Supply Chain Resilience in the Fourth Industrial Revolution

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Introduction

"From a 'lost generation' of disillusioned young people, to long-term financial crisis and even state collapse, the world could be feeling the fallout of the COVID-19 crisis for years to come" World Economic Forum (2021)

Businesses have been facing catastrophic events, disruptions, and volatilities since the inception of the first firm on the earth; however, the way novel coronavirus SARS-CoV2 (commonly known as COVID19) pandemic has hit the businesses is unprecedented and unmatchable. To date, COVID19 has become the largest disruptive event in human history, which has unequivocally disrupted the economic spectrum across the globe. According to Congressional Report Service (CRS) (2021, p.1), *"…economic crisis [due to COVID19] that affected the $90 trillion global economy beyond anything experienced in nearly a century*. Further, it is reported*," the loss of global economic output between 2020 and 2025 as a consequence of the pandemic would total $28 trillion"* (p.13). Experts believe that the volume of these losses could have been reduced if the world economies worked on their resilience. Further, it is claimed that one of the major causes of the extolling business losses could be the lack of resilient supply chains. Therefore, it has created concern among practitioners and scholars to identify as to how a firm's supply chain resilience (SCRE) can be improved to encounter massive supply chain disruptions and bounce back effectively (Pettit et al., 2019; Mubarik et al., 2021). Ambulkar et al., 2015, defines SCRE as *"The capability of the firm to be alert to, adapt to, and quickly respond to changes brought by a supply chain disruption."* While . SCRE empowers the system to reinstate its original or a new, more desired state after experiencing inevitable risks (Carvalho & Cruz Machado, 2007; Jüttner, & Maklan, 2011). Furthermore, it also ensures the continuity of operational and logistical activities, such as delivery to the final destination (Pettit et al., 2019; Ambulkar et al., 2015).

The temporary disruptive events have low probability and high impacts, which are difficult to anticipate and handle traditionally and imply a certain level of turbulence across the whole supply chain (Pettit et al., 2019; Ralston & Blackhurst, 2020). Such events can lead to financial loss, market share loss, reputation loss, deterioration in share value, or lost/missed market opportunities (Jüttner, & Maklan, 2011; Morisse and Prigge, 2017). Industry 4.0 (I4.0) and intelligent systems offer improved supply chain performance through digitisation (Luthra et al., 2020). By restructuring the system and employing the resources effectively, firms can achieve greater flexibility in their processes and keep the systems capable of dealing with the changes in the external environment (Kalsoom et al., 2020; Ahmed et al., 2021). I4.0 systems and approaches bring a technology-driven proactive mechanism of dealing with the

fluctuations in the external environment. This system can play a crucial role in uplifting the resilience of a supply chain manifold.

Despite the plethora of literature on I4.0, the questions about how I4.0 could contribute to SC resilience, the artefact of such a system, and how a firm can adopt I4.0-driven-resilience are yet to be comprehensibly addressed. This acts as an impetus for the present study, leading us to explore the role of I4.0 in SC resilience. In doing so, we introduce attributes and characteristics of I4.0 driven SCRE. The study takes a qualitative approach and reviews the available literature to synthesise the characteristics and attributes of I4.0 driven supply chain. The synthesis of this chapter can pave the way to undertake further research to explore how I4.0 could be capitalised on for effective SCRE and sustainability. The chapter has been divided into four major sections. Section 2 briefly delineates the historical evolution and dimensions of I4.0. It is followed by a discussion on the linkage of I4.0 and supply chain management in section 3. This section paves the way to discuss I4.0 in the context of SCRE in section 4. The last section, i.e. 5, provides concluding remarks.

2. Industry 4.0: Evolution and Dimensions

The world has witnessed three evolutionary phases since industrialisation. These industrial revolutions brought about some radical changes in the practices followed by the industry in manufacturing the products and services (Kalsoom et al., 2020; Luthra et al., 2020; Morisse & Prigge, 2017). All these revolutionary changes helped the firms increase their productivity several times.

