Operations Management Research

Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research

--Manuscript Draft--

Manuscript Number:	OMRA-D-21-00222R1
Full Title:	Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research
Article Type:	Original Research
Keywords:	Artificial intelligence; supply chain; resiliency; STM; project management; COVID-19; text mining; Big data analytics
Corresponding Author:	Rohit Agarwal Indian Institute of Technology Delhi Delhi, INDIA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Indian Institute of Technology Delhi
Corresponding Author's Secondary Institution:	
First Author:	Farheen Naz
First Author Secondary Information:	
Order of Authors:	Farheen Naz
	Anil Kumar
	Abhijit Majumdar
	Rohit Agarwal
Order of Authors Secondary Information:	
Funding Information:	

Title Page w/ ALL Author Contact Info.

Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research

Farheen Naz
Institute of Economics,
Hungarian University of Agriculture and life sciences, Godollo, Hungary.
farheen.naz@phd.uni-szie.hu

Anil Kumar
Guildhall School of Business and Law,
London Metropolitan University, London, UK
A.Kumar@londonmet.ac.uk

Abhijit Majumdar
Department of Textile and Fibre Engineering
Indian Institute of Technology Delhi, New Delhi 110016, India
majumdar@textile.iitd.ac.in

Rohit Agrawal*
Department of Textile and Fibre Engineering
Indian Institute of Technology Delhi, New Delhi 110016, India
mailerrohit@gmail.com

***Corresponding author**

Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research

Abstract

The challenging situations and disruptions that occurred due to the outbreak of the COVID-19 pandemic have created a severe need for supply chain resiliency (SCR). There has been a growing interest among researchers to investigate the resiliency in supply chain operations to overcome risks and disruptions and to achieve successful project management. The supply chain of every business requires innovative projects to accomplish competitive advantage in the market. This study was conducted to identify the significance of artificial intelligence (AI) for creating a sustainable and resilient supply chain, and also to provide optimum solutions for supply chain risk mitigation. A systematic literature review has been conducted to examine the potential research contribution or directions in the field of AI and SCR. In total, 162 articles were shortlisted from the SCOPUS database in the chosen field of research. Structural Topic Modeling (STM), a big data-based approach, was employed to generate several thematic topics of AI in SCR based on the shortlisted articles, and all topics were discussed. Furthermore, the bibliometric analysis was conducted using R-package to investigate the research trends in the area of AI in SCR. Based on the conducted review of literature, a research framework was proposed for AI in SCR that will facilitate researchers and practitioners to improve technological development in supply chain firms. The purpose is to combat sudden risks and disruptions so that project management will perform well Post COVID-19. The study will be also helpful for future researchers and practitioners to identify research directions based on existing literature covered in this paper in the field of SCR. Future research directions are proposed for AI-enabled resilient supply chain management. This study will also provide several implications for supply chain managers to achieve the required resilience in their supply chains post COVID-19 by focusing on the elements of the proposed research framework.

Keywords: Artificial intelligence; supply chain; resiliency; STM; project management; COVID-19; text mining; Big data analytics.

1. Introduction

The coronavirus (COVID-19) outbreak has not only brought global tragedy to human lives, but has also affected business and economic activities, for instance, manufacturing processes, logistics and supply chains, hospitality, and many other (Golan et al., 2020). COVID-19 has challenged scholars and practitioners for the smooth flow of process, as this pandemic became one of the most severe supply chain disruptions in history (Spieske and Birkel, 2021). These disruptions, either human-caused or natural, are an integral part of all supply chains globally, irrespective of the nature of goods or services provided or the niche market in which these supply chains operate (Golan et al., 2020). Most companies all over the world face tremendous challenges at every stage of their supply chains. Delivery obligations that are not met by suppliers, unpredictable customer demands, and panic buying are some of the challenges faced by the companies (Ivanov, 2020b). These risks and disruptions created the need to improve the resilience of supply chains to face such types of sudden risks and disruptions. In addition, the change in the market environment is forcing businesses to frequently update their processes and products (Haus-Reve et al., 2019). To achieve effective leadership in the market, managing and launching innovation projects become crucial, which make supply chain management (SCM) further complicated (Kwak et al., 2018). Also, digital transformation leads to several technological developments in the supply chain (Kwak et al., 2018), and for this reason, project management becomes vital for SCM (Gaudenzi and Christoper, 2016). Likewise, Shishodia et al. (2019) in their study emphasized a project-driven supply chain which is a combination of both project management and supply chain and requires coordination among on-site project activities and off-site supply chain processes.

Furthermore, some negative consequences lead to low company performance, which involve delays in deliveries, share losses in sales and market, and decrease in service level and consumer satisfaction, all of which directly affect the image of the company (Kara et al., 2020; Spieske and Birkel, 2021). These severe negative and unpredictable impacts forces supply chain resilience (SCR) to be the focus of the companies and scholars (Reeves and Whitaker, 2020). To improve the SCR, companies should expand analytical capabilities by efficiently applying the resident company knowledge, thus improving the existing information capabilities of the organization (Wong et al., 2020). As far as artificial intelligence (AI) enabled technology is concerned, prior studies have proven that algorithms offer solutions by promoting innovations to improve supply chain performance (SCP) (Baryannis et al., 2019a; Nayal et al., 2021). According to Ivanov et al., (2019), emerging technologies like industry 4.0, AI, product

tracking advanced applications, and additive manufacturing have considerable potential for supply chain risk analytics, thus strengthening SCR and managing projects. Integration of advanced technologies makes the supply chain resemble large-scale projects to coordinate and manage several activities, that enables smooth project management (Gaudenzi and Christoper, 2016). Wei et al. (2021) clarified that the increasing complexity of project management and SCM inclusion in it makes it critical for project managers to manage and coordinate requirements by adopting the best approach. For instance, it is advantageous in the ship building industry to integrate project management information systems along with SCM, where time-phased requirements are managed by project management and supply chain issues are tackled by SCM (Braglia and Frosolini, 2014).

As far as SCR is concerned, its main objective is to quickly regain from supply chain disruptions and to improve the original performance of the supply chain (Ponomarov and Holcomb, 2009). The impact of any disruption intensifies as supply chains have become more complex in a global context (Kwak et al., 2018). Thunberg et al (2017) stated that project management processes and supply chain are interlinked and often affect each other. In this regard, supply chain performance could be enhanced through adaptation capabilities and information processing offered by AI techniques (Belhadi et al., 2021a). Similarly, for successful projects, AI was applied in several sectors to improve flexibility, communication, and reducing unnecessary fluctuations (Lalmi et al., 2021). In recent years, AI applications have developed due to the growing computing power availability, growth in machine learning approaches, and big data analytics. This has led supply chain researchers to consider the potential of AI techniques in terms of risk identification, assessment, prediction, and response (Baryannis et al., 2019b). To overcome the impact of risks and disruptions, Katsaliaki et al., (2021) suggested that it is necessary to build resilience by integrating three aspects, i.e., long-term partnerships, IT applications to enhance business, and government policies that facilitate flexibility.

Furthermore, the COVID-19 outbreak has attracted a lot of attention from scholars to build SCR (Kumar and Managi, 2020) and project management agility (Bushuyev et al., 2020). Creating agility in large-scale projects through adaptation of various strategies will develop SCR, if the project processes are managed at an early stage (Thunberg et al., 2017). Also, the short-term direct impact of AI on SCR has been noticed, and it is proposed to utilize its capability of processing information to build SCR, thereby improving long-term SCR (Belhadi et al., 2021a). This can be done by deploying emerging technologies in the entire supply chain

network (Ivanov et al., 2019) and managing projects thereby. For this purpose, the current study was conducted to analyse the significance of AI in SCR post COVID-19. The disruptions caused by the COVID-19 pandemic in the entire supply chain and project management created a need for a robust literature review in the related field to analyse the existing problems and solutions. The studies involved in this paper were conducted before and during the COVID-19 pandemic, hence it provides relevant evidence of AI in SCR. It is crucial to better understand the relevance and practical implication of existing AI-based models to solve issues concerning SCR that exists during or post COVID-19 disruptions. To the best of the authors' knowledge, this study is the first attempt to show the role of AI in SCR during or post COVID-19 pandemic. For this, a systematic review was presented by collecting articles in the field of AI and SCR. To gather papers, the SCOPUS database was used by using relevant keywords in AI and SCR. 162 articles were chosen to perform the systematic review. First, the structural topic modeling (STM) based text mining approach was used to produce thematic topics. Secondly, based on the generated thematic topics, the shortlisted articles were reviewed. Then, the bibliometric study was performed to examine the research trends in the fields of AI and SCR. Finally, a conceptual framework was suggested which incorporates AI and SCR practices. The following research questions are formed to answer in this study:

RQ1. What are the AI techniques that could help make a resilient supply chain?
RQ2. What are the current research trends associated with AI in SCR?
RQ3. What are the potential future research directions in AI in SCR?

This study starts with a systematic literature review to answer the above questions. To generate the topics, an STM-based text mining technique was employed. Various aspects of AI and SCR were explored and several AI techniques were investigated to adopt for SCR and risk mitigation. To analyse the research trends, a bibliometric analysis was carried out. Further, a conceptual framework was proposed to provide utilization of AI techniques in the SCR post-COVID-19.

The remaining sections of this article are as follows: Section 2 shows the systematic literature review methodology, Section 3 shows the bibliometric analysis, Section 4 shows the STM approach, whereas the review of articles based on generated topics were presented in section 5. Discussion and implications were presented in Section 6, while Section 7 shows conclusions of the study.

2. Systematic Literature Review

A systematic review literature methodology was used in this paper to gain comprehensive insights concerning previously conducted studies on SCR and AI. The SLR methodology adopts a replicable, scientific, and transparent procedure that differs from traditional narrative reviews (Tranfield et al., 2003). The current study followed the SLR methodology as conducted by Agrawal et al. (2021). For this purpose, the published articles from the SCOPUS database were collected, as it is among the largest databases which consist of a large number of peer-reviewed articles. Through the SCOPUS database, an SLR was presented by defining keywords and searching articles about selected keywords (Vinodh et al., 2020). The study's SLR is based on the four-stages review approach as depicted in Figure 1. Moreover, several researchers were involved in this study to prevent individual biases (Tranfield et al., 2003).

In the first stage of this four-stages methodology, retrieval of articles was done based on searching of articles on SCR and AI. The shortlisted keywords were used to collect the articles from the SCOPUS database.

The next stage involved the bibliometric study of the collected articles. For this purpose, the R package and VOSviewer were used. After that, the research fields were analysed concerning the investigating area, which is done by using STM. The STM approach was performed using the R package to generate ten emerging research fields in SCR and AI. In the third stage, the identified evolving research themes were discussed, and future direction propositions were stated. Finally, in the last stage, a future research framework was proposed, and a conclusion was made based on the results generated.

3. Bibliometric Study

In recent years, bibliometric analysis has gained massive popularity in the research field of business and management (Donthu et al., 2021). The bibliometric methods are used to provide quantitative analysis of written papers or publications (Ellegaard and Wallin, 2015). The analysis is conducted based on the identification of the amount of literature concerning an investigating area. Various statistical tools are used rapidly to perform bibliometric analysis, for instance, R package, Pajek, Histcite, Bibexel, and Gephi (Agrawal et al., 2021).

