Impact of COVID-19 on Supply Chains: Lessons learned and future research directions

Abstract

Purpose- This study aims to review and organize the research articles which focused on the impact of COVID-19 pandemic in the supply chain (SC) domain through a bibliometric and network analysis.

Design/methodology/approach- Initially, a total of 772 research articles with selected keywords were retrieved from the Scopus database for the year 2020 (with the commencement of COVID-19 outbreak). After the filtration and refinement, 484 research articles were found relevant and unique. Further, this study systematically reviews and evaluates the 484 research articles including influential authors, keys journals, influential research work, and collaboration among the countries and institutes with the help of bibliometric analysis tool. The emergent research clusters are identified and established.

Findings –The findings reveal that the total number of related publications are steadily growing with the United States leading the way. European countries have made notable accomplishments as well. In addition, both the most cited publications and the keyword distribution provide research guidance for future research.

Practical implications- This study focuses on the need and advancement of the literature on the impacts of the COVID-19 pandemic on SCs to frame a research agenda for researchers and practitioners.

Originality/value- The present study offers future research directions in the area of SC under the pandemic situation.

Keywords- COVID-19; Supply chains; Bibliometric analysis; Scientometric analysis

Paper type- Literature review paper

1. Motivation and Introduction

Global SCs have always been vulnerable to unprecedented infectious diseases that occur in the major exporting countries. (Chang et al., 2020). Many infectious diseases have already occurred in the past, such as the Swine flu, Ebola, and Influenza worldwide (Dasaklis et al., 2017; Büyüktahtakın et al., 2018; Lin et al., 2020; Queiroz et al., 2020). World health organization (WHO) reported 1438 epidemics that disrupted SCs in the past (Hudecheck et al., 2020). These outbreaks created substantial disruption[1] with significant negative impact across the global SCs, including the reduction of their efficiency and performance (Guan et al., 2020) and propagating ripple effects[2] that affect their resilience and sustainability (Ivanov and Dolgui, 2020). The previous pandemic proffers imperative lessons in the context of SCs. Unlike other previous outbreaks, Corona Virus Disease 2019 (COVID-19) is a more severe, intensified, and dynamic global disaster that not only relentlessly affected humans but also global SCs (Haren and Simchi-Levi, 2020).

It is observed that 94% of the Fortune 1000 companies were experiencing severe disruption across the SCs due to the COVID-19 outbreak (Fortune, 2020). After evaluating the transmission intensity across the countries, WHO announced the COVID-19 outbreak as a pandemic (Rathore and Gupta, 2020). Furthermore, this pandemic impacted every SCs member such as supplier, manufacturer, distributor, and consumer in a multi-dimensional way (Chowdhury et al., 2020a). Figure 1 presents the several challenges across all SCs members. For instance, demand for essential goods and item such as personal protective equipment (PPE) kit[3], Mask, and processed food has increased. Meanwhile, manufacturer confronted several challenges to shrink their capacities, such as, raw material shortage[4], labor shortage[5], restriction on vehicle movement due to national and international border closure around the world. (Paul and Chowdhury, 2020b). Such challenges have substantially impacted the supplier's capability to deliver goods and services on time to the consumers (Ivanov and Das, 2020). In the advanced and globalized world, firms are sourcing raw materials from all over the world. After the emergence of COVID-19 outbreak and

[1] https://www.nytimes.com/2020/02/07/business/coronavirus-business-impact.html
[2] https://www.wsj.com/articles/the-global-logistics-logjam-shifts-to-shenzhen-from-suez-11623403801
[3] https://www.wsj.com/articles/u-s-supplies-of-covid-19-ppe-fall-short-of-targets-11607509800
[4] https://www.nytimes.com/2020/04/10/business/economy/global-trade-shortages-coronavirus.html
[5] https://www.wsj.com/articles/consumer-demand-snaps-back-factories-cant-keep-up-11614019305

international border closure, suppliers facing shortage of raw material. Consequently, manufacturing operations have been shut down and caused supply disruption for manufacturers. Similarly, restriction in vehicle movement have caused delays and negatively affected the smooth flow of goods and services and also disrupted the international trade (Deaton and Deaton, 2020).

Due to these reasons, it is predicted that world trade may fall by 13-32% in 2020 (WTO, 2020). Moreover, World Economic Forum (WEF) reported that economic activities have been reached at the lowest point and declared an economic recession and global financial crises. Thus, COVID-19 pandemic forced the entire SCs firms to rethink and transform their model to tackle the business disruption and SC challenges (Remko 2020; Deloitte, 2020). In response to such situation, the digitization of SCs could manage the disruptions due to pandemic by increasing SCs flexibility (Ivanov et al. 2019).

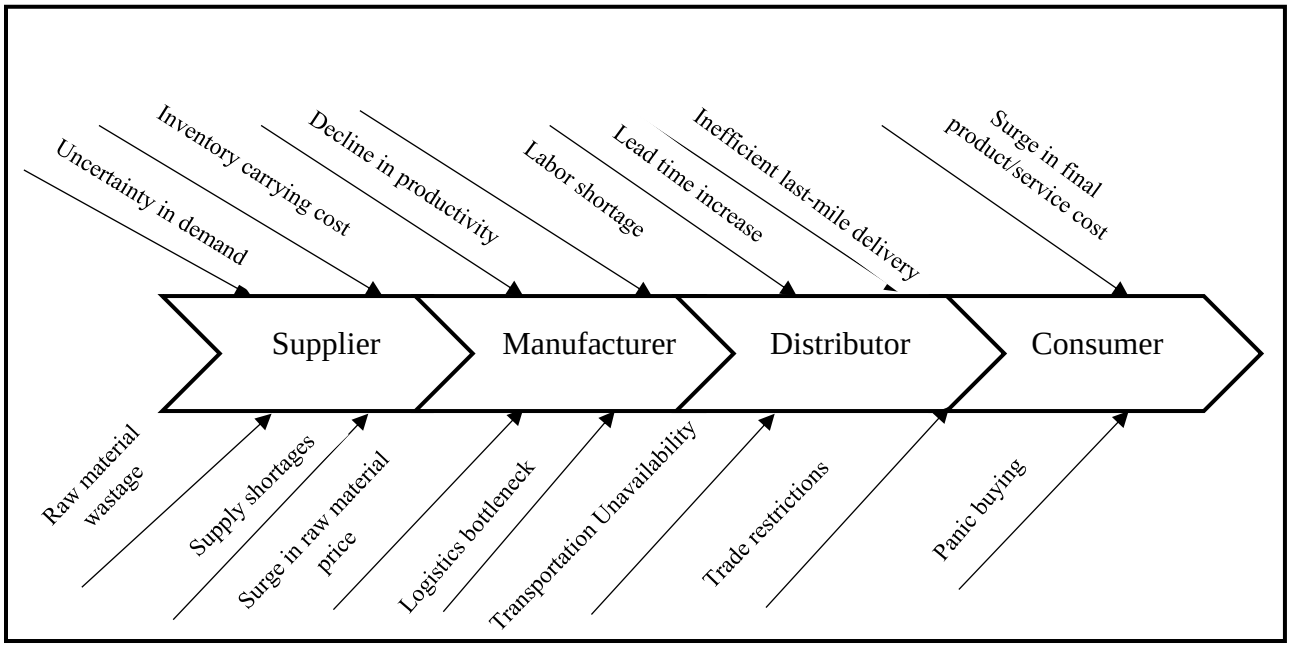


Figure 1 Impact of COVID-19 on Supply Chains

Due to the severe impact of the COVID-19 pandemic on SCs, many researchers and industry experts have shown their interest to explore the impact of this pandemic on SCs (Choi, 2020, Ivanov, 2020. PWC, 2020 and Fortune, 2020). Consequently, many research studies on the impact of COVID-19 in SC domain have been published since 2020. As the second wave of COVID-19 is reported in some places, this research area is considered promising and crucial (Ivanov 2020). Therefore, this paper aims to represent the comprehensive evaluation of the

research studies focusing on the impact of COVID-19 in SCs area through *bibliometric tools and network analysis*. Recently, bibliometric and network analysis are gaining significant attention as prominent and scientifically structured approaches to review academic literature in a specific domain (Albort-Morant *et al.*, 2016; Vallaster *et al.*, 2018; Riahi et al., 2021) or examining the temporal evolution of published articles in a particular academic outlet (Martínez-López *et al.*, 2018; Trianni *et al.*, 2018; Gaviria-Marin *et al.*, 2018).