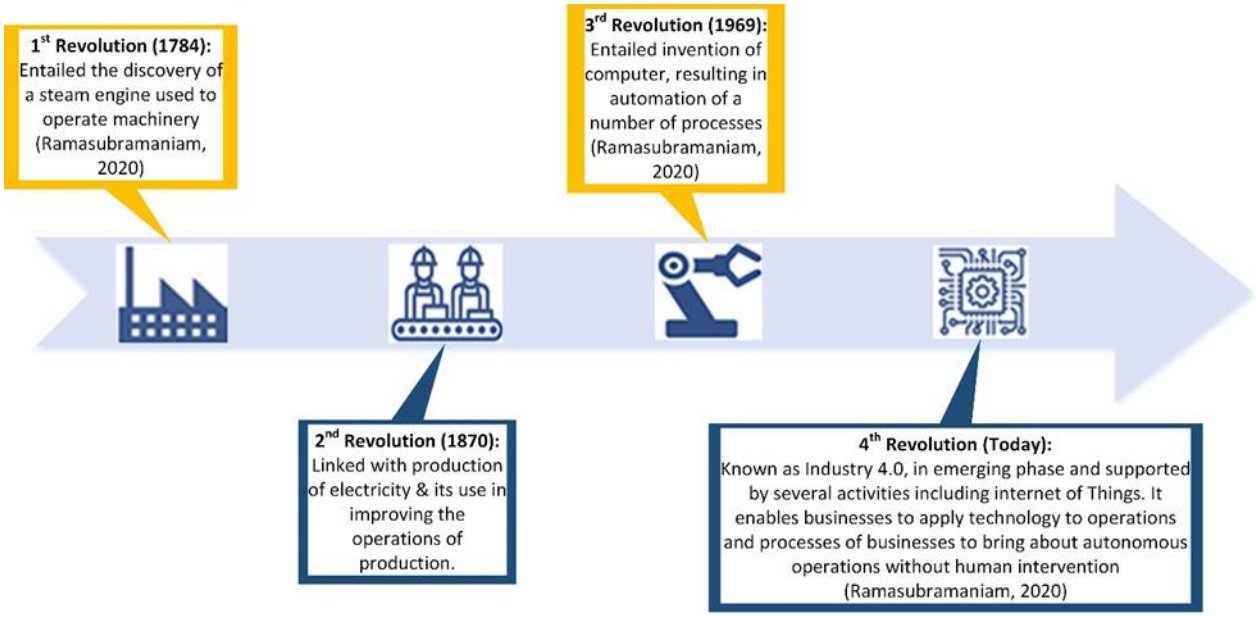

Figure 1 Industrial revolutions

The term I4.0 is used for the fourth iteration of the Industrial Revolution. It emerged in 2011 in Germany to label the strategic German industrial policy that fostered the computerisation of manufacturing (Kalsoom et al., 2020; (Leitão, Colombo and Karnouskos, 2016). Since its inception, I4.0 has greatly influenced industrial systems over the past few years. Similarly, previous technological advancements have led to severe disruptions and caused paradigmatic changes in economies as a whole (Ivanov et al., 2019; Luthra et al., 2020). Therefore, it is

significant to understand the previous three industrial revolutions for an in-depth comprehension of the fourth industrial revolution. The 1st industrial revolution laid the foundation for industrialisation. In the 2nd industrial revolution, the concept of intricate automation emerged. It was followed by the 3rd industrial revolution, which coined the idea of flexible automation. In the 4th industrial revolution, modern information and communication technologies appear as a significant breakthrough (Ivanov et al., 2019 Atif et al., 2021). These innovative technologies include integrating industrial automation, modern manufacturing (3D printing, intelligent production, remote operations, human-computer interaction etc.) and data networks (Mubarik et al., 2021; Atif et al., 2021). I4.0 driven technological innovations such as the Internet of Things (IoT), Artificial intelligence (AI), Machine to Machine communication, Big Data Analytica (BDA) and Cyber-Physical System (CPS) brings decentralisation in business processes (Basl, 2017; Atif et al., 2021). I4.0, through CPSs and Internet, creates a business environment where employees, devices, machinery, and enterprise systems are interconnected (Basl, 2017).

Furthermore, I4.0 introduces a new frontier for the world economy by influencing many industries and impacting how goods are produced, sold, and serviced (Ralston and Blackhurst, 2020). It does so by applying digital technologies such as big data, simulation, additive manufacturing, autonomous robots and vehicles, horizontal/vertical system integration, blockchain and cybersecurity, augmented and virtual reality, cloud, fog and edge technologies and Internet of Things (IoT), ((Kuo and Kusiak, 2019);(Vernadat et al., 2018)). The basic principle of I4.0 is that it creates intelligent networks along the entire supply chain by autonomously connecting machines, digital operations, and systems (Ahmed *et al.*, 2021; Kuo and Kusiak, 2019). Moreover, I4.0 also assists intelligent systems that autonomously utilise and integrate human interaction but avoid unnecessary human management and oversight (Kuo and Kusiak, 2019).

