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Supply chain management during and post-COVID-19 pandemic: Mitigation strategies and practical lessons learned

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ABSTRACT

The COVID-19 pandemic has affected global supply chains at an unprecedented speed and scale. This paper investigates the supply chain challenges that manufacturing organizations have faced due to the COVID-19 outbreak, particularly in emerging economies. We present a conceptual framework under the dynamic capability theory to analyze challenges and their pertinent mitigation strategies. Ten major challenges are identified based on a literature review, evaluation of several news articles, and discussions with experts. Further, the Grey-Decision-making Trial and Evaluation Laboratory (Grey-DEMATEL) method is applied to analyze the relationships between various supply chain challenges. Scarcity of Labor (PSL) emerges as the most significant challenge, closely followed by Scarcity of Material (SSM). The results also suggest that Inconsistency of Supply (PIS) is the challenge that correlates the most with other factors. Finally, in this paper we also provide guidelines and strategies for practitioners and scholars to better address supply chain challenges post-COVID-19 outbreak.

1. Introduction

The world has recently been severely engulfed by an unprecedented crisis, in the form of the COVID-19/SARS-CoV-2 outbreak (Donthu & Gustafsson, 2020; Verma & Gustafsson, 2020). The initial cases of the novel coronavirus emerged in Wuhan, in the Hubei province of China, as early as December 2019 (Ivanov & Dolgui, 2020). However, in the subsequent months, the pandemic spread all over the world, affecting billions of people, both directly and indirectly. It has gained much attention among supply chain scholars (Choi, 2020a,b; de Sousa Jabbour et al., 2020; Govindan et al., 2020) and practitioners (Business Insider 2020; Deloitte 2020; Fortune 2020) alike. While some sectors witnessed a decline in demand, others saw a sudden spike in demand. Economic activities came to a standstill in many countries such as India, which imposed one of the strictest lockdowns. The outbreak has affected every aspect of business, particularly global supply chains (Ivanov & Dolgui, 2020). It has caused numerous impacts which are sure to have long-term effects (Govindan et al., 2020), creating serious disruptions in supply

chains (Ivanov, 2020a); for instance, 94% of the Fortune 1000 companies have already faced supply chain disruption due to COVID-19 (Fortune, 2020).

The effects of the coronavirus outbreak on global supply chains have emerged in three different sides: supply side, demand side, and logistical side (Mishra et al., 2021; Sharma & Kumar, 2021). Multinational corporations faced a supply-shock, for instance, as the infection spread across India, exports of face masks stopped. Similarly, several companies faced a demand-shock. An increase in demand for essential products was witnessed, while, on the other hand, concerns arose regarding postponed deliveries, delays in securing merchandise, unanticipated travel disruption, and shortage of labor (due to reverse migration of laborers from cities). Therefore, gaps between supply and demand increased¹. Before the COVID-19 era, supply chain managers generally focused on just-in-time inventory management, which helps to reduce costs and increase efficiency. However, following the COVID-19 outbreak, it has become clear that this approach fails to prepare global supply chains to combat extreme shocks, such as those owing to the COVID-19 pandemic

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¹ <https://www.livemint.com/money/personal-finance/labour-shortage-due-to-reverse-migration-to-hit-real-estate-hard-11586723305797.html>. accessed on 01.07.2020

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(Govindan et al., 2020). Furthermore, the way that the coronavirus pandemic has affected global supply chains has only increased the importance of risk management and mitigation strategies. Organizations need to evaluate their supply chain strategies, supply chain designs, and supply chain dependencies to avoid improvised reactions to future natural disasters and prepare themselves to adequately address unexpected disruptions.

Supply chain research in the context of COVID-19 is, by necessity, in its early stages. Few studies have been carried out on a micro level, while those that do exist tend to focus on theoretical attempts to best explain the COVID-19 situation. Some studies suggest future research directions based on a literature review. However, the supply chain-related challenges that companies presently face due to COVID-19, and its mitigation strategies are largely missing from the current debate on global supply chains. These challenges have also invoked supply chain managers to rethink their supply chain strategies to avoid such type of disruption in future. COVID-19 pandemic not only disrupted supply chains' operations but also affected the relation between tiers as well firms' policies in networks of interconnected relationships in many ways. For instance, (a) firms are shifting their sourcing strategies from global to local (Choi et al., 2021; Donthu & Gustafsson, 2020), (b) this pandemic might alter power dynamics within supply chains (Craighead et al., 2020), (c) supply chains have to become more resilient (Craighead et al., 2020; Verma & Gustafsson, 2020), and (d) firms are changing their inventory strategy (Sodhi et al., 2021). Thus, it is important to investigate how COVID-19 related disruptions affect interconnected business landscape of supply chains. With the intention of bridging this gap, this paper aims to address the following research questions:

- a) What are the key supply chain challenges arising from the COVID-19 pandemic?
- b) How do these challenges influence each other?
- c) What mitigation strategies are suitable to address these supply chain challenges?
- d) How COVID-19 disruptions could affect the supply chains' policies in networks of interconnected relationships in future?

To answer the abovementioned research questions, we present a conceptual framework under the dynamic capability perspective and supply chain resilience. After identifying supply chain challenges from literature and consulting with experts, this paper follows a Grey Decision-Making Trial and Evaluation Laboratory (Grey-DEMATEL) approach to examine how supply chain challenges are related with each other. Our study is the first comprehensive that examines supply chain challenges during the COVID-19 pandemic in an emerging economy such as India. This is novel because, to our knowledge, there has been no previous study targeting supply chain challenges that take place in an emerging economy owing to a pandemic as massive as the one caused by the novel coronavirus. Further, supply chains in emerging nations have their own specific characteristics compared to established supply chains in highly developed markets. Thus, a study of an emerging nation such as India may make a positive contribution towards understanding the nuances of supply chains and their key challenges in the event of a global pandemic. We discuss mitigation strategies to overcome the identified supply chain challenges due to COVID-19 pandemic with support from the dynamic capability theory. In doing so, we also highlighted how companies should transform their supply chains to withstand any disruptions in the future.

The rest of this paper is organized as follows: Section 2 presents a contextual literature review; Section 3 describes how the Grey-DEMATEL method was applied to study supply chain challenges; Section 4 presents the key findings; Section 5 discusses mitigation strategies to tackle the challenges identified; Section 6 discusses impacts of COVID-19 in networks of interconnected relationships; Section 7 presents the implications of the study, and, finally, Section 8 presents the conclusions and limitations of the study.

2. Literature review

This literature review is divided into two subsections to provide a better understanding of the concepts behind the supply chain issues that companies have faced during the COVID-19 pandemic. The first subsection presents our analysis of existing COVID-19-related research towards supply chain issues, while the second subsection discusses the supply chain challenges that companies have faced due to the COVID-19 outbreak.

2.1. Research on supply chains and COVID-19

COVID-19 has created a most severe impact on supply chains in recent history and caused one of the biggest disruptions in the history of humankind (Ivanov & Dolgui, 2020). Its disruptions have propagated through entire systems of supply chains, with devastating results (de Sousa Jabbour et al., 2020). It has created a ripple effect in several supply chain areas (Govindan et al., 2020). Several studies in the past have suggested that small disruptions in supply chains create ripple effects (Scheibe & Blackhurst, 2018). However, the COVID-19 pandemic has been much more severe than any other previous outbreak, as it has disrupted the supply, demand and logistical sides (Queiroz et al., 2020; Mishra et al., 2021; Sharma & Kumar, 2021).

To analyze the various issues that have arisen due to the COVID-19 outbreak, several papers have explored different aspects, such as production recovery strategies (Paul & Chowdhury, 2020), the ripple effect (Ivanov & Das, 2020; Ivanov, 2020a, 2020b), decision support systems to manage demand (Govindan et al., 2020), mobile service operations (MSO) during the COVID-19 pandemic (Choi, 2020a) and the effect of COVID-19 on the Indian supply chain (Agrawal et al., 2020; Biswas & Das, 2020). However, none of these papers have investigated the supply chain challenges that companies are facing as well as how these challenges influence each other.

Differing from previous studies, we have investigated the challenges that companies are facing due to the COVID-19 outbreak in the supply chain context and also investigated their relationships. Companies are facing a plethora of challenges based on their geographical conditions and the varying levels of preparedness and resilience of their supply chains (de Sousa Jabbour et al., 2020). India has been chosen as the geographical region for this study because it is one of the most prominent manufacturing hubs in the world, the second most populous country in the world, and also the third most affected by COVID-19, after the US and Brazil (The Guardian, 2020). Therefore, it is important to investigate the supply chain challenges faced by Indian companies and suggest suitable mitigation strategies.

To mitigate the supply chain challenges resulting from the COVID-19 outbreak, it is important to improve supply chain resilience (Belhadia et al., 2020; Ketchen & Craighead, 2020; Queiroz et al., 2020). Craighead et al. (2020) investigate different theories and suggest how these theories can help to tackle such challenges. Remko (2020) and Golan et al. (2020) observe that during this outbreak, supply chains experienced a lack of preparedness, shortcomings in their response plans, and a need for better resilience in the supply chain. Some papers have investigated supply chain resilience under the context of the agriculture supply chain, airlines and the automobile industry (Belhadia et al., 2020). Queiroz et al. (2020) carried out a systematic literature review related to pandemics and epidemic outbreaks and suggested that adaptation, the ripple effect, recovery, digitalization, preparedness and sustainability are vital aspects to be considered in designing supply chains. Belhadia et al. (2020) suggest short-term and long-term plans to improve supply chain resilience.