In the past, scholars have applied different software packages and tools for bibliometric analysis with diverse capabilities and limitations, such as CiteSpace, Publish or Perish, HistCite, and BibExcel. This study applied the bibliometrix package in R due to its core statistical computing and graphical functionalities. R is a complete package of statistical software that eases scientific tasks (Liu et al., 2005; Gagolewski 2011). Other software packages cannot perform such detailed network analysis and require additional tools to visualize the associated network (Gephi, Pajek, and VOS viewer). With an open-source platform that includes statistical algorithms, mathematical functions, and visualization capabilities, R's bibliometrix package is an excellent choice for bibliometric analysis (Aria and Cuccurullo, 2017). This R's bibliometrix package allows the scholars (i) to examine the contemporary themes of literature in a specific domain; (ii) to conduct an exhaustive assessment of published articles along with trends and patterns; (iii) offers motivation and potential directions for future research work; (iv) to use network analysis in identifying existing and emerging research areas; (v) to categorize the published articles in clusters of co-related scholars; (vi) to trace the relationships among co-citations of academic journals, authors, and keywords used in a specific research area. In addition, this analysis would be helpful for the researchers to identify the potential research gaps under this pandemic situation.

The rest of the paper is structured as follows. In Sections 2, we present the systematic literature review methodology adopted in this study. In Sections 3 and 4, we perform the bibliometric and network analyses. In Section 5, we discuss the results generated from the analysis and their implications, followed by identifying current and future research trends. Finally, we conclude the paper in Section 6.

2. Data source and methodology

In this review article, Systematic literature review (SLR) is performed on our research theme with the help of designed research protocol, as shown in Table 1. We designed the research protocol for the sake of objectivity and reliability of this study and conducted the literature review

to search the relevant articles using the keywords through Scopus database (Cooper et al., 2018). In this study, we only considered the research articles that met our designed research protocol. Moreover, we applied quantitative R-tool software called Bibliometrix for science mapping and analysis (Aria and Cuccurullo, 2017; Zhou et al. 2019). Finally, we stated the main findings from the analysis of papers and explored areas of research theme. This led to reveal of possible future research directions.

Table 1. Research protocol

Protocol	Descriptions
Research theme	COVID-19 in the context of Supply chains
Time period	The time period for consideration was complete 2020
Search Database	Scopus
Publication type	Peer-review journals
Language	Articles written in English
Search field	Title, Abstract, and Keywords
Keywords	"COVID-19", Supply chains", "Supply chain disruption", "Supply chain risk"
Criteria for inclusion	Article reported COVID-19 outbreak in supply chain context
Criteria for inclusion	Non-refereed articles
Data extraction and analysis	R-tool software Bibliometrix and content analysis approach

2.1. Data retrieval

Scopus database was used to retrieve the relevant research papers for bibliometric analysis. *Scopus* globally recognized as the most widely used citation database of peer-reviewed articles[6]. It

[6] Scopus is the largest abstract and citation database of peer-reviewed literature: https://blog.scopus.com/about/

comprises articles from more than 20,000 peer-reviewed journals published by reputed publishing houses such as Taylor and Francis, Elsevier, Informs, Emerald, Springer, and Inderscience. The *Scopus* database is more detailed and extensive than the Web-of-Science database, whereas it contains only ISI-indexed articles (Yong-Hak, 2013). In this study, we focused on articles published in renowned and international peer-reviewed journals. Therefore, the *Scopus* database served our purpose as a reliable source of academic articles in *SCs*. Our study focused on the literature published after the emergence of the COVID-19 pandemic because the COVID-19 virus is relatively unidentified and emerged in December 2019 in Wuhan, China.

We used the following keywords for our bibliometric data analysis: "*COVID-19*", "*Supply chain*", *"Logistics"*, "*healthcare supply chain*", *"Supply chain disruption"*, "*agricultural supply chain*", and "*Food supply chain*". These keywords were selected based on published research articles on related areas. We cautiously ensured the choice of keywords such that those combinations comprehensively encompassed all possible dimensions indicated by "*supply chain*" and "*COVID-19*" while preventing the inclusion of any spurious literature in our analysis, in line with the PRISMA methodology (Liberati et al., 2009). The PRISMA methodology and framework employs a set of methods and guidelines to search articles systematically for review-based studies (Moher, 2013). Moreover, this methodology includes the formulation of inclusion and exclusion criteria for any type of study that systematically assesses the quality of chosen papers. The aim of considering this methodology in our study is to improve the quality of systematic review protocols, (Stewart et al., 2015). Furthermore, PRISMA also considered as a vital tool for the critical appraisal of published systematic reviews (Stovold et al., 2014).

2.2. Selection of the present body of literature (Inclusion and Exclusion criteria)

In this study, we adopted a two-step approach to extract the papers for bibliometric analysis. First, an initial search was performed between 1st January 2020 to 31st December 2020. These results were collected in CSV format to retrieve essential tags such as title, abstract, author, institute of affiliation, and country. The initial search led to 772 papers that fits our search term criteria. To ensure inclusion of relevant papers, we read the paper's abstract. The papers that appeared non relevant, white papers, working papers, duplicate papers and non-English were discarded to make a consistent focus of the study. On the basis of this, 288 papers were discarded, and 484 papers were found unique and related, as shown in Figure 2. These scientific papers are classified as articles, out of which only 351 (73%) of the total 484 are peer-reviewed journal articles, and the

remaining are conference proceedings (203), reviews (16), books (5), short surveys (3), book chapters (21), editorials (3), letters (1), and notes (1). Figure 3 presents the distribution of research papers after filtering and refinement. 484 articles were written by 1873 authors in a various domain of SCs. There are 88 single-author publications out of 484 total papers. The collaboration index among authors who work on SC under COVID-19 pandemic is 4.58. The complete descriptive Information about Scientific Papers is presented in Table 2.