The concept of I4.0 entails intelligent and automated operations such as data analytics by converging the global operations of different industries, including manufacturing, computer technologies, and network connectivity (Morisse & Prigge, 2017). This fourth industrial revolution characterises intricate, well-integrated and complex networks of production and delivery systems and processes (Morisse & Prigge, 2017; Verdouw et al., 2015). The I4.0 revolution had brought the firm's focus towards restricting their systems and organisation according to the needs and wants of the customers (Mubarik et al., 2021; Morisse & Prigge, 2017). I4.0 technologies make it easier for the management to access large volumes of data and make rational decisions backed by in-depth analysis and reasoning, making decision-making more accessible and transparent (Ivanov et al., 2019; Morisse & Prigge, 2017; Kalsoom et al., 2020). These technologies help the firms enhance the operations of their value chains by bringing about greater integration and coordination among the constituents of the value chain (Ahmed et al., 2021; Ivanov et al., 2019). It also helps in bringing the costs down and employing resources efficiently and effectively. I4.0 is based on the development and implementation of the latest digital technologies and highly coordinated vertical as well as horizontal integration (Al-Talib et al., 2020; Lee & Lee, 2015). Implementation of I4.0 demands changes in the production and delivery systems to reduce the delivery times and achieve greater levels of customer satisfaction by fulfilling customer demands more rapidly Lee & Lee, 2015). The companies are transforming their structural units by developing smaller and decentralised production units rather than large centralised units to cater to the demands of the local customers at relatively minor costs and shorter delivery times (Al-Talib et al., 2020; Lee & Lee, 2015).

I4.0 is a new avenue for the success of global economies. The concept of I4.0 has changed the way goods and services are developed, sold and offered (Ralston & Blackhurst, 2020). I4.0 is the integrated coordination system between machines, processes and methods of different firms operating in a business environment (Ralston & Blackhurst, 2020). The underlying concept of I4.0 states that firms can develop creative and digital solutions to support the operations of the supply chains by bringing about autonomous coordination among the systems and machines (Ralston & Blackhurst, 2020; Ivanov et al., 2019). In addition, I4.0 seeks to achieve greater levels of customer satisfaction by fulfilling their requirements and bringing autonomy in the way the machines, systems, and processes are connected and operated.

Moreover, this concept accedes to increasing coordination among different business activities and developing digital networks to enhance synergy among all the supply chain actors that aim to produce and deliver goods to meet the customers' demands (Ralston & Blackhurst, 2020). Thus, the concept of I4.0 entails an intelligent system designed to cope with the changes in the external environment of the business by utilising effective solutions that integrate human interactions. Such systems, however, do not need human supervision for their operation and management (Kuo & Kusiak, 2019; Ralston & Blackhurst, 2020).

3. Industry 4.0 and Supply Chain Management

In the context of supply chain management, I4.0 provides efficient resources and flexible integration of customers and business partners (Fallahpour *et al.*, 2017). It visualises that the products and equipment are interlinked in supply chains (Brandon-Jones *et al.*, 2014). They communicate, exchange, collect, and analyse data through the internet and processes in the system using Cyber-Physical Systems (CPS). For connecting physical devices and computational assets, CPS is understood as transformative technology (Leitão, Colombo and Karnouskos, 2016). I4.0 improves supply chain performance and promises to enhance the resilience of the supply chains to disruptive events (Ralston and Blackhurst, 2020). The ability to handle disruptions is the key to resilience (Ambulkar et al., 2015). The critical factor in SCRE is the system's ability to adapt and reconfigure to mitigate the continuity of risks in supply chain operations (Ivanov et al., 2021). The traditional system's complex supply chain risks are too simplistic (Pettit et al., 2019). Therefore, for superior supply chain performance, an intelligent strategy is need of the hour. On the one hand, I4.0 will make the industry more efficient and flexible, while on the other hand, it will improve the functionality of the existing products (Kalsoom et al., 2020; Ahmed et al., 2021)