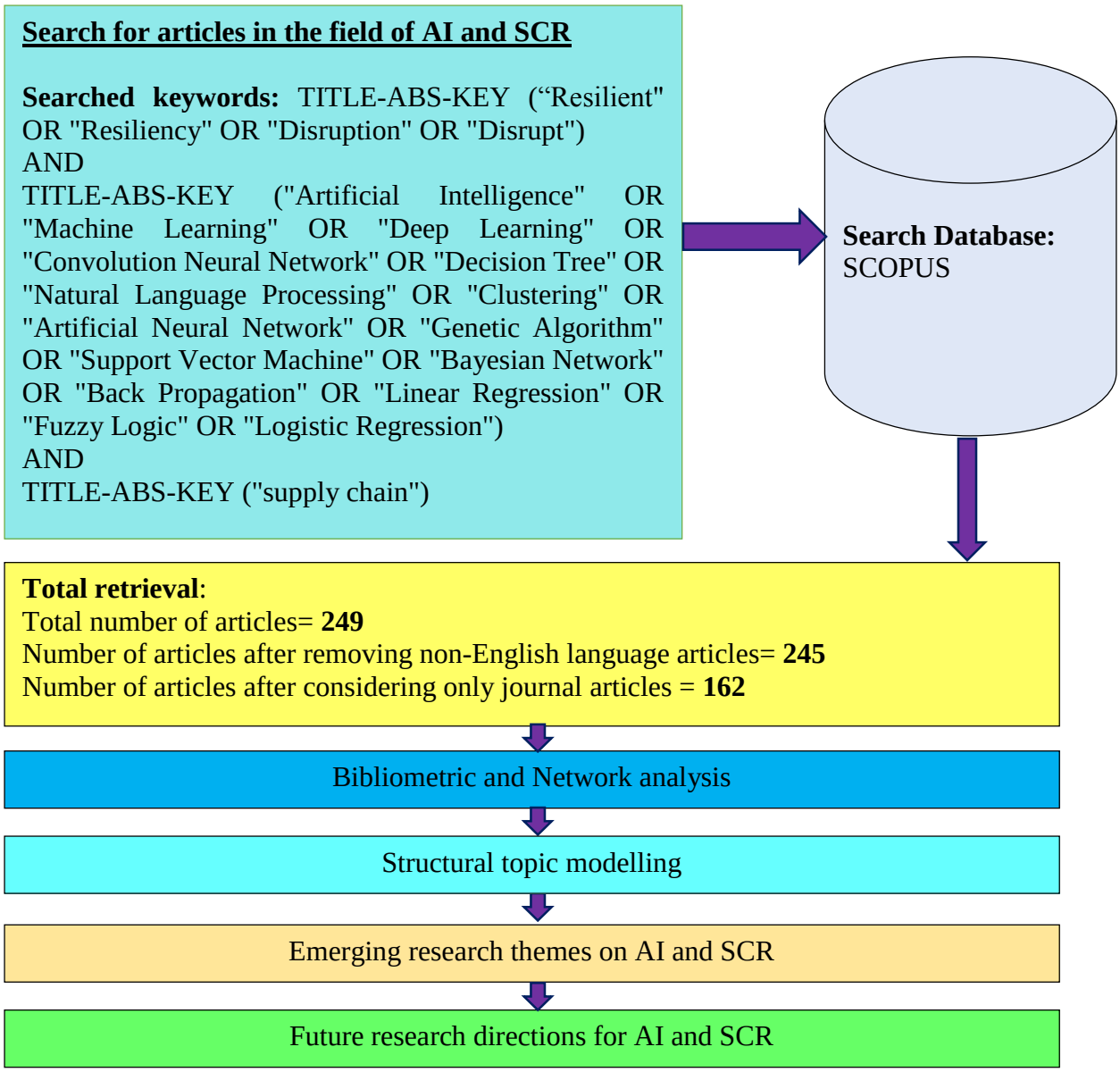


Figure 1. SLR flowchart

In business research, the popularity of bibliometric analysis is due to the manifestation of its efficiency to handle large quantity of scientific data and creating high research impact (Donthu et al., 2021). To perform the bibliometric analysis, R package was used. . A web interface of the R package named biblioshiny was employed, allowing users to conduct relevant bibliometric and visual analyses. Biblioshiny is an interactive web interface that greatly reduces the information input intensity of users and usage threshold as well (Xie et al., 2020). Table 1 presented the main information of the shortlisted articles about SCR and AI.

Table 1. Main information collected about AI and SCR articles

Description	Results
Main Information About Data	
Timespan	2005:2021
Sources (Journals, Books, etc)	107
Documents	162
Average years from publication	3.51
Average citations per documents	20.27
Average citations per year per doc	4.243
References	9078
Document Types	
Article	152
Review	10
Document Contents	
Keywords Plus (ID)	1046
Author's Keywords (DE)	557
Authors	
Authors	464
Author Appearances	522
Authors of single-authored documents	10
Authors of multi-authored documents	454
Authors Collaboration	
Single-authored documents	11
Documents per Author	0.349
Authors per Document	2.86
Co-Authors per Documents	3.22
Collaboration Index	3.01

The year-wise publications of the articles in SCR and AI are indicated in Figure 2. An increasing trend starting from 2005 can be seen in this field of research. However, a rapid increase in this trend was witnessed since 2018, whereas in 2019 there was an 81% increase in publications in comparison to 2018.

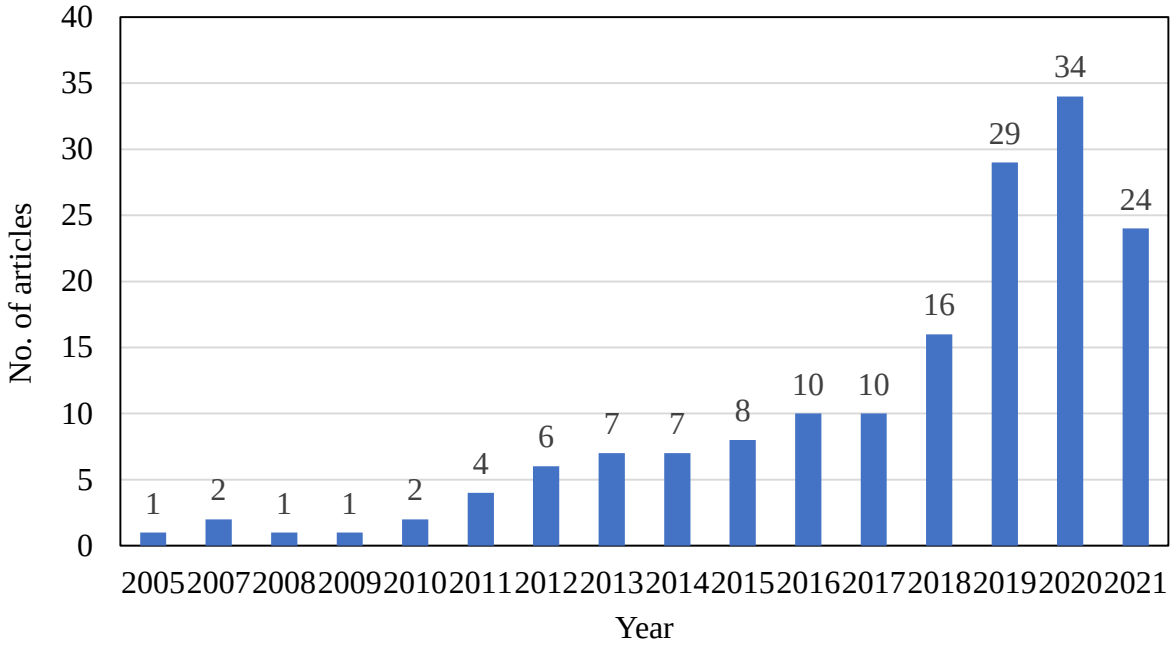


Figure 2. Year-wise publication of articles in the field of AI in SCR.

Figure 3 demonstrates the country-wise number of articles published in SCR and AI. It is apparent from Figure 3 that the United States is the leading country in terms of publications in this field. Iran and China are in the second and third positions, respectively with significant contributions in the field of SCR and AI.

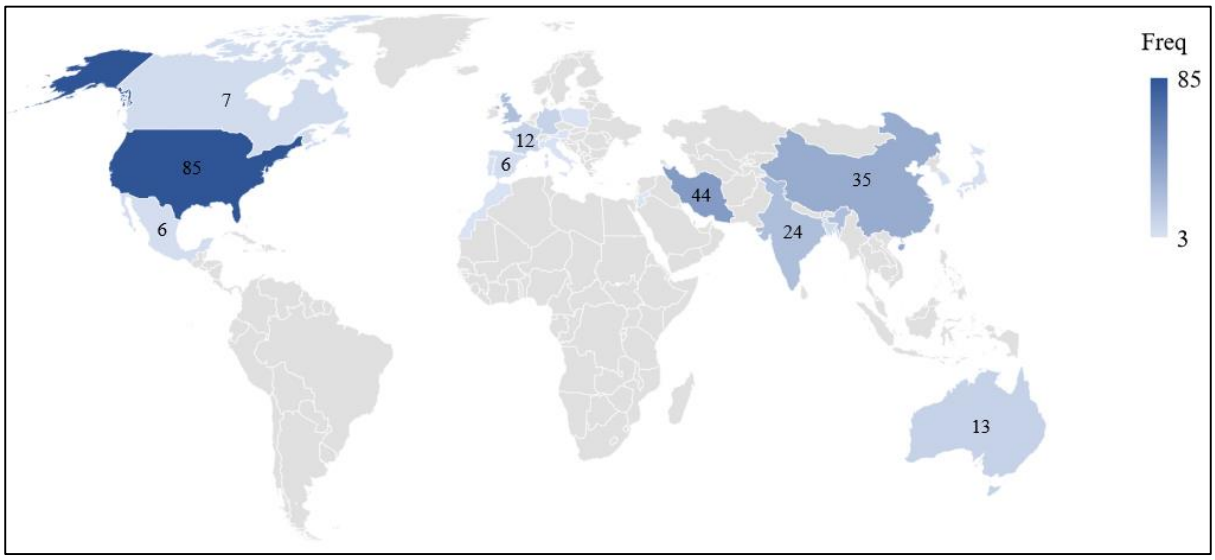


Figure 3. Country-wise number of articles published in AI and SCR

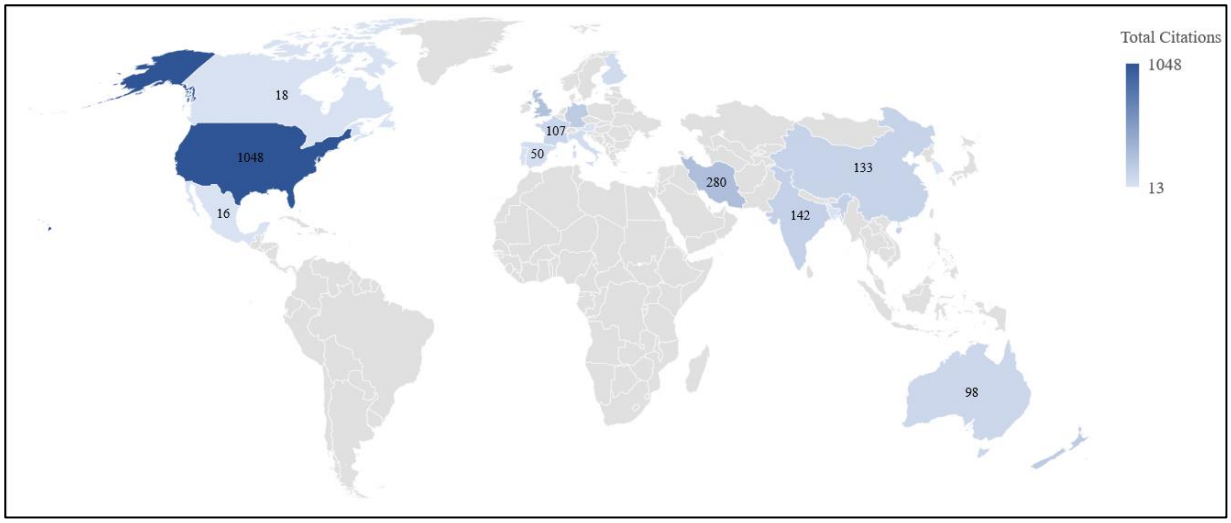


Figure 4. Country-wise citations in the field of AI and SCR

From Figure 4, it is found that the United States is the leading country in terms of citations received in the field of AI and SCR. It is followed by Iran and UK..