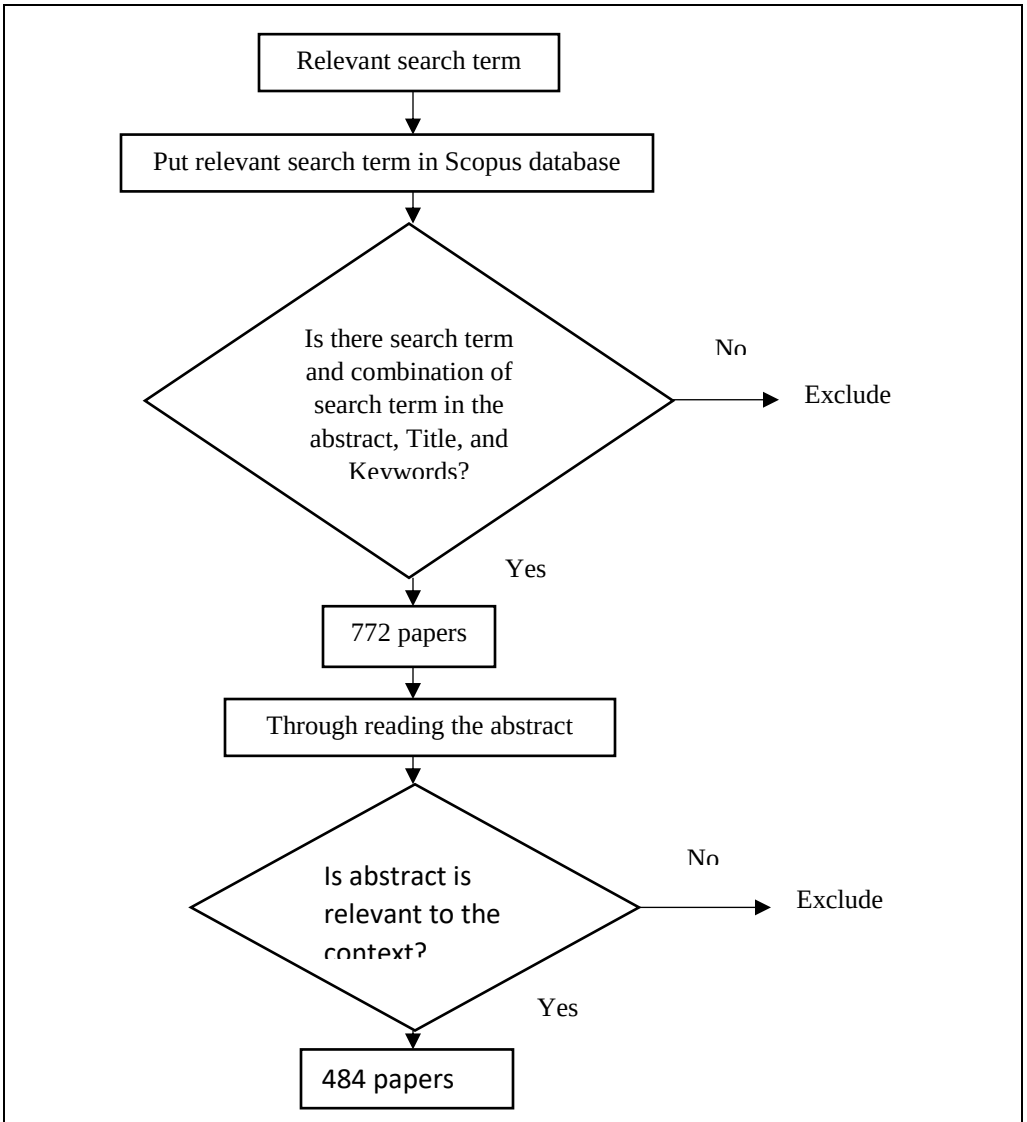


Figure 2. Research methodology for finalizing the articles for analysis

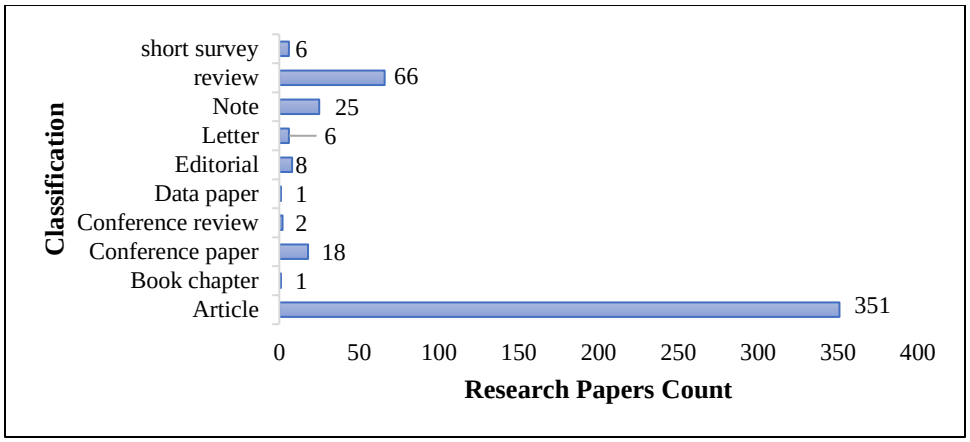


Figure 3. Typology of research papers after filtering and refinement

Table 2. Detailed Information about research papers
Source: Bibliographic information obtained from Scopus database

SCIENTIFIC PAPERS	484
PAPERS CONTENTS	
Keywords Plus (ID)	2216
Author's Keywords (DE)	1462
AUTHORS	
Authors	1873
Author Appearances	1985
Authors of single-authored documents	88
Authors of multi-authored documents	1785
AUTHORS COLLABORATION	
Single-authored documents	94
Documents per Author	0.258
Authors per Document	3.87
Co-Authors per Documents	4.1
Collaboration Index	4.58

3. Bibliometric Analysis

3.1. Publications by journals

This analysis revealed a pattern of how literature in a subject is distributed in journals. It is useful for the librarians because it helps in identifying the core sets of journals, which publish the most articles of SC under COVID-19 outbreak context. Table 3 presents the top seven relevant journals which published articles on the impact of COVID-19 on different SCs. Our bibliometric analysis indicates that there are 32 journals, and they contributed to the 484 papers. Further, we found that among these 32 journals, the top 15 journals have contributed 106 articles and constitute approximately 22% of the total articles.

Among these, the top three are: (i) *Sustainability (Switzerland)* has published 19 papers, followed by (ii) *Applied economic perspectives and policy* with 9 papers, and (iii) *Canadian journal of agricultural economics* with 8 journal publications, respectively.

Table 3. Top 7 journals published papers on SC domain under COVID-19 context

Journal	No of publications
Sustainability (Switzerland)	19
Applied economic perspectives and policy	9
Canadian journal of agricultural economics	8
Proceedings of the international conference on industrial engineering and operations management	8
Smart and sustainable manufacturing systems	8
IEEE engineering management review	7
Resource's conservation and recycling	7
China agricultural economic review	6
International journal of environmental research and public health	6
Science of the total environment	6
Food security	5
IEEE access	5
International journal of operations and production management	4
International journal of supply chain management	4
Annals of operations research	4

3.2. Most productive authors

Many researchers have significantly shed light on the impact of COVID-19 in SC domain. Our bibliometric analysis revealed that 1873 different authors published these 484 papers. Among them, pioneers' authors are identified on the basis of number of publications who can be consulted for further analysis, policy development, and guidance for organizational problems. Table 4 shows the top five productive authors who have substantially explored this research domain and intends to unlock scholarly discussions on "*the impact of COVID-19 on the supply chain"*. It is significant to note that these researchers have discussed several themes, such as *supply chain disruptions, supply chain resilience, supply chain risks, viable supply chain, supply chain sustainability,* and *network design solutions* during the pandemic. Further, we identified the ranking of most productive authors/researchers based on the number of articles published. The bibliometric analysis revealed that *Ivanov D* (Dmitry Ivanov) is the most productive and influential author with nine publications and 330 citations.

Table 4: Top 5 productive authors based on number of articles published

Authors	NP	Articles Fractionalized	h_index	g_index	m_index	TC	PY
Ivanov D	9	4.83	7	9	7	330	2020
Liu H	5	1	1	2	1	4	2020
Awwad M	4	0.7	0	0	0	0	2020
Dolgui A	4	1.75	3	4	3	138	2020
Li J	4	1.65	1	4	1	25	2020
Li S	4	0.81	1	4	1	21	2020
Paul SK	4	1.39	2	4	2	19	2020
Sharma A	4	1.13	1	3	1	13	2020
Wang Y	4	0.84	2	4	2	18	2020
Kumar A	3	1.38	1	1	1	2	2020
Luthra S	3	0.78	1	1	1	2	2020
Rowan NJ	3	1.5	2	3	2	57	2020
Wang H	3	0.41	2	3	2	24	2020
Wang J	3	0.78	1	2	1	6	2020
Wang S	3	0.42	1	3	1	20	2020
Zhang y	3	0.59	3	3	3	17	2020
Alcoba-florez J	2	0.25	2	2	2	12	2020
Ali SM	2	0.31	0	0	0	0	2020
Apostolopoulos Y	2	0.58	1	1	1	1	2020

*NP = Number of papers; TC = total citation, PY = Publication year

h-index: It is an indicator for evaluating the cumulative impact of an author's scholarly output and performance

m-index: It is defined by h/n, where h is the h-index and n is the number of years since the first published paper of the author.

g-index: The index is calculated based on the distribution of citations received by a given author's publications

3.3. Most Influential research studies

While a bibliometric analysis of the most productive authors presents vital information about individual contributions and their influence in the development of a field of research, it is equally important to identify most influential/cited research articles that have shaped the knowledge domain. Hence, we identified the most Influential research studies on the basis of received citation and their contribution on the impact of COVID-19 on SCs. These important studies have a great contribution in shaping the knowledge domain of a research field. Table 5 lists the top 10 most influential research works on the basis of their citations received in the domain of SC.

Our bibliometric analysis revealed that Ivanov D (2020a, 2020b, 2020c, 2020d) has significantly contributed to the epidemic outbreak (COVID-19) by his high cited studies in this domain. His studies have contributed to the domain of global SCs with agility, resilience, and sustainability perspectives. The second most influential work has been contributed by Rowan NJ, (2020). Their research work identified the challenges of PPE shortage and also provided the solutions to reduce the shortage.

Table 5. Top 10 most influential research works

S.No	Author	Tittle	Journal	TC
1	Ivanov D, (2020a)	Predicting the impacts of epidemic outbreaks on global supply chains: a simulation-based analysis of the COVID-19/SARS-CoV2 case	Transportation Research – Part E	134
2	Ivanov D, (2020b)	Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak	International Journal of Production Research	88
3	Rowan NJ, (2020)	Challenges and solutions for addressing critical shortage of supply chain for personal and PPE kit arising from Coronavirus disease (COVID19) pandemic – Case study from the Republic of Ireland	Science of The Total Environment	53
4	Ivanov D, (2020c)	A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0	Production planning and control	39
5	Ivanov D, (2020d)	Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic	Annals of Operations Research	36
6	Haghani M, (2020)	The scientific literature on Coronaviruses, COVID-19 and its associated safety-related research dimensions: A scientometric analysis and scoping review	Safety science	24
7	Govindan K, (2020)	A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19)	Transportation Research Part E: Logistics and Transportation Review	23
8	Siche (2020)	What is the impact of COVID-19 disease on agriculture?	Scientia Agropecuaria	23
9	Queiroz MM, (2020)	Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review	Annals of Operations Research	22
10	Cappelli A, (2020)	Will the COVID-19 pandemic make us reconsider the relevance of short food supply chains and local productions?	Trends in Food Science & Technology	17

*TC= Total citation

3.4. Country-wise analysis of articles published

This analysis identifies the geographical distribution of documents in the area of SC under COVID-19 outbreak. From this analysis, the top 5 active countries in terms of the number of publications in the current research domain i.e., *"impact of COVID-19 on SC"* in 2020 are presented in Table 6. The USA is at the top of the list with 38 publications.