However, the question of what mitigation strategies should be implemented as lessons learned from the challenges faced is a topic that is still missing in the current debate on global supply chains and the coronavirus outbreak. Some authors argued that it is also important to analyze and take a fresh look of current supply chain and formulate

suitable strategies in order to help managers and practitioners for better preparedness to mitigate future supply chain disruptions (Choi et al., 2021; Craighead et al., 2020; Donthu & Gustafsson, 2020).

A summary of the literature review conducted as part of this research is presented in Appendix A-Table A.1. We can observe that research dealing with supply chain challenges due to COVID-19 is missing. To bridge this gap, we have investigated (a) the supply chain challenges that companies are facing, (b) how companies should prioritize their strategies to tackle these challenges and, subsequently, (c) how companies should consider mitigation strategies to improve supply chain resilience, and (d) how these strategies help to mitigate future supply chain disruptions.

2.2. Potential supply chain challenges within a pandemic context

To investigate supply chain challenges, a two-step procedure was followed. In the first step, relevant articles were identified via the SCOPUS database search engine, using the keywords- “TITLE-ABS-KEY (“COVID-19”) OR TITLE-ABS-KEY (“SARS-CoV-2”) AND TITLE-ABS-KEY (SUPPLY CHAIN CHALLENGES/ BARRIERS)”. The SCOPUS results initially suggested 17 articles. There are few studies specifically discussing the challenges to the supply chains during COVID-19 pandemic; thus, other relevant articles on supply chain challenges were also investigated, from business magazines, various reports, and World Economic Forum documents. Several challenges were commonly identified in these reports. Two of the authors of this paper independently reviewed all the articles to finalize the list of challenges to be covered in this study. Several challenges were also commonly identified across these papers. Ten distinct challenges were categorized by considering and collating these challenges. Several authors used similar approaches to identify and categorize distinct barriers in a number of other fields (Raj et al., 2020; Rajesh & Ravi, 2015).

In the second step, we presented these supply chain challenges to fifteen experts to assess their relevance and uniqueness. All the experts consulted have worked in the field of supply chain and logistics for more than 8 years. Details of the challenges identified are presented in Appendix A-Table A.1. All the experts agreed upon the supply chain challenges identified and confirmed that the identified challenges are relevant and distinct in the Indian context. However, they also suggested some minor changes in the description and terminology used to refer to the identified factors. We designed the final questionnaire based on this expert input.

The final list of challenges and relevant references is presented in Table 1, and detailed discussions related to these ten challenges are presented in the subsequent subsections.

We categorize these challenges in three different clusters as supply side, demand side and logistical side. Firms need to develop capability to mitigate such challenges in future which we discuss in Section 5. Fig. 1 demonstrates a framework to study supply chain disruptions using dynamic capabilities leading to supply chain resilience in case of a focal manufacturing firm. Supply chain resilience can help organizations manage supply chain disruptions while ensuring operational excellence (Mishra et al., 2021). This is backed by a detailed study conducted jointly by Accenture and The World Economic Forum (2013, 2020b) which emphasizes the importance of supply chain resilience and suggests that over 80% of the top global firms are now considering its importance in their supply chain network. Further, several recent COVID-19 related studies have indicated that improving supply chain resilience is paramount to mitigating supply chain related challenges (Belhadia et al., 2020; Ketchen & Craighead, 2020; Queiroz et al., 2020).

Supply chain resilience is based on a set of capabilities that enable firms to maintain and enhance operational and competitive position in the market (Birkie and Trucco, 2020). The novel coronavirus has brought with itself a rapidly changing environment and firms would need to adopt, respond and proactively mitigate disruptions by dynamically synergizing, integrating and rebuilding its competencies,

Table 1
Supply chain challenges.

Sr. No.	Key challenges	Code	Implied Meaning	References
1	Uncertainty of Demand	PLD	Irregularity and inconsistency in orders received from customers due to shifts in buying behaviour, including decline in consumption of high-value commodities, lack of awareness regarding COVID-19, and non-consumption of certain food items causing demand disruption.	Okorie et al. (2020), Hippold (2020)
2	Inconsistency of supply	PIS	Constraints and uncertainty at the vendor’s end coupled with volatility in price and quantity of essential raw material leading to the barrier of inconsistent supply.	Okorie et al. (2020), Paul and Chowdhury (2020), Razdan and Kumar (2020)
3	Scarcity of Material	SSM	Scarcity of material in the market due to surges in demand caused by hoarding and panic buying, coupled with questionable continuity of operations at supplier’s end, including unavailability of imported goods owing to nationwide lockdown situation.	Agrawal et al. (2020), Biswas and Das (2020), Okorie et al. (2020), Doshi (2020), Razdan and Kumar (2020)
4	Delay in Delivery	SDD	Restrictions on imports as well as local transport, coupled with certain routes involving detours due to restricted zones, slower movement of goods, higher lead times, thus leading to delay in delivery as a supply chain barrier.	Biswas and Das (2020), Hippold (2020)
5	Suboptimal Substitute Adoption	SSA	Closure of operations of existing critical suppliers, coupled with the availability of suboptimal alternatives/ substitutes in the market, leading organizations to procure such alternatives, causing poor quality, rework, and other supply chain issues.	Deloitte (2020), Razdan and Kumar (2020)
6	Scarcity of Labour	PSL	Imposed lockdown restrictions leading to a reduction in wages, lack of employment and sustenance issues, causing skilled migrant workers to move back to their respective states,	International Labour Organization (2020), World Economic Forum (2020a), Agrawal et al. (2020), Biswas and Das (2020), Okorie et al. (2020),

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Table 1 (continued)

Sr. No.	Key challenges	Code	Implied Meaning	References
			leading to scarcity of workforce and a major barrier to efficient supply chain operations in an emerging economy like India.	The Economist (2020)
7	Suboptimal Manufacturing	PSM	The majority of manufacturing hubs across India being located in regions that were categorized as red (restricted) zones, with complete closure leading to limited manufacturing activity. Further, uncertain demand and inconsistent supply led to the manufacturing of a suboptimal product portfolio mix further contributing as a barrier to the supply chain.	World Economic Forum (2020b) , Agrawal et al. (2020) , Gupta et al. (2020) , Razdan and Kumar (2020)
8	Constraint in Capacity (Storage)	SCC	Declining consumer optimism and lack of demand for high-value non-essential commodities leading to the stocking of products in warehouses and distribution hubs, causing working capital blockage and liquidity issues	Razdan and Kumar (2020) , Gupta et al. (2020) , Hippold (2020)
9	Vehicle Unavailability and Delays	DVU	Lack of commercial trucks travelling between key routes, severe restrictions on exports, and local transport coupled with delivery routes in restricted zones leading to vehicle unavailability and delays in delivery as a supply chain barrier.	Doshi (2020) , Hippold (2020) , Biswas and Das (2020) .
10	Last-Mile Delivery Challenges	DLM	Most urban areas, which contain the majority of the population, being categorized as a restricted zone. Switching routes to bypass these zones leading to in-transit delays. Local and state-level regulations and delays associated with electronic pass issuance, compliance, and validity contributing to last-mile delivery challenges.	Agrawal et al. (2020) , Ketchen and Craighead (2020) , Gupta et al. (2020) , Razdan and Kumar (2020) , Choi (2020)

resources and overall capabilities. The dynamic capability view of an organization highlights its ability to adapt, amend and reconfigure its internal and external resources and capabilities in response to the rapidly changing environmental conditions ([Teece, 2007](#)). Past research has sufficiently indicated that resilience is seen to be a significant

dynamic capability that can assist an organization to navigate through turbulent situations ([Ponomarov, 2012](#); [Singh et al., 2020](#); [Mishra et al., 2021](#)). This motivates us to consider the dynamic capability view. The dynamic capability theory has been considered over other management theories such as the resource-based view of the firm because the pandemic has caused environmental changes and it is dynamic in nature. While the resource-based view is more suitable for static situation and not in a dynamic environment.

2.2.1. Uncertainty of demand

[Hippold \(2020\)](#) suggests that the COVID-19 pandemic will lead to a shift in the buying behavior of consumers, creating disruptions in demand. Outbreak of COVID-19 pandemic has triggered an all-time low demand for certain commodities, leading to a significant impact on manufacturing sector companies and their upstream suppliers. For example, the dairy and poultry industry has been greatly affected due to a lack of demand. Only raw milk to be consumed by households has been considered an essential commodity. However, a large part of the demand for milk has traditionally come from its use as a raw material in sweet shops, bakeries, tea stalls, and ice cream production. The reduction in demand for these products has led to a 30% drop in milk procurement in some parts of India. A primary reason for this is fear of potential exposure to the virus through interaction with people and the consumption of certain kinds of products. Misinformation among consumers has also affected the demand for chicken and eggs. Farm-gate chicken prices have dropped by about 60% to an average of about Rs 30/kg in southern India, from Rs 72.50/kg in January, after rumors on social media linking chicken consumption with Covid-19 ([The Economic Times, 2020](#)). Due to future uncertainties and loss of income, many people are shifting their consumption patterns to only 3 basic meals a day with no extravagances, leading to a decrease in consumption of expensive goods. Such uncertainty and disruption in demand will act as a major challenge affecting the supply chain.

