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Modeling Impacts of COVID-19 in Supply Chain Activities: A Grey-DEMATEL Approach

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Abstract: The purpose of this study was to identify and exhibit the interrelationships among COVID-19's impacts on supply chain activities. Based on a literature review and the manager's input, twenty COVID-19 impacts were collected. An integrated approach of exploratory factor analysis (EFA) and grey-decision-making trial and evaluation laboratory (G-DEMATEL) was used to reveal the causal interrelationships among the COVID-19 impacts. Initially, a questionnaire survey was administered among 220 respondents for EFA. Based on the outcome of EFA, the twenty COVID-19 impacts were categorized into seven critical areas. Then, based on the experts' inputs, G-DEMATEL was utilized to reveal the causal interrelationships among various COVID-19 impacts. The results indicate that disruption management, relationship management, and production management are the top three critical areas that need to be addressed in the COVID-19 crisis. Disruption in supply, ripple effect on supply chain operations, and obsolescence of machines were found to be the most influential impacts while disproportionateness between supply and demand, difficulty in demand forecasting, and reduced cash inflow were found to be the most influenced impacts. This study's outcomes will help policymakers and supply chain managers develop strategies to restructure supply chain networks. This study is an original contribution to the analysis of COVID-19 impacts in the supply chain activities in India due to the use of EFA and G-DEMATEL. This study considers India only, and hence, the outcomes lack generalizability. A study considering multiple developing countries could generalize these findings.

Keywords: COVID-19; supply chain management; exploratory factor analysis (EFA); grey-decision-making trial and evaluation laboratory (G-DEMATEL)

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1. Introduction

The global spread of novel coronavirus (COVID-19) has undoubtedly raised questions regarding the effectiveness and robustness of the healthcare system of global nations [1,2]. In addition to claiming human lives, the COVID-19 outbreak has also shaken the base of economic activities. It has had a devastating impact on industrial activities. Industrial organizations have faced many challenges in this unprecedented COVID-19 pandemic situation [3]. Depending on the severity of the outbreak, the magnitude of the challenges has varied. One of the major impacts of COVID-19 is that it completely collapsed the supply chain management of business activities. Supply chains have encountered many challenges during earlier outbreaks. For instance, the World Health Organization reported 1438 epidemics from 2011 to 2018 [4], and during this phase, the supply chains survived. Still, the present COVID-19 pandemic situation is distinctive and intense. In comparison to earlier epidemics such as SARS, MERS, and H1N1, it has had a severe and dynamic global impact [5,6]. COVID-19 has drastically affected all nodes of the supply chain. Moreover,

each member (manufacturers, suppliers, and retailers) involved in a supply chain have been separated by this COVID-19 pandemic. Reasons such as border closure, suspension of international trade, workforce shortage, and interruption in vehicle movements have shortened supply, transportation, and manufacturing units [7,8]. These kinds of challenges have severely impacted supply chain activities. Such impacts affect the sustainability of the supply chain industries. The suspension of supply chain activities leads to job losses, ultimately increasing the chance of poverty. According to the World Trade Organization (WTO), the trade volume was expected to rise by 8% in 2021, falling by 5.3% in 2020 [9].

The global supply chain (GSC) is slowly returning to normalcy. Conversely, the COVID-19 situation has disrupted the local supply chain and the global supply chain [10]. The functioning of GSC mainly depends on the local supply chain. GSC mainly involves the supply of raw materials and spare parts from one part to another part of the world. Disruption in GSC leads to inventory shortages. The suspended supply of commodities includes high-tech products, automobile parts, medical devices, and food items [11]. The sudden surge in demand for food items was the result of panic buying and hoarding of people. On the one side, the demand for food items has surged. On the other side, the unavailability of workers due to lockdown restrictions has prevented the procurement and sale of food items [12]. Next, the worst affected sector is the automotive sector. Since the medical society advised the public to avoid close contact and crowds, most people prefer automobiles. Although the demand for automobiles has increased, the production side cannot meet the demand as there is a shortage of automotive chips and other spare parts such as brake systems and gearboxes [13].

Being a major issue of this time, supply chain disruption has emerged as a major area of research. Barbier and Burgess (2020) [14] concluded that developing countries face a financial burden because of the COVID-19 impact, which will blockade these countries' sustainable performance. Ivanov (2020) [15] specified that the different opening and closing times of the various stakeholders involved in a supply chain network has severely impacted the resilience and robustness of the supply chain performance. These impacts include a shortage of supply and production stoppage. Additionally, Sarkis (2020) [16] stated that joint investigation will only achieve sustainability and resilience in the supply chain. Further, COVID-19 may have provided temporary environmental benefits and a lasting detrimental economic and social impact, which deserves special attention. According to Pereira et al. (2021) [17], social sustainability has largely been affected as the shutdown of global economic activities resulted in the stagnation of supply chain activities. The suspension of supply chain activities has resulted in the loss of jobs, thereby aggregating poverty. Ranjbari et al. (2021) [18] elucidated that the COVID-19 pandemic has immensely impacted all three pillars of sustainability and has become a matter of concern as it determines the progress towards the sustainable development goals (SDGs).

The most general objective considered by previous researchers regarding the supply chain during COVID-19 is the analysis of the barriers or challenges in supply chain activities. However, consideration of the adverse impacts of COVID-19 on supply chain activities is important. Compared with developed countries, developing countries are facing greater difficulty in achieving economic development. Economic development mainly depends on the effectiveness of supply chain activities. During COVID-19, supply chain activities were interrupted and affected the social, economic, and environmental aspects of sustainability. Hence, it is essential to analyze the impacts of COVID-19 on supply chain activities.

Given the importance of the severity of COVID-19's impacts on supply chain activities, this study addresses the critical gaps in the literature. First, it identified the various impacts of COVID-19 on the supply chains. Based on the inputs from the respondents, by carrying out EFA, the COVID-19 impacts were then classified into seven critical areas, namely production management (PM), supply management (SM), disruption management (DM), relationship management (RM), inventory management (IM), logistics management (LM), and organizational management (OM). Second, it reveals the causal interrelationships among the impacts, which provides better insights into the impacts. Finally, an understand-

ing of the relationships between impacts will guide industrial management in mitigating the severity of the COVID-19 impact.

This study was carried out to understand the impacts of COVID-19 on supply chain activities from the perspective of an emerging country. Accordingly, in this study, India was chosen as it is one of the rapidly emerging countries that has been severely affected by the COVID-19 epidemic. Therefore, this study intended to answer the following research questions:

- What are the various impacts of COVID-19 on supply chain activities?
- How can the causal interrelationships among the various COVID-19 impacts be revealed?
- Do the outcomes provide better insights for industrial practitioners to formulate strategies in overcoming the COVID-19 impacts?