Table 2 shows the top leading journals in the AI and SCR field.

Table 2. Important journal publishing articles in the field of AI in SCR

Journals	**Articles**
International Journal of Production Research	16
Computers and Industrial Engineering	8
International Journal of Production Economics	5
Annals of Operations Research	4
European Journal of Operational Research	4
IEEE Transactions on Engineering Management	4
Supply Chain Management	4
Expert Systems with Applications	3
Mathematical Problems in Engineering	3
International Journal of Information Management	2

Table 2 depicts that the International Journal of Production Research is the leading journal to publish the most number of articles (*n*=16) in the field of AI and SCR. However, the other journals are Computers and Industrial Engineering and the International Journal of Production Economics with a significant number of published articles in this field.

As far as the contribution of the authors in this research field is concerned, Table 3 presented the top ten influential authors with a maximum number of published articles in this area. Ivanov D and Hosseini S are two leading authors to contribute to this field of research with 7 and 6 published articles, respectively.

Table 3. Important authors publishing articles in the field of AI in SCR

Authors	Articles
Ivanov D	7
Hosseini S	6
Azeem A	4
Aghaie A	3
Blackhurst J	3
Tiwari MK	3
Ali SM	2
Amer Y	2
Antoniou G	2
Azad N	2

Table 4 represents the top ten organizations contributing to the research field of SCR and AI. Among these organizations, Islamic Azad University, Iran is the leading organization to publish 11 articles in this area. This is followed by the Berlin School of Economics and law, Iran University of Science and Technology, and the University of Southern Mississippi with 6 published articles, each.

Table 4. Important organization publishing articles in the field of AI in SCR

Affiliations	Articles
Islamic Azad University	11
Berlin School of Economics and Law	6
Iran University of Science and Technology	6
University of Southern Mississippi	6
Indian Institute of Technology	5
North Carolina State University	5
Bangladesh University of Engineering and Technology	4
University of Huddersfield	4
University of Technology Sydney	4
Cracow University of Technology	3

In Table 5, the occurrence of top keywords in the field of SCR and AI are shown. It shows that the keyword 'supply chains' occurred 80 times in the search for the articles concerning the studied area. It is followed by 'supply chain management' and 'decision making' that occurred 42 and 33 times, respectively. Table 5 shows 20 such keywords and their occurrences in the field of AI and SCR. Figure 5 depicts the 'word cloud' of the keywords present in the abstracts of the articles and highlights the most common words available in the database. Consequently, the size of the word represents the occurrence of the keyword in selected articles. As depicted in Figure 5 that the keywords of this study are supply chains, SCM, and AI, which are at the center of the map. These keywords occurred multiple times in the selected articles and were constant throughout the research.

Table 5. Top keywords in the field of AI in SCR

Words	Occurrences	Words	Occurrences
Supply Chains	80	Optimization	13
Supply Chain Management	42	Supply-Chain Disruptions	13
Decision Making	33	Uncertainty Analysis	13
Risk Management	25	Stochastic Systems	11
Artificial Intelligence	24	Costs	10
Genetic Algorithms	24	Economic and Social Effects	10
Risk Assessment	24	Supplier Selection	10
Bayesian Networks	23	Supply Chain Network	10
Decision Support Systems	17	Forecasting	9
Manufacture	13	Integer Programming	9

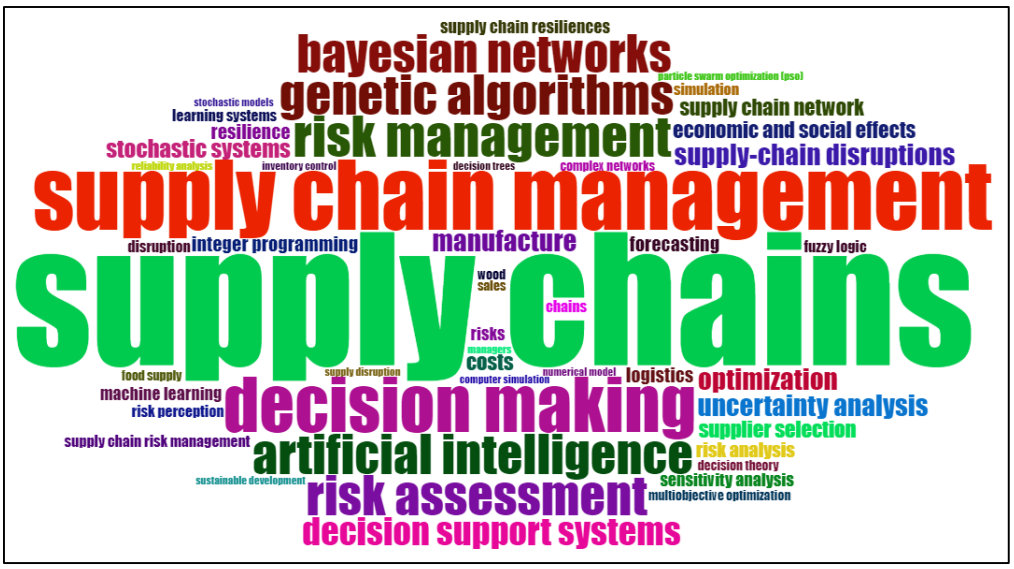


Figure 5. Word Cloud for AI and SCR research work

Network analysis was carried out to understand how countries and authors have collaborated based on co-authorship. For this purpose, the VOS viewer package was used to examine the collaboration network among countries as well as among authors. A total of 162 articles were considered in this study and there are 464 authors in the considered articles. We made a cluster by considering all authors. Figure 6 shows the authors collaboration network in the field of AI and SCR. From the authors' collaboration network, we can see that 6 clusters were formed which includes 27 authors while other authors are removed due to low connectivity of them with other authors. The figure shows six different networks where the size of the nodes depicts the number of collected publications, whereas the colour of the nodes represents the cluster in which these publications belong. The developed network has six clusters with 52 links and 56 total link strengths. The red cluster is the largest cluster with seven authors, whereas the green, blue, and yellow clusters have five authors each. The sixth cluster is the smallest one which includes only three authors. The author collaboration network also shows that the author Ivanov D has the maximum connection with other authors with a total of 12 links and the total link strength is 15.

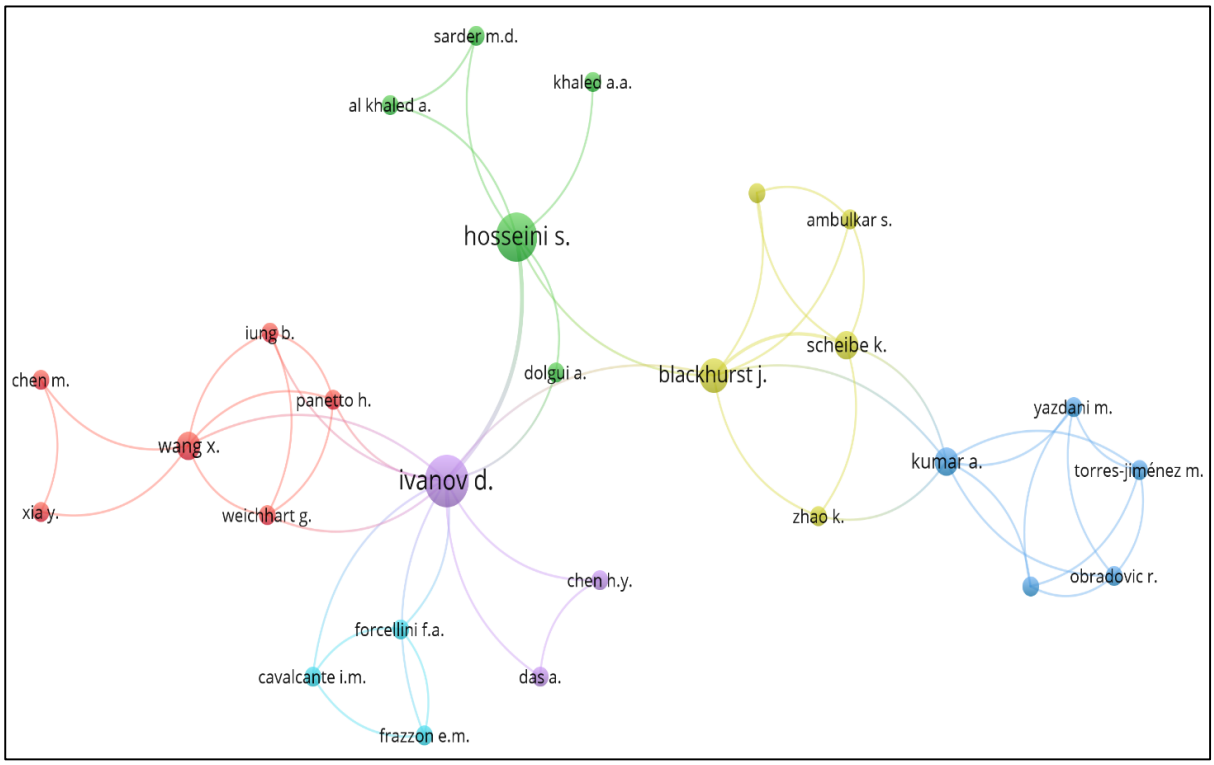


Figure 6. Author collaboration for AI and SCR research work

The country-wise collaboration network is presented in Figure 7. It shows the collaboration of different countries with each other to conduct research related to SCR and AI. A total of 55

countries is involved in the publication of the 162 articles. We made a cluster by considering all countries. From the country collaboration network, we can see that eight clusters were formed which include 33 countries while other countries are removed due to low connectivity of them with other countries. The United States and Iran have contributed significantly to the research field of AI and SCR and have published a considerable number of scientific research in this area. The developed network has eight clusters with 69 links and 91 total link strengths. The top five clusters (red, green, dark blue, yellow, and violet) have five countries each whereas the brown cluster is the smallest one which includes only two countries. The country collaboration network also shows that the country United States has the maximum connection with other countries with a total of 16 links and total link strength of 26. Based on the network analysis, the United States, China, and the United Kingdom can be considered as the core countries of this network as they established collaborated research with all other top countries researching SCR and AI.