2.2.2. Inconsistency of supply

According to [Razdan & Kumar \(2020\)](#), supply-side capacity constraints and volatility in price and quantity constitute a major disruptor owing to the COVID-19 pandemic. Supply shortages and associated inconsistencies have been seen in the case of Micro, Small and Medium Enterprises (MSMEs), which are widely dispersed across India ([The Economic Times, 2020](#)). Furthermore, the nation also saw numerous inconsistencies in the supply of essential commodities. A recent report in [Business Standard \(2020\)](#) suggests that essentials such as grains and pulses have become scarce in the market. Purchases of grain in the city of Mumbai itself have doubled to over 100,000 30 kg bags per day since the outbreak of the pandemic. This is because every actor across the supply chain, from wholesalers to retailers, has been hoarding, thus creating a state of artificial scarcity. It is evident that such practices will lead to supply constraints, resulting in volatile prices, which will in turn motivate inconsistency in supply, which will act as a barrier to the smooth operation of the supply chain.

Indeed, supply chain is network of different entities. Traditionally focal firms rely on immediate suppliers. Mapping is important to maintain the visibility across a supply chain supply chain network ([Sodhi et al., 2021](#)). However, supply chain network mapping is still missing from most of the supply chain network. Poor visibility across supply chains created inconsistency of supply in supply chain.

2.2.3. Scarcity of material

With the advent of the pandemic and the subsequent lockdown of several nations, and India, in particular, the global market has become uncertain. The surge in demand for select essentials, owing to panic buying coupled with uncertain continuity of operations at the supply end, both during and after lockdown, is seen as a big risk to the availability of key materials and services ([Razdan & Kumar, 2020](#)). The availability of raw materials is proving to be a huge problem for

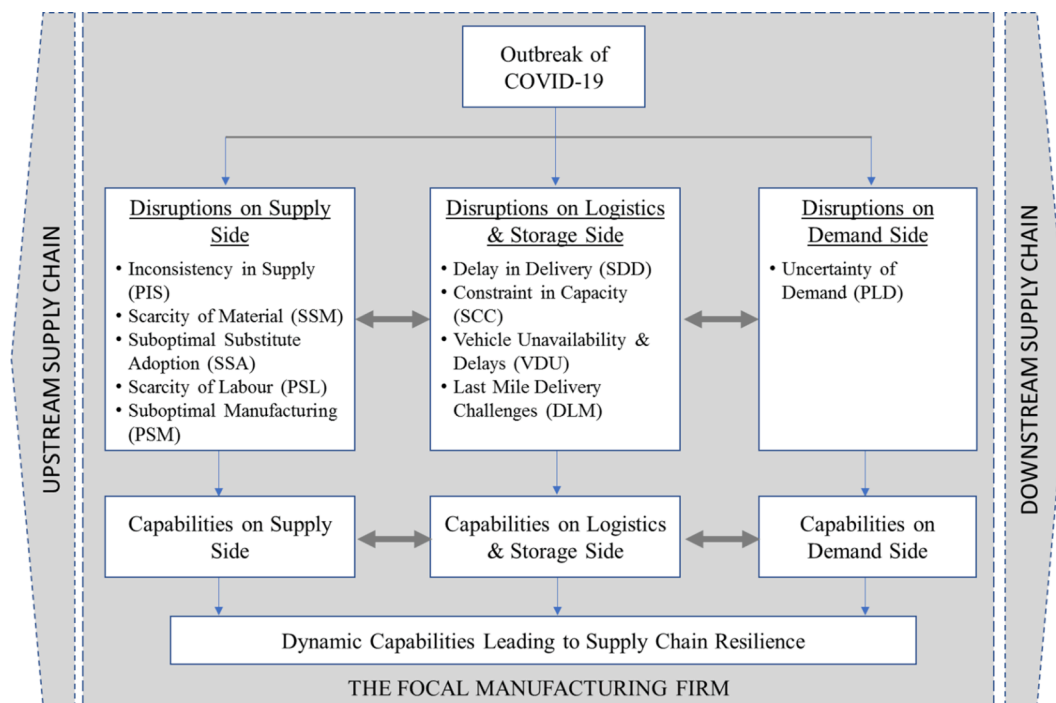


Fig. 1. Framework to study supply chain challenges.

manufacturing companies, especially in the packaging industry, in trying to restart their activities. Companies are unable to obtain raw materials that were previously sourced from Mumbai and Pune, as both cities are completely locked down. Furthermore, as per a [Bloomberg \(2020\)](#), it is understood that imports were completely stopped during the lockdown period and have seen minimal resurgence over the course of weeks, even after certain lockdown restrictions were lifted. Various sectors, such as pharmaceuticals, automobiles, electronics, and chemical products, etc. are facing a shortage of required components, since China accounts for 27% of India's automotive part imports. Around 55% of electronics are also imported from China, supplies of which have dropped dramatically. This will create additional scarcity, contributing to scarcity of material.

2.2.4. Delays in delivery

The biggest challenge for almost every organization is to strike a balance between the time taken to source, manufacture, and distribute products to customers and the customers' willingness to wait. Furthermore, it is usually the case that customers are not prepared to wait for long durations, especially in cases where substitute products are available in the market. Additionally, for all organizations, the time currently taken to procure raw materials is rather uncertain, because it is dependent on external suppliers and is hence beyond the control of the organization. The COVID-19 pandemic has led to restrictions in transportation and movement of goods and materials, especially through areas that are under restricted or containment categories. This, in turn, has led to higher lead times, thus impacting the delivery timelines of critical raw materials and semi-finished goods ([Hippold, 2020](#)). As per [Entrepreneur.com](#), for the suppliers of Anvyl in China, lead times have increased by an average of 20 days since the end of 2019. Such delays in delivery of raw materials and semi-finished goods will have a cascade effect on the processing and delivery of goods to the end consumer, thus posing a barrier to the normal functioning of the supply chain.

2.2.5. Adoption of suboptimal substitutes

The advent of COVID-19 and lockdown restrictions has disrupted the continuity of operations for suppliers and vendors alike. It is during

times like these that alternate vendors and product substitutes tend to be considered, with a view to mitigating sourcing risks ([Deloitte, 2020](#); [Razdan & Kumar, 2020](#)). According to a recent article in [The Hindu Business Line \(2020\)](#), severe supply chain disruptions in China have caused a ripple effect in global trade flow, and India is no exception. With the aim of reducing stockpiling of inventory, most organizations in India had moved toward 'just in time' delivery systems. However, certain industries in India, such as pharmaceutical, automotive, chemical and textiles, have been severely affected, with as much as over 70% of raw material components being imported from China. In times like these, most companies would need to switch to domestic suppliers as an alternative. However, it is pertinent to note that embracing poor alternatives and substitutes may lead to suboptimal product quality and could have long-term detrimental effects on the supply chain, including rework and additional costs.

2.2.6. Scarcity of labor

According to the latest COVID-19 pandemic report released by The International Labor Organization (2020), about 2 billion workers (approximately 25% of the world population) are employed in the unorganized sector, with most of these workers belonging to emerging economies. With regards to India, the number of such workers affected because of the lockdown and containment measures is a staggering 400 million (over 90% of the working population). The logistics sector in India alone employs more than 40 million people and contributes more than \$200 billion to the economy. Most of these workers are unskilled, engaged in manual loading, unloading and material handling. Due to safety concerns and lockdown restrictions, workers involved in the supply chains of essential commodities are often unable to continue working.

Furthermore, the [World Economic Forum \(2020a\)](#) indicates that approximately 139 million workers in India belong to the migrant worker category. Additionally, an article in [The Economist \(2020\)](#) claims that up to 80 million such migrant workers travelled back to their villages and hometowns due to lockdown restrictions and their consequent reductions in wages or loss of employment entirely. Due to this reverse migration, agriculture and logistics are likely to be among the hardest hit sectors, as these sectors are largely informal and heavily

dependent on migrant labor. Azadpur Mandi, Asia's largest fruit and vegetable wholesale market near Delhi, is currently only able to operate at 25% of its normal capacity.

It is common knowledge that workers are the backbone of any manufacturing and service industry, especially in emerging economies like India, which rely hugely on the informal economy (Carnevale & Hatak, 2020). With the displacement of migrant workers in such huge numbers, scarcity of labor is a critical issue and a key challenge to the regular functioning of the supply chain.

2.2.7. Suboptimal manufacturing

According to a report by the World Economic Forum (2020), India ranks in the top 10 manufacturing countries in the world, with a contribution of 3% of global manufacturing output. During the COVID-19 pandemic and consequent declaration of nationwide lockdown, India was classified into 3 zones by the Indian Ministry of Health and Family Welfare (MoHFW); namely, green, orange and red zones. Over 130 districts, including the most urbanized and industrial parts of India, and contributing around 41% of national economic activity, were placed in the red zone (the most restricted zone), which created a massive challenge to manufacturing activities (McKinsey, 2020). Additionally, owing to an unprecedented surge in demand for certain products and lack of demand for other products, it has been a challenge for manufacturing companies to manage their product portfolio mix, typically in cases where products share resources such as equipment, infrastructure, raw material and labor (Razdan & Kumar, 2020). The aforementioned restrictions have a direct impact on manufacturing and are a major challenge to the supply chain.

2.2.8. Constraint in capacity (storage)

While Razdan & Kumar (2020) suggest that panic buying has been on the rise for essential commodities during the lockdown situation, India has not seen a similar trend for all types of products. Consumer optimism has declined across the country with the advent of the COVID-19 pandemic, and consumers are expected to continue to reduce their spending for a considerable period (McKinsey, 2020). This could result in overstocking of materials at warehouses and distribution facilities waiting for demand to pick up at a future date, thus creating storage and capacity constraints at warehouses and local distribution hubs (Hippold, 2020). Excess stocking of inventory for indefinite periods will, in turn, lead to potential damages, perishability issues and working capital blockages, leading to liquidity issues for organizations across supply chains. Considering the above, excess stocking, inventory pile up and blockage of working capital is a major roadblock to successful supply chain operations.