A literature review and interaction with industrial professions were used to strengthen the theoretical foundation of this study. As a result, the adverse impacts of COVID-19 on supply chain activities were identified. Then, using the responses of 220 respondents, exploratory factor analysis (EFA) was carried out and 20 COVID-19 impacts were classified under 7 critical areas of impacts. Then, G-DEMATEL was utilized to reveal the causal interrelationships between the various COVID-19 impacts on supply chain activities. Based on the outcomes, implications were provided for practitioners.

The remainder of the paper is structured as follows: a literature review is provided in Section 2. In Section 3, the methodology used in this study is explained. The results and discussions of this study are given in Section 4. The implications of this study are presented in Section 5. Finally, this study is concluded in Section 6.

2. Literature Review

This section provides an overview of the supply chain activities and its significances and explains how the COVID-19 pandemic has impacted the supply chain activities. Finally, it highlights the research gaps that demand this study.

2.1. Supply Chain Management

The success of any industry largely depends on the seamless communications between the information flow, raw materials, money investment, workforce, and machinery. In general, the supply chain efficiency of the company measures its success. However, the supply chain is a complex and intricate topic that includes the whole production and distribution channels [19]. Commonly, the supply chain activities include procuring raw materials to deliver the finished products to the customers. To be precise, the main function of the supply chain is to deliver the right product in the right quantity at the right time in the right place [20]. Nowadays, the supply chain has become more dispersed and diverse in terms of its structure and business nature. Hence, the supply chain network is susceptible to risks and challenges. Further, globalization and trade openness have increased the risk vulnerability in the supply chain network [21]. In addition, supply chain activities represent a major share of the total financial expenses of an organization. Most companies are facing difficulties in optimizing the functioning of the supply chain network. The definition of the supply chain is modified from time to time depending on the needs that arise. Concepts such as lean, agile, resilient, and green were added to supply chains in the past [22]. Further, to improve the transparency in supply chain activities, blockchains are increasingly used [23]. In addition, the concept of sustainability is being added to supply chain activities, and the sustainable supply chain (SSC) has been a hot topic [24]. The sustainability concept has emerged in response to growing concerns about the depletion of future generations' natural resources. This growing interest in SSC research has led to diversified definitions. Wittstruck and Teuteberg (2012) [25] defined SSC as an extension of the conventional supply chain practice involving social and environmental aspects.

Information technology systems such as ERP (enterprise resource planning), MES (manufacturing execution system), PPC (production planning and control), and SCADA

(supervisory control and data acquisition) have been used in the management of logistics and supply chain activities. Unlike the earlier days, where the function of the supply chain was only to ensure timely product delivery, nowadays, the supply chain has to account for its social and environmental impact. Hence, supply chain activities can no longer be viewed as mere economic activities [26]. Instead, the economic, social, and environmental aspects must be considered. Rising environmental awareness among the public, competition for survival in the business market, pressure from stakeholders, and stringent environmental laws have pushed the industrial community to follow SSC practices. Nonetheless, globalization, a reduced product lifecycle, the location of shareholders in multiple locations, and fluctuation in the market demand also necessitate SSC practices [21]. The critical aspects of sustainability, i.e., economic, environmental, and social aspects, align with the triple bottom line concept [27]. Hence, the adoption of the sustainability concept has become an imperative objective for industrial sectors. Although the SSC practices offers many benefits to industrial management, their adoption is hampered by many challenges related to operation, technical, economic, and social challenges [28].

2.2. COVID-19 Impacts on Supply Chain Activities

Although SSC offers many benefits to the industrial community, thereby enhancing the wellness of the society, it is often susceptible to disruption. Disasters, either natural (earthquake, tsunami, landslide) or man-made (political dispute, strike), often question the robustness of supply chain activities [29,30]. Having become accustomed to the above-mentioned disasters, supply chain management has devised certain strategies to handle such situations. However, the disruptions caused by the unprecedented COVID-19 pandemic are unique and intricate [31]. It has caused unforeseen fragility in supply chain activities. It has disrupted all quarters of supply chain activities (supply, demand, and logistical sectors) [32]. A shock that occurs at one node of the supply chain has consequences on the other nodes. Such consequences result in a ripple effect on the supply chain activities, leading to significant uncertainty at all supply chain nodes. COVID-19 has raised questions regarding the flexibility, robustness, and recovery of the supply chains, which directly affects the supply chain's resilience in this volatile market [33]. Questioning of the supply chain's resilience creates a debate over the efficiency of the lean and agile concepts. In some cases, the impact of COVID-19 is localized without a cascading effect on the global supply chain. However, the impacts collapse the upstream activities, which directly affects global trade [34].

Companies engaged in supply chain activities are faced with multiple challenges based on their geographical locations, resilience, and level of preparedness. One of the severe impacts of the COVID-19 pandemic is the stoppage of production. Automobile industries such as Hyundai, General Motors, Toyota, Volkswagen, Honda, and Fiat have halted car production, citing a shortage in spare parts from China and India [35]. The suspension of industrial activities has resulted in an increased level of unemployment. According to a recent report of the Federal Reserve Bank of Cleveland, the unemployment caused by COVID-19 was severe and will have a long-term impact that requires more time to normalize [36]. It is well-known that unemployment has a direct relationship with poverty. Thus, COVID-19 has directly disturbed the socio-economic conditions of global nations, especially developing countries, which are already significantly affected by poverty. According to a report by the International Labor Organization (ILO), 34% of global informal workers, 21% of upper-middle-income countries, and 56% of lower-middle-income countries were pushed into poverty due to the industrial shutdown that was caused by COVID-19 [37]. During the past three decades, developing countries have been actively involved in GSC. Additionally, most of the production processes of GSC are carried out in developing countries. So, GSC demands greater efficiency and competence from the suppliers (developing countries) [38,39]. During this pandemic, development has been heavily affected, leading to a shutdown of industrial activities, and causing disruptions in the supply chain.

In a previous study, Narasimha et al. (2021) [40] observed that the major Indian seaports witnessed drastic negative growth in cargo handling and a lower number of vessels in comparison with the pre-COVID-19 situation. Similarly, a study by Singh et al. (2021) [12] on a public distribution system identified that the strict lockdown restrictions have greatly affected the demand and supply as the manufacturing and logistics activities were suspended. A sharp fall in the demand for a product and high levels of layoff have been identified as the major COVID-19 impacts in the Bangladesh garments industry [41]. Similar to other industries, food industries have also been significantly impacted by the COVID-19 outbreak. Workforce shortages, fluctuations in consumer demand, and financial stress are some of the key COVID-19 impacts [42]. Additionally, it has been identified that the impacts of COVID-19 differ from country to country depending on the level of preparedness and socio-economic status. Compared with developed countries, developing and underdeveloped countries are hardly impacted by COVID-19 [43]. Poor logistics infrastructure and coordination among various stakeholders have been cited as the major reasons for adverse COVID-19 impacts.