Adopting I4.0 could improve the supply chain functions and bring several benefits to the firms' value chain. Therefore, to utilise the maximum potential of I4.0, the manufacturing industries in developed countries are embracing technological advancements extensively (Brandon-Jones et al., 2014; Mccoll-kennedy et al., 2015; Vernadat et al., 2018). Moreover, in recent years, through real-time tracking and transparency among actors, I4.0 has streamlined and facilitated the flow of information across different organisations and entities. It enabled effective communication among different supply chain actors and avoided unnecessary delays due to a lack of transparency (Ahmed et al., 2021; Kalsoom et al., 2020). I4.0 establishes the possibility of autonomous linkages between the different operations of the firm and between firms. It enables production, enhanced flow of the information across the departments, efficient distribution and delivery of the final goods and/or services to the customers (Mccoll-kennedy et al., 2015). In a few ways, the digital connection between the businesses acts like complex adaptive systems. In a supply chain, the benefits of implementing I4.0 include faster processes,

streamlined operations, smooth flow of information and effective communication, greater accuracy, greater resilience, more flexibility, and granularity (Kuo & Kusiak, 2019; Ralston & Blackhurst, 2020). The granularity aspect of I4.0 arises from identifying the types and nature of the products and services that customers want and the ability to fulfil individual orders and making deliveries (Hess et al., 2014; Kuo & Kusiak, 2019; Ralston & Blackhurst, 2020). Stated otherwise, the core concept of I4.0 lies in the ability of the firms to standardise the processes of their supply chains and strive to achieve economies of scale. At the same time, the order customisation takes place only and when necessary (Mccoll-kennedy et al., 2015).

Hence, it is evident that introducing I4.0 technologies to the supply chains will bring numerous advantages to the businesses, including flexibility, reduction in costs, and elimination of inefficiencies and inaccuracies (Al-Talib et al., 2020; Ivanov et al., 2021).

4. Industry 4.0 and Supply Chain Resilience

The term resilience is extensively used in business, economics, and engineering (Morisse & Prigge, 2017). It can generally be defined as the ability of a system to maintain the original state under the challenging circumstances of the external environment (Ismail et al., 2011). On the level of an organisation, resilience is defined as the ability of a firm to maintain its original state and recover from the disruptions caused by the external environment (Ambulkar et al., 2015; Ismail et al., 2011). The disruptive risks posed to the operations of the businesses are characterised by events that are less probable to occur but leave a substantial impact on the operations of the business. Such events are often difficult to be anticipated and prepare for in advance (Jüttner, & Maklan, 2011). Disruptive risks can endanger the business in many ways, including a decrease in the market share, loss of the image, reduced value generation, and threat to the firm's capabilities (Ambulkar et al., 2015; Jüttner, & Maklan, 2011. I4.0 equips businesses with capabilities to deal with turbulent times and keep the organisation on the right track (Ivanov et al 2019). Achieving resilience in the supply chain operations helps the firms achieve better performance and gain a competitive advantage (Pettit et al., 2019; Ambulkar et al., 2015;).

I4.0 epitomises the digital and autonomous linkages within and between the firms (Alicke, Rexhausen and Seyfert, 2016). These links optimise the production process and make operations more accurate and flexible (Kuo & Kusiak, 2019; Atif et al., 2021). The flexible aspect caters for the need of the clients and ensures timely delivery. Supply chain resiliency to cope with unprecedented changes is a hallmark. I4.0 and intelligent systems not only help in mitigating actual disruptions but also proactively avoid future troubles. Resilience to supply chain disruptions needs continuous monitoring of the system to reconfigure necessary resources Ambulkar et al. (2015). The I4.0 key initiatives include decentralisation, virtualisation, interoperability, modularity, service orientation and real-time capabilities to build resilience through automated supply chain processes (Gupta, Kumar and Wasan, 2021).