2.2.9. Vehicle unavailability and delays

Bloomberg's (2020) report states that, while the lockdown in India led to a huge reduction in transportation activities, the scenario did not improve significantly even after the government lifted lockdown restrictions. Out of a total capacity of 9 million commercial trucks in the country, a meager 15–20% were in action on the roads. Similarly, export operations were completely shut down during the lockdown period, and this area saw minimal resurgence for weeks, even after certain lockdown restrictions were relaxed. A contraction also occurred in air freight capacity, which was constrained to accessible and operational flights carrying only cargo. Furthermore, the COVID-19 pandemic has led to restrictions in the transportation and movement of goods and materials, especially on routes that traverse restricted or containment areas. This, in turn, has led to higher lead times, thus impacting the delivery timelines of finished goods to the end customer (Hippold, 2020). Shipping vessels are now being placed under quarantine for long periods of time before being permitted into ports, thereby slowing down procedures and lengthening lead times. There are also problems with transporting people to workplaces, as public transportation hasn't yet reopened. The usual public transport options are not functional, and companies often

do not have enough vehicles for conveyance of all workers. The requirement of social distancing measures also means that the available vehicles cannot be utilized at full capacity. The above transportation issues have contributed to unprecedented delays in delivery of consignments to end customers and can be considered a challenge toward the harmonious functioning of the supply chain.

2.2.10. Last mile delivery challenges

In the wake of the pandemic, most organizations have responded to customer requirements to minimize physical touch points and are seen to be revamping their supply chains. There is a growing discussion among organizations as well as practitioners regarding how to create a resilient supply chain. Brands are either moving towards fully captive in-house delivery services or integrating with last mile delivery partners with a view to attracting customers (Razdan & Kumar, 2020). However, with most urban areas included in the red zone and containment categories during lockdown (McKinsey, 2020), it has been a challenge for last mile delivery partners to deliver products to the customer's doorstep. Additionally, the local authorities of the worst affected cities, such as Mumbai, have different rules compared to the rest of the nation, thus affecting the delivery of products located in cross-country warehouses. Furthermore, even if products do make it to the delivery locality, the transporter may have to navigate through a containment zone and may also have to select an alternate route, leading to delivery delays. Finally, with local bodies issuing e-passes with different rules for each state, the demands of compliance and validity also require consideration. All of the above factors have added to challenges for last mile delivery.

In the next section, we discuss the research methodology that has been followed to identify the causal and effect groups among the ten challenges identified.

3. Research methodology

The methodology followed in this paper comprises four stages. First, we identified a set of key challenges based on a literature review and discussion with experts. Further we categorize these challenges in three clusters. Second, we conducted a survey of experts and academics to obtain the relevant information on how a given challenge would influence other challenges. Third, we applied the Grey-DEMATEL process to this data with the following intentions: a) to rank the challenges and b) to segregate them into cause-and-effect categories. DEMATEL is a widely used method in the field of multi-criteria decision-making (Raj et al., 2020). Fourth, a mitigation strategy was formulated in terms of short-term and long-term strategies to tackle supply chain challenges under the dynamic capability perspective.

3.1. The grey-DEMATEL method

Two of the core research questions for this study are a) what are the key supply chain challenges during the Covid-19 pandemic? and b) how do these challenges causally influence each other? To analyze this type of problem, a multiple-criteria decision-making approach (MCDM) is the most suitable approach (Luthra et al. 2018; Raj et al., 2020). Therefore, we selected a MCDM tool for our analysis. There are several MCDM tools which can be applied, such as the Analytic Hierarchy Process (AHP), Interpretive Structural Modelling (ISM), Analytic Network Process (ANP) and Decision-Making Trial and Evaluation Laboratory (DEMATEL). However, we preferred a Grey-based DEMATEL methodology over other MCDM approaches. AHP can be used to determine the ranking of elements, while ISM assesses logical connections between them. ANP assesses rankings, helps with uncovering interdependencies between components and deals with the problem of consistency, although it has limited applications because of the complexity of the procedure (Luthra et al. 2018; Mangla et al., 2018).

DEMATEL can be considered better than other methods, as it also reveals the relationships between different factors (Cause and Effect),

ranks the factors in relation to the types of associations and highlights the strength of one factor over another. The advantages of DEMATEL over AHP, ISM and ANP are well established in the literature (Luthra et al. 2018; Mangla et al., 2018). However, the DEMATEL (Decision Making Trial and Evaluation Laboratory) method has its own set of drawbacks. It cannot function under ambiguous and uncertain conditions or where there is a shortage of information or in case of conflict resolution amongst experts. Real life situations such as the COVID-19 pandemic are very uncertain, complex and filled with ambiguity and vagueness of data and information, leading to inaccurate human judgment and consequent decision-making. In such situations, the usual DEMATEL methodology may fall short of effectively managing such forms of uncertainty (Xia et al., 2015). To avoid such uncertainties, fuzzy theory or a “grey” approach can be integrated with the normal DEMATEL method (Xia et al., 2015). Moreover, fuzzy theory is itself not without its shortcomings. For instance, it has a drawback when mapping membership functions, such as those that are triangular and trapezoidal in nature (Khompatraporn & Somboonwiwat, 2017). In order to resolve such issues, the Grey theory can be combined with DEMATEL techniques. With a view to addressing the above shortcomings we have selected Grey-based DEMATEL as our research methodology. Many studies have suggested that the hybrid Grey-DEMATEL method is better than DEMATEL alone (Rajesh & Ravi, 2015).

This approach involves 9 steps, which are explained in the Appendix B (adapted from Bai & Sarkis, 2010).

3.2. Applying Grey-DEMATEL

In the first step, we identified experts from academia as well as industry, based on a purposive sampling approach. Purposive sampling is a non-probability sampling technique that relies on selected respondents to provide appropriate and useful information. This sampling approach is a suitable approach for the Grey-DEMATEL technique, and many papers have used this method in the past (Raj et al., 2020a, 2020b).

In all, 24 experts were contacted via email between the months of May and June 2020. There was a nationwide lockdown in India before May 2020, during which few organizations were allowed to operate. We selected respondents that were working in manufacturing plants and in units that were operating during the COVID-19 outbreak. The manufacturing plants contacted all have over 1000 full time employees and contract workers, operating primarily in the oil and energy, cement and construction, chemical and heavy engineering sectors.

A total of 15 completed responses were received. Out of these, 12 were from industry experts and 3 were from academic experts. These experts were chosen in such a way that each of them has encountered one or more of the identified supply chain challenges during the COVID-19 crisis. Furthermore, all the industry experts had a minimum of 8 years of experience across various domains, such as sourcing, operations, demand management, logistics and accounts. The profile of respondents reveals that all experts had a university degree as a minimum qualification level. Thus, these experts are appropriate for this study. The details of the experts are presented in Appendix A-Table A.2. The various challenges identified were presented to the experts in an Excel spreadsheet document. The description of each challenge was explained in the first sheet, while the experts' opinions about the degree of impact of each challenge were recorded on the remaining sheets using a linguistic scale (“No influence” to “Very high influence”; see Appendix A-Table A.3). Thus, 15 direct-relation matrices, each of size 10×10 , were obtained.

The approach taken in Steps 2–9 is indicated in the Appendix B. The average grey-relation matrix was obtained using Eqn. (3), as shown in Appendix A-Table A.4. The crisp values were obtained using Eqn. 9, as shown in Appendix A-Table A.5. The normalized direct-relation matrix was obtained using Eqn.11 and was converted into the Total-Relation Matrix using Eqn. (12), as presented in Appendix A-Table A.6. Finally, row sums D_i and column sums R_j were obtained based on the

“PROMINENCE” and “NET INFLUENCE” factors, which were calculated as shown in Table 2.

In the final step, step 9, the Influence-Prominence Map (IPM) was plotted, as shown in Fig. 2. In this process, each factor (i.e., each supply chain challenge) is plotted on a 2D plane. This graph is drawn using $D + R$ (x-coordinates) and $D - R$ (y-coordinates). This graph is known as the values' Influence Prominence Map (IPM). The $D + R$ value denotes the prominence of each supply chain challenge within the system of challenges, since a high $D + R$ indicates that a challenge simultaneously has a high influence on the other challenges and is influenced highly by them, while a low $D + R$ indicates that both types of influence are minimal. The $D - R$ value stands for the net influence of a challenges since it is the difference between how much a challenge influences other supply chain challenges and how much it is influenced by them. The x-axis and y-axis of this graph represent the “PROMINENCE” and “NET INFLUENCE” factors. “NET INFLUENCE” is also divided into two parts: a “cause” group ($D-R > 0$ or above the $y = 0$ line) and an “effect” group ($D-R < 0$ or below the $y = 0$ line). However, the factors which are further along the x-axis have greater prominence compared to those on the left.

4. Results and discussion

The first and most significant group is termed the ‘prominent factors’. However, the prominent factors consist of both cause (influencing) and effect (resulting) factors. Analysis of the prominent factors suggest that these are challenges or barriers which require immediate attention. However, cause (influencing) and effect (resulting) factors each require attention at different times (Bai & Sarkis, 2013). So, for the sake of clarity, we discuss each type of factors separately and evaluate each of their relationships.

4.1. Prominent challenges

The factors can be sorted in terms of significance, as follows: $PIS > PSM > DVU > SDD > SSM > SCC > PLD > PSL > SSA > DLM$. The four most prominent factors are therefore identified as PIS, PSM, DVU and SDD.