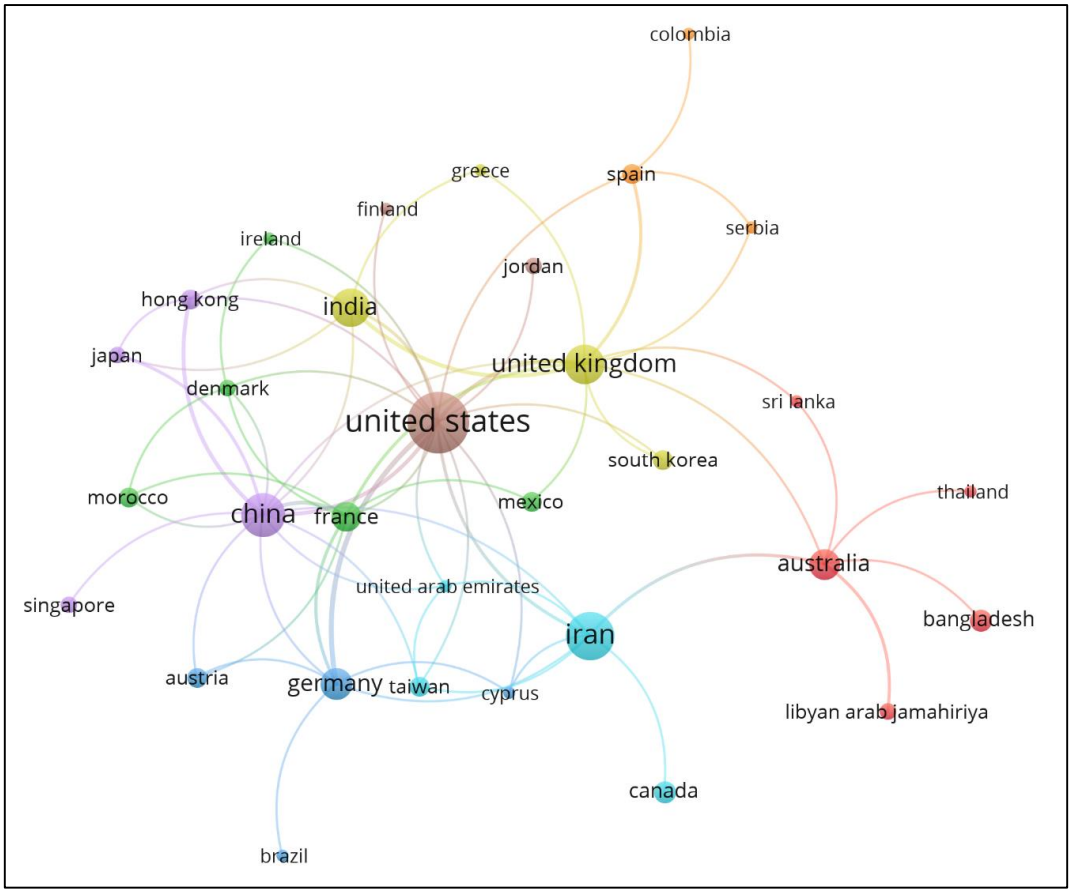


Figure 7. Country collaboration for AI and SCR research work

4. Text Analytics using Structural Topic Modeling

Topic modeling (TM) is used to scan and analyse texts from a set of documents, and it is considered an unsupervised machine learning technique. It is an essential technique that clusters word-groups automatically, learn itself by clustering similar expressions, and explore different themes that best describe the collected documents (Kuhn, 2018; Sharma et. al., 2021). The TM allows researchers to organize and study many documents. A probabilistic method to define the collected documents in terms of topics is called structural topic modeling (STM), which is a form of STM (Kuhn, 2018). STM's goal is to enable a researcher to document metadata by finding topics and analysing their connection (Roberts et. al., 2019).

Based on the frequency and similarity of words, text was analysed from the documents and thematic topics were generated using STM. It is a generative model of word counts, which implies that for each document the data generating method is defined. Then by using the data, it finds the most probable values for the parameters in the model (Roberts et. al., 2019). The generative process of STM is specified in the following steps:

Step 1: Analyse the topic parameter θ_d for each word in document d by using the log-normal linear model from the vector of document covariates X_d.

$$\overrightarrow{\theta_d}|X_d, \Sigma \sim Logistic\ Normal(\mu = X_d, \Sigma) \quad (1)$$

Where, X_d represents 1-by-P vector, Υ represents P-by-(K-1) matrix of coefficients, and Σ represents a covariance matrix of (K-1)- by- (K-1).

Step 2: Generate the topic model β that represents words of each topic (K, by utilizing baseline distribution (m) of length V, the topic-specific deviation $K_{k,v}^{(t)}$ of topic k, the covariate group deviation $K_{yd,v}^{(c)}$ of topic K, and the interaction between each topic and group deviation $K_{yd,k,v}^{(i)}$

$$\beta_{d,k,v} = \frac{\exp(m_v + K_{k,v}^{(t)} + K_{yd,v}^{(c)} + K_{yd,k,v}^{(i)})}{\sum_v \exp(m_v + K_{k,v}^{(t)} + K_{yd,v}^{(c)} + K_{yd,k,v}^{(i)})} \quad (2)$$

Step 3: For every word in collected documents ($n \in \{1,2,3, \ldots \ldots N_d\}$):

Draw word topic assignment based on an unsupervised model that can be generated from the multinomial distribution:

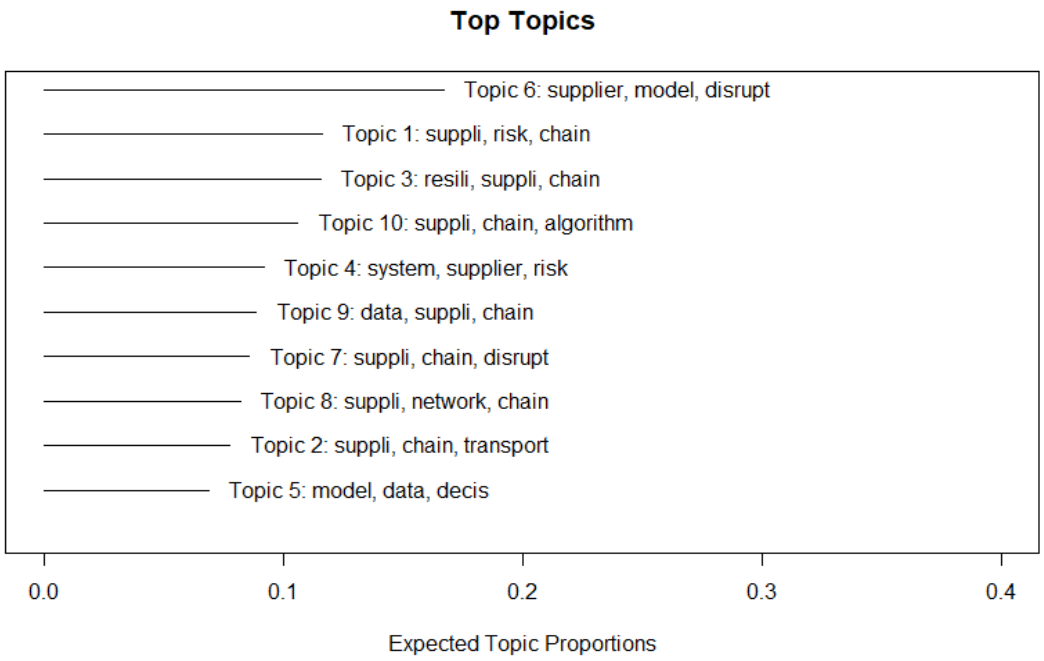
$$Z_{d,n}|\overrightarrow{\theta_d} \sim Multinomial(\overrightarrow{\theta_d}) \quad (3)$$

$$W_{d,n}|Z_{d,n}, \beta_{d,k=Z_{d,n}}\overrightarrow{\theta_d} \sim Multinomial(\beta_{d,k=Z_{d,n}}) \quad (4)$$

To produce thematic topics from selected documents, the text from the article title, abstract, and keywords were combined to prepare a text corpus and used as the input in the STM approach. At first, text cleaning was done by removing commonly used words or stop. Secondly, special characters, numbers, equations, and non-English words were also eliminated to make text corpus compatible for STM approach.

A total of 162 articles were selected (Table 1). R-package is used to perform the STM approach by using the inbuilt STM library. The generated thematic topics from the STM approach are shown in Figure 8.

Figure 8. Generated topic labels from the STM approach



Topic labels were generated from Figure 8. Topic 1 labels "Risk associated with supply chain management" generated from the probabilistic distribution of most frequently used keywords like, 'supplier', 'risk', 'chain', 'network', 'disrupt', 'model', and 'cost'. Similarly, other topics are generated from respective keywords which are presented in Table 3.

Topic 1: Risk associated with supply chain management, *Topic 2:* Sustainable transportation and logistics, *Topic 3:* Resiliency in supply chain, *Topic 4:* Supplier risk management, *Topic 5:* Data-driven supply chain, *Topic 6:* Decision model in supply chain, *Topic 7:* Technology management in supply chain firms, *Topic 8:* Network design in supply chain, *Topic 9:* Machine learning in supply chain, *Topic 10:* Optimization algorithm in supply chain.

Table 3. Top identified words under each topic

S. No.	Topic label	Words with the highest probability	Frex	Lift
1.	Risk associated with supply chain management	Supplier, risk, chain, network, disrupt, model, cost	Risk, probability, take, propagate, global, chain, total	Partner, pre-emptive, acknowledge, brand, encounter, inter-depend, scan
2.	Sustainable transportation and logistics	Supplier, chain, transport, system, supplier, network, perform	Transport, secure, interdepend, infrastructure, ANN, theft, combine	Forest, terminal, cargo, cover, rail, surround, unimodal
3.	Resiliency in supply chain	Resilient, supplier, chain, network, use, perform, research	Resiliency, literature, capable, design methodology approach, originality value, purpose, key	Absorption, agency, alike, answer, nation, synthesis, threat
4.	Supplier risk management	System, supplier, risk, studies, management, supplier, resiliency	Active, aggregate, prepared, contract, weight, proactive, goal	Aggregate, date, duration, gather, prepared, water, layer
5.	Data driven supply chain	model, data, Decision, inform, demand, product, use	Forecast, lockdown, local, monitor, data, real-time, covid-	Policy maker, lockdown, move, peak, stock, Basel, license
6.	Decision model in supply chain	Supplier, model, disrupt, supplier, algorithm, chain, proposed	Retail, supplier, profit, genetic, region, decision support system, algorithm	Multi-period, assign, avers, capacity, cost-risk, JIT (just in time)
7.	Technology management in supply chain firms	Supplier, chain, disrupt, technology, firm, effect, management	Technology, firm, innovation, food, ripple, pandemic, adopt	Care, magnitude, multi-stage, high-risk, indirect, organization, patient
8.	Network design in supply chain	supplier, network, Chain, improve, management, perform, cluster	Cluster, flexible, improve, logistics, farm, inventories, topology	Inbound, tend, remove, storage, waste, person, character
9.	Machine learning in supply chain	Data, supplier, chain, disrupt, use, machine, predict	Feature, machine, lean, learn, infer, data	Clarities, list, transit, wait, regular, seamless
10.	Optimization algorithm in supply chain	Supplier, chain, algorithm, optimization, model, disrupt, cost	Multi-object, optimization, genet, algorithm, minim, solution, configuration	Interdictor, queue, refineries, bi-level, classic, intense, later

The highly frequent words under each generate topic are shown in Table 3. Two other metrics, Frex and Lift are also presented, where lift shows frequent words which have importance for only a particular topic and can be regarded as rare words. Frex, on the other hand, denotes frequent and exclusive words to a specific topic. After the topic's generation by STM approach, articles based on each topic were reviewed. The discussion for each topic has been provided in the next section. The world map of evolving research themes is shown in Figure 9.