Furthermore, I4.0 promotes decentralisation that can help in better usage of available resources. For instance, virtualisation can decrease industrial waste by increasing recycling opportunities. Interoperability can help improve and enhance the machine life cycle, modularity allows for better usage of industrial assets, and service orientation can elevate final products. Adapting as required during unanticipated disruption is the key to SCRE Ambulkar et al. (2015). I4.0 promises to enhance the functioning of the supply chains, making them more resilient to tackle disruptions effectively (Ralston & Blackhurst, 2020). Ambulkar et al. (2015) stated that the

ability to adapt to the changes in the external environment is the key to the success of the supply chains, and resilience helps the supply chains to adapt to the changes and disruptions occurring in the business environment. The interaction between the risks that supply chains are vulnerable to and the implementation of digital technology is significant (Ralston & Blackhurst, 2020). In this sense, to efficiently deal with the disruptions, reconfiguring the functions and operations of the supply chain is the key to achieve resilience and help the firms achieve connectivity, flexibility and continuity in the operations of their supply chains (Ralston & Blackhurst, 2020; Ivanov et al., 2019). SCRE enables the supply chains to adapt to the external environment without harming the business operations. I4.0 plays a significant role in helping the supply chains be resilient (Ivanov et al., 2019; Ralston & Blackhurst, 2020). Traditional supply chain systems are too simple to deal with the modern complexities, uncertainties, and disruptions in the global supply chains (Ralston & Blackhurst, 2020). Hence, employing innovative and digitalised systems is the key to the efficient management of the supply chains (Ralston & Blackhurst, 2020).

Employing I4.0 and digital systems in the supply chains helps the firms achieve greater resilience in the operations of their supply chains. A significant reason for it is because autonomy is utilised (Ralston & Blackhurst, 2020). I4.0 is recognised as the fourth evolutionary stage of the industrial revolution (Kalsoom et al., 2020; Ralston & Blackhurst, 2020). Technological advancements in businesses' ways have disrupted production, industry trends, and economic conditions (Hess et al., 2014). I4.0 comprises an integrated and digitalised system of production backed by an efficient communication system between businesses, business environments, and customers (Ralston & Blackhurst, 2020; Atif et al., 2021). The firms implementing I4.0 can share information regarding any operations of the value chain with other business segments. For example, the information regarding the production operations can be shared with the distribution function in real-time to support decision making and achieve efficiency (Vernadat et al., 2018). The real-time sharing of information supported by I4.0 brings numerous advantages to the business, including meeting the customers' demands more efficiently and predicting future demands (Mccoll-kennedy et al., 2015; Ralston & Blackhurst, 2020).

Moreover, to be resilient, the supply chains need to consistently monitor the changes in the environment and develop the ability to reconfigure the supply chains' sources if any changes or disruptions occur in the external environment (Ambulkar et al., 2015). Therefore, the ability of the supply chains to adapt to the changes in the external environment is attributed to resilience. This discussion was also acceded by Ivanov et al. (2019) and Ralston & Blackhurst (2020). They studied that SCRE is the ability of the supply chains to maintain their primary forms by relying on the adaptive systems as the external environment is susceptible to changes all the time. I4.0 promises to develop resilience and adaptation abilities across all partners of the supply chains. Therefore, it is essential to explore I4.0 in the resilience of the supply chains as they face disruptions (Ivanov et al., 2019; Ralston & Blackhurst, 2020).

There is some evidence stating that the resilience of the supply chains can be enhanced by reducing the reliance on other firms (Ambulkar et al., 2015; Hess et al., 2014; Ralston & Blackhurst, 2020). Studies targeting traditional supply chains state that relationships between firms can lead to greater resilience; however, firms need to develop connections with other firms, not relationships with the employees (Ambulkar et al., 2015; Ralston & Blackhurst, 2020). I4.0 ideology proposes that firms reduce reliance on workers and adopt automated processes and systems to achieve their objectives (Ambulkar et al., 2015). Therefore, the

following subsection proposes some key characteristics that enable firms to reduce their dependence on other actors and deal with the disruptions in the supply chains using I4.0.

Supply chain visibility is considered an essential requisite for SC resilience. One of the significant examples highlighting the need for visibility is the horse meet scam of TESCO. According to Brooks et al. (2017, p.1), "beef meat was fraudulently adulterated with horse meat causing widespread recalls and subsequent investigations across both retail and foodservice markets in the European Union (EU)". I4.0 technologies offer an effective solution to such problems by helping companies to map their supply chain. I4.0 driven supply chain mapping allows a firm to visualise an upstream supply chain. It further helps to zoom in on the business processes and preamp any such issue proactively, contributing to SC resilience of the firm.

In the past major supply chain disasters like a failure of Nike's planning system, resulting in 10 million revenue shortfalls, inventory management disaster in 2001, substantially decreasing its stock prices, or Hershey Foods 1999 order management failure had fatal impacts upon the firms' fate (Supply Chain Digest 2006). I4.0 technologies can also help to encounter such disasters effectively.

