021). The Sustainable Supply Chain Risks have normally been characterized under the heads of Technical Risks, Environment Risks, Social Risks, Institutional Risks, Economic Risks, Supply Risks and Demand Risks. A number of studies have been conducted to specify and identify various Sustainable Risks in a number of industrial sectors like Textile, Leather, Fashion, Agri-Food, Manufacturing etc. (Moktadir et al., 2021; Majumdar et al., 2021). How the enterprise reacts to these sustainable risks is of importance. But even more so is the advanced concept of response of a geographically spread Supply Chains response to the Sustainable risks. Increasing disasters and disruptions due to climate change in the form of floods, tsunamis, cyclones, storms and earthquakes are in occurrence. The disasters and the damage caused by their occurrence is increasing with each coming decades. The field of Disaster Management has evolved and Global Supply Chains not only have to deal with minor fluctuations but also major natural disruptions (Elluru et al., 2019). How an effective supply chain deals with these minor and major Sustainable Risks is an interesting proposition to investigate? The field of Supply Chain Risk Management has evolved into Supply Chain Resilience. SC Risk Management is based on probability of occurrence and probability of impact. The risks are identified, monitored, assessed and removed through the management of risk practices.

The approach is followed across the whole Supply Chain and contingency plans are placed to counter any occurrence of disruption. The risk response is drawn on occurrence after detection. Risks which are a cause of minor fluctuations are easily addressed through this technique and mechanisms (El Baz and Ruel, 2021). However, for large impact low frequency disruptions like earthquakes, Tsunamis etc. impacting a large major area and effecting production require a different response. This response is in the form of Supply Chain Resilience which implies “The return of the Supply Chain towards coherence, connectedness and control at a better state than before by drawing out a resilient response from the system following a large scale disruption”. The concept of SC Resilience is mapped in Fig. 1 (Ponomarov and Holcomb, 2009). The Sustainable Supply Chain Risks have to be identified, assessed, monitored and responded through Supply Chain Resilience Capabilities. The resilience concept has evolved from various streams of knowledge such as ecology, evolutionary science, engineering, economics and management (Adobor and McMullen, 2018). Its theory is based on the resource based view (RBV) which emphasizes the combination of many resources being bundled together to form resilience capabilities. Multiple capabilities have been identified in the Literature which include, Flexibility, Visibility, Redundancy, Collaboration, Agility, Velocity, Trust, Leadership, Risk Culture, Capacity, Knowledge Management, Communication etc. exhibited in Fig. 2 (Kamalahmadi and Parast, 2016). These capabilities enabled by combination of unique resources strategically maintained at each Supply Chain node is a source of productivity and Competitive advantage over competing Supply Chains (Singh et al., 2019).

The relational constructs such as communication, trust, partnership, collaboration, interdependence also complement the Supply Chain Resilience capabilities (Mandal, 2013). Leadership and Top Management Support towards building such strategic capabilities and the understanding towards such issues with insight and critical thinking is required. An innovative response drawn from knowledge and learned experience gives better resilience strategy (Hohenstein et al., 2015). The complete understanding of the phenomenon of Supply Chain resilience can be obtained through the findings from major research works summarized in Table 1.

In Industrial Engineering and Manufacturing through efficient response to risks reduces disruptions, wastages and breakdown to build sustainability in the System. These practices and building of capabilities have to be balanced to avoid wastage and at the same time be available when required. The buffers and resilience capabilities have to be planned strategically to counter risks and disruptions for economic return, efficiency, productivity, competitive advantage and sustainability. These capabilities in association with types and phases of resilience are presented in Fig. 3. Supply Chains across multiple geographical regions have to develop and elicit their own unique response. The modern trend is to innovate and improve the resilience capabilities through the Information Technology, Smart Technology, 4th Industrial Revolution and Modern Communication of the Supply Chain systems developed across the globe.

Table 1. Summarized Table of Supply Chain Resilience for Alleviating Sustainable Risks and Disruptions.