2.3. Research Gaps

The present literature on the analysis of the impacts of COVID-19 has not considered supply chain activities. Instead, most studies on the COVID-19 impact have focused on humanitarian supply chain management, medical supply chain management, and food supply chain management [12,44,45]. However, supply chain activities were badly affected during this COVID-19 pandemic, which may have a long-term impact on workers' socio-economic conditions and further postpone the attainment of SDGs [46,47]. Many developing countries are already facing challenges in attaining SDGs. In the meantime, COVID-19 has heightened the challenges and increased the gap in moving towards SDGs. As SDGs cover three major aspects i.e., economic, environmental, and social aspects, the COVID-19 impacts have heavily affected the progress of each country towards SDGs. COVID-19 has impacted economic activities, education, energy sectors, and manufacturing activities [48]. The prolonged suspension of supply chain activities has affected the regular income of daily wages and forced the masses into poverty. Hence, the absence of supply chain activities has greatly affected socio-economic conditions. So, it is imperative to assess COVID-19's impacts on supply chain activities, especially in developing countries, as they have been affected worse. Hence, by investigating COVID-19's impacts on supply chain activities, the present study contributes to the literature. Moreover, this study aimed to reveal the interrelationships between the impacts to help understand the severity of the impacts. Further, this study was carried out in the Indian supply chain activities context, which helps to understand COVID-19's impacts from the perspective of a developing country [49,50]. In the post-COVID-19 situation, developing countries need to concentrate on SDG 1, 3, 8, 9, and 11 to achieve economic recovery [48].

3. Research Methodology

The research framework followed in this study is depicted in Figure 1. From Figure 1, the research work was carried out in three stages, with the first stage focusing on the identification of the impacts of COVID-19 on supply chain activities, the second stage concentrating on the categorization of the identified COVID-19 impacts, and the third stage aiming to reveal the causal interrelationships among the COVID-19 impacts. The steps involved in the three stages are presented in the following sections.

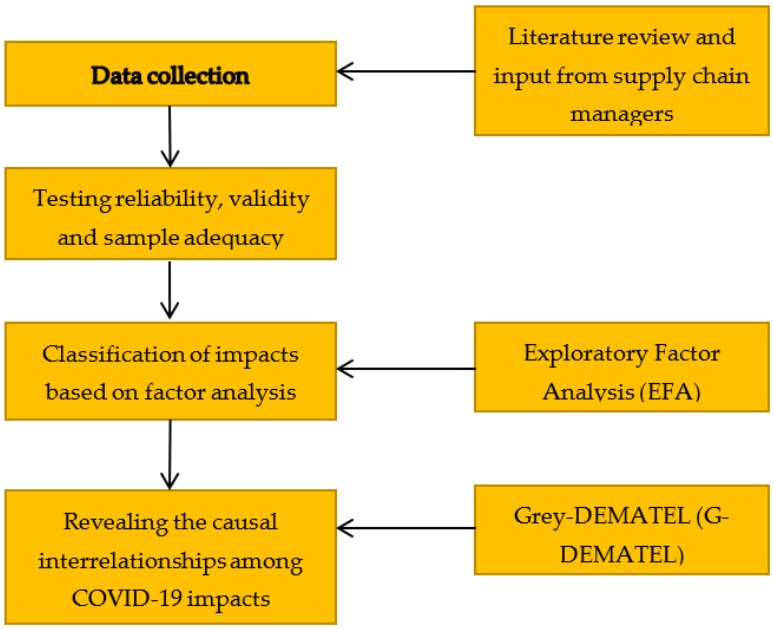


Figure 1. Research framework.

3.1. Data Collection

The first part of this study aimed to build the theoretical base. With the help of primary and secondary data, the common COVID-19 impacts in supply chain management were identified. Here, a data triangulation approach was used to identify the impacts from three sources:

- First, a literature review was carried out to collect research articles for this study. Articles were identified in scientific databases such as SCOPUS, Web of Science, Google Scholar, EBSCO, and ScienceDirect. Several keywords such as 'COVID-19 AND developing countries', 'Impact of COVID-19 in supply chains', 'COVID-19 AND sustainability', 'COVID-19 AND SDGs', and 'COVID-19 AND global trade' were used for the collection of the articles. In the initial stage, 100+ articles were taken from a variety of journals. Next, a screening process was introduced to find the most relevant papers. The articles included in the literature review were selected based on the following inclusion criteria: (i) articles published in English only considered, (ii) must be peer-reviewed, and (iii) articles focusing on the COVID-19 impacts on supply chains were considered. The exclusion criteria included conference proceedings, short communications, and duplicative works. After the final screening, only 33 articles were found to match the criteria to conceptualize this study's supply chain disruption risk constructs and variables. Therefore, these articles were acknowledged in this study.
- However, to identify the impacts in a real-life scenario, in-depth interviews with supply chain managers were conducted from November 2020 to May 2021. Fifty-five supply chain managers engaged in global trade were approached for the interviews via email and, out of 55, only 32 were interviewed. The interview started with a basic introduction of COVID-19 and how it has affected industrial activities. Finally, the interview focused on identifying the COVID-19 impacts on supply chain activities. From these interviews, few impacts were identified.
- Finally, a workshop was conducted with the 32 supply chain managers (6—import/export specialist, 8—demand planning manager, 8—transportation planner, 6—distribution manager, and 4—business analyst). These 32 managers were from the automobile sector, leather sector, agricultural sector, handicraft sector, and textile sector. Managers from these sectors were chosen as these sectors were considered to be a lifeline source of income for semiskilled and economically marginalized people. Similar to other sectors, during COVID-19, these sectors were forced to shut down their activities. Such

a shut down hardly impacted the socioeconomic conditions of the people who relied on these sectors. The profiles of the managers and their respective companies are given in Tables 1 and 2. The companies considered in this study are located in Chennai and companies from this region were selected as this region significantly contributes to the gross domestic product (GDP) of India and has been a job provider for semiskilled people. Here, a list of 25 COVID-19 impacts on the supply chain was identified from the literature review and interviews were carried out with the managers. They were asked to mark the impacts that appeared to be significant from their view and the neglect impacts that they felt were insignificant. By consolidating the responses of the 32 managers, 20 common impacts were selected. The finalized COVID-19 impacts considered for this study are given in Table 3.

Table 1. Profile of the managers of the companies.

Characteristics			*n*	%
Managers (n = 32)	Job title	Import/export specialist	6	18.75
		Demand planning manager	8	25
		Transportation manager	8	25
		Distribution manager	6	18.75
		Business analyst	4	12.5
	Experience	Up to 10 years	8	25
		10–15 years	6	18.75
		16–20 years	8	25
		20–25 years	10	31.25
	Educational qualification	Graduate	14	43.75
		Post-graduate	10	31.25
		Doctorate	8	25

Table 2. Profile of the companies.