4.1 Industry 4.0 for Resilient Supply Chain: Attributes and Characteristics

The characteristics of resilience help the firm attain competitiveness in the market and mitigate the disruptions caused in the supply chains (Pettit et al., 2019; Ralston & Blackhurst, 2020; Vernadat et al., 2018). Traditional supply chain practices impact SCRE in several ways (Ralston & Blackhurst, 2020). These factors include the higher costs, inaccuracies, and extensive risks that the traditional supply chains are vulnerable to (Pettit et al., 2019). In addition, before adopting I4.0 in managing the businesses' supply chains, data used to be shared with a single supply chain partner; this raised several questions on the transparency of the data and information (Kuo & Kusiak, 2019). Al-Talib et al. (2020) and Pettit et al. (2019) highlight the following attributes of resilient supply chains:

4.1.1 Visibility

According to Al-Talib et al. (2020), visibility refers to transparency and accurate and reliable information sharing among the supply chain actors. As visibility increases along a supply chain, the trust among different partners increases, resulting in greater confidence among the stakeholders regarding the performance of the business. I4.0 equip the supply chains to enhance their visibility (Al-Talib et al., 2020). It enhances the ability of a supply chain to track the products, check the status of the deliveries, improve the flow of information, and make the

processes more efficient. Visibility improves the real-time sharing of information among the supply chain partners and increases the levels of customer satisfaction. For example, RFID tracks can enhance the visibility of the supply chain activities (Al-Talib et al., 2020; Ivanov et al, 2021).

4.1.2 Collaboration

Effective sharing of information across different supply chain activities results in reduced risks and a more remarkable ability to deal with the disruptions impacting the operations of the supply chain. Therefore, efficient communication and better visibility help reduce threats posed to the operations of the supply chains and improve the supply chain performance (Al-Talib et al., 2020; Ivanov et al, 2021). Moreover, collaboration refers to access to information and required knowledge among different supply chain actors (Al-Talib et al., 2020). Since resilience demands a holistic approach and can only be enhanced if all the components of a supply chain can effectively deal with the disruptions, it is necessary to ensure greater collaboration and equal access to the information among all the partners (Al-Talib et al., 2020; Ivanov et al, 2021). Implementing I4.0 gives rise to transparency and entails sharing data among all supply chain partners in real-time. In traditional supply chains, visibility of the data and information was also a significant issue – due to the unavailability of data in real-time, there were higher chances of errors and uncertainties across the supply chains. This lack of transparency, complexity and uncertainty gave rise to many supply chains issues, such as mistakes in delivering and distributing the goods resulting in the waste of valuable resources and time (Ambulkar et al., 2015). Implementation of I4.0 revolutionised the business model of the supply chains and brought about greater accuracy in the operations (Al-Talib et al., 2020; Pettit et al., 2019; Ivanov et al., 2021; Ahmed et al., 2021).

4.1.3 Flexibility

Similarly, flexibility entails the ability of a supply chain to deal with any disruptions or changes in the external environment without taking any negative impact on its operations and processes (Al-Talib et al., 2020). In other words, the reconfiguration of the systems, processes and products according to the customer's demands (Al-Talib et al., 2020; Ivanov et al., 2021). Furthermore, as the connectivity of all the actors of the supply chain increases, the flexibility of the supply chain increases, simplifying the sharing of information among all the partners, ultimately leading to greater levels of customer satisfaction (Al-Talib et al., 2020; Mccoll-kennedy et al., 2015; Ahmed et al., 2021). Furthermore, by introducing I4.0 in the operations of the supply chains, their process can be made more efficient and flexible to avoid any damage caused by the disruptions (Al-Talib et al., 2020; Ahmed et al., 2021).

The digitalised supply chains equipped with the technologies of I4.0 directly impact the flexibility. For example, the digital contracts between different parties allow technology-supported transactions by employing the internet of things (Ahmed et al., 2021; Kalsoom et al., 2020). Furthermore, by expanding the collaboration and extending the connectivity among other supply chain players, the firms can achieve greater flexibility, which positively impacts the performance of the supply chains (Al-Talib et al., 2020). Thus, supply chain connectivity helps the firms increase flexibility and effectively deal with the changes in the external environment. Moreover, flexibility brings numerous advantages to the firm, including better quality of the products and services, more excellent responsiveness, rapid delivery and distribution, greater production levels, etc. (Closs et al., 2005). Therefore, to be more flexible

in effectively dealing with the disruptions, a supply chain must depict higher velocity and speed to manage the operations across different activities. Hence I4.0 enabled SCRE is an arguably better solution to deal with disruption risks.