Table 6. Top 5 relevant Countries by Corresponding Author

Country	**Articles**	**Frequency**	**SCP**	**MCP**	**MCP Ratio**
USA	38	0.27338	30	8	0.211
China	13	0.09353	6	7	0.538
Canada	8	0.05755	5	3	0.375
United Kingdom	8	0.05755	6	2	0.25
France	7	0.05036	5	2	0.286
India	7	0.05036	6	1	0.143
Italy	5	0.03597	4	1	0.2
Spain	5	0.03597	4	1	0.2
SCP- Single country publication, MCP- Multiple country publication,					

3.5. Affiliation analysis of academic institutes that publish article

This analysis helps to analyze the affiliations associated with an author and their contribution in terms of number of publications. We identify and report the top five performing institutes based on number of publications in the current research domain i.e., *"impact of COVID-19 on SC"*, as shown in Figure 4. In this list of top 5 contributing institutes, the *University of Toronto* in Canada ranks first with 11 articles. The *Berlin school of economics and law*, Germany, and the *Ohio state university* secured the second position with 9 papers.

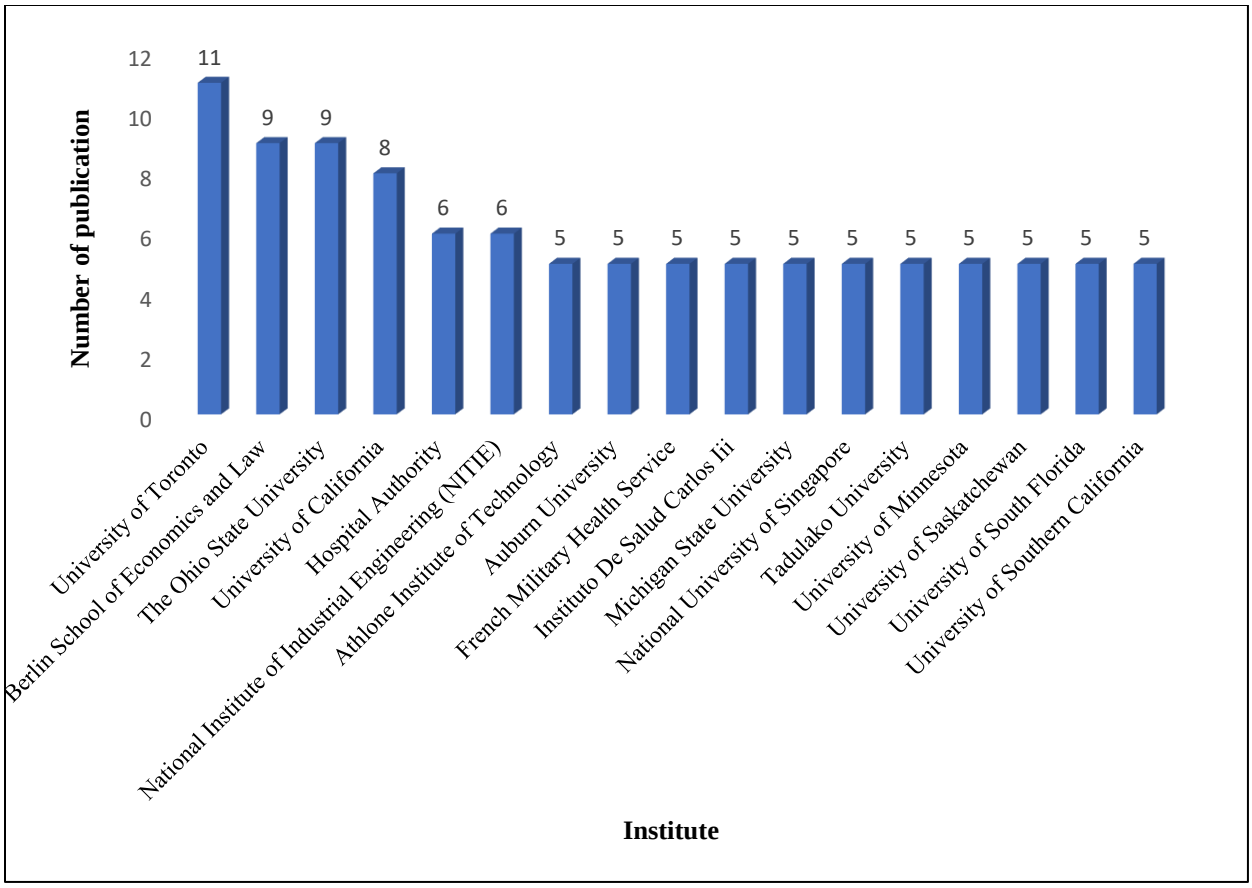


Figure 4. Top 5 highest contributing institutions

3.6. Word Tree Map dynamics

Word tree map is generated by providing the author's keywords from our dataset (484 papers). Figure 5 presents the dynamics of word tree map based on keywords plus. In this Figure, the size of rectangle box represents the frequency of the keywords, while colors signify the relationship with the keywords. Keyword segments such as "*Pandemic*", "*beta coronavirus*", "*Human*", "*Viral*", "*Supply chain* ", "*Food supply chain*" are relatively recognizable whereas small size rectangle boxes have several related keywords like "*Drug supply*", "*healthcare*", and "*Food security*" are less recognized and these would be considered as emerging areas for future research.

From the word Tree map dynamics, we can interpret that the following keywords: '*supply chain resilience'*, '*supply chain disruptions'*, *"supply chain viability" and "supply chain risk*" are scant. Therefore, our study identifies potential research domains under this current pandemic situation.