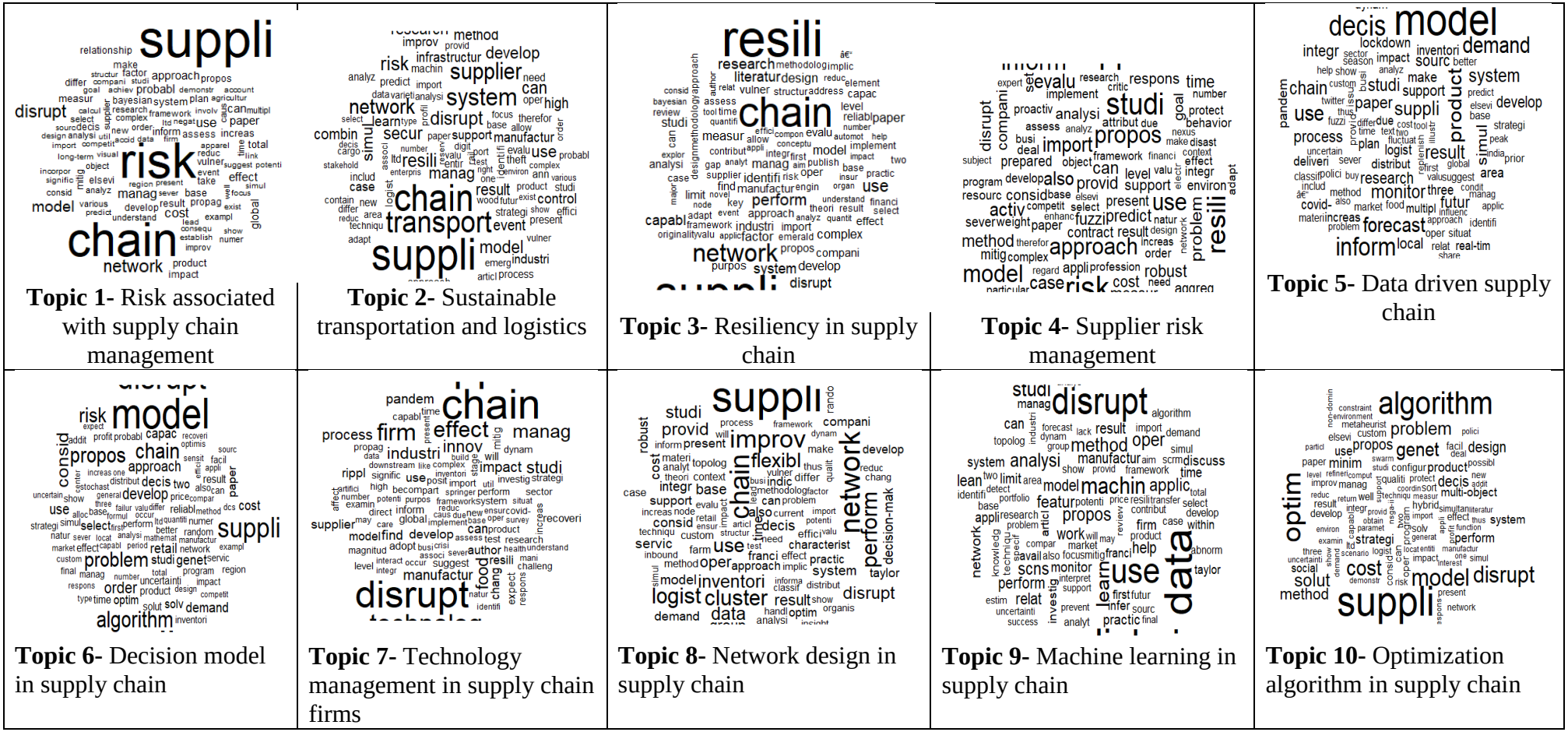


Figure 9. Word map of ten emerging research topics of AI and supply chain resiliency

5. Emerging research themes of AI and supply chain resiliency

5.1. Risks associated with supply chain management

In this context, risk can be defined as the possibility of arising unexpected or unwanted negative repercussions from an activity or event (Rowe, 1980), and manmade or natural disasters (Shahed et al., 2021). The risks associated with the supply chain can be defined as the disruption caused by exposure to an event or activity that affects the management of the supply chain network (Christopher and Lee, 2004). In this modern and global environment, managing risks is gradually becoming challenging because of the uncertainties associated with demand and supply, outsourcing from global companies, and short life cycles of products (Ghadge et al., 2012). Also, the risks associated with poorly handled project management reflects in the entire supply chain because the project risks are not well communicated all through the supply chain (Thunberg et al., 2017). Similarly, Zuo et al., (2009) asserted that the availability of international sources is not beneficial anymore because of the lack of communication between project management and procurement teams and because of lack of management in the entire supply chain. On the other hand, global sourcing is often linked with complexities comparing to a simple internal supply chain or project, for instance, export regulations, taxes, import and export duties, exchange rate fluctuations, increased transportation costs, etc. (Tang and Musa, 2011). Shahed et al. (2021) referred to the supply chain risks experienced due to disruptions caused by natural disasters like an outbreak of coronavirus. Since November 2019, coronavirus (SARS-COV-2) has become a disruption risk and has destroyed the whole supply chain activities (Taqi et al., 2020) through restrained air transport facilities, unavailability of raw materials supply, border closure, and the entire shutting down of production activities (Chowdhury et al., 2020). The ongoing pandemic has significantly affected every type of supply chain, like, the food supply chain (Barman et al., 2021), medicine supply chain (Goodarzian et al., 2021a), commercial products supply chain (Paul and Chowdhury, 2020), etc.

The pandemic created dual disruptions like a rapid increase in demand for high-demand products like hand sanitiser, toilet paper, etc., and a decrease in the supply of the raw material in supply chains (Koonin, 2020). To reduce the negative impacts of the COVID-19 pandemic agile project management was proposed (Koch and Schermuly, 2021). A production recovery model was established by using a mathematical modeling approach to overcome these disruptions in the supply chain of high-demand and essential products during the pandemic (Paul and Chowdhury, 2020). To develop sustainable SCM, an operational excellence approach was applied through the role of big data analytics (Bag et al., 2020). Furthermore, 33 barriers were identified in innovations for sustainable SCM in the manufacturing industry of a

developing country, and a framework to overcome these barriers was provided by using the best-worst method (Gupta et al., 2020). However, Fasan et al., (2021) reported that companies with green SCM practices experienced less negative abnormal stock returns during the pandemic. They suggested that green SCM is identified as an effective risk management tool. Thus, we proposed the following propositions:

Proposition 1: To develop a supply chain model using AI techniques to mitigate sudden risks and disruptions caused by the COVID-19 pandemic.

Proposition 2: To recommend applicability and benefits of emerging technology like AI, 3D printing solutions, blockchain, automation, etc., in solving real-time issues and creating a resilient supply chain post-COVID-19.

Proposition 3: To assess both strengths and weaknesses of AI-enabled technologies in project management and SCR post-COVID-19.

5.2. Sustainable transportation and logistics

The growth and development of an economy lead to a massive rise in transportation activities. In industrialized countries, transportation has become a crucial and basic activity for social and economic development. As the gross domestic product grows, transportation activities certainly increase (Faulin et al., 2019). Transportation is linked to various adverse external effects like air and noise pollution, greenhouse gas emissions, accidents, etc. Also, it is a major contributor to human-induced climate change. It is reported that greenhouse gas emissions have grown globally at a faster rate in the transportation sector than in any other sector (Tchanche, 2021). Logistical and transportation activities have numerous detrimental effects on the societal and natural environment which are necessary to be reduced. Therefore, sustainable development of transportation and logistics necessitate sustainable activities that reduce adverse environmental impacts and significantly bring social and economic benefits (Abbasi and Nilsson, 2016).

The transport system comprises passenger mobility and freight transportation, which involves numerous additional processes like inventory management, storage management, returns and waste issues, project management, etc. These activities make it more challenging and concerning for further research regarding sustainable development (Gonzalez-Feliu, 2020). To support decision making, quantitative methods are being applied in many fields such as logistics, transportation, SCM, and risk minimization (Render et al., 2017). Pishvaee and Razmi, (2012) proposed a fuzzy mathematical programming model which is used to develop an environmental supply chain during disruptions. An integrated approach was presented based

on system dynamics simulation and an analytic network process to examine policies for sustainable transport (Sayyadi and Awasthi, 2020). Neto et al., (2008) reviewed the main activities in logistic networks that affect cost efficiency and environmental performance. They highlighted the benefits of using multi-objective programming (MOP) to develop or design a sustainable network. Nonetheless, a hybrid multi-criteria method is used to examine economic, social, environmental and risk aspects, by employing fuzzy analytic hierarchy process (AHP) and fuzzy vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) methods for creating sustainable supply chain and logistics (Wang et al., 2021). Thus, we proposed the following:

Proposition 4: To analyse the effectiveness of advanced technologies in reducing social, economic, and environmental impacts of transportation and logistics.

Proposition 5: The COVID-19 emergency implies the critical necessity of implementing sustainable practices in logistics and transportation.

Proposition 6: To develop an AI-based model to solve social and environmental issues in supply chains and link it with sustainable development.

Proposition 7: Future studies may evaluate the impact of different sustainable transport and logistics practices such as eco-design, net-zero carbon supply chain, research and development management, etc.

5.3. Resiliency in supply chain

Many failures or disruptions have been observed in the supply chain by which firms get affected because of the unexpected changes in consumer demand and partly due to the inability of new technological innovation adoption (Singh et al., 2019). Recent economic and business risks that occurred due to the outbreak of the COVID-19 pandemic have shifted the focus of the practitioners and researchers to develop a resilient supply chain network (Spieske and Birkel, 2021). Although resilience is regarded as a broad concept, core concern involves measurement of the effectiveness and performance of the entire system which comprises production line, supply chain network, telecommunication network, etc (Singh et al., 2019). In the entire project, even delay in some activities can disrupt the whole network and reduce project resilience. In this regard, the disruptions caused by the COVID-19 pandemic are probably the most severe in the last decade to the global supply chain (Araz et al., 2020). Previous literature gives evidence from various studies to explain the antecedents of SCR (Bode et al., 2011; Kim et al., 2015).

To efficiently managing disruptions in the supply chain in case of a pandemic, a decision support system based on the Fuzzy Inference System (FIS) is effective to manage the demand for healthcare supplies (Govindan et al., 2020). Considering the outbreak and the corresponding risks in the supply chain, a simulation model is proposed to manage global supply chain disruption and to predict the severe outcomes of COVID-19 impact on supply chain performance (Ivanov, 2020a). Kumar and Anbanandam, (2020) offered an SAP-LAP framework to enhance the supply chain resilience and to initiate resilience-building processes. Furthermore, an agent-based model (ABM) was developed using simulation software providing recovery plans and several strategies to manage skyrocketing demand of essential items during pandemic (Rahman et al., 2021). Thus, we proposed the following propositions:

Proposition 8: Supply chain recovery model using innovative technology and big data analytics is required to overcome the SCR issues during an outbreak.

Proposition 9: The COVID-19 emergency has created a need for resilient strategies to reduce production and delivery complexities.

Proposition 10: To evaluate not only short-term recovery model for SCR but also long-term strategies to recover and regain strength post-pandemic by using AI efficiency.

Proposition 11: Future studies must integrate the role of project management in SCR post pandemic because only a limited number of studies exists concerning project management and SCR.

5.4. Supplier risk management

Supplier risk management considers the risks associated with the wrongdoing or misconduct of suppliers (Canzaniello et al., 2017). The supplier selection decision is regarded as one of the major issues in the context of project management (Sabbaghi, 2020) and SCM faced by managers to retain competitiveness (Bai and Sarkis, 2010). The risk associated with supplier selection can cause disruptions in entire project management and subsequently affect the supply chain. Also, the overall purchasing cost is influenced by the selection of the right supplier, which impact the overall cost of the final product (Pazhani et al., 2015).