PIS (inconsistency of supply) is found to be the most prominent challenge. This was further verified by industry experts, who concluded that the supply of materials is deeply affected by factors like vehicle availability, in-transit delays due to rerouting, suboptimal manufacturing and overstocking at warehouses to combat uncertainty of supply. Supply inconsistency is also a direct antecedent to scarcity of materials and leads manufacturers to embrace and adopt suboptimal substitutes. Hence, it can be noted that PIS as a challenge that correlates most with other factors. Additionally, Razdan & Kumar (2020) further reaffirm the aforesaid findings by stating that supply is bound to be inconsistent under present conditions and that this is one of the most prominent challenges, owing to market volatility, supply side constraints and questionable continuity of operations by vendors and transporters alike. PSM (Suboptimal manufacturing) emerged as the second most prominent challenge to supply chains amidst the COVID-19 scenario. Manufacturing is the engine of any emerging economy and India is no exception. However, the pandemic and associated nationwide lockdown not only led to the fleeing of millions of migrant workers from urban industrial hubs, but also saw the complete shutdown of these areas. Further to our discussion with industry experts, it was noted that uncertain demand coupled with inconsistent supply led to manufacturing of a suboptimal product mix in order for companies to stay afloat. Additionally, last minute searches for alternate sources of raw materials also led to losses owing to poor quality, as well as rework in many cases.

DVU (Vehicle Unavailability and Delays) is the third most prominent challenge. As highlighted by Kleindorfer & Saad (2005) in their seminal work on managing disruptions within the supply chain, focus on transportation is extremely important, particularly in times of supply chain

Table 2
Degree of prominence and net cause/effect values.

	D	R	D + R	D-R	Prominence Rank (as per D + R)	Net Influence rank (as per D-R)	C/E
PLD	0.216	0.460	0.677	-0.244	7	10	E
PIS	0.509	0.647	1.156	-0.138	1	9	E
SSM	0.478	0.355	0.833	0.123	5	2	C
SDD	0.401	0.432	0.833	-0.032	4	8	E
SSA	0.325	0.286	0.611	0.038	9	4	C
PSL	0.386	0.227	0.614	0.159	8	1	C
PSM	0.546	0.513	1.059	0.033	2	5	C
SCC	0.335	0.359	0.694	-0.024	6	7	E
DVU	0.465	0.387	0.852	0.077	3	3	C
DLM	0.253	0.246	0.499	0.007	10	6	C

Note: C: Cause group, E: Effect group

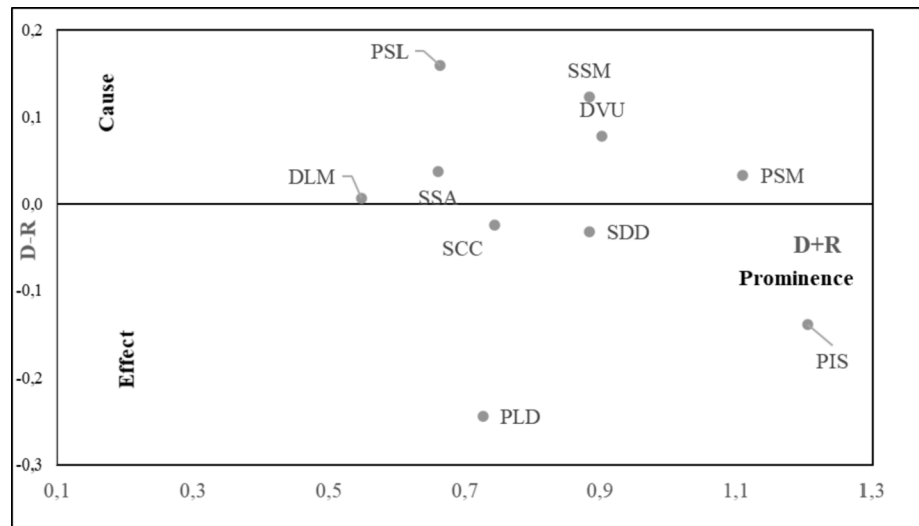


Fig. 2. Influence Prominence Map.

disruption. This is mainly because transportation is the backbone of any supply chain and connects all its partners. This point was subsequently reaffirmed by industry experts, who further added that unavailability of vehicles in turn leads to other supply chain challenges, such as scarcity of raw materials at the inbound side and delay in delivery of finished goods at the outbound side of the supply chain. Our results are in accordance with a recent [Bloomberg \(2020\)](#) report, which indicates that the nationwide lockdown in India severely impeded availability of vehicles, and this scenario failed to improve for weeks after the lockdown was called off. Statistically speaking, of the 9 million trucks across the nation, a meager 15–20% of trucks were active between critical destinations during the lockdown period. The above had an immediate cascade effect on the consistency of supply and delivery timelines, which further led to warehousing and storage capacity issues, including blockage of working capital and suboptimal manufacturing.

SDD (Delay in Delivery) of both raw materials and finished goods was the fourth most prominent challenge identified in our study. As is evident, delivery delay is a direct consequence of inconsistent supply, transportation challenges, challenges with manufacturing and labor-related issues. Further, [Hippold \(2020\)](#) indicates that delay in delivery is a critical disruption caused by the lockdown and can be chiefly attributed to vehicle availability challenges and rerouting due to containment zones, including restricted movement of vehicles. The above complements our finding that delay in delivery is a notable prominent challenge to supply chain operations.

4.2. Causal/Influencing group

The most important influencing factors have been identified based

on the highest D-R scores. According to [Fig. 2](#) and [Table 2](#), we can rank the causal factors in the following order: PSL > SSM > DVU > SSA > PSM > DLM.

Amongst the six identified causal factors, PSL (Scarcity of labor) leads the causal group, indicating that this is the most important influencing or causal factor. To reinforce this result, we discussed our findings with industry experts, who accepted this as holding true. Further, a recent article from [The Economist \(2020\)](#) states that around 80 million migrant workers (approximately 60% of the total migrant worker population of India) are known to have travelled back to their villages and hometowns owing to lockdown restrictions, due to the consequent reduction in wages and often loss of employment during the COVID-19 pandemic. It is common knowledge that in an emerging economy such as India, such a migrant workforce forms the backbone of manufacturing and related services rendered by any organization. This reaffirms our findings, suggesting that scarcity of labor and workers is perhaps the biggest barrier to the functioning of a supply chain during the COVID-19 pandemic.

SSM (Scarcity of material) is the second most prominent causal challenge to smooth supply chain operations. During the COVID-19 pandemic, the demand for selected items saw a surge on account of panic buying as well as hoarding, leading to artificial scarcity of materials and a resultant increase in per unit price of certain materials. Furthermore, as per a recent report by [Razdan & Kumar \(2020\)](#), the turbulence and volatility of the market due to the pandemic and the consequent nationwide lockdown has raised questions regarding the continuity of operations of several vendors and material suppliers. To add to this, the ban on imports of materials during the same period further led to materials becoming scarce in the market ([Bloomberg,](#)

2020). Thus, the above factors, coupled with testimony from practicing industry experts, proves that scarcity of materials is indeed a major hindrance in the management of supply chains.

DVU (Vehicle unavailability and delays) is the third greatest causal challenge and is generally caused by restrictions on transportation and movement, including rerouting to avoid containment zones, excess demand on selected routes and lack of availability of drivers. This was confirmed by industry experts, as well as by a recent Bloomberg (2020) report, which stated that out of a total capacity of 9 million commercial

trucks in the country, a meager 15–20% were active on the roads during this period. The challenges SSA, PSM and DLM are also positioned in the causal group. However, they have very limited influence on the challenges in the effect group.

4.3. Effect/resulting group

The effect factors, on the other hand, can be ranked as follows: SCC > SSD > PIS > PLD. These four factors are influenced by the previously