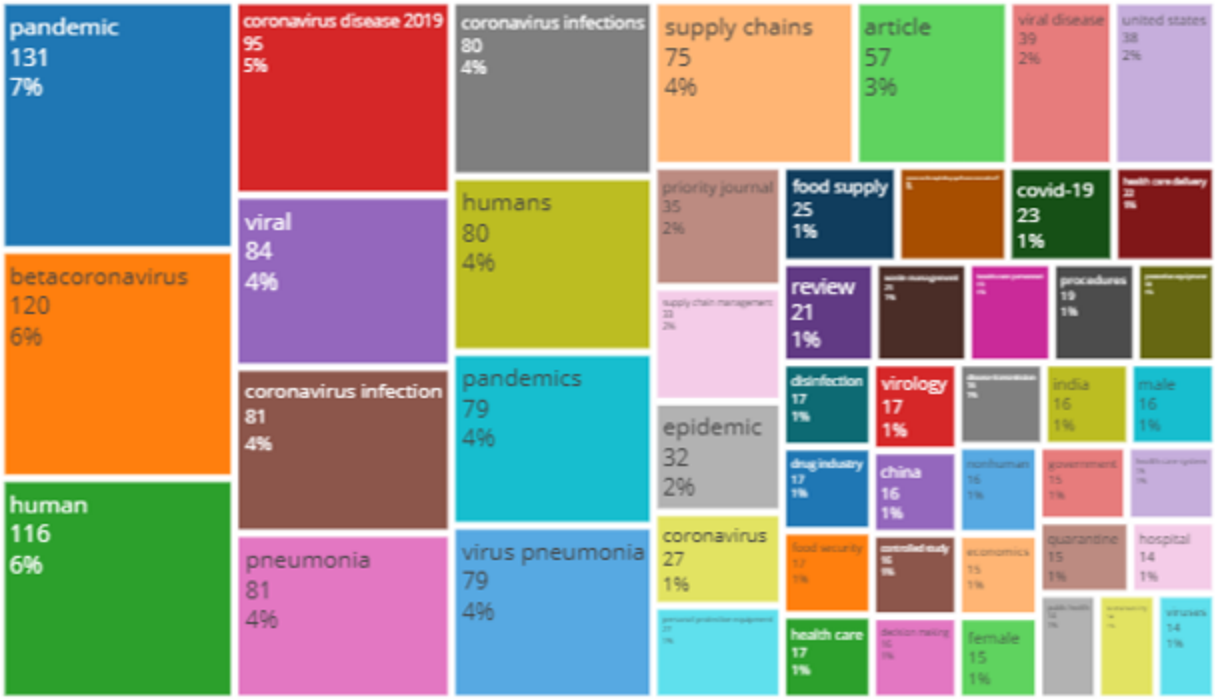


Figure 5. Word Tree Map dynamics

4. Network analysis

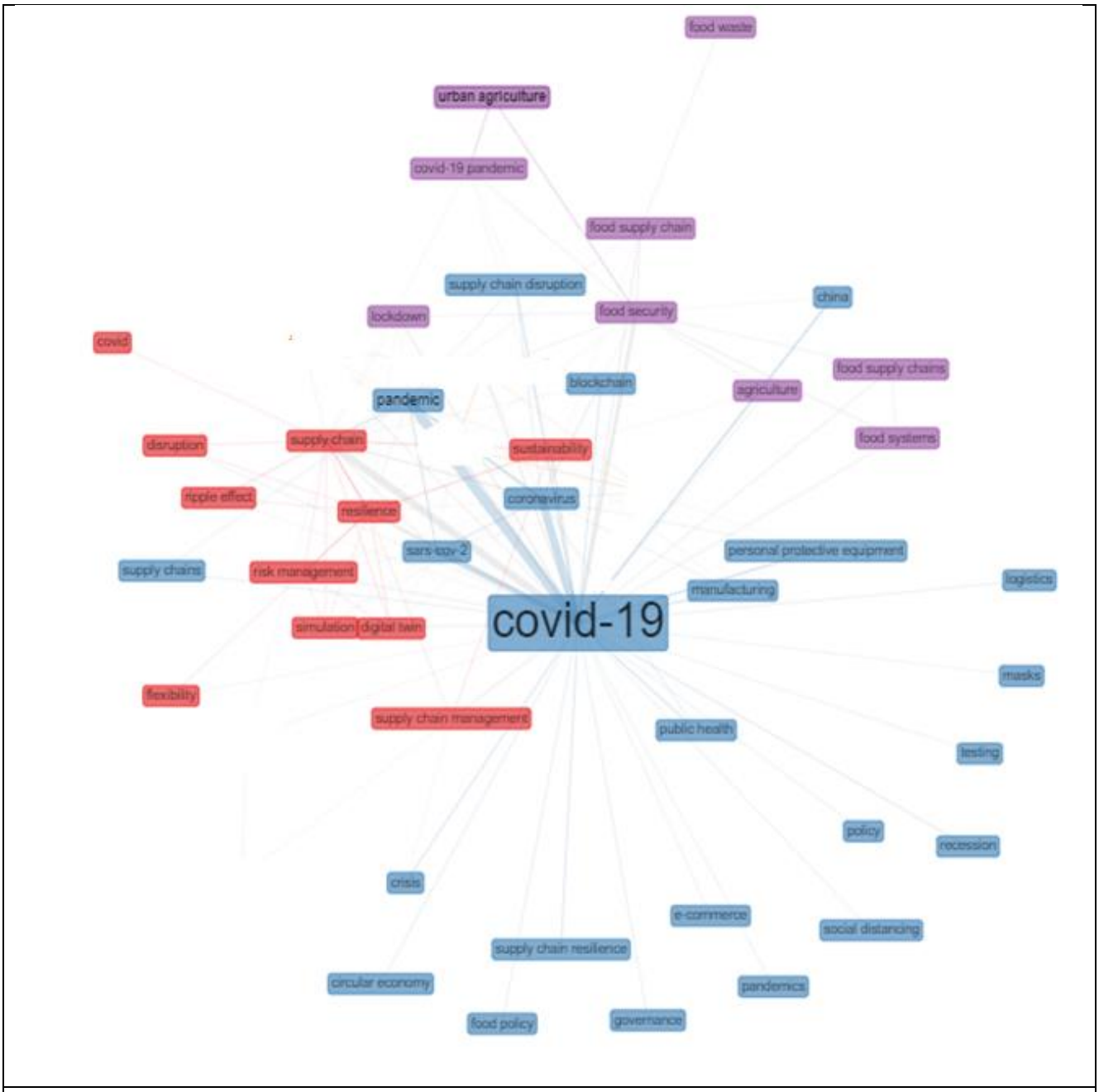
4.1. Keyword co-occurrence network

A keyword co-occurrence network helps to identify the primary keywords included in the papers within a specific research area and understand its primary themes. Keywords and co-occurrences across various publications can be derived from various bibliometric fields such as title, abstract, and keywords for subsequent network analysis. This network provides the information about the keywords that are listed in the same paper and also reflects the knowledge structures of SC under COVID-19 outbreak on meso, macro, and micro levels (Su and Lee, 2010). We used R *bibliometrix* package to visualize the keywords' co-occurrence network and presented them in Figure 6. While generating the network, we considered the top 50 co-occurring keywords, and the isolated nodes were removed to improve the clarity of the network diagram.

In Figure 6, Cluster 1 (BLUE colour) is the largest among the clusters in the entire keyword co-occurrence network and consists of twenty-three nodes. This cluster is primarily associated with the top three keywords as follows: *Covid-19* , *Coronavirus*, and *Pandemic*. This cluster basically belongs to the nomenclature of COVID-19 used searching for COVID-19 outbreak articles like pandemic, epidemic, and sars-cov-2.

Cluster 2 (RED colour) is the medium one compared to other clusters and consists of ten nodes. The intra-cluster coherence is moderate. This cluster is primarily associated with the top three keywords as follows: *Supply chain*, *Sustainability*, and *Resilience*. This cluster basically focused on the disruption caused by the COVID-19 pandemic and ripple effect across the SCs that affect their resilience and sustainability.

Cluster 3 (Purple colour) is the smallest cluster and consist of nine keywords nodes such as Food supply chain, COVID-19 pandemic, and Food security. This cluster has research articles that primarily focused on the supply disruption in food sector due to COVID-19 pandemic. This disruption has severe negative impact on the food supply firms globally including panic buying, labour storage, facility failure, increased demand, and increased product cost. According to the Food and Agriculture Organization (FAO, 2020) report, this pandemic impacts the food SC in two vital aspects: the demand and supply for food in weaker section of the society. To tackle this emergency situation, Indian government developed and run a simulation model called public distribution system for ensuring the food security to the weaker section of the society at a reasonable price.



Cluster 1-BLUE colour; Cluster 2- RED colour and Cluster 3- Purple colour

Figure 6. Keyword co-occurrence network analysis using author keywords

4.2. Co-citation network analysis of most influential studies

Co-citation network analysis help to establish a relationship between two published articles (Trianni et al., 2018). This network analysis is used to visualize the co-citation structure map and to identify the core papers in the network (Tang et al., 2021). Co-citation occurs when two articles are cited in a third paper concurrently is deemed to be co-cited (Small, 1999). Their mutual

association improves as more articles begin to cite them jointly (Small, 1973; Small, 1999). Chen et al. (2010) stated that a co-citation network provides a detailed analysis and finds a specific research area's periodic progression. Figure 7. presents the network visualization, which includes spatial locations for most of the cited work. While generating the network, we considered up to the top 100 co-cited authors, and the isolated nodes were removed to improve the clarity of the network.

In a co-citation network, the node size denotes the count of citations received, and the closeness between two nodes denotes the strength of their mutual relationship. Therefore, the nodes that are closer to each other indicate articles that are co-cited many times. In contrast, the nodes that are far apart, represent the articles written by authors who do not collaborate frequently. Our study's co-citation network (see Figure.7) consists of different clusters, and each cluster is highlighted with a distinct color. Every cluster presents a particular theme of study in the domain of *supply chain*.

In Figure 7 , the Red cluster (Cluster 1) is focused on the global SCs disruption due to COVID-19 outbreak and challenges for managing SC resilience (Ivanov D, 2020a 2020b. 2020c Hobbs J.E 2020), which is further linked to another cluster. Some studies in this cluster have explored the agricultural SCs risk caused by disruption during COVID-19 (Sharma et al., 2020). This cluster also presents review articles that compare the impact of SC due to epidemic outbreaks such as Ebola, Influenza, and COVID-19 (Queiroz et al., (2020)) and explores the future research agenda.

The Blue cluster (Cluster 2) developed the framework for enhancing the survivability of sustainable SC to survive in and post-COVID-19 pandemic. The consideration of sustainability in SC is a new approach in epidemic outbreak literature. This cluster effectively addresses the critical role of Industry 4.0 and digital manufacturing to control ripple effect and manage the SCs disruption (Hosseini et al., 2019). In this emergency, 3D printing is considered as empowered manufacturing technology that has been used to fabricate temporary emergency dwellings, PPE kit, personalized 3D-printed face masks, and ventilators (Choong et al., 2020). Similarly, Blockchain has great potential to meet the requirements of the global PPE SC system, such as monitoring PPE supply, distribution, and consumption to predict potential distribution needs or supply pitfalls during outbreaks (Reddy et al., 2021; Ting et al., 2020). Moreover, organization

that are successful in digital manufacturing networks appear to be better positioned in COVID-19 and in the coordination of future recovery processes (Choi et al., 2020).