Sun et al. (2012) proposed a quality risk management model and developed a P-chart solution model to mitigate quality risks in a supplier-assembler structure supply chain. The issue in the manufacturing supply chain was studied that comprises multiple suppliers and multiple uncertainties, and an integrated inventory management policy was formulated by using the stochastic dynamic programming approach to enable supplier risk management (Song et al., 2014). Wu et al. (2010) developed a fuzzy multi-objective programming model for supplier

selection considering risk factors. Many studies related to supplier risk management have similarities with decision modeling work. A decision model was developed by applying a traditional supply risk management approach in consideration with qualitative and quantitative risk factors in the selection of suppliers and evaluating other strategies for risk mitigation (Yoon et al., 2018). In addition, a data mining approach was used for supplier risk management by ascertaining latent association among pre-qualification data of supplier and overall rating of the supplier (Jain et al. 2014). However, there are many techniques in AI like Bayesian networks, fuzzy logic, differential evolution, etc., that are not employed in this field of research of supplier risk management (Hamdi et al., 2018). In the field of supply chain risk management and supplier selection, Hamdi et al. (2018) conducted a literature review study and concluded that the research in this field is not considered enough in comparison to other fields of supply chain risk management. Thus, we proposed the following propositions:

Proposition 12: To develop an AI-enabled framework to mitigate the risks associated with supplier selection and project management.

Proposition 13: To develop supplier risk management model using AI techniques like fuzzy logic, Bayesian networks, artificial neural networks (ANNs), differential evolution, etc.

Proposition 14: There is a need for more scientific research in this field of SCM that offers optimum solutions using big data analytics.

Proposition 15: Future studies may incorporate green SCM practices in supplier selection management.

5.5. Data-driven supply chain

A data-driven supply chain is a supply chain that employs big data as the core of qualitative and quantitative techniques to improve supply chain competitiveness (Shamsuzzoha et al., 2020). Today, companies are investing greatly in projects based on information technology to optimize inventory levels, automate transactions, track supply and operations, and various supply chain decisions (Yu et al., 2018). This trend of the automated or data-driven supply chain provides significant prospects to enhance efficiency and reduce cost (Wu, 2016). The worldwide scope of the supply chain brings a large volume of collected data from its numerous processes. This big data is analysed and interpreted by the supply chain professionals to support decisions and to recommend new organizing techniques of the supply chain (Hazen et al., 2014). A big data strategy implementation in the project management and supply chain could bring potential improvements in effectiveness and efficiency through all project activities like

demand forecasting, location monitoring, supply planning, product, and service acceptance, understanding supplier and customer behaviour, etc. (Kwon et al., 2014).

Over the next decade, tremendous changes are expected in the supply chain and logistics, such as technology influence on information or data flows, autonomous decision making, new cooperation models in value networks connections, big data analytics, etc. (Nitsche et al., 2021). Wanke et al., (2017) suggested that a good inventory allocation model manages various decisions regarding the logistic plan of inventories from sellers to consumers when there is insufficient stock to meet each consumer demand. A data-driven approach can be employed to ascertain factors enabling resilience in the supply chain and the importance of quality information sharing, and swift trust can be emphasized (Papadopoulos et al., 2017). Cavalcante et al., (2019) developed a data-driven hybrid technique to theorize the concepts of resilient supply chain performance. Furthermore, based on the information sharing and using hybrid industry 3.5 strategy, a material resource allocation, and management approach can also be developed in supply chains which can meet around 90 percent consumer material fulfilment rate (Kuo et al., 2021). Thus, we proposed the following propositions:

Proposition 16: A multi-product and multi-horizon approach using big data and AI should be developed to bring resiliency in the supply chain post-COVID-19.

Proposition 17: The COVID-19 emergency indicates a need for a data-driven forecast model that provides demand and supply surges during an outbreak and enables supply chain firms to monitor their operations accordingly.

Proposition 18: In a rapidly changing scenario, modification of existing strategies is required to overcome supply chain disruptions during the pandemic.

5.6. Decision model in supply chain

At each level in the supply chain, effective decision-making plays a vital role in the reduction of inventory cost, fulfil consumer demands, expand market share, and enhancing customer service level (Singh et al., 2019). Similarly, a significant impact is posed by decision-making on the resilient abilities of the company. For this purpose, developing a decision support system by supply chain automation is among the several approaches of optimum decision making (Wang et al., 2017). Riahi et al. (2014) established a mathematical decision-making model to evaluate the security score of the container by using analytical hierarchy and the Bayesian network process. This model was used to reduce the risks in the logistic process, to analyse security-based disruptions, and provide an acceptable security level. To quantify several resilient strategies for risk mitigation, a decision support model can be developed with the

combination of layered analytic network process (ANP) and grey theory as in the casestudy of electronics producing companies conducted by Rajesh, 2020.

An ontology-based decision support system is recommended to strengthen resilience in the supply chain during a disruption by using PSO-DE as an optimization technique (Singh et al., 2019). By contemplating the awareness of online consumers regarding carbon emissions, a low-carbon decision-making model can be established based on online shops and sellers (Wu et al., 2021). Pamucar et al. (2020) proposed a fuzzy neutrosophic approach for decision-making for the selection and evaluation of suppliers. Furthermore, the impact of COVID-19 disruptions on supply chain decisions must be examined and a stochastic optimization model may be proposed for sharing and allocating a critical resource during a pandemic (Mehrotra et al., 2020). Thus, we proposed the following propositions:

Proposition 19: To investigate the enablers of a sustainable supply chain and propose an AI-based decision model to overcome the challenges that occur due to pandemics.

Proposition 20: To develop the model using fuzzy MICMAC and fuzzy TISM and based on experts' recommendations without biasness.

5.7. Technology management in supply chain firms

Technology management is defined widely as "*a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization*" (Cetindamar et al., 2009). It is crucial to evaluate the impact of information technology on today's organization as it has become a fundamental aspect of SCM. An efficient and successful SCM relies on the management of the quality and technology within the technical and social system of the supply chain. These technical and social systems are established on the connections of several factors that lie within quality and technology management (Kuei et al., 2001). In transportation and logistics, technological development is bringing efficiency and improvements. The activities related to technological innovation can help supply chain firms to increase productivity, reduce risks and costs (Fu et al., 2021).

Lee et al. (2018) stated that technology innovation is an important factor for the sustainable growth of the company and in recent years, many companies are shifting their attention to technology management to achieve competitive advantage. For this purpose, they proposed an ensemble model to support technological integration for achieving companies' sustainable growth. On the other hand, for freight transportation, sustainable technologies were evaluated by using spherical fuzzy AHP and TOPSIS approach (Jaller and Otay, 2020). The impact of

technology management was investigated on the sustainable performance of the company through empirical research (Tasleem et al., 2019). Furthermore, the adoption barriers of blockchain technology were investigated for accomplishing a sustainable supply chain (Kouhizadeh et al., 2021). A two-stage strategic framework was established by Kuei et al. (2002) that provide strategies for technology management and supply chain quality enhancement. However, by thoroughly reviewing the literature it is found that there is a dearth of literature regarding supply chain firms and technology management models. Thus, we proposed the following propositions:

Proposition 21: To develop a framework using AI techniques to facilitate recovery strategies and sustainable operations in supply chains covering various sectors.

Proposition 22: To identify the drivers and barriers in technology management to create a sustainable and resilient supply chain.

5.8. Network design in supply chain

Network design in the supply chain is sometimes regarded as strategic supply chain planning which is a part of the SCM planning process. It governs the physical structure and infrastructure of the supply chain (Govindan et al., 2017). A firm's or system's capability to revert to its initial condition or rather to a more advantageous state after disruption is called resilience (Tang, 2006). This ability in SCM is directly influenced by the network design, which is one of the most important parts of any project. However, a resilient network of the supply chain must operate effectively in both situations, either normally or during disruptions (Hasani et al., 2021). In the area of creating reliable supply chain network design models, many studies undertake failure probability as a pre-specified constraint for transportation or facility under disruptions (Hatefi et al., 2015). As far as disruptions caused by the COVID-19 pandemic are concerned, there is a critical need for a sustainable network design to overcome the present and upcoming challenges. According to Majumdar et al. (2020), during COVID-19 the growing concern to fulfil environmental and social requirements are pushing pharmacies/hospitals to contemplate the influence of sustainable supply chain network design on the environment and society. Though, there is a dearth of good mathematical models in this area of research (Goodarzian et al., 2021a).

Fattahi (2020) proposed a data-driven approach for the development of socially accountable supply chain networks under disruptions. A multi-objective optimization model was proposed to enable a sustainable supply chain network design under uncertainty by using strength Pareto evolutionary algorithm 2 (SPEA2) (Hasani et al., 2021). Zahedi et al., (2021) developed a relief

supply chain network using the internet of things (IoT) to analyse several suspected cases during the pandemic. Mehar approach was suggested to solve the distance problem in the supply chain network, by using the lexicographic method to compare interval-valued Pythagorean fuzzy numbers (Bhatia et al., 2021). To establish a sustainable supply chain network Lahri et al. (2021) proposed a multi-objective possibilistic integer linear programming model using the integrated possibilistic programming, TOPSIS, BWM, and Epsilon (ε) constraint method. Thus, we proposed the following propositions:

Proposition 23: Use of AI technique to minimize the risks for two-echelon resilient supply chain network design.

Proposition 24: To explore the role of industry 4.0 techniques in creating resilient supply chain network design.

Proposition 25: To ascertain the effectiveness of AI applications in managing and recovering the supply chain from sudden disruptions like a pandemic.

5.9. Machine learning in supply chain

Machine learning is the tool that facilitates the reduction and elimination of the negative impact of data interpretation because it does not entail direct human involvement. It responds quickly to the demands of the industries by incorporating the large data set as the input into the system (Tiahjono et al., 2017). To survive the increasing competition, automation is growing rapidly in industrial entities where they use software-enabled systems as the communication medium (Siderska and Jadaan, 2018). Machine learning is considered one of the best tools in the present scenario as it focuses on resource optimization in the supply chain (Nagar et al., 2021). Machine learning helps project managers to easily organize thousands of tasks while managing all resources and project. Sindhwani et al. (2019) reported that the data input and analysis in the traditional supply chain and project management were performed manually which constraints the effective handling of the issues throughout the supply chain. In addition, data analysis was not adequate in some cases which led to interpretation of negative influence of the reliability of business operations (Kersten et al., 2019).

Therefore, to mitigate these risks and adverse effects of disruptions in the supply chain, the application of machine learning has received growing attention in recent years (Baryannis et al., 2019b). To measure the risk behaviour Bayesian network theory was used to examine the multi-echelon network-facing real-time disruptions in the supply chain (Ojah et al., 2018). A hybrid technique that combines machine learning and simulation was developed and used to examine its applicability in decision-making support in SCP and resilient supplier selection

(Cavalcante et al., 2019). Furthermore, Wichmann et al. (2020) discussed automated supply chain mapping to maintain supply chain structural visibility by using deep learning which facilitated automatic extraction of the supplier-buyer relation from natural language text. It enabled firms to validate existing supply chain maps, generate fundamental supply chain maps automatically, and enhance existing maps with further information of the suppliers. Thus, we proposed the following propositions:

Proposition 26: To explore other machine learning techniques and a more feature-rich dataset like deep learning and neural networks etc. and to examine its applicability and effectiveness.

Proposition 27: To identify the barriers in SCR and big data solutions using machine learning techniques by applying cause-effect relationships.