Researcher	Model Constructs and Description	Applications and Advantages	Limitations
Christopher and Peck (2004)	Process Risk and Control Risk are inter firm, Demand Risk and Supply Risk are inter supply chain and PEST Risk are external to the firm. The Resilience Framework is based on re-engineering supply chain through understanding and mapping at every node. Fostering collaboration across all nodes is crucial along with sharing of vital information. Agility should be built by increasing visibility, velocity and acceleration. Building a supply chain risk management system by taking decisions factoring on risks is also important.	Informative and useful for research, managerial practices for building resilience. One of the earliest works on Supply Chain Resilience. Identifies and integrates the basic constructs drawn from Supply Chain Management, Supply Chain Risk Management. Enables professional to build resilience in supply chain and develop capabilities to overcome the effect of disruptions and build competitiveness.	Basic, simple, introductory article on the concept of Supply Chain Resilience. Simple Model exhibiting general integration between constructs. Basic factors of Supply Chain Management and Supply Chain Risk Management are integrated to build supply chain resilience.
Ponomarov and Holcomb, (2009)	A theoretical and conceptual framework for resilience which explores the logistics capabilities relationship with continuity, coherence and connectedness in terms of readiness, response, recovery and renewal. The capabilities are identified which could be supply side, manufacturing, information and learning aspects. The supply chain risk assessment, sharing is enabled and capabilities identified. Top management support is the driving force. Supply Chain Resilience results in competitive advantage for the firm.	A conceptual study which highlights mapping, assessment and sharing of risks across the supply chain through top management support. Helps in understanding Resilience at a strategic level. A novel definition has been developed through integrating various research streams. Important work for researchers and managers to understand and perform further research towards building new theories. Gives insight on how to measure Supply Chain Resilience in organizations.	There are certain limitations like limited capabilities discussed. The model focuses on logistics capabilities and its effects on fostering supply chain resilience. Empirical validation needs to be done.
Mandal, (2013)	The framework is based on the constructs of relational management defined and adapted for supply chain. The primary relational constructs are trust, cooperation, commitment, communication, adaptability and interdependence. The environmental uncertainty has a moderating role and results in fostering dynamic supply chain resilience enhancing performance, resilience, innovation, business continuity and supply chain security.	The frame work can be applied to supply chains impacted by disruptions and vulnerable because of risks. The relational factors extended between all nodes of supply chain to build resilience can be identified. The framework can be empirically tested at various case organizations and supply chains. Highlights the importance of relational theory and factors especially in terms of Supply Chain Resilience. How the factors interrelate in a dynamic integrated supply chain and impact resilience is interesting area to explore.	The framework proposes interactions of relational constructs only. It would be interesting to include other capabilities constructs in conjunction with these relational factors. A holistic and more complete model can be created.

Scholten et al., (2014)	The model proposed is based on the juxtapositioning of disaster management operations with supply chain resilience framework across the four disaster stages mitigation, preparedness, response and recovery. The supply chain resilience constructs are collaboration, agility, supply chain reengineering, risk awareness and knowledge management related with operational steps of disaster management. A qualitative analysis is done and the model developed is used to test the resilience capability during Hurricane Katrina.	Past, present and future analysis can be done of humanitarian and commercial supply chains qualitatively. Two streams of research are connected to generate the relationship between operational plans, disaster phases and supply chain resilience principles. The study highlights the importance of integrating the streams of disaster management and supply chain resilience. A novel methodology has been developed. The mitigation aspects were observed to be most important for resilience.	Study results may be different across various case scenarios, links and organizations. Developing countries may need to be studied keeping the context of growth and development. More detailed study in commercial supply chain could be attempted.
Hohenstein et al., (2015)	The four disaster phases which are readiness, response, recovery and growth are segregated into having a proactive and reactive approach. The elements of supply chain resilience are identified which are different in importance and usage across phases. The readiness phase is proactive and most important. The definition of resilience, literature review, resilience stages and elements have been arranged and future directions for research have been provided. The framework underscores the importance of growth or renewal. The resilience elements will be having different capabilities during stages and various links of supply chain.	Can be applied proactively and reactively across the supply chain for building resilience. The links across different stages of supply chain are optimized and balanced for building resilience. Growth is an important phase which involves learning and gathering of knowledge. The variance, changes and volatility of change cause the system to be turbulent which returns and adapts to a better state by balancing the vulnerabilities and capabilities across the phases of disaster. Gives a fresh perspective of the synthesis of literature on supply chain resilience and helps in defining and understanding supply chain resilience.	The combination of elements and resources to develop supply chain resilience is unexplored. The deviation in culture, development, growth, politics, social and geographical across supply chains needs to be examined in regard to the framework. Also the disruption may vary in scope, time and intensity.
Kamalahmadi and Parast, (2016)	The proposed framework of Supply Chain Resilience builds on Supply Chain Re engineering, Collaboration, Agility and SCRM Culture. The further constructs are Node complexity, density and criticality for Supply Chain Reengineering. Trust and Information sharing for Collaboration. Visibility and Velocity for Agility. Lastly Leadership and	The understanding of Supply Chain Resilience based on past research is done. The frame work builds on establishing grounds for measurement and operationalization of Supply Chain Resilience in firms. Strategies are also discussed to build resilience. The important aspect is to discuss Enterprise Resilience	Constructs are considered mostly in linear relationship however their nature is largely dynamic and these constructs may be interacting with each other. In terms of a resilient system more than a single construct may combine together to provide the resilient capability.