Features	Company 1 (Automobile Sector)	Company 2 (Agricultural Sector)	Company 3 (Leather Sector)	Company 4 (Handicraft Sector)	Company 5 (Textile Sector)
Year of establishment	1998	2000	2001	2000	2003
Workforce strength	>100	100–150	80–100	50–100	100–150
Products	Gears, chain sprocket	Pulses, cereals, nuts	Belt, jacket, shoes	Decorative items	Shirts and pants
Annual turnover (in INR)	100 crores	60 crores	50 crores	30 crores	60 crores

Table 3. COVID-19 impacts on supply chain activities.

COVID-19 Impacts	Definition	References
Technical workforce shortage	Restricted movement of labor results in technical workforce shortages	[11,51,52]
Stalled industrial activity	Lack of workforce and demand halted industrial activity	Input from managers
Difficulty in demand forecasting	Being unsure about the buying capacity of people, it is difficult to predict the demands	[53]
Reduced production capacity	Insufficient demand in the market results in a reduction of production capacity	[3]
Disproportionateness between supply and demand	Supply and demand equation has been collapsed due to panic buying	[54]
Obsolescence of machines	Prolonged suspension of production made the machine obsolete	Input from managers
Production disruption and backlog	Industries were unable to complete the earlier committed assignments	[54]

Table 3. *Cont.*

COVID-19 Impacts	Definition	References
Disruption in supply	Lockdown restriction prohibited the movement of supply	[54]
Pilling up of inventory	Absence of market demand increased the inventory	[54,55]
Increased transportation cost	Limited transportation option is directly proportional to increased transportation cost	[54,56]
Lack of supplier engagement	Citing uncertainty in the global market, most of the suppliers disengage from the supply chain network	[3,57]
Increased lead time to delivery	Collapsed supply chain network increase the delivery time	[53]
Lack of international trade	Segmented lockdown restricted global trade	[55]
Supply chain collapse	Individual lockdown by different countries collapsed the supply chain network	[11]
Lack of physical distribution channel	Disengagement of suppliers creates a void in the supply chain network	[58]
Ripple effect on supply chain operations	Suspension of supply chain activity in one end creates catastrophe at the other end	[3]
Mass layoffs	Absence of industrial activity leads to mass layoffs	[52,55,58]
Lockdown restriction	Imposed to control COVID-19 outbreak	[51]
Distress on Return of investment	Stalled industrial activity raised a question on the return of investment	[52]
Reduced cash inflow	Absence of supply and demand activity reduced cash inflow	[55]

3.2. Testing Reliability, Validity, and Sampling Adequacy

The appropriateness of the identified impacts of COVID-19 was checked by measuring the reliability and validity. Reliability indicates the degree of consistency and validity indicates how the considered factors assessed the intended purpose. For this, a questionnaire (Table A1 of Appendix A) consisting of the identified impacts was provided to 350 respondents with a 5-point Likert scale (5—completely agree, 4—agree, 3—neutral, 2—disagree, 1—completely disagree). Here, a focus group survey was adopted. Further, the purposive sampling technique was followed to select the respondents. Respondents with an average of ten years of experience were considered for this survey. These respondents were, directly and indirectly, related to supply chain management. The questionnaire was mailed to the respondents. The respondents were provided with a time window of one week to respond. Further, frequent remainders were given, and the responses were collected. Out of these 350 respondents, 220 respondents answered the questionnaire. Hence, the response rate was 67.6%, which is good and acceptable [59]. Finally, Cronbach's α, Barlett's test of sphericity, and the Kaiser–Mayer–Olkin (KMO) test were conducted to test the reliability, validity, and sampling adequacy. The Cronbach's α value of the data used in this study was 0.706, which is acceptable (above 0.7 is recommended). Next, Barlett's test of sphericity, which measures the general correlation of all factors under consideration, was measured. Generally, a high value of the test statistics for sphericity with a small significance level (less than 0.05) indicates that the factors under consideration are correlated. The χ^2 value of 337.559 with 190 degrees of freedom at a 0.00 significance level is a good value for all 20 impacts of COVID-19. The KMO value in this study was 0.551, which is above the minimum suggested value of 0.5. Additionally, the non-response bias and common method bias were examined using the paired t test and Herman's single factor test. The statistical data of the impacts of COVID-19 obtained using SPSS 20.0 are given in Table 4.

Table 4. Descriptive data statistics.

COVID-19 Impacts	Mean	Standard Deviation	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha If Item Deleted
Technical workforce shortage	4.3833	0.92226	0.251	0.312	0.755
Stalled industrial activity	4.3500	0.87962	0.198	0.277	0.758
Difficulty in demand forecasting	4.0500	1.03211	0.125	0.307	0.763
Reduced production capacity	4.0667	1.17699	0.366	0.514	0.746
Disproportionateness between supply and demand	4.1500	1.17639	0.234	0.573	0.757
Obsolescence of machines	4.1833	1.01667	0.221	0.428	0.757
Production disruption and backlog	4.1500	1.07080	0.402	0.518	0.744
Disruption in supply	4.0167	1.15702	0.291	0.607	0.752
Pilling up of inventory	4.0833	1.09377	0.184	0.525	0.760
Increased transportation cost	4.1833	1.03321	0.313	0.462	0.750
Lack of supplier engagement	4.1000	1.05284	0.557	0.478	0.733
Increased lead time to delivery	4.1667	1.07619	0.304	0.319	0.751
Lack of international trade	4.3000	0.92608	0.410	0.518	0.745
Supply chain collapse	4.3000	0.84973	0.539	0.553	0.738
Lack of physical distribution channel	4.0000	1.14980	0.104	0.442	0.767
Ripple effect on supply chain operations	4.0833	1.12433	0.458	0.621	0.739
Mass layoffs	4.0667	1.08716	0.363	0.499	0.747
Lockdown restriction	4.0167	1.17158	0.339	0.402	0.749
Distress on Return of investment	4.1667	1.07619	0.260	0.393	0.754
Reduced cash inflow	3.9000	1.13047	0.569	0.565	0.730

3.3. Exploratory Factor Analysis (EFA)

To identify the strength of the relationships among the impacts, principal component analysis (PCA) and varimax rotation were carried out using SPSS 20.0. All 20 impacts considered were categorized under three categories using PCA. The factor loadings, representing the strength of the relationships between the impacts, are given in Table 5. Factor loadings above a value of 0.5 are fit for further analysis [60]. Then, all 20 impacts were categorized into three groups, namely production management (PM), supply management (SM), disruption management (DM), relationship management (RM), inventory management (IM), logistics management (LM), and organizational management (OM), as shown in Table 5 [3]. The categorization of the impacts was also discussed with the experts, and they found that it was appropriate. The impacts under production management represent the consequences of COVID-19 on the production sector. Likewise, respective impacts were categorized under respective areas.

Table 5. EFA statistics.