5.10. Optimization algorithm in supply chain

An optimization algorithm is a method to compare various solutions until an effective and optimum solution for a problem is generated (Sadeghi et al., 2021). In this age of digitalization and AI, regulating the supply chain through emerging technologies becomes an integral part of the firms to generate sustainable output. Optimization algorithm provides an effective system to manage and control large projects. The scope of big data in many fields is massive but there is a shortage of literature in designing and formulating optimization models using big data analytics for the problems related to the supply chain (Goodarzian et al., 2021b). A two-stage supply chain distribution optimization model was proposed using a modified particle swarm optimization (MPSO) to solve inventory control and integrated location problems (Mousavi et al., 2017). Fathi et al., (2021) developed an optimization model for location-inventory supply chain by employing a two-phase approach based on stochastic optimization and queuing theory, and a hybrid genetic algorithm was created to mathematically tract the problem. Nevertheless, to solve the substantial problems in the supply chain using big data characteristics two hybrid meta-heuristic algorithms were proposed (Goodarzian et al., 2021b). Thus, we proposed the following propositions:

Proposition 28: The AI algorithms adoption to perform real-time data analysis in solving the resiliency issues in the supply chain during disruptions.

Proposition 29: To explore the strength of AI techniques and optimization algorithms in finding solutions to create sustainable multi-stage or multi-channel supply chain networks.

6. Discussion and Proposed Research Model

The current study was conducted to analyse the impact of AI techniques in creating a resilient supply chain. The study has also taken into consideration the disruptions caused by the COVID-19 pandemic on the global SCM. The STM approach and a systemic literature review was adopted to explore the research on SCR and AI. The generated thematic topics, such as Risk associated with SCM, sustainable transportation, and logistics, resiliency in supply chain, supplier risk management, data-driven supply chain, decision model in supply chain, technology management in supply chain firms, network design in supply chain, machine learning in supply chain, optimization algorithm in supply chain have been identified. A significant contribution has been observed in respect to SCR and the application of AI. It was also reported that industry 4.0 technologies can facilitate risk mitigation ability to the firms to continue their operations during disruptions (Zhang et al., 2020). Shih (2020) supported this condition of current pandemic, where the unavailability of human labour is the most critical issue which potentially harms the operations of the supply chain. Subsequently, many researchers suggested that technologies of industry 4.0 such as AI, the IoT, and big data analytics, can help in building resilience in SCM (Dolgui and Ivanov, 2020; Birkel and Hartmann, 2020; Nayal et al., 2021).

The outbreak of the novel coronavirus (COVID-19) has uncovered the vulnerability of the supply chains at the beginning of the year 2020 (Govindan et al., 2020), although supply chains are under extreme pressure before this pandemic as well (Lechler et al., 2019). However, the disruptions necessitate resilience in a single supply chain only, but the systemic threats and pandemics disturb an entire supply chain that involves multiple value and supply chains only in a short time (Golan et al., 2020). The pandemic and lockdown in a country lead to logistic disruptions along with a shortage of labour force which eventually caused supply-side shocks to the supply chain. Furthermore, it brings an unexpected surge in the demand-side of the food supply chain because of hoarding behaviour and panic buying among consumers (Hobbs, 2020). Hence, the logistic system becomes vulnerable in managing sudden disruptions and recovering the supply chain (Choi, 2020) which brings forth the need for a stronger, more innovative and resilient supply chain. The literature recognizes that AI is considered a pathbreaking analytics tool to improve the performance of the supply chain (Grover et al., 2020). Several studies were conducted to analyse AI effectiveness in handling the supply chain disruption due to COVID-19 (Ivanov and Dolgui, 2020; Nayal et al., 2021; Belhadi et al., 2021a).

Nayal et al. (2021) evaluated the challenges of employing machine learning and AI in the agriculture supply chain to reduce the impacts of COVID-19 by using a hybrid approach of

Delphi ISM-Fuzzy MICMAC-ANP. They reported that data privacy and security are the biggest challenges in the implementation of machine learning and AI in the supply chain, although these technological applications turned out to be a powerful enabler to accurately predict and minimize uncertainties. The IoT is a robust tool for SCR as it enables items to track and determine crucial metrics along the entire supply chain (Kara et al., 2020). In another study, the short-term and long-term strategies were adopted, and the SCR model was developed by using sequential mixed-method for resilience evaluation, Financial Impact (FI) analysis, and integrating Time-to-Recovery (TTR). The results of the study supported the advanced use of industry 4.0 technologies in mitigating the risks related to the pandemic, also big data analytics play a crucial role in supply chain activities by providing real-time information to reduce disruptions (Belhadi et al., 2021b). Moreover, it is recommended that at the retail store level, companies should implement a contactless payment system to ensure safety measures (Mollenkopf et al., 2020). Similarly, easing capital flow was proposed to deal with the scarcity of capital for digitalization and restructuring the supply chain during or post COVID-19 (Deaton and Deaton, 2020).

Improving technological capability in supply chains is crucial to overcome the disruptions caused by the pandemic. Therefore, requirements and acceptance of mobile services have grown significantly as customers prefer to receive products and services at their doorstep during COVID-19 (Choi, 2020). For this purpose, it is suggested that companies should use online sales, digitalization, mobile services, and information technology to observe the supply chain and mitigate associated risks. In this regard, several technologies like, AI, 3-D printing, Big data analytics, cloud computing, and the IoT are recommended (Chowdhury et al., 2021). Also, to predict supply chain disruptions, adding agility to the data is suggested (Brintrup et al., 2020). A future research framework is proposed in Figure 10.

The proposed research framework comprises ten emerging research themes of SCR in the first stage. The second stage involves several AI techniques that can be incorporated to achieve resiliency in the supply chain. In the last stage, the benefits of deploying AI techniques into SCM are presented. These benefits can be achieved during or post-pandemic to overcome disruptions.

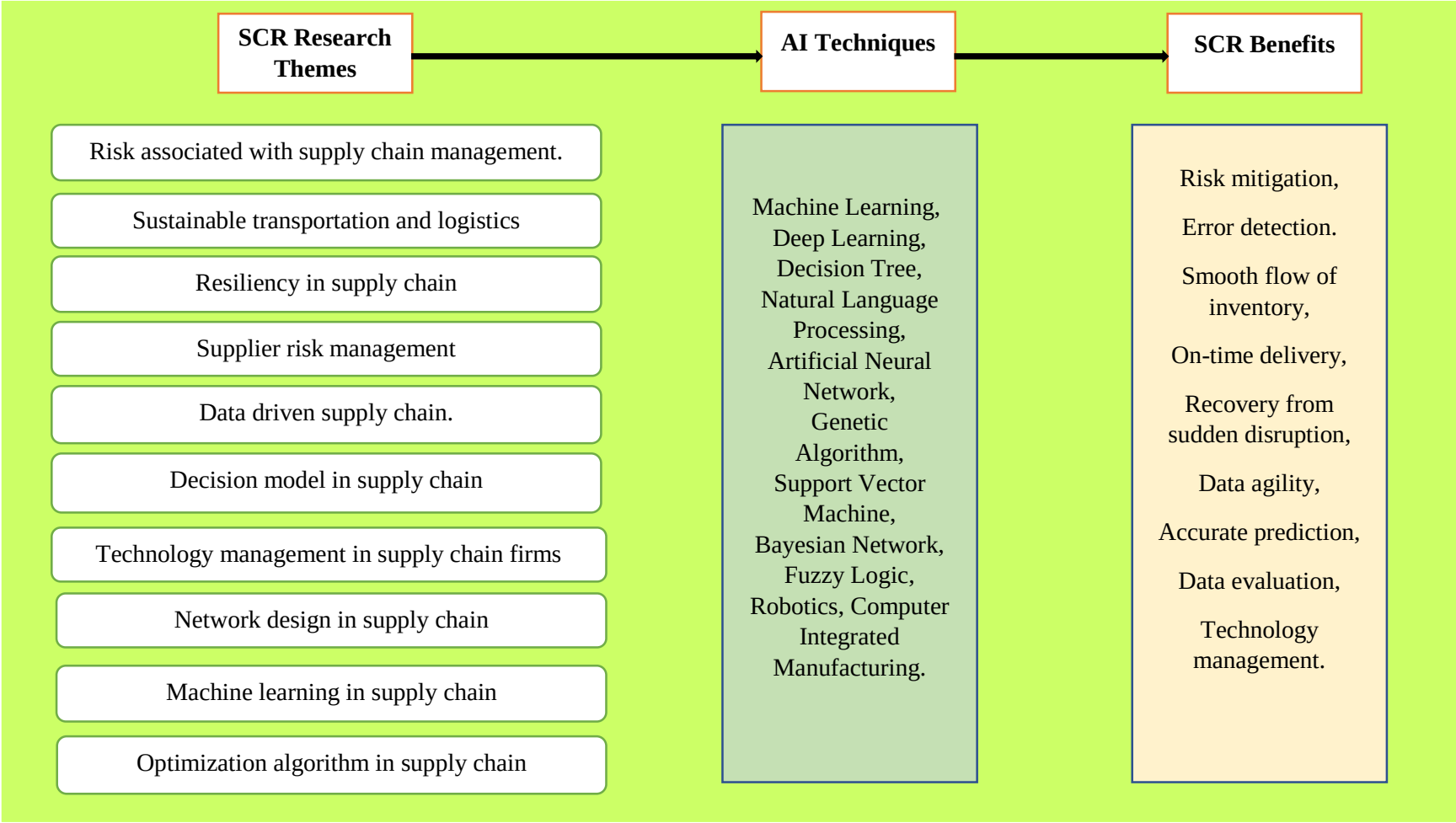


Figure 10: A proposed research framework for AI in SCR

6.1 Implications

The present study was conducted using bibliometric analysis and STM to examine the previous literature on AI in SCR. Based on STM-generated topics, a systematic literature review is carried out. This study contributes to the literature by providing a review of existing studies in the field of AI, project management, supply chain, and SCR. The current study provides a review of the studies conducted before and during the COVID-19 pandemic related to SCR. It adds to the literature by providing a systematic literature review along with the application of bibliometric technique and network analysis to identify the most influential works in this field of study.

The outcome developed from the previous studies will help managers to utilize AI and industry 4.0 technique to achieve resilience in the supply chain during or post-pandemic. This study will also help firms and practitioners by providing future research propositions. The implementation of AI techniques will enable firms and managers to mitigate sudden disruptions caused by any virus outbreak and to recover the supply chain instantly. The technological innovations and AI applications will help in creating a resilient supply chain and further facilitate risk mitigation, supplier selection, decision modeling, technology management, network design, data-driven and optimization algorithm in the supply chain.

7 Conclusions

The widespread transmission of the novel COVID-19 has developed grave uncertainties in the global supply chain. The effects of the pandemic have disrupted the entire supply chain mostly in every sector. In this regard, scholars and practitioners have shifted their focus to create a more sustainable and resilient supply chain. For this purpose, AI-based technological development has provided tools and techniques to implement in supply operations. The current study focuses on research work conducted in the field of AI in SCR. The various topics were identified, namely Risk associated with SCM, sustainable transportation and logistics, resiliency in supply chain, supplier risk management, data-driven supply chain, decision model in supply chain, technology management in supply chain firms, network design in the scs, machine learning in supply chain, optimization algorithm in SCs. Bibliometric analysis and STM were conducted to comprehend the research trends in AI and SCR. This research will provide a deeper and better insight into the implication of AI in SCR and it will help the SCM to mitigate the associated risks. An attempt is made to include most of the previous works related to AI in SCR based on the identified themes. The study is limited to only journal articles and does not include other papers such as conference papers, field reports, company reports,

book chapters, etc. The bibliometric analysis will enable a researcher to classify the growth pattern and the amount of the previous literature available on AI in SCR. Consequently, we recommend future studies on the implication of AI and mitigating barriers in SCR. It is also recommended to analyse the detrimental impact of AI on SCR, and to provide evidence regarding the weakness and challenges of AI-enabled technologies in the context of SCR.