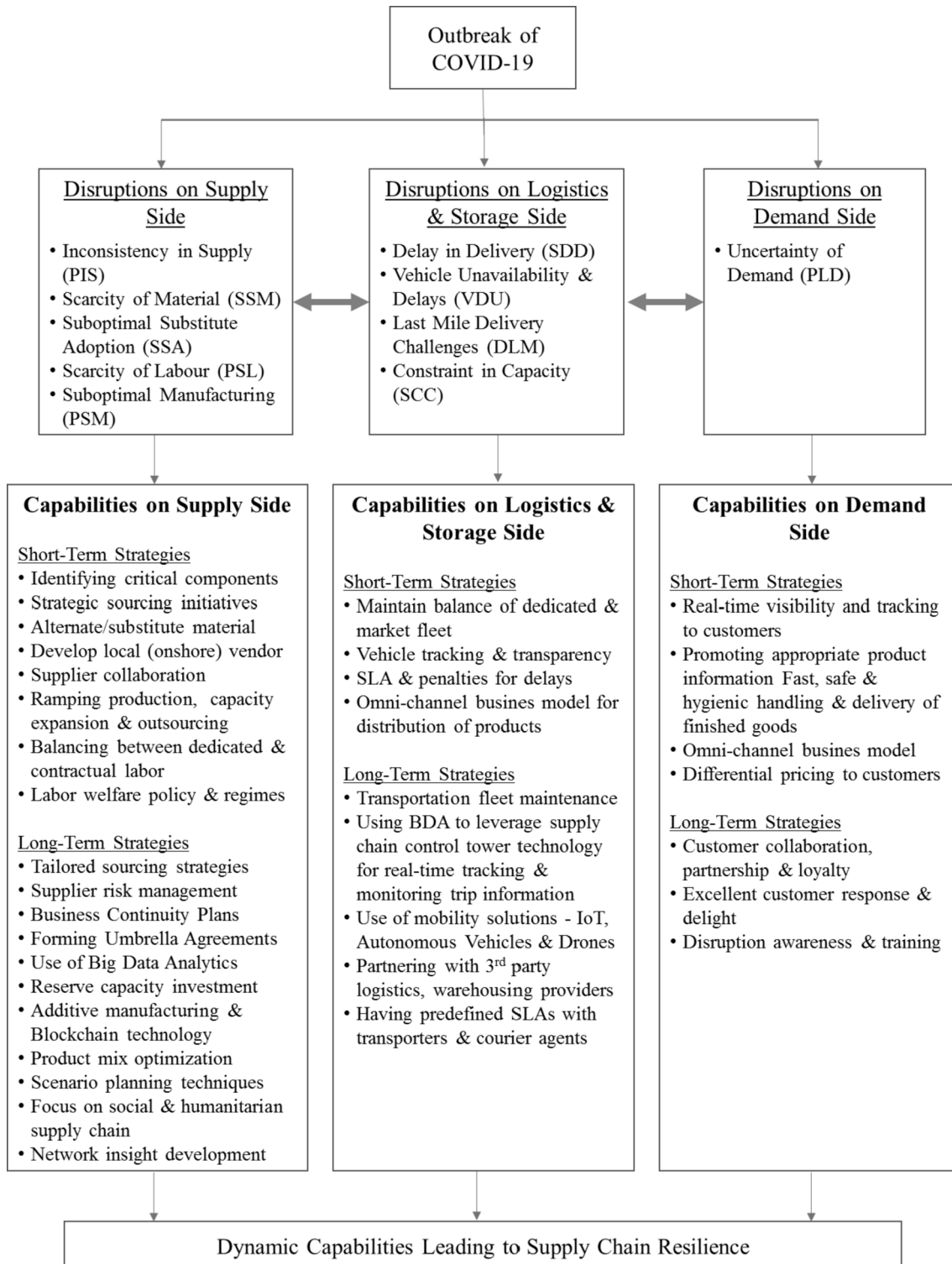


Fig. 3. Details of disruptions and firm’s capabilities leading to supply chain resilience.

discussed six causal factors, which are roadblocks to the successful functioning of supply chains. Out of these four challenges, SCC (Constraint in capacity) is the closest to the causal group, and experiences very little influence from the causal factors. Uncertainty of demand and supply can lead manufacturing companies to produce and stock excess goods, leading to constraints in storage capacity at warehouses and distribution hubs (Hippold, 2020). This, coupled with blockage of working capital, can in turn damage regular supply chain operations.

Two other challenges, namely SSD (Delay in delivery) and PIS (Inconsistency of supply), have very limited influence on the supply chain when compared to the causal factors. Based on our findings, PLD (Uncertainty in demand) is the challenge with the least influence on supply chain operations. This is because the uncertainty in demand experienced was merely a perception on account of changed buying behavior, coupled with panic buying, delays in replenishment, lack of transportation, rerouting, hoarding of goods and artificial scarcity, which interrupted the regular flow of demand during the limited nationwide lockdown period. Thus, there was always a demand for certain goods, particularly essential commodities.

5. Mitigation strategies related to supply chain challenges during COVID-19 and post-COVID-19

With a view to analyzing the findings and developing a suitable way forward to mitigate the challenges identified to supply chains, we shared our observations with four senior level industry practitioners. We identified these experts based on a purposive sampling approach. We ensured that this group of experts did not include those who participated in the initial pairwise comparison which is required for Grey-DEMATEL analysis. We set a threshold for the participants' level of industry experience of at least 15 years. We also include respondents in our sample from different company departments, so that they could provide different views. Based on these criteria we selected four senior level (labeled P1, P2, P3, and P4) industry practitioners to analyze the findings and develop a suitable way forward to mitigate the challenges identified to supply chains. Appendix A-Table A.7 summarizes the profile of these four experts, with an average of 23 years of experience across domains including sourcing, settlement, operations, sales, distribution, logistics and consulting.

We propose our mitigation strategies under all three categories (supply side, logistic and storage side, and demand side) to improve the capability under dynamic conditions that developed due to COVID-19 pandemic (Refer Fig. 3) based on the dynamic capability theory. The dynamic capabilities perspective emphasizes the role of firms' capabilities in sensing opportunities and threats, seizing potential opportunities, managing threats, and reconfiguring resources and capabilities to gain sustained competitive advantage in a dynamic business environment. Thus, it is an ideal theoretical perspective to analyze the mitigation strategies due to COVID-19 outbreaks.

While our mitigation strategies are based on the key challenges identified in manufacturing supply chains during the COVID-19 pandemic, we believe that these strategies and solutions may be extended beyond the COVID-19 pandemic to similar natural or man-made disasters that may arise in the years to come. These mitigation strategies have been examined into key capabilities and resources which the focal manufacturing firm would need to identify and embrace from the supply, demand and logistics point of view in order to make its supply chain more resilient to combat future adversities. All the experts (P1-P4) agreed that firms faced an unprecedented situation during the pandemic and two types of strategy are required for mitigation as a) short-term and b) long-term. The literature also suggests that supply chain managers should make both short-term and long-term plans for the mitigation of pandemic in future similar to COVID-19 (Belhadia et al., 2020; Verma & Gustafsson, 2020). The forthcoming section elaborately details out the condensed mitigation strategies highlighted

in Fig. 3 in terms of supply, demand and logistics disruptions and further sub-classifies each of these in the short-term and long-term perspective.

5.1. Capabilities on supply side

In this section we discuss mitigation strategy related to supply side challenges to develop supply side capabilities. Inconsistency of Supply (PIS) has been identified as the most prominent challenge and is associated with uncertainty of supply from upstream vendors, irregular and indefinite lead times and price volatility (Okorie et al., 2020; Paul & Chowdhury, 2020; Razdan & Kumar, 2020). Similarly, Scarcity of Material (SSM) is the second most influencing challenge and is associated with panic buying, hoarding, artificial scarcity, increase in per unit price, import restrictions and questionable continuity of suppliers (Agrawal et al., 2020; Biswas & Das, 2020; Okorie et al., 2020; Doshi, 2020; Razdan & Kumar, 2020). Further, growing trade barriers, working across several time zones and expectation of a faster response time have led to the gradual dissolution of large global supply chains into smaller local ecosystems typically during the pandemic (Xu et al., 2020).

5.1.1. Short-term strategy

As a short-term approach to immediately respond and manage supply side risks including material scarcity during the COVID-19 pandemic, organizations would need to identify components and raw materials that are critical to manufacturing, and which carry a major interruption risk (Paul & Chowdhury, 2020). The focal firm would need to develop strategic sourcing teams, which would mitigate the risks associated with sourcing from a single vendor (Zhu et al., 2020). Wherever possible, alternate materials should be considered in collaboration with the research and development departments of the vendor, sub-contractor and customer to source critical components and raw materials, to ensure seamless supply during emergencies (indicated by P1 and P3). Furthermore, alternate vendors should be explored to ramp up production capacity in case of sudden surges in demand. The above strategies complement the findings of Paul & Chowdhury (2020), who propose a similar twofold strategy to combat the issues associated with sudden demand and scarce supply of material. Further, vital make-versus-buy decisions for critical components may need to be reconsidered in order to reduce vendor dependencies. This would also address the challenge of adopting suboptimal substitutes for existing raw materials. Additionally, as suggested by Sarkis et al. (2020), firms would need to reconsider their configuration and arrangements with existing suppliers and establish relationships with local vendors to avoid risks owing to supply fluctuation (Queiroz et al., 2020). Wherever possible, explore local suppliers closer to the manufacturing facility in place of distant/cross border suppliers to cater to demand spikes. Focus on being shifted from globalized to localized supply chain in such times (Choi et al., 2021).

As an immediate remedy to the challenge of suboptimal manufacturing, manufacturing firms should use the available data to perform retrospective analysis of the wavering demand and available supply and can reinstate optimum manufacturing conditions for future batches or cycles by ramping up capacity, increasing production shifts, utilization of excess capacity, commissioning new machinery, utilization of excess labor and outsourcing (Paul & Chowdhury, 2020; mentioned by P3 and P4). Further, collaboration and collective sharing of feedback with vendors would ensure reduced losses owing to delays and rework.

Imposed lockdowns, reduction of wages and sustenance issues that consequently compelled the movement of migrant workers back to hometowns are associated with the challenge of PSL (International Labour Organization, 2020; World Economic Forum, 2020a; The Agrawal et al., 2020; Biswas & Das, 2020; Okorie et al., 2020; The Economist, 2020). One step towards mitigating the challenge of labor unavailability could be for organizations to not rely entirely on contracted labour and to strike a balance by employing dedicated workers on their payroll, engaging with them to address their concerns, investing in adequate

accommodation and implementing other welfare policies. This in turn would motivate workers to continue to render their services during challenging situations. Our suggestions here are in line with the recommendations of [Queiroz et al. \(2020\)](#), who suggest that recovering from supply chain disruptions amidst a pandemic owing to shortages of labor and materials is highly region-specific and is bound to undergo delays. Recovery from such disruptions is possible by engaging and interacting with internal and external stakeholders, formulating policies along with streamlining manufacturing strategies (indicated by P1, P2, and P3). This aside, turning our attention towards managerial professionals, it has been observed that there has been a severe lack of significant organizational learning and knowledge of managing supply chains during previous emergencies resulting in the focal firm being grossly unprepared to survive the COVID-19 crisis ([Shih, 2020](#)).