	Innovation for SCRM Culture. The relationships between these factors are investigated and further possibilities are present which should be explored. The supply chain resilience framework along with the relationships is established. The strategies for reducing the effects of disruptions and building resilience are researched.	along with supply chain resilience and build the research. The move towards Lean Green Agile Resilient LGAR Framework becomes much more clear. The need to investigate Supply Chain Resilience in context of the Tradeoff theory is highlighted. Some constructs can be preferred or reduced depending upon the industry, firm, disruption or environment.	
Adobor and McMullen, (2018)	The framework is built under the theoretical lens of Complex Adaptive System and utilizes the in depth study of literature on engineering resilience, ecological resilience and evolutionary resilience. The fundamental elements, capabilities and strategies in each stream is compared for building synergy and tradeoff in the supply chain. The supply chain resilience is evaluated across the four phases on disruption. The features and capabilities of each stream across each phase of disruption increases the possibility of creating a multidimensional model based on constructs identified in novel combinations.	The framework can be applied to study and improve supply chain resilience across various stage of disruption like readiness, response, recovery, growth and renewal. Emphasizes the complexity and dynamic status of supply chain systems. A detailed theoretical towards building supply chain resilience based on engineering, ecological and evolutionary resilience. Each of the three streams along with definitions, constructs and principles have been identified. It is possible to adopt multiple branches and constructs in synergy and tradeoffs.	Should move towards empirical research. Resilience may vary across time and space and requires further theoretical and empirical research. Improvements can be made for more elaborate, multidimensional models on supply chain resilience.
Singh et al., (2019)	The researchers conducted a comprehensive literature review to outline 17 indicators of supply chain resilience having an impact on organization performance. These resilience indicators and performance factors are presented earlier and are arranged in a framework across three phases of anticipation, resistance and recovery. Each phase has a set of indicators associated with dominating performance factor.	Can be applied to plan for building capabilities across each phase. Helpful in determining what resilience capabilities to build before disruption, during disruption and the response. The bundle of organization resources combines to form resilience capabilities.	How the resources are grouped together under capabilities is an area to explore. It has been justified through previous research that these factors are influential in mitigating and handling risks causing disruption in supply chain. These indicators enabling performance can be used and handled in multiple ways. Effort is needed to make optimal use of these factors and indicators in supply chain.

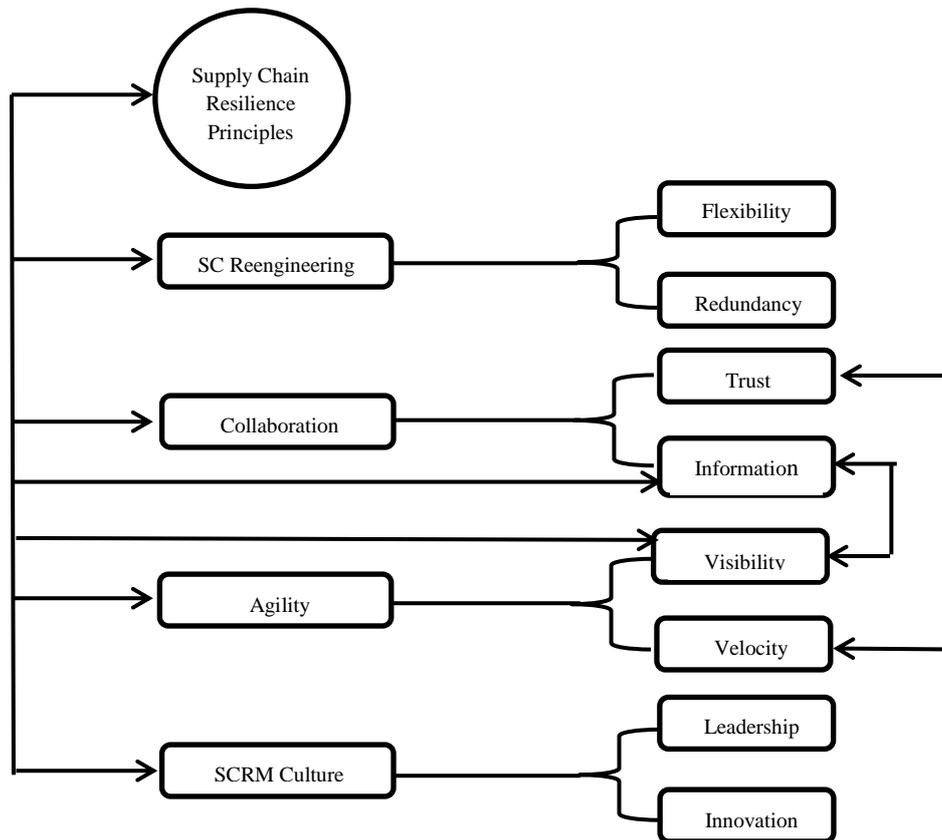


Fig. 2. Resilience Capabilities Framework. (Kamalahmadi and Parast, 2016).