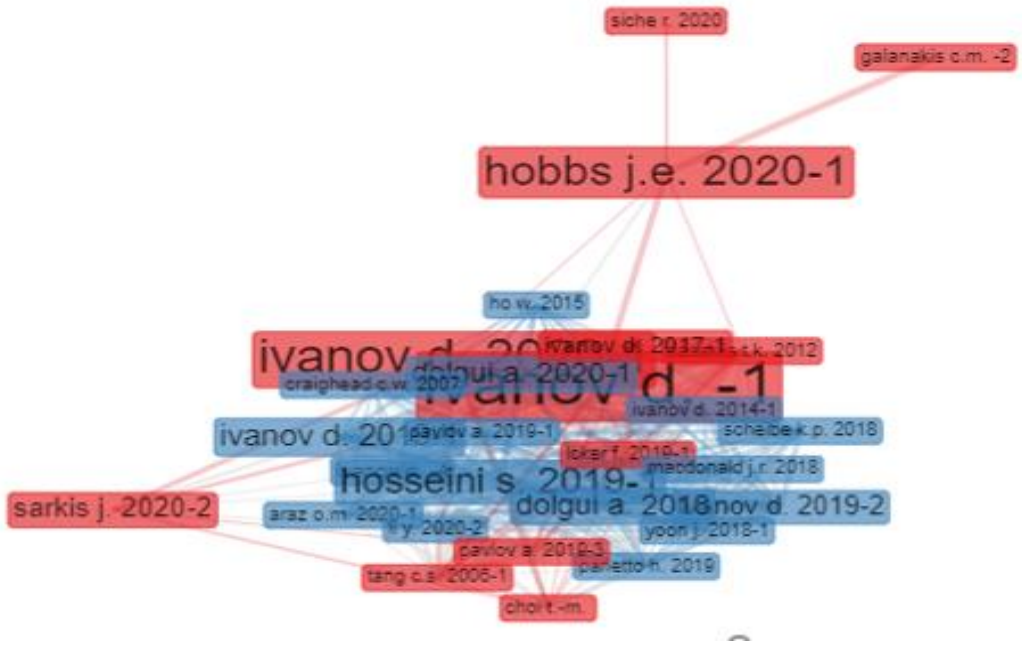


Figure 7. Co-citation Network Analysis of most cited papers

4.3. Bibliographical coupling network

In the bibliographical coupling network, two studies are supposed to be bibliographically coupled if both cite the same third study. A bibliographic coupling network offers an insightful way to analyze current trends and also provide any changes in an author's network over time (Radjiyev et al., 2015). We used R *bibliometrix* package to visualize the bibliographical-coupling network for the top 100 most productive authors and were analyzed according to the full-counting method to create a bibliographic-coupling network. The analysis generated a network of two clusters, and it is shown in Figure 8. While generating the network, we considered up to the top 100 bibliographically coupled co-authors, and the isolated nodes were removed to improve the clarity of the network diagram. The size of each node indicates the strength of the connection of the productive authors inside the cluster. This finding also indicates that those sets of references generate the highest degree of cohesion inside the cluster. This co-citation network reveals two primary clusters and is denoted by two distinct colors as follows:

Cluster 1 (Blue, Wang) is the largest with 35 authors, among them significant are: Wang, Zhang, and Chen. The papers included in this cluster are grounded in the scholarly works of Wang and is located at the top of the network (see Figure 8). In this cluster, the papers focus on disruption occurred in different domain of SCs. such as agricultural, SMEs, healthcare, and food.

Cluster 2 (Red, Ivanov) is the smallest one as compared to blue cluster in the bibliographical network. It is primarily connected with the following authors: Ivanov, Zhao, Choi, and Tang. Cluster 2 focuses on the impact of COVID-19 on SC resilience angles towards survivability, and viable SC model. Furthermore, studies in this cluster also address the issues of critical shortage for healthcare supplies such as PPE, ventilators, and sanitizers due to COVID-19 (Rowan NJ, 2020). A significant contribution from this cluster is the development of "viable supply chain model" to manage the SC disruption risk during this outbreak and generate resilience.

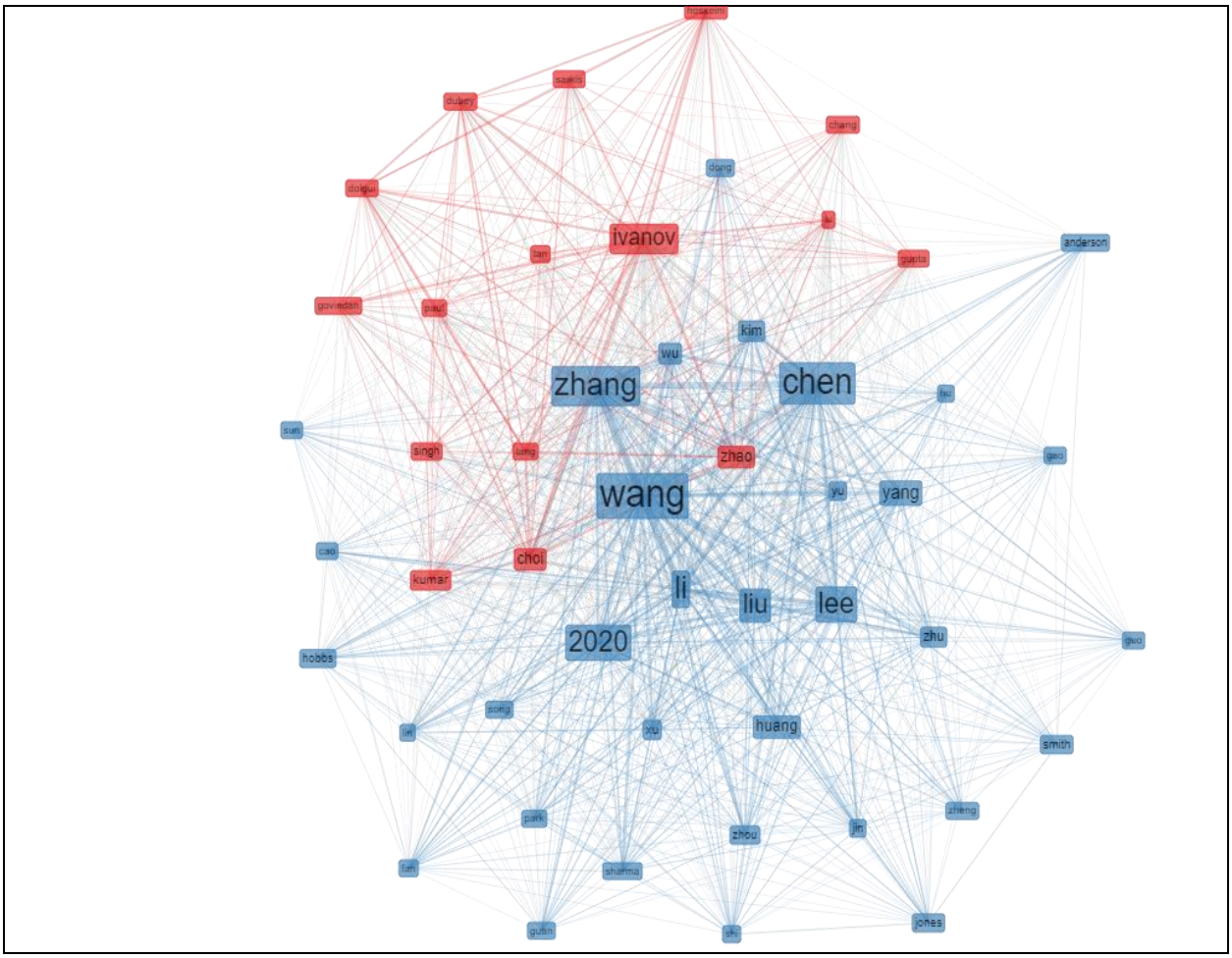


Figure 8. Bibliographical coupling network-based Authors

5. Discussion and current research trend

This study presented a systematic review of the literature on *COVID-19 in the area of supply chain management* through bibliometric and network analysis. As the second wave of COVID-19 outbreak arrives worldwide, this area of research is gaining more attention from researchers and practitioners. Therefore, there is a need for a study that presents the current state of the literature and provides future research directions on the impact of epidemics on the SCs. In this context, our study attempted to bridge this gap by identifying the current trends of publications, influential authors and their academic works, and emergent research clusters through bibliometric and network analysis. Following are the major and significant findings of our study:

- To summarize, 1873 different authors published an overall 484 papers. These publications received an average citation of 7.91 per paper.
- *Dmitry Ivanov* is the most productive and influential author in the area of *COVID-19 in the SC domain,* with a total of 9 publications and overall 330 citations.
- More than 80% of the studies were based on theoretical framework and modeling perspectives. The findings also reported a dearth of empirical research in this area, which could be improved using more extensive data sets.
- *USA*, *China*, and *Canada* are the leading countries that contribute to the maximum publications. Country-wise, the *USA* is at the top of the list with 38 publications.
- The University of Toronto in Canada is the leading academic institute in terms of publication count.
- *Sustainability (Switzerland)* is the most productive *proceeding* for research publications related to *COVID-19 in the area of SC.*
- The results from the keywords' co-occurrence network revealed that there are two primary clusters. Among them, the top three most co-cited keywords are *COVID-19*, *SCs*, and the *Coronavirus*.
- The results from the co-citation network revealed three major clusters with the top two most co-cited papers are *Ivanov D*, (2020a, b, c) and *Hobbs J.E* (2020).
- The results from the bibliographic-coupling network (author-based) revealed two clusters. *Wang* (Cluster 1), and *Dmitry Ivanov* (Cluster 2) are the top two bibliographically coupled authors across the entire network.