Area of Impacts	COVID-19 Impacts	Factor Loadings
Organization management (OM) Cronbach α 0.655	Distress on return of investment (OM1)	0.695
	Mass layoffs (OM2)	0.644
	Difficulty in demand forecasting (OM3)	0.594
	Production disruption and backlog (OM4)	0.505
	Technical workforce shortage (OM5)	0.422
Supply management (SM) Cronbach α 0.782	Supply chain collapse (SM1)	0.755
	Disruption in supply (SM2)	0.559
	Reduced production capacity (SM3)	0.550
	Increased lead time to delivery (SM4)	0.529
Disruption management (DM) Cronbach α 0.846	Ripple effect on supply chain operations (DM1)	0.749
	Reduced cash inflow (DM2)	0.670
Production management (PM) Cronbach α 0.765	Stalled industrial activity (PM1)	0.774
	Lack of international trade (PM2)	0.636
Relationship management (RM) Cronbach α 0.627	Obsolescence of machines (RM1)	0.740
	Lack of physical distribution channel (RM2)	0.563
	Disproportionateness between supply and demand (RM3)	0.532
Inventory management (IM) Cronbach α 0.796	Lockdown restriction (IM1)	0.467
	Pilling up of inventory (IM2)	0.867
Logistics management (LM) Cronbach α 0.823	Lack of supplier engagement (LM1)	0.735
	Increased transportation cost (LM2)	0.508

Note: Total of 62.6% of the variance explained and KMO value of 0.619.

3.4. Grey-DEMATEL

During the evaluation, experts faced difficulty in expressing their judgements as specific numbers. To overcome such difficulty, linguistic terms were used to improve the efficiency of the evaluation. However, these linguistic terms contained a qualitative feature that needed to be converted into comparable numbers. Regarding this, grey numbers were used to deal with the conversion, as shown in Table 6 [61]. Here, grey numbers were used over fuzzy numbers as they are capable of generating a possible outcome with limited partial incomplete data. The following three steps were used to convert the grey numbers into crisp numbers.

Table 6. Linguistic terms and grey numbers.

Linguistics Terms	Score	Grey Numbers
Very high influence (VH)	4	(0.75, 1.00)
High influence (H)	3	(0.50, 0.75)
Low influence (L)	2	(0.25, 0.50)
Very low influence (VL)	1	(0.00, 0.25)
No influence (N)	0	(0, 0)

A grey number of $\otimes a = \left[\otimes a_{ij}, \overline{\otimes} a_{ij}\right]$ is assumed, where $\otimes a_{ij}$ and $\overline{\otimes} a_{ij}$ are the lower and upper limit value of $\otimes a$.

Step 1: Normalize the grey numbers:

$$\overline{\otimes} a_{ij} = (\overline{\otimes} a_{ij} - \min \overline{\otimes} a_{ij}) / \Delta_{\min}^{\max} \text{ and } \otimes a_{ij} = (\otimes a_{ij} - \min \otimes a_{ij}) / \Delta_{\min}^{\max} \quad (1)$$

where $\Delta_{\min}^{\max} = \max \overline{\otimes} a_{ij} - \min \otimes a_{ij}$.

Step 2: Standardize the total crisp value:

$$S_{ij} = \frac{(\otimes a_{ij}(1 - \otimes a_{ij}) + (\overline{\otimes} a_{ij} \times \overline{\otimes} a_{ij}))}{(1 - \otimes a_{ij} + \overline{\otimes} a_{ij})} \quad (2)$$

Step 3: Compute the final crisp values:

$$F_{ij} = \min \overline{\otimes} a_{ij} + S_{ij} \Delta_{\min}^{\max} \quad (3)$$

The DEMATEL (Decision Making Trial and Evaluation Laboratory) method is a technique that reveals the interrelationship among the factors by generating a cause and effect diagram. Additionally, the weights of the factors under consideration are also calculated. The steps given below are used in grey-DEMATEL [62].

Step 1: Establish the direct influence matrix Z using the inputs given by experts.

Step 2: Construct matrix Z using Equations (1)–(3).

Step 3: Construct a standardized matrix N:

$$N_{ij} = \frac{Z_{ij}}{M} \quad (4)$$

where $M = \max\left\{\max_{1 \le j \le n} \sum_{j=1}^{n} Z_{ij}, \max_{1 \le i \le n} \sum_{j=1}^{n} Z_{ij}\right\}$.

Step 4: Compute total influence matrix T:

$$T = X(1 - X)^{-1} \quad (5)$$

Step 5: Calculate the prominence and cause–effect group:

$$P = [p_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \tag{6}$$

$$Q = [q_j]_{n\times 1} = \left[\sum_{i=1}^{n} t_{ij}\right]_{n\times 1} \tag{7}$$

where $(P + Q)$ denotes the degree of relation between each factor with others and $(P - Q)$ denotes the severity of the influence for each factor.

Step 6: Construct the causal diagram using the $(P + Q)$ and $(P - Q)$ values.

Step 7: Weight of each factor:

$$w_j = \frac{\left[(p_j + q_j)^2 + (p_j - q_j)^2\right]^{1/2}}{\sum_{j=1}^{n}\left[(p_j + q_j)^2 + (p_j - q_j)^2\right]^{1/2}} \tag{8}$$

The application of the G-DEMATEL technique was demonstrated as explained below.

First, two types of the questionnaire were prepared using the COVID-19 impacts identified via the literature review and industrial interaction (Table 3). One questionnaire (Table A2 of Appendix B) was used to evaluate the interrelationship between the areas of impacts while the second questionnaire (Table A3 of Appendix C) was used to evaluate the interrelationships between the COVID-19 impacts. Along with the questionnaires, the grey scale (Table 6) was also provided to the experts. An expert panel consisting of 10 experts was formed. To ensure heterogeneity, experts from various backgrounds such as industrial, academics, and research were included in this study. Among the 10 experts, 3 have more than 10 years of experience in the healthcare industry, 2 have more than 5 years of experience in academic research, 3 have more than 15 years of experience in supply chain management, and 2 have more than 20 years of experience in business activities. The experts were requested to express their opinions regarding the listed COVID-19 impacts on supply chain activities. The linguistic responses of the experts were converted into grey numbers and the grey numbers were converted into crisp values using Equations (1)–(3). The responses of the experts were consolidated and then normalized. Then, a standardized matrix (N) was established using Equation (4). Additionally, using Equation (5), the total influence matrix (T) was formed. Utilizing Equations (6) and (7), the values of P and Q were calculated. Finally, the values of $(P + Q)$ and $(P - Q)$ were calculated and a digraph was drawn. Table 7 shows the values of $(P + Q)$ and $(P - Q)$ for the area of impacts. The causal interrelationships between the area of impacts are depicted in Figure 2. Similarly, the values of $(P + Q)$ and $(P - Q)$ for the COVID-19 impacts are given in Table 8. Diagraphs revealing the causal interrelationships among the COVID-19 impacts are shown in Figure 3.