4.1.4 Control

SCRE cannot be explained in an exhausted manner without discussing control and connectedness among the different supply chain actors. Control can be defined as the impact that a supply chain possesses, which enables it to deal with the catastrophic impact of any disruption or unforeseen situation affecting the operations of a supply chain. This is the essence of SCRE since it measures the ability of a supply chain to deal with disruptions (Al-Talib et al., 2020). Real-time monitoring and data sharing in I4.0 enable better control and quality assessment across the supply chain operations (Verdouw et al., 2015). Control in the supply chain activities eliminates the need for human intervention and supervision (Verdouw et al., 2015). To augment a supply chain's productivity while reducing costs, businesses must implement effective control measures (Verdouw et al., 2015). I4.0 can help achieve better control outcomes and predict the changing patterns of the external environment (Verdouw et al., 2015). The costs associated with the control measures of the supply chains can be reduced by employing internet of things technology (Verdouw et al., 2015).

SCRE is compulsory to deal with the disruptions in the short run and become agile and robust in the long run (Lee & Lee, 2015; Ralston & Blackhurst, 2020). Visibility, collaboration, flexibility and control are the significant characteristics of resilient supply chains (Ralston & Blackhurst, 2020). There is scarce literature discussing the significance of the internet of things and digital technologies in achieving SCRE (Lee & Lee, 2015; Ralston & Blackhurst, 2020). However, to achieve SCRE by successfully employing I4.0, effective collection, handling, and data analysis should be the primary concern for the firm managers (Ahmed et al., 2021). Redesigning the supply chains by employing I4.0, the supply chain managers can attain greater SCRE by overcoming the weaknesses in the conventional supply chain management techniques. Replacing the outdated practices and systems of supply chain management with the intelligent, digital techniques and implementations of I4.0, the managers can achieve greater flexibility in the operations of the supply chain and collaboration among all the supply chain partners (Ahmed et al., 2021; Closs et al., 2005).

5. Concluding Remarks

I4.0 seeks to align and establish a cyber-physical link between different supply chain functions, such as manufacturing, logistics, distribution, information sharing (Ivanov et al., 2021; Ahmed et al., 2021). Previously, numerous unsuccessful attempts to explore the various perspectives targeting the concern regarding availing the firm's information technology and data analytics capabilities to identify the future trends and demands have been made (Ivanov et al., 2021;). However, I4.0 has revolutionised how the supply chain operates (Ahmed et al., 2021). It has provided several predictive capabilities to the supply chains to mitigate and anticipate any risk or disruption caused by the changes in the external environment (Ahmed et al., 2021; Closs et al., 2005). The autonomous system provides heads up regarding any approaching disruption and makes arrangements in advance. The real-time monitoring and efficiently managed information sharing system have made the supply chains more resilient to the changes (Ahmed et al., 2021). Implementing an advanced technological system influences the operations of the supply chains from multidimensional perspectives, hence promising resilient supply chains

(Ahmed et al., 2021). Innovative technologies equip the supply chains with the capabilities necessary to deal with external shocks and disruptions without undergoing severe changes in their structures and systems (Lee & Lee, 2015). For instance, smart scheduling methods help the supply chains achieve greater flexibility (Ivanov et al., 2021; Lee & Lee, 2015).

Both practitioners and researchers agree that I4.0 can enable firms to be more efficient and innovative. The I4.0 revolution has transformed the global economic structure and made it imperative for organisations to adopt its developments. Initiatives of I4.0 offers strong foundations to evaluate the resilience of their supply chain and assists firms in making appropriate strategies to improve it. SCRE and digital technologies can magnify the inefficiencies in the micro part of the entire supply chain, which will help firms be more resilient. Thus, I4.0 can effectively play an instrumental role in controlling the supply chain chaos and losses. I4.0 and intelligent systems have obvious merits to combat supply chain risks and positively impact SCRE. Nevertheless, firms need to be more careful when enacting I4.0 initiatives as the supply chain represents a network of related activities. Building resilience at one node of a supply chain influences the overall SCRE.

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