5.1 Current research trend

This study uses multiple correspondence analysis (MCA) on the author-keywords extracted from the 484 published papers and then plots them in two-dimensional space. In an MCA-based analysis, the keywords approaching the center indicate that they have received greater attention in recent time, whereas the keywords nearer to the edge indicate that the theme of study has diminished over time or transitioned to other themes. Figure 9 presents the MCA analysis for the associated papers published between 1995 and 2020, with the concepts separated into two dimensions. The first dimension accounted for the majority - 67.37% of the variations, and the second dimension accounted for 8.76% of the variations. Additionally, the MCA plot reveals three major conceptual clusters, - two large clusters: one being RED and the other being GREEN, followed by a small BLUE cluster. The RED cluster is built around the centroid and comprised of the following keywords – *environmental impact*, *food security*, *viral disease*, *Europe*, and *India*. The BLUE cluster is built around the centroid and comprised of the following keywords – *supply chains, artificial intelligence, supply chain disruptions, global supply chains,* and *manufacturing*. The GREEN cluster is built around the centroid and comprised of the following keywords – *coronavirus infection, beta Coronavirus, humans, pandemics, viral, pneumonia, organization, and management*. If some keywords are closer among themselves than others are, it indicates that those keywords have more published papers in common than other distant keywords. For instance, in the GREEN cluster, the keywords *pandemics*, *pneumonia*, *viral*, *Coronavirus*, *infections,* and *humans* are closely placed on the MCA plot, indicating that they have many papers in common than from the keyword's *personal protective equipment* and *quality control*. Table 7 provides the complete information about the current studies and their recommendations.

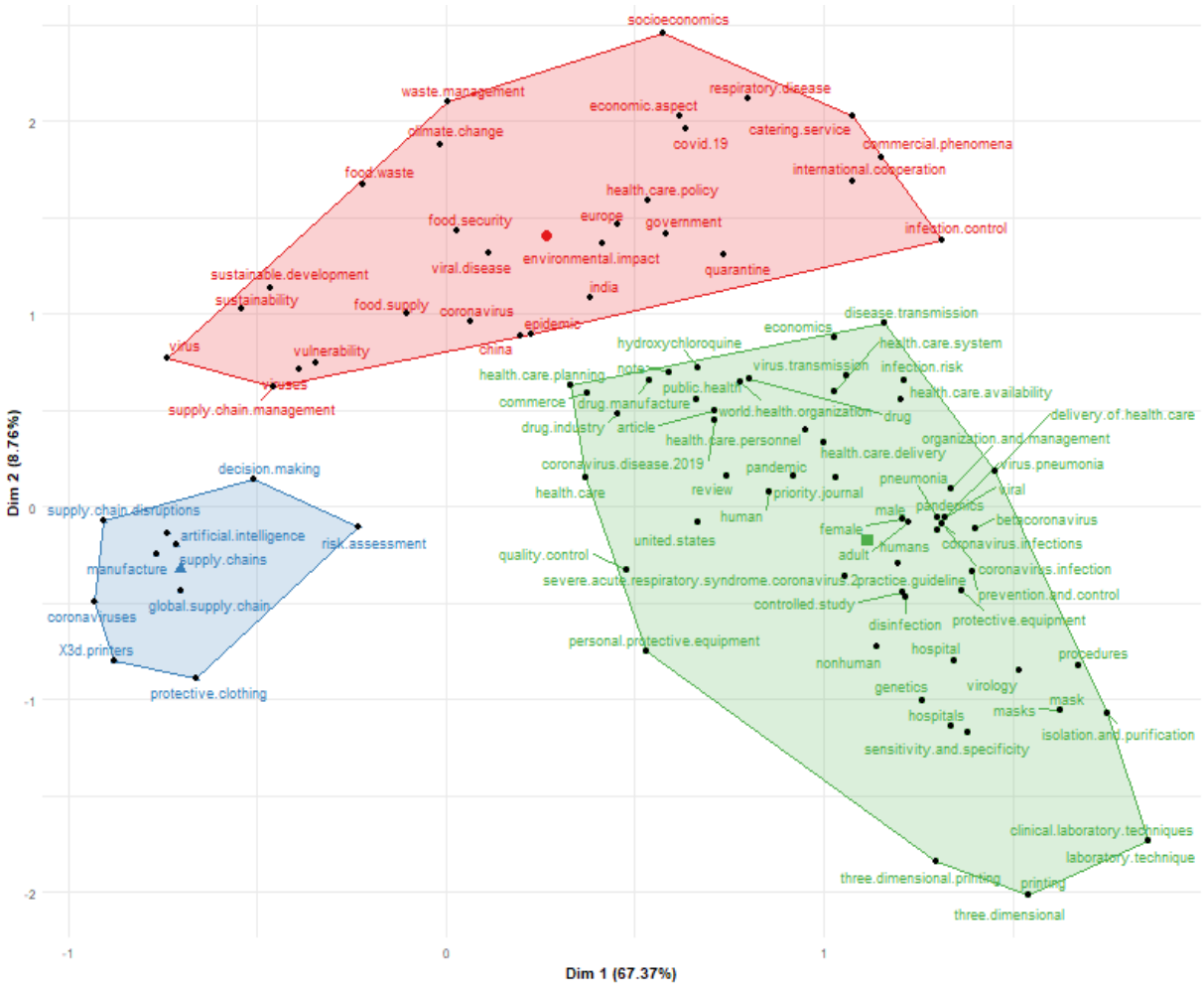


Figure 9: Generation of conceptual structure map using MCA technique

Table 7 Studies investigating the impact of COVID-19 in SCs area and their recommendations

S.No	Author	Aspect	Title of the Study	Key findings	Key recommendations
1	Aigbedo, (2021)	Hospitality	Impact of COVID-19 on the hospitality industry: A supply chain resilience perspective	• Impact on accommodation • Impact on food services	Resilience mechanisms for navigating the COVID-19 pandemic • Government mandated • Supplier's action • Competitor action
2	Wang and Wang, (2020)	Agricultural	Evaluation of impact of COVID-19 outbreak on agricultural supply chain	• Impact on price and consumption. • Delay in import shipment.	Models analyze and project the impact of COVID-19 over a five year period.
3	Rizou *et al.*, (2020)	Food	Encapsulates the potential ways of COVID-19 transmission in food SCs	• Urgent need for detection tools during COVID-19 for ensuring food safety and prevent disruption in food SCs	Development of analytical protocols for the safety of food SCs as well as environmental
4	Sharma *et al.*, (2020)	General	COVID-19's impact on supply chain decisions: Strategic insights from NASDAQ 100 from using Twitter data	Challenges faced by firms • Demand-supply mismatch • Technology • Development of a resilient supply chain	• Demand for evaluation of Sourcing strategies in real-time. • Need to assess the vulnerabilities across the supply chain .
5	Luckstead *et al.*, (2020)	Food	Impacts of COVID-19 on supply chain labor engaged in essential jobs	• Need for shifting views on labor security	Develop the strategies and method to prevent workers from the risk of infection.
6	Mahajan and Tomar, (2020)	Food	Examine the impact of COVID-19 outbreak on perishable and nonperishable food by employing event study framework	• Perishable food supply chains for long distance have been badly hit during COVID-19	Technology enabled warehousing can create resilience against such supply disruptions

7	Hobbs, (2020)	Food	Assess the implications of COVID-19 outbreak for food supply chains.	• Labor shortage is considered as potential cause for supplier -side disruption in Canadian agricultural SC.	Measures are required to mitigate panic buying and stockpiling behavior by customer
8	Aday and Aday (2020)	Food	Summarize the impact of COVID-19 outbreak on food supply chain and also provide the steps to minimize these effects	• Border closer for workers and trading, change in demand of customers, Shutdown in production facilities, restricted trade policies are keys impact on food SCs.	Digital and advanced warehouse can reduce the loss of foods in the food SCs
9	Govindan *et al.*, (2020)	Healthcare	Design of novel DSS in order to assist the demand management in the healthcare SCs	• Efficiency and accuracy of proposed DDS is confirmed and checked by taking real time data	Need for development and design of accurate DSS
10	Leite *et al.*, (2020)	Healthcare	Evaluate the impact of COVID-19 outbreak on healthcare systems demand, capacity, and resources	• Focuses on "flattening the curve of infection" to protect the healthcare SC practices from disruption	Need for assessment and evaluation of current impact of COVID-19 and rework on contingency plan accordingly in healthcare SCs
12	Sharma *et al.*, (2020)	Sustainable	Development of framework for improving survivability of SSC to endure during and after COVID-19 outbreak	• SC network Viability is considered as most essential criteria to develop SSC in COVID-19 outbreak.	There is a demand to redesign the business strategies to curb the supply chain disruption
13	Karmaker *et al.*, (2020)	Sustainable	Examination of drivers of SSC to deal with supply chain disruptions during pandemic in emerging economies.	• There is an urgent need of financial support from the government as well as from the SC partners to combat the impact on SCS due to COVID-19.	The organization should focus on integration and collaboration with stakeholders that would be important to rebuild market foundations
SSC-Sustainable supply chain; IoT-Internet of Thing; BT-Blockchain Technology; BDA-Big data analytics; DT-Digital twins; DSS-Decision support system					

5.2. Future research directions

To examine the future trends in the area of SCs under the context of COVID-19 outbreak, we adopted a novel yet robust methodology based on information retrieval (Manning et al., 2008); text mining (Biswas et al., 2020), followed by topic-analysis (Blei et al., 2003).