Table 7. Cause–effect relationships and weights of the COVID-19 impacts.

Area of Impacts	*P*	*Q*	*P* + *Q*	*P* − *Q*	Cause/Effect	Weight
OM	10.78	13.26	24.04	−2.47	Effect	0.1367
SM	12.41	13.60	26.02	−1.19	Effect	0.1473
DM	16.59	11.28	27.88	5.31	Cause	0.1605
PM	10.41	10.23	20.64	0.18	Cause	0.1167
RM	13.60	11.75	25.35	1.85	Cause	0.1438
IM	11.82	14.53	26.34	−2.71	Effect	0.1498
LM	12.35	13.31	25.66	−0.96	Effect	0.1452

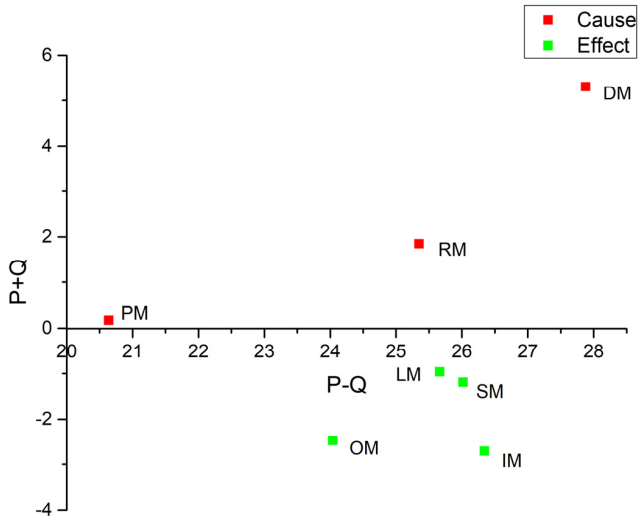


Figure 2. Causal interrelationships among the areas of impacts.

Table 8. Cause–effect relationships and weights of the COVID-19 impacts.

COVID-19 Impacts	*P*	*Q*	*P* + *Q*	*P* − *Q*	Cause/Effect	Weight
OM1	8.41	9.86	18.27	−1.45	Effect	0.0460
OM2	9.36	8.78	18.14	0.58	Cause	0.0455
OM3	7.05	13.15	20.20	−6.09	Effect	0.0529
OM4	9.22	10.82	20.04	−1.60	Effect	0.0504
OM5	11.53	8.05	19.58	3.47	Cause	0.0499
SM1	10.18	7.72	17.89	2.46	Cause	0.0453
SM2	13.29	8.80	22.09	4.50	Cause	0.0565
SM3	8.87	9.92	18.78	−1.05	Effect	0.0472
SM4	8.65	9.33	17.98	−0.68	Effect	0.0451
DM1	14.19	9.84	24.03	4.35	Cause	0.0613
DM2	5.30	12.25	17.55	−6.95	Effect	0.0473
PM1	9.28	9.22	18.50	0.06	Cause	0.0464
PM2	10.13	9.71	19.84	0.43	Cause	0.0498
RM1	10.78	7.26	18.04	3.51	Cause	0.0461
RM2	11.32	9.73	21.04	1.59	Cause	0.0529
RM3	7.40	11.64	19.04	−4.24	Effect	0.0489
IM1	10.91	9.17	20.08	1.74	Cause	0.0506
IM2	8.24	10.30	18.54	−2.06	Effect	0.0468
LM1	12.33	10.11	22.44	2.22	Cause	0.0566
LM2	10.45	11.25	21.70	−0.80	Effect	0.0545

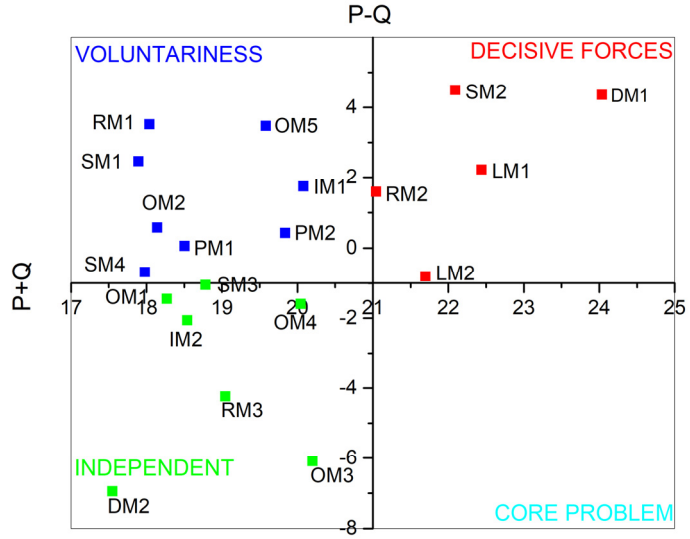


Figure 3. Diagraph revealing the causal interrelationships among the COVID-19 impacts.

4. Results and Discussions

According to the $(P - Q)$ values given in Table 7, three areas of impacts, namely disruption management (DM) > relationship management (RM) > production management (PM), were categorized into a cause group area of impacts. These areas of impacts have to be addressed earliest as it may provide a chance for other impacts to increase. This is because the influential power (P) of these areas of impacts was higher than the influenced power (Q). Likewise, other areas of impacts such as organization management (OM) > supply management (SM) > inventory management (IM) > logistics management (LM) were categorized into an effect group based on the $(P - Q)$ values. These areas of impacts may have been easily influenced by others as their $(P - Q)$ values are negative.

When the $(P + Q)$ values are considered, the areas of impacts with high values must be given immediate attention as they easily affect and are affected by other impacts. These areas of impacts are considered as the central area of impacts that need to be addressed in the short term. With respect to the $(P + Q)$ values, the areas of impacts are ranked as follows: DM > IM > SM > LM > RM > OM > PM. Hence, DM shows the highest relation with the other areas of impacts.

From the results, it is clear that DM is a major issue encountered by the supply chain industry during this pandemic. Even though the supply chain industry has faced many disruptions during the past, such as earthquakes, floods, and political disharmony, the current COVID-19 pandemic appears to be different. Most of the discussed disasters were endemic or epidemic, i.e., localized. Further, most of the discussed disasters are seasonal and, hence, databases about these disasters are maintained. Using these databases, the supply chain industry can tackle these disruptions. In the case of COVID-19, it was difficult to maintain a database as there was no earlier data. Additionally, COVID-19 is sometimes classified as an epidemic and sometimes as a pandemic [3]. With this uncertainty, it is difficult to regard COVID-19 as a pandemic or epidemic and develop strategies for overcoming the disruptions. Such uncertainty has forced various nodes of the supply chain network to disengage from normal functioning. This disengagement of various nodes or stakeholders in the supply chain network has made relationship management (RM) difficult [45]. This kind of disengagement from various stakeholders has created a scarcity of physical distribution channels. Consequently, the equation between supply and demand has collapsed. This situation places greater pressure on inventory management (IM) [31]. As the normal functioning of the supply chain activities has collapsed, the suppliers, i.e., manufacturers, are unable to transport products. This leads to the piling up of products. Hence, the pressure on the inventory department increases abruptly. Due to their inability to carry out supply activities, most industries have halted production activity. The suspension of supply chain activities has affected global business activities.