5.1.2. Long-term strategy

In the long-term, organizations need to create and periodically revisit their Business Continuity Plan (BCP) ([Queiroz et al., 2020](#)). This plan should include risk mitigation strategies, typically aimed toward setting up alternate suppliers closer to the parent organization's manufacturing facility to avert inconsistency in supply of raw material and critical components ([Belhadia et al., 2020](#)). With a view to maintain constant supply of material, the focal firms ought to indulge in tailored sourcing strategies which primarily requires having two sourcing channels. The known or fixed quantity of the demand can be sourced from global supply chain to leverage economics of scale, and lower cost. However, degree of flexibility and responsiveness is lower in globalized supply chain. Thus, firms may choose local supply chains for better responsiveness for the uncertain demand in supply chains ([Shih, 2020](#)). This clearly demonstrates how the sourcing and procurement function of organizations is changing its focus from selecting the most cost-effective vendor to the most responsiveness vendor having shorter lead times.

In the long-term strategy to mitigate future disruptions, firms should leverage disruptive technologies such as Big Data Analytics (BDA), Additive manufacturing, and Blockchain. Thus, adoption of disruptive technologies in supply chains process the information efficiently and help the mitigate the future disruption. Based on demand, available supply constraints as well as agreed service level agreements (SLAs)/penalties between supply chain entities, firms would need to optimize its product mix using scenario planning techniques ([Belhadia et al., 2020](#); [Paul & Chowdhury, 2020](#)). On the basis of BDA, the focal firm should invest to increase flexibility and augment capacity. The firm can have an optimal mix of dedicated and flexible manufacturing facilities to produce regular items in bulk to leverage economics of scale and use its flexible setup to produce specialized items to quickly respond against uncertain demand. Additionally, firms should invest in reserve capacity for both manufacturing as well as for storage. While this increases the cost for maintaining idle resources such as machines, warehouse rentals and inventory carrying costs. However, potential gain due to reduction of risk in supply network disruption outweighs the incurred costs in maintaining the idle resources ([Sodhi et al., 2021](#)).

5.2. Capabilities on logistics and storage side

In this section we discuss mitigation strategy related to logistics, transportation network and distribution (Vehicle Unavailability and Delays) to develop logistics and storage side capabilities to deal with future disruptions. Vehicle Unavailability and Delays (DVU) and Delay in Delivery (SDD) are important issues in this category.

5.2.1. Short-term strategy

As an immediate solution, the focal firm typically dealing regularly with large volumes of material inflow and outflow ought to maintain a healthy mix of dedicated and market owned fleet of vehicles and promote greater transparency through the use of vehicle tracking devices (indicated by P3 and P4). In exceptional scenarios, joint consent

business interaction ([Mouzas and Ford, 2006](#)) would be recommended as it would be possible to negotiate particular conditions of delivery. In case of surges in demand, additional market vehicles may be hired with adequate caveats, and contractual risk exposure can be covered with use of a penalty clause for in-transit delays ([Belhadia et al., 2020](#); [Singh et al., 2020](#)). To ease the burden of distribution, coupled with inconsistent demand and with a view to providing more options to the customer, larger firms can setup an omni-channel distribution model. This involves creation of multiple channels to distribute products including a healthy mix of traditional brick and mortar stores, smart pickup points and online formats thus making the distribution network more resilient by giving customers several options to order products. Such considerations are most vital typically during COVID-19 when the rush for online sales has received a tremendous impetus owing to social distancing and other lockdown restrictions ([Sodhi et al., 2021](#)).

5.2.2. Long-term strategy

To address logistical challenges across haulage operations, larger firms possessing their own fleet need to consider that transportation is the backbone of any supply chain, and therefore lifeline maintenance of the fleet should be performed periodically. Further, firms could explore the use of autonomous vehicles for fixed point-to-point movement, which would limit dependency on human drivers, typically during times such as the COVID-19 pandemic ([Singh et al., 2020](#)). To resolve challenges pertaining to last mile operations, as part of their long-term strategy, firms should explore the use of drone technology to reach the most inaccessible places (indicated by P1 and P4). While drones may not be able to carry very heavy consignments nor travel long distances, organizations can partner with third party logistics service providers and adopt the use of truck-drone synchronized delivery systems for better reach and higher volume of last mile delivery ([Ketchen & Craighead, 2020](#); [Singh et al., 2020](#)). Further, typically in case of firms that do not possess their own fleet, it is strongly recommended to reconfigure the way logistics and transportation systems are embedded across the current interconnected network of supply chains. As defined by [Sodhi et al. \(2021\)](#), logistics is responsible for transportation of products across the extended segments of the supply chain such as sub-vendor to the principal vendor or vendor to the focal firm and focal firm to its distributors and customers. As an immediate consequence of the pandemic, there has been a surge in demand for Third Party Logistics (TPLs) providers leading to a drastic shift of power from the hands of the shipper to that of the TPLs. This paradigm shift is an opportunity for focal firm to concentrate only on its core competence and let transportation specialists such as TPLs focus on their expertise. Further, the focal firm should install a culture conducive for the formation of strategic alliances with TPLs, vendors and customers to enhance partnership and visibility across interconnected supply chains. This perspective is aligned with the multilateral connectivity of business interactions ([Mouzas and Ford, 2006](#)). For instance, Microsoft is recently seen to form a triadic relationship with its 3PL namely, C. H. Robinson and its longstanding network of vendors spread across China ([Sodhi et al., 2021](#)). Finally, whether the focal firm utilizes its own fleet or hires market vehicles and other 3rd party logistics providers, the trip data should be integrated through Application Programming Interfaces (APIs) and be available at the focal firm's control tower for real-time tracking and course correction, if needed. Thus, the pandemic has led the focal firms to think of newer ways of doing business some of which may permanently transform the way firms operate leading us to think about the future of supply chains.

5.3. Capabilities on demand side

In this section we discuss vital mitigation strategies that will strengthen the capabilities on the demand side thus preventing any disruptions across the supply chain. Uncertainty of Demand (PLD) has been identified to be the most critical disruption under this category. As

previously elaborated in Section 2.2.1, changing patterns in buying behaviour coupled with misinformation on certain products owing to the spread of coronavirus and overstocking of select essential commodities has led to disruptions on the demand side (Hippold, 2020; The Economic Times, 2020).

5.3.1. Short-term strategy

As an immediate measure, firms would need to provide end to end visibility to customers (indicated by P1-P4), this would imply milestone-based tracking from the time of order booking to dispatch and final delivery of product to customer. This would instill a sense of trust and cooperation amongst customers. Since there has been a drastic shift in buying pattern owing to inappropriate information with regards to the coronavirus and use or consumption of certain products, firms would need to invest in campaigns to promote correct information. Additionally, firms would need to reassure its consumers that the products and finished goods are being handled safely and hygienically across the value chain (Mishra et al., 2021). For customers who prefer shopping from home during the pandemic, as an immediate measure, firms could provide omni-channel options by partnering with 3rd party delivery agents who could provide local last mile deliveries to customers (Sodhi et al., 2021). Further, differential pricing based on order volume and delivery timelines could help the focal firm manage and compensate for losses (Mishra et al., 2021). The above steps would encourage customers to purchase products thus maintaining consistency in demand.

5.3.2. Long-term strategy

In the long-term, the focal firm would need to identify, partner and collaborate with key customers. While this would be easier in the B2B setup, developing products in close coordination and partnership with customers and promoting brand loyalty through schemes and campaigns would ensure retention of B2C consumers as well (indicated by P1). Providing timely response and satisfactory resolution to customer queries would lead to greater customer satisfaction and delight. Training the personnel of the focal firm on disruption awareness and management would ensure better mitigation of future adversities (Mishra et al., 2021). While as an immediate response to the pandemic the focal firm could begin omni-channel distribution by providing home delivery of products through tie ups with local delivery agents, firms would need to develop a more robust and sustainable business model by creating its own omni-channel distribution network to prevent dependencies in future (Sodhi et al., 2021). The above would involve high setup costs but would ensure the existence of adequate channels for customers to order products leading to stabilized demand.

6. COVID-19 disruptions and its impact on supply chain networks

Supply chain consists of different interconnected agents and focal firms depends upon different interconnected agents. Our result suggest that firms are facing challenges due to supply, demand and logistics side. Particularly due to globalized and lean structures in supply chain, firms have become more vulnerable to COVID-19 outbreak. Dynamic capability perspective suggest that firms need to develop capability to improve resilience to better deal with future pandemic. We have noted that the PIS challenge, which includes supply side constraints, questionable continuity of key vendors and shortage of material in the market, has had a detrimental effect on the continuity of several firms. Hence, while supplier collaboration and partnership are critical to reduce costs, it is for organizations to manage the tightrope walk of choosing whether to pay the premium towards developing alternate vendors or suffer at the outbreak of a similar global catastrophe in future.

PIS issues accentuated during COVID-19 because majority of the firm's supply chains are global in nature. In the post pandemic regime, reshaping the sourcing strategy from global to local will become a

necessity. This will be one of the major shifts in interconnected supply chain. Thus, supply chain managers should act to reshape their global sourcing and strive to identify and promote local sources providing similar quality raw materials within the vicinity of their respective manufacturing premises (Sarkis et al., 2020). Furthermore, managers may consider partnering with vendors to make provision for substitute materials, typically in case of items that are imported (Paul & Chowdhury, 2020). To the extent possible, onshoring of all major activities is paramount during a pandemic such as COVID-19. Firms would also need to consider refocusing on the core competencies of their firm and outsourcing activities such as transportation to third-party service providers, thus ensuring the transfer of risk of ownership of material during times like these. Finally, due consideration must be provided to skilled migrant workers by ensuring the firm and local governments cater to their immediate needs of shelter, adequate wages, and similar welfare measures (Belhadia et al., 2020).