Step1: We extracted the section's textual contents, such as "Future Research Directions," "Future Scope," from the 484 articles to create text files from them.

Step2: We applied text mining after data pre-processing and indexing to create the document-term matrix consisting of the top keywords based on these 484 articles and presented in Figure. 10.

Step3: We applied topic-analysis with the Latent Dirichlet Association (LDA) to extract the topics embedded in the "Future Research Directions" of these 484 articles. Our analysis reveals the five topics on "Future Research Directions" and their associated keywords which are given below and presented in figure 10:

a) Topic 1: "resilience" (shoring, covid, impact, resilience, improving, challenges)
b) Topic 2: "supply chain disruption" (term, covid, supplies, manufacturing, impact, essential)
c) Topic 3: "resilience" (resilience, implementation, outbreak, covid, strategies, challenges)
d) Topic 4: "sustainable supply chain" (covid, sustainable, practices, impact, outbreak, analyze)
e) Topic 5: "technology" (outbreak, covid, waste, transportation, delivery, drone)

After critical examination of literature, this study uncovers several research directions on SC domain under pandemic situation. Many studies have been published since the COVID-19 started but still there is scarce of empirical studies and conceptualized research. This study provides some future research directions that need to be explored. Table 8. suggested some future research directions in different domain of SC.

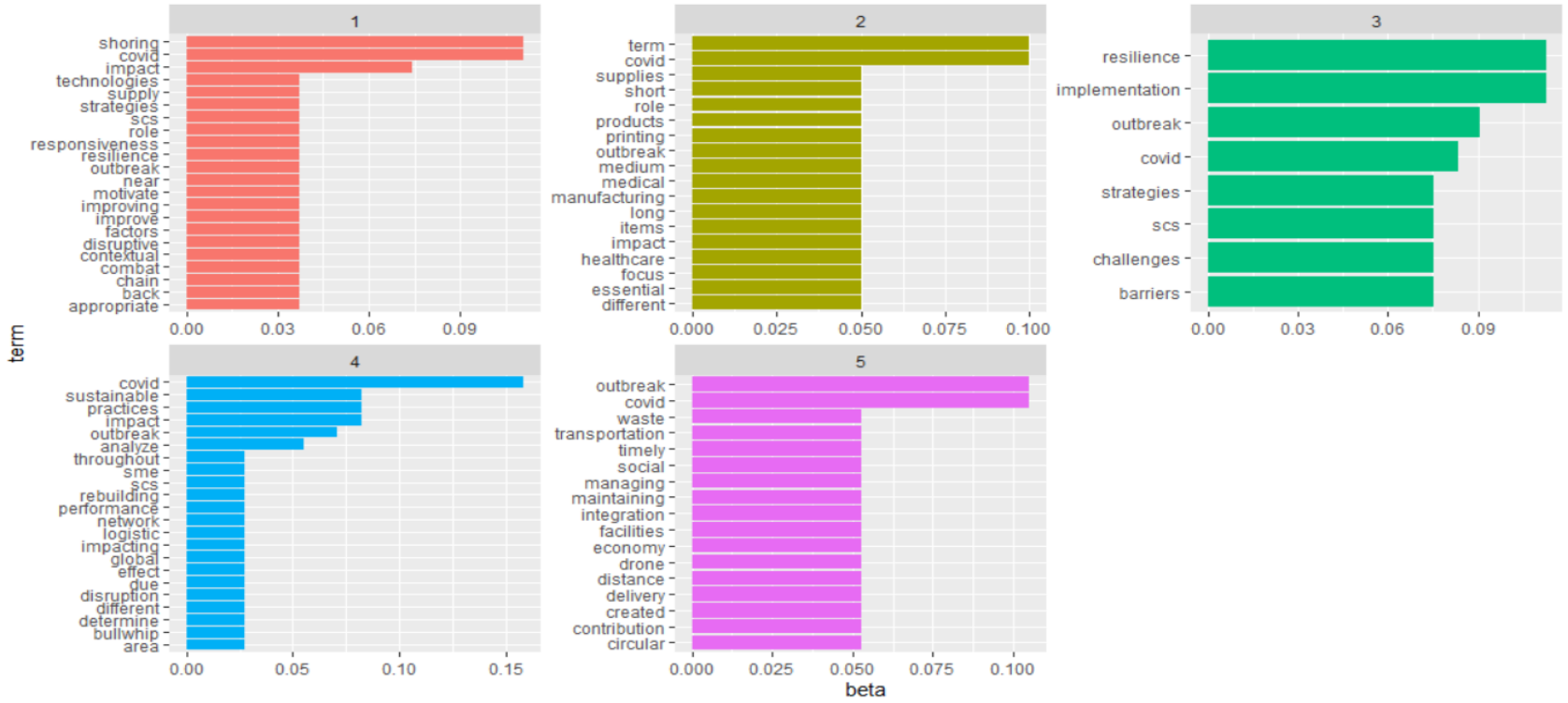


Figure 10 - Top five embedded topics and associated keywords (with association probabilities "beta") extracted from the "Future Scope and Conclusions" of the selected articles on "Impact of COVID-19 on SCs"

Table 8. Summary of suggested research direction

Dimension	Suggested research direction
Supply chain disruption	i. Contextual factors motivate the impact of COVID-19 on SCs. ii. Determine the impact of COVID-19 on SME SC. iii. Analyze the disruption area throughout SC. iv. Focus on short term, medium- and long-term impact of COVID-19 on different SC. v. Analyze the bullwhip effect in the SC due to COVID-19.
Sustainable supply chain	i. Impact of COVID-19 on sustainable practices in different SCs. ii. Impact of sustainable practices on SC performance during COVID-19 outbreak. iii. Role of sustainable practices on SC for enhancing resilience during COVID-19 outbreak. iv. Contribution of circular economy for managing waste created during COVID-19 outbreak.
Technology	i. Role of disruptive technologies to combat the impact of COVID-19 on SCs and improve its responsiveness. ii. Role of 3-D printing in manufacturing of essential items, medical supplies, healthcare products during COVID-19 outbreak. iii. Integration of drone facilities in transportation for timely delivery with maintaining social distance during COVID-19 outbreak. iv. Barriers/challenges in the implementation of emergent technologies in SCs during COVID-19 outbreak.
Resilience	i. Appropriate strategies (such as near shoring, back shoring and re-shoring) for improving resilience during COVID-19 outbreak. ii. Barriers/challenges in the implementation of resilience strategies in SCs during COVID-19 outbreak. iii. Rebuilding of logistic and SC network impacting global SC during COVID-19 outbreak. iv. Role of stakeholders in the implementation of resilience strategies during global SC disruption in pandemic.

6. Conclusion and Implications

COVID-19 pandemic can extremely wreak havoc the SCs around the world. This review addressed a systematic analysis of the impact of COVID-19 outbreak on SCs. There have been many research articles which focus on the impact of COVID-19 in SC domain. Although some literature reviews on the impact of COVID-19 in SC domain have been published but none of the studies focused on bibliometric and network analysis. As per our knowledge, this is first study which presents a consolidation of academic research on impact of COVID-19 on SCs using quantitative techniques such as bibliometric and network analysis to identify and analyze the current literature since 2020 and provides potential research avenues for the researchers and practitioners. We firmly believe

that research scholars and professionals in this domain will apply the findings from our study and plan their future research.

Managerial implications of this study are threefold: First, this study provides the understanding of the simultaneous deployment of the ripple effects and epidemic outbreaks on SCs. Second, SCs' managers must operate their business with newer and more resilient ways across the world. Third, global SCs firms should focus on reducing of risks caused by pandemic with the help of centralized risk management system. Moreover, this study digs out some future research questions from literature and urges to the practitioners and researchers from SC management area to investigate the impact of COVID-19 pandemic on SCs in future. The followings are the future research questions:

What are the worst and most severe disruption effects on SCs that lead to a ripple effect amplification?

How can the global SCs prepare and maintain a flexible humanitarian operation response plan to a pandemic crisis anywhere in the world?

How can disruptive technologies contribute to develop responsive SC models in epidemics scenarios (Such as, drone for supply network, blockchain for responsive traceability, and 3D printing for manufacturing essential supplies)?

Like the other studies, this study is not exempt from limitations. First, the citation database was restricted to Scopus. Although Scopus is one of the largest abstracts and citation databases of peer-reviewed publications, scholars can consider other indexing databases such as Web of Science and Google Scholar as potential future extensions of this study. Second, a structured network analysis may not always indicate a significance analysis of the correlated publications. Therefore, a modified bibliometric tool can be designed to include the relative importance of the papers while analyzing an academic collaboration network.

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