Next, the identified COVID-19 impacts were charted into four quadrants (decisive, voluntariness, independent, and core problems), as depicted in Figure 3. The COVID-19 impacts in quadrant I (decisive) have high relations and prominence over other impacts. Here, five COVID-19 impacts (DM1, LM1, LM2, SM2, and RM2) are in quadrant I. These five impacts are the potential impacts of COVID-19. Among the COVID-19 impacts in the decisive quadrant, disruption in supply (SM2) has the highest $(P - Q)$ value of 4.50, which indicates that SM2 has been a major impact of COVID-19. Additionally, the $(P + Q)$ value of SM2 is 22.09, which further indicates the need to address this impact as early as possible. In an attempt to curb the spread of COVID-19, many countries imposed a partial or complete lockdown. The imposition of such a lockdown halted or interrupted the normal supply chain activities, causing a ripple effect (DM1). In a previous study, [34] endorsed this finding, stating that the different countries' lockdowns during different times affected supply chain activities to a large extent. The occurrence of a ripple effect on the supply chain network completely collapsed normal business activities. Additionally, the COVID-19 pandemic altered the supply–demand equation. Because of the lockdown restrictions, many supply chain networks have stopped routine activities. Lockdown restrictions paved the way for the lack of supplier engagement (LM1). Stakeholders involved in the supply chain

network disengaged from supply chain activities, citing stringent lockdown restrictions [31]. As more stakeholders disengaged, this resulted in a scarcity of the physical distribution channel (RM2). As there were only a few distribution channels, the transportation cost (LM2) was very high.

Next, the COVID-19 impacts in quadrant II (voluntariness) need to be addressed. The impacts under quadrant II have a high relation and low prominence with other impacts. Here, the following COVID-19 impacts: RM1, SM1, IM1, PM1, OM2, PM2, SM4, and OM5, are in quadrant II. Due to lockdown restrictions, supply chain collapse (SM1) has resulted in significant economic loss and inflation in many countries, especially emerging countries. A report from Fortune 2020 claims that nearly 94% of the Fortune 1000 companies have witnessed a severe disruption of supply chain activities due to the COVID-19 pandemic [63]. The COVID-19 impact is not uniform and heterogeneity exists. Compared with developed countries, developing countries have been significantly affected by the consequence of the pandemic situation. This seems to be true as the economies of most developing countries mainly depend on export activities. As a manufacturing hub, most developing countries manufacture individual components that are exported to developed countries, where the individual components are assembled [64]. Without a proper supply from developing countries, the demand for assembled products and other items has increased rapidly in developed countries. The lockdown restrictions (IM1) imposed by various countries have heavily affected international trade activities and eventually halted international economic activities [65]. The absence of international trade (PM2) has increased the anxiety and fear of companies regarding their return on investment. Another major impact caused by the pandemic is mass layoff (OM2). Due to the absence of economic activities, most manufacturing and supply chain industries have halved their workforce. Such a move by the industrial community has led to joblessness and forced the workforce into poverty. This forced entry into poverty poses questions regarding progress towards social sustainability. According to the ILO report, it was estimated that around 25 million jobs were lost worldwide and the workforce lost US$3.4 trillion of income by the end of 2020 [66]. Prolonged production stoppages have resulted in the obsolescence of machines (RM1). Furthermore, as there is fluctuation in the demand, manufactured products have been stored in the inventory thus far. Stocking large quantities of products has increased the inventory cost. Border blockades and lockdown restrictions have increased the complexity of supply chain activities and the inventory management process. Due to the uncertainties caused by the pandemic situation, the traditional supply and demand equations have been changed and virtually every inventory management system was ineffective [67].

Similarly, the following COVID-19 impacts: OM1, SM3, IM2, OM4, RM3, OM3, and DM2, are in quadrant III (independent). Impacts in quadrant III have a low prominence and relation with other impacts. Problems related to supply chain activities also harm production activities. As supply chain activities were halted, most manufacturing industries have reduced their production capacity (SM4) and some have stopped their production activities. Inventory-related problems during a crisis are critical as the continuity of supplies is subjected to threats that affect the financial security of companies. Prolonged inventory holding may result in sales and marketplace losses, which increases in uncertain conditions. A study by [68] that analyzed COVID-19's impact on fashion retail revealed that fashion industries have faced difficulties in inventory management. Since COVID-19 resulted in the collapse of the supply and demand equation, industrial communities have faced acute demand forecasting (OM3). Difficulties in demand forecasting have significantly reduced the interest of industries in production activities. Such difficulties have resulted in production disruption and backlog (OM4). A study by [69] that analyzed COVID-19's impact on industrial activities highlighted that with robust technological infrastructure, developed countries have somehow managed the production disruptions caused by COVID-19. However, in the case of developing countries, this situation is completely different. Unlike developed countries, where industrial activities are mainly dependent on technological support, industrial activities are heavily reliant on workforces in developing countries [65].

The lockdown restrictions imposed by countries restricted the movement of the workforce from one place to another, resulting in a technical workforce shortage (PM1).

Quadrant IV (core problems) indicates impacts with a high prominence and low relation. Here, no COVID-19 impacts are in quadrant IV.

Comparison with Other Studies

Realizing the adverse impact of COVID-19 on routine industrial activities, many studies have been carried out [70–72]. Many of these studies analyzed the possible impact of COVID-19 from the perspective of SDGs and positive environmental impacts such as a reduction in pollution levels. In addition, some studies have addressed the disruptions induced by COVID-19 in supply chain management activities [51,68]. However, these studies are mainly confined to an analysis of COVID-19's impact on specific industries such as agriculture and the fashion retail industry. Earlier studies failed to capture and represent COVID-19's impact on the supply chain activities of industries in a generalized manner. A study by [73] that analyzed the buying preferences of customers during the COVID-19 pandemic indicated that the time pressure and scarcity of products have largely influenced the purchasing capacity. This study also identified that the pandemic has resulted in the collapse of the equation of supply and demand. As mentioned by [73], lockdown restrictions influenced the purchasing capacity of customers. In addition to this, the panic buying of customers has created unexpected and unnecessary demand for certain products, which is unusual. This finding is in line with the study by [65], which highlighted that the economic measures taken by different countries in handling the pandemic situation and overload of mistrustful information regarding economic measures increased panic buying.