Adoption of suboptimal substitutes is another major issue in supply chain network. Post pandemic firms might think to reduce the dependency by adopting advanced manufacturing process such as additive manufacturing. Additive manufacturing can produce the parts without tools which are required to support the parts during manufacturing. So, if dependency reduces it lessen the disruption in supply chain. Prior to the pandemic, Just in Time (JIT) policy was the norm across manufacturing firms. In a just-in-time policy, supply chain agents keep little finished-goods or raw material inventory in the supply chain network. During the pandemic, supplier's facilities were slowed or shut down. However, demand for some of the items such as toilet papers and hand sanitizers increased drastically. So, firms were facing acute shortage of raw material and capacity to produce the items. This provides a powerful message that the pandemic questioned the JIT policy since stockouts becoming a common phenomenon during pandemic. Hence, the above response to COVID-19 suggests that traditional models like Just in Time (JIT) may ensure leaner supply chains and lower inventory costs but are unsuitable in times of crisis and managers need to strike a balance in order to protect themselves during supply fluctuations (Belhadia et al., 2020; Zhu et al., 2020).

7. Implications of this study

In this paper, we have identified the supply chain challenges that manufacturing organizations have faced in the wake of the COVID-19 outbreak, specifically in the context of an emerging economy, and have suggested suitable mitigation strategies. COVID-19 was one of the most impactful events in the supply chain management realm. Despite previous efforts and preparations, majority of supply chains have suffered. This has created an opportunity for managers to foster better preparedness to cope with future pandemics and disasters. Our discussion in this study not only helps to mitigate the current ongoing crisis rather it will also help to mitigate future disruptions. In the subsequent subsections, we highlight important implications to literature and managers.

7.1. Contribution to the literature

From the theoretical perspective, this study revisits the dynamic capability theory to the effective supply chain management during pandemics and their mitigation strategies. While multiple scholars have focused on analyzing several supply chain related issues, no prior studies on this topic have investigated the supply chain challenges that companies are facing and their causal influence, particularly in the context of a pandemic. In doing so, we make multiple contributions to the theory on supply chain management.

Theoretical underpinning pertaining to supply chain disruption owing to the coronavirus pandemic and other catastrophes and supply chain resilience have continued to evolve in tandem (Singh et al., 2020). However, very few studies have attempted to synergize the two

concepts. Recently, [Mishra et al. \(2021\)](#) have used the dynamic capability theory to understand challenges due to COVID-19 in the agricultural sector. To our knowledge, there is no other study that has utilized dynamic capability view of the firm to suggest mitigation strategies to achieve adequate resilience required for combating current and future disruptions in the manufacturing context. This makes our study distinct, both in terms of its theoretical contribution as well as empirical insights.

From the perspective of selection of generic supply chain strategies, this paper simultaneously considers supply, demand and logistical side challenges. We, demonstrate that the criticality of supply inconsistency, coupled with vehicle unavailability and transportation delays, is a major cause of disruption in supply chains, and its mitigation is pivotal for the efficient running of operations. Hence, we broaden the existing literature on the formulation and selection of generic supply chains by arguing that supply, including logistical and demand uncertainties are important to manage during pandemic.

While the basic premise of our paper is to analyze the disruptions caused by COVID-19 pandemic and ascertain the capabilities that are required to have a resilient supply chain we identify certain gaps in the existing literature on supply chain resilience. We highlight the role of monitoring and proactive mitigation of supply chain challenges in logistics, particularly in the case of last mile deliveries and their importance in building a resilient supply chain. While previous research in this field has focused on different aspects of supply chain resilience, such as re-engineering, collaboration, agility, risk management culture, vulnerabilities, capabilities and their interdependence ([Christopher & Peck, 2004](#); [Pettit et al., 2010](#)), limited research has focused on understanding the role of logistics and its monitoring in the field of supply chain resilience ([Ponomarov & Holcomb, 2009](#)). One reason for this is that there has very recently been a tremendous focus on last mile delivery and logistics visibility using real-time big data analytics, owing to the coronavirus pandemic. Another mitigation strategy to achieve supply chain resilience covered in our study recommends that organizations ought to instill a culture that harnesses and taps into the social and humanitarian aspects of the supply chain. This would include creating welfare regimes for migrant workers, providing incentives and subsidies to ensure greater motivation levels and more loyalty towards the focal firm. This is contrary to conventional wisdom on supply chain resilience, which suggests that creating a supply chain risk management culture by setting the tone at the top, having representation at all levels of the firm including the board room, having cross functional teams and ingraining risk assessment into every decision-making process is enough to manage the human and cultural aspects of resilience ([Christopher & Peck, 2004](#)). One reason why the human labor aspect has not been covered in such detail in the past is because previous theories pertaining to resilience have focused on developed nations, while our study is situated in an emerging economy which is highly dependent on labor. Hence with the above, we broaden the existing literature on supply chain resilience by providing due consideration to last mile logistics and social supply chain.

Our aforementioned contributions towards different facets of supply chain management theory indicates a critical need to take stock of the key inadequacies and shortcomings in the traditional supply chain management literature, thereby demanding that these factors are revisited in the wake of the novel coronavirus pandemic.

7.2. Implications for managers

The COVID-19 pandemic has caused disruption which propagated through multiple stages, known as a ripple effect ([Ivanov & Dolgui, 2020b](#)). From our analysis we can observe that several of the challenges identified are related with each other, while the sources of challenges come from different locations at different times. This propagates the disruption through the supply chain network. Based on identified challenges and our suggested short-term and long-term mitigation strategies managers can organize their business continuity plans to

mitigate the future disruptions.

The structured analysis might be helpful for managers for identifying problem areas during pandemic and the factors that need to be focused upon for mitigation of these challenges. From the supply side, manager would need to revisit their BCPs, identify critical components, shift focus on local vendors and levy more emphasis on welfare regime of labours. From the demand side, the focal firm would need to urgently provide end to end order lifecycle visibility to the customer, offer omni-channel purchasing options and also train their personnel with regards to safety, hygiene and other protocols to follow during similar disruptions. These would instill trust and cooperation with customers which would in turn stabilize demand. From the Logistical side, since unavailability and delay of vehicles emerged as a major issue during COVID-19 pandemic, managers should seriously consider the use of vehicles fitted with GPS devices and setting up control towers that enable the use of big data ([Belhadia et al., 2020](#)) from all partner IoT devices and monitor real time tracking and movement of material across the supply chain. Firms may eventually need to embrace the use of autonomous vehicles for point-to-point movement of vehicles under fixed routes and should also consider utilizing drone technology for last mile delivery fulfillment to customers ([Ketchen & Craighead, 2020](#)).

8. Conclusions and limitations

The novel coronavirus (COVID-19/SARS-CoV-2) pandemic which emerged almost two years has now turned out to be a global crisis and continues to have an irrevocable impact on all of humanity ([Ivanov and Dolgui, 2020](#)). While continents and nations have faced the wrath of the virus, manufacturing organizations operating across the globe have faced innumerable challenges. India was chosen for our study as it is an emerging economy, is seen as a potential global manufacturing hub and is one of the top countries to be affected by the pandemic. Further, emerging nations have a different set of supply chain challenges compared to their developed counterparts. In the same vein, to our knowledge no prior research has been performed in the context of an emerging economy while studying supply chain challenges across the manufacturing sector during the COVID-19 pandemic. Taking the above factors into consideration, our research is novel and perhaps the first of its kind.

Our paper highlights ten supply chain challenges under a framework that manufacturing organizations have faced during this unprecedented time. These challenges to supply chains in the manufacturing context have been identified after consultation with experts and a literature review of recent academic work, as well as work published in leading business magazines and consultancy reports pertaining to COVID-19. These challenges and disruptors have been further classified across the supply side, demand side and logistical side of the supply chain. Following this literature review, we analyzed the relationship between these challenges by exploiting a hybrid Grey-DEMATEL approach.

Our results suggest that inconsistency in supply and suboptimal manufacturing are the most prominent challenges, followed by scarcity of labor and vehicle unavailability and delays. We discussed these challenges in detail with experts to identify suitable mitigation strategies in the short and long-term. With a view to addressing each of the identified challenges and drawing from the dynamic capability theory as a tool to achieve supply chain resilience, we have formulated suitable mitigation strategies to combat these challenges, both short-term and long-term. These strategies are not only helpful to mitigate the current crises but also helpful to mitigate future adversities of similar nature and scale. Some of the short-term strategies include selection of multiple vendors located closer to the primary firm's manufacturing facility, redefining safety and reserve stock levels and implementing employee welfare regimes to motivate skilled migrant workers. Similarly, some of the long-term strategies include embracing end to end digital technologies, deeper use of AI, ML techniques, setting up real-time visibility control towers that utilize big data, formulating Business Continuity

Plans and considering the use of autonomous vehicles and drones for line haul trips and last mile deliveries, respectively.

Despite several contributions made by this paper, it also suffers from certain limitations and shortcomings. First, this study has been carried out in the Indian context. Thus, the research findings should be considered with regard to the characteristics of the Indian manufacturing sector, which, for example, still relies on manual and casual labor. However, similar types of study could be extended to other countries in order to perceive similarities and differences. Second, for the sake of clarity, we have condensed the number of supply chain challenges in the manufacturing context and limited these to ten in number. Future research could be performed with a greater number of challenges. Third, our research has been performed with the manufacturing sector in mind. Future studies may be performed to consider challenges in the service industry as well. Finally, we would encourage future researchers to use other econometric methods which may be analyzed to assess the robustness of our results.

CRedit authorship contribution statement

Alok Raj: Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Abheek Anjan Mukherjee:** Data curation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. **Ana Beatriz Lopes de Sousa Jabbour:** Writing – review & editing, Supervision. **Samir K. Srivastava:** Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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