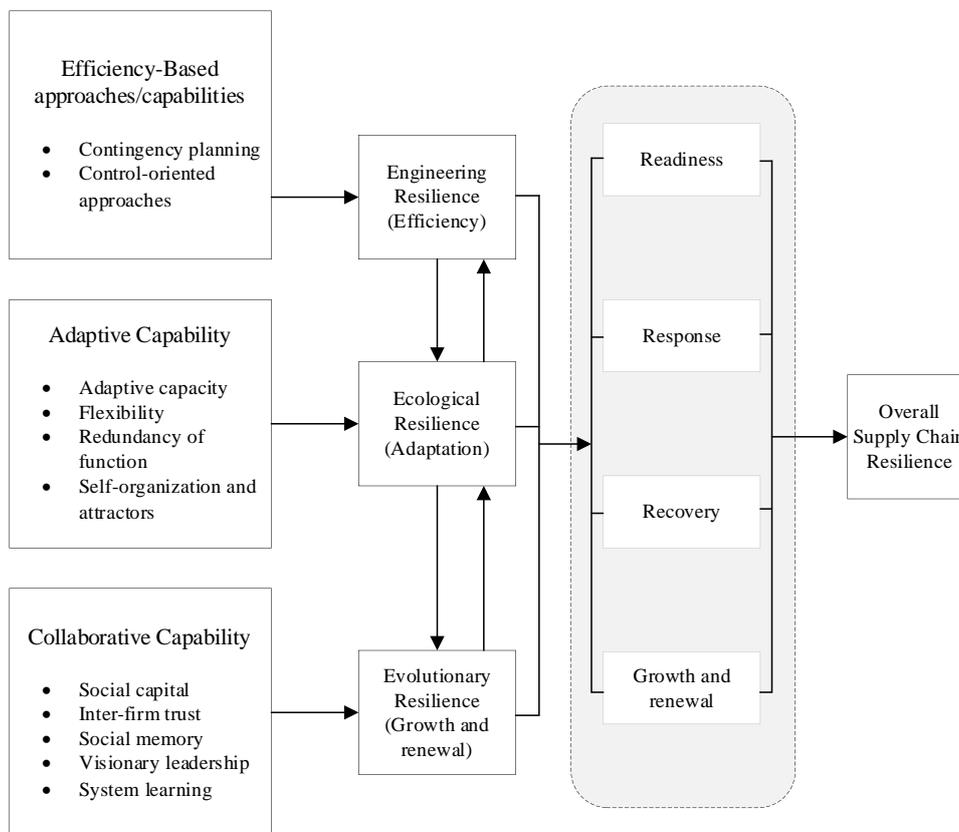


Fig. 3. Supply chain resilience framework of phases, types and capabilities (Adobor and McMullen, 2018).

4. Conclusion

The importance of the field of Supply Chain Management in terms of risk assessment and response through developing resilience practices has been presented. The understanding of Supply Chain Resilience Concept

through a Literature Review has been made. The findings have been summarized and the body of knowledge presented in the form of tables, figures and text integrates the SC Resilience between Sustainable Risks and Competitive advantage. Resilience has been drawn from various subject fields such as ecology, engineering and evolution science. The definition, synthesis and conceptualization of Supply Chain Resilience in a simple formative manner for understanding has been presented.

Resilience concept and strategies are being implemented at the individual, organizational and supply chain level through combining the research and structure of various fields such as ecology, engineering and evolution. The flexibility and agility of supply chains is an objective which is increasingly being recognized. Supply chains have to be lean, reduce waste, address sustainability while at the same time have to be responsive and ensure continuity in operations. This balance to avoid surplus resources or lack of capabilities to respond to disruption has been a major strategic response in supply chain by managers. The leadership. Knowledge, innovation and learning of management all matter. This is especially more so important with evolving technologies and modernization involving techniques such as Information and communication technology, smart manufacturing, machine learning, robotics, artificial intelligence, augmented reality, vertical integration, horizontal integration and supply chain 2.0. How the coming years with increasing occurrence of disasters and increased risks with more focus on sustainability impacts the globe through harnessing the balance of resilience is an extremely important area to understand and research.

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