Other than panic buying, another major impact of lockdown restrictions was supply chain disruption. This severely affected the social and economic sustainability of the concerned industry and workers. When supply chain activities are halted, other related activities will also reach a standstill. The suspension of product movements results in the pilling up of stocks, placing greater pressure on inventory management. Arya et al. (2021) [74] also pointed out that the pandemic has worsened industries' progress towards sustainability. Furthermore, the stoppage of industrial activities has led to mass layoff of workers. The layoff of workers has led to unemployment. Regardless of its nature, unemployment gives rise to poverty. Many earlier studies also mentioned job losses as the major COVID-19 impact [75–77]. One main factor that has not been mentioned in earlier studies is the cost associated with the transportation of products. Since the supply chain network was disrupted due to lockdown restrictions, the transportation costs of essential commodities have increased due to the respective supply chain management. An increase in transportation costs has a direct relationship with the cost of the product being transported. The elevated cost of the products owing to the increase in the transportation cost results in a reduction in sales.

5. Implications of the Study

This study offers valuable contributions to the literature on COVID-19's impact on supply chain management in emerging economies. Existing studies [78–80] on the analysis of COVID-19's impact approached the situation from a positive environmental view and a mere economic view. These studies argued that the lockdown restrictions imposed because of the COVID-19 pandemic situation significantly helped to lower pollution levels and insisted that it has affected the economic condition of daily-wage laborers. Though these studies analyzed the impacts of COVID-19, they failed to evaluate the impacts on supply chain management. Taking this into consideration, this study examined the adverse impacts of COVID-19 on sustainable supply chain management. This study identified a pool of COVID-19 impacts on supply chain activities and their adverse effect on related activities. A total of twenty significant COVID-19 impacts were identified via a literature review. Based on the EFA result, these impacts were categorized under three groups. The

main contribution of this study is its identification of the causal interrelationships between the various COVID-19 impacts using EFA and CFA.

Based on the outcomes, this study suggests some measures that the industries and government may follow in lowering the COVID-19 impacts. The outcome of this study specifies that problems at the organization level directly impact supply chain activities. Hence, at the organization level, some considerable modifications must be carried out. The first problem that needs to be addressed is lockdown restriction. Restrictions halted the movement of products from one place to another place. So, strategies such as complete lockdown must be uplifted. The relaxation of lockdown restrictions will ease the movement of products and enhance industrial activities. In managing the required workforce, industries need to follow shift-based work. Citing the severity of COVID-19, the government insisted on avoiding crowds in work and public places [81]. The crowding of workers can be avoided by increasing the number of shifts. An increase in the number of shifts provides more employment opportunities and ensures the normalcy of production activities. Once the industrial activities are started, supply chain activities will also start as they have a pivotal role in industrial activities.

6. Conclusions

COVID-19 has affected routine industrial activities to a large extent. Supply chain management, a vital part of the industrial activity chain, has been negatively affected by the COVID-19 complications. Furthermore, the prevailing pandemic situation has questioned the sustainable performance of industries regarding each activity. So, the analysis of the impact of COVID-19 on supply chain management activities is of great significance. This study analyzed COVID-19's adverse impacts on supply chain management by conducting CFA. Twenty critical impacts of COVID-19 were identified through a literature review and categorized into three groups based on the outcome of exploratory factor analysis. The categorization of the impacts into three groups was carried out based on a discussion with experts. The outcomes of this study indicate that organizational problems negatively impact supply chain activities, negatively affecting production activities.

This study offers valuable contributions to the literature on the adverse impact of COVID-19 on supply chain management. First, this study provides a comprehensive list of COVID-19's impacts on the supply chain. Such a list of impacts provides better insight into the consequences of COVID-19. Next, the casual relationship between the impacts was revealed using CFA. Understanding the relationship between the impacts will help policymakers and practitioners develop policies to combat the adverse impacts of COVID-19.

The outcome of this study provides a structural outline of the relationship between the identified impacts. This structural representation acts as a guide for industrial practitioners in understanding the relationship and developing strategies to reduce and eliminate the impacts.

By contributing significantly to the literature, this study also has some limitations. First, this study only completed EFA and CFA to better understand the relationship between the effects of COVID-19. However, a future study that integrates any MCDM techniques, preferably the weight calculation technique, will reveal the weight significance of each impact. Next, this study was carried out in the context of a developing country. Hence, it lacks generalizability. Finally, as the future scope of this study, a comparative study on the impact of COVID-19 in developing and developed countries could be carried out.

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Appendix A

Table A1. This work attempts to evaluate the COVID-19 impacts on supply chain activities. Regarding this, you are requested to rate the COVID-19 impacts using five point Likert's scale (5—completely agree, 4—agree, 3—neutral, 2—disagree, 1—completely disagree).

S. No	COVID-19 Impacts	Likert's Scale (5—Completely Agree, 4—Agree, 3—Neutral, 2—Disagree, 1—Completely Disagree)
1	Technical workforce shortage (OM1)	
2	Stalled industrial activity (OM2)	
3	Difficulty in demand forecasting (OM3)	
4	Reduced production capacity (OM4)	
5	Disproportionateness between supply and demand (OM5)	
6	Obsolescence of machines (SM1)	
7	Production disruption and backlog (SM2)	
8	Disruption in supply (SM3)	
9	Pilling up of inventory (SM4)	
10	Increased transportation cost (DM1)	
11	Lack of supplier engagement (DM2)	
12	Increased lead time to delivery (PM1)	
13	Lack of international trade (PM2)	
14	Supply chain collapse (RM1)	
15	Lack of physical distribution channel (RM2)	
16	Ripple effect on supply chain operations (RM3)	
17	Mass layoffs (IM1)	
18	Lockdown restriction (IM2)	
19	Distress on Return of investment (LM1)	
20	Reduced cash inflow (LM2)	

Appendix B

Table A2. Questionnaire given to experts to rate the significance of COVID-19 area of impacts on supply chain activities using a grey five-point scale.

Area of Impacts	OM	SM	DM	PM	RM	IM	LM
OM	0						
SM		0					
DM			0				
PM				0			
RM					0		
IM						0	
LM							0

Where OM—Organization management; SM—Supply management; DM—Disruption management; PM—Production management; RM—Relationship management; IM—Inventory management; LM—Logistics management.

Appendix C

Table A3. Questionnaire given to experts to rate the significance of COVID-19 impacts on supply chain activities using a grey five-point scale.

COVID-19 Impacts	OM1	OM2	OM3	OM4	OM5	SM1	SM2	SM3	SM4	DM1	DM2	PM1	PM2	RM1	RM2	RM3	IM1	IM2	LM1	LM2
OM1	0																			
OM2		0																		
OM3			0																	
OM4				0																
OM5					0															
SM1						0														
SM2							0													
SM3								0												
SM4									0											
DM1										0										
DM2											0									
PM1												0								
PM2													0							
RM1														0						
RM2															0					
RM3																0				
IM1																	0			
IM2																		0		
LM1																			0	
LM2																				0

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