References

Abbasi, M., & Nilsson, F. (2016). Developing environmentally sustainable logistics: Exploring themes and challenges from a logistics service providers' perspective. *Transportation Research Part D: Transport and Environment*, *46*, 273-283.

Agrawal, R., Wankhede, V. A., Kumar, A., Upadhyay, A., & Garza-Reyes, J. A. (2021). Nexus of circular economy and sustainable business performance in the era of digitalization. *International Journal of Productivity and Performance Management*. Vol. ahead-of-print No. ahead-of-print. doi.org/10.1108/IJPPM-12-2020-0676

Araz, O. M., Choi, T. M., Olson, D., & Salman, F. S. (2020). Data analytics for operational risk management. *Decision Sciences*, *51*(6), 1316-1319.

Bag, S., Wood, L. C., Xu, L., Dhamija, P., & Kayikci, Y. (2020). Big data analytics as an operational excellence approach to enhance sustainable supply chain performance. *Resources, Conservation and Recycling*, 153, 104559.

Bai, C., & Sarkis, J. (2010). Integrating sustainability into supplier selection with grey system and rough set methodologies. International Journal of Production Economics, 124(1), 252-264.

Barman, A., Das, R., & De, P. K. (2021). Impact of COVID-19 in food supply chain: Disruptions and recovery strategy. *Current Research in Behavioral Sciences*, 2, 100017.

Baryannis, G., Dani, S., & Antoniou, G. (2019b). Predicting supply chain risks using machine learning: The trade-off between performance and interpretability. *Future Generation Computer Systems*, 101, 993-1004.

Baryannis, G., Validi, S., Dani, S., & Antoniou, G. (2019a). Supply chain risk management and artificial intelligence: state of the art and future research directions. *International Journal of Production Research*, 57(7), 2179-2202.

Belhadi, A., Kamble, S., Jabbour, C. J. C., Gunasekaran, A., Ndubisi, N. O., & Venkatesh, M. (2021a). Manufacturing and service supply chain resilience to the COVID-19 outbreak: Lessons learned from the automobile and airline industries. *Technological Forecasting and Social Change*, 163, 120447.

Belhadi, A., Mani, V., Kamble, S. S., Khan, S. A. R., & Verma, S. (2021b). Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism: an empirical investigation. *Annals of Operations Research*, 1-26. https://doi.org/10.1007/s10479-021-03956-x

Bhatia, T. K., Kumar, A., Appadoo, S. S., Gajpal, Y., & Sharma, M. K. (2021). Mehar Approach for Finding Shortest Path in Supply Chain Network. *Sustainability*, 13(7), 4016.

Birkel, H. S., & Hartmann, E. (2020). Internet of Things–the future of managing supply chain risks. *Supply Chain Management: An International Journal*, 25(5), 535-548.

Bode, C., Wagner, S. M., Petersen, K. J., & Ellram, L. M. (2011). Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives. *Academy of Management Journal*, 54(4), 833-856.

Braglia, M., & Frosolini, M. (2014). An integrated approach to implement project management information systems within the extended enterprise. *International Journal of Project Management*, 32(1), 18-29.

Brintrup, A., Pak, J., Ratiney, D., Pearce, T., Wichmann, P., Woodall, P., & McFarlane, D. (2020). Supply chain data analytics for predicting supplier disruptions: a case study in complex asset manufacturing. *International Journal of Production Research*, 58(11), 3330-3341.

Bushuyev, S., Bushuiev, D., & Bushuieva, V. (2020). Project management during Infodemic of the COVID-19 Pandemic. *Innovative Technologies and Scientific Solutions for Industries*, 2 (12), 13-21.

Canzaniello, A., Hartmann, E., & Fifka, M. S. (2017). Intra-industry strategic alliances for managing sustainability-related supplier risks: Motivation and outcome. *International Journal of Physical Distribution & Logistics Management*. 47(5), 387-409.

Cavalcante, I. M., Frazzon, E. M., Forcellini, F. A., & Ivanov, D. (2019). A supervised machine learning approach to data-driven simulation of resilient supplier selection in digital manufacturing. *International Journal of Information Management*, 49, 86-97.

Cetindamar, D., Phaal, R., & Probert, D. (2009). Understanding technology management as a dynamic capability: A framework for technology management activities. *Technovation*, 29(4), 237-246.

Chai, J., Liu, J. N., & Ngai, E. W. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert systems with applications*, 40(10), 3872-3885.

Choi, T. M. (2020). Innovative "bring-service-near-your-home" operations under Corona-virus (COVID-19/SARS-CoV-2) outbreak: Can logistics become the messiah?. Transportation Research Part E: Logistics and Transportation Review, 140, 101961.

Chowdhury, M. T., Sarkar, A., Paul, S. K., & Moktadir, M. A. (2020). A case study on strategies to deal with the impacts of COVID-19 pandemic in the food and beverage industry. *Operations Management Research*, 1-13. https://doi.org/10.1007/s12063-020-00166-9

Chowdhury, P., Paul, S. K., Kaisar, S., & Moktadir, M. A. (2021). COVID-19 pandemic related supply chain studies: A systematic review. Transportation Research Part E: Logistics and Transportation Review. 148, 102271.

Christopher, M., & Lee, H. (2004). Mitigating supply chain risk through improved confidence. *International journal of physical distribution & logistics management*. 34(5), 388-396.

Deaton, B. J., & Deaton, B. J. (2020). Food security and Canada's agricultural system challenged by COVID- 19. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 68(2), 143-149.

Dolgui, A., & Ivanov, D. (2020). Exploring supply chain structural dynamics: New disruptive technologies and disruption risks. *International journal of production economics*, 229, 107886.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296.

Ellegaard, O., & Wallin, J. A. (2015). The bibliometric analysis of scholarly production: How great is the impact? *Scientometrics*, 105(3), 1809-1831.

Fasan, M., Soerger Zaro, E., Soerger Zaro, C., Porco, B., & Tiscini, R. (2021). An empirical analysis: Did green supply chain management alleviate the effects of COVID- 19? *Business Strategy and the Environment*, 30(5), 2702-2712. https://doi.org/10.1002/bse.2772

Fathi, M., Khakifirooz, M., Diabat, A., & Chen, H. (2021). An integrated queuing-stochastic optimization hybrid Genetic Algorithm for a location-inventory supply chain

network. *International Journal of Production Economics*, 237, 108139. https://doi.org/10.1016/j.ijpe.2021.108139

Fattahi, M. (2020). A data-driven approach for supply chain network design under uncertainty with consideration of social concerns. *Annals of Operations Research*, 288, 265-284.

Faulin, J., Grasman, S. E., Juan, A. A., & Hirsch, P. (2019). Sustainable transportation: concepts and current practices. *Sustainable Transportation and Smart Logistics*, 3-23. https://doi.org/10.1016/B978-0-12-814242-4.00001-6

Fu, H., Ke, G. Y., Lian, Z., & Zhang, L. (2021). 3PL firm's equity financing for technology innovation in a platform supply chain. Transportation Research Part E: Logistics and Transportation Review, 147, 102239.

Gaudenzi, B., & Christopher, M. (2016). Achieving supply chain 'Leagility'through a project management orientation. *International Journal of Logistics Research and Applications*, 19(1), 3-18. https://doi.org/10.1080/13675567.2015.1073234

Ghadge, A., Dani, S., & Kalawsky, R. (2012). Supply chain risk management: present and future scope. *The international journal of logistics management*, 23(3),313-339.

Golan, M. S., Jernegan, L. H., & Linkov, I. (2020). Trends and applications of resilience analytics in supply chain modeling: systematic literature review in the context of the COVID-19 pandemic. *Environment Systems and Decisions*, 40, 222-243.

Gonzalez-Feliu, J. (2018). Sustainability evaluation of green urban logistics systems: literature overview and proposed framework. *Green Initiatives for Business Sustainability and Value Creation*, 103-134. 10.4018/978-1-5225-2662-9.ch005

Goodarzian, F., Kumar, V., & Abraham, A. (2021b). Hybrid meta-heuristic algorithms for a supply chain network considering different carbon emission regulations using big data characteristics. *Soft Computing*, 25(11), 7527-7557. https://doi.org/10.1007/s00500-021-05711-7

Goodarzian, F., Taleizadeh, A. A., Ghasemi, P., & Abraham, A. (2021a). An integrated sustainable medical supply chain network during COVID-19. *Engineering Applications of Artificial Intelligence*, 100, 104188.

Govindan, K., Fattahi, M., & Keyvanshokooh, E. (2017). Supply chain network design under uncertainty: A comprehensive review and future research directions. *European Journal of Operational Research*, 263(1), 108-141.

Govindan, K., Mina, H., & Alavi, B. (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, 138, 101967.

Grover, P., Kar, A. K., & Dwivedi, Y. K. (2020). Understanding artificial intelligence adoption in operations management: insights from the review of academic literature and social media discussions. *Annals of Operations Research*, 1-37. https://doi.org/10.1007/s10479-020-03683-9

Gupta, H., Kusi-Sarpong, S., & Rezaei, J. (2020). Barriers and overcoming strategies to supply chain sustainability innovation. Resources, Conservation and Recycling, 161, 104819.

Hamdi, F., Ghorbel, A., Masmoudi, F., & Dupont, L. (2018). Optimization of a supply portfolio in the context of supply chain risk management: literature review. *Journal of intelligent manufacturing*, 29(4), 763-788.

Hasani, A., Mokhtari, H., & Fattahi, M. (2021). A multi-objective optimization approach for green and resilient supply chain network design: a real-life Case Study. *Journal of Cleaner Production*, 278, 123199.

Hatefi, S. M., Jolai, F., Torabi, S. A., & Tavakkoli-Moghaddam, R. (2015). A credibility-constrained programming for reliable forward–reverse logistics network design under uncertainty and facility disruptions. *International Journal of Computer Integrated Manufacturing*, 28(6), 664-678.

Haus-Reve, S., Fitjar, R. D., & Rodríguez-Pose, A. (2019). Does combining different types of collaboration always benefit firms? Collaboration, complementarity and product innovation in Norway. *Research Policy*, 48(6), 1476-1486.

Hazen, B. T., Boone, C. A., Ezell, J. D., & Jones-Farmer, L. A. (2014). Data quality for data science, predictive analytics, and big data in supply chain management: An introduction to the problem and suggestions for research and applications. *International Journal of Production Economics*, 154, 72-80.

Hobbs, J. E. (2020). Food supply chains during the COVID- 19 pandemic. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, 68(2), 171-176.

Ivanov, D. (2020b). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review, 136, 101922.

Ivanov, D., & Dolgui, A. (2020a). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, 32(9), 1-14.

Ivanov, D., Dolgui, A., & Sokolov, B. (2019). The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 57(3), 829-846.

Jain, R., Singh, A. R., Yadav, H. C., & Mishra, P. K. (2014). Using data mining synergies for evaluating criteria at pre-qualification stage of supplier selection. *Journal of Intelligent Manufacturing*, 25(1), 165-175.

Jaller, M., & Otay, I. (2020, July). Evaluating Sustainable Vehicle Technologies for Freight Transportation Using Spherical Fuzzy AHP and TOPSIS. In International Conference on Intelligent and Fuzzy Systems. Springer, Cham. 1197, 118-126.

Kara, M. E., Fırat, S. Ü. O., & Ghadge, A. (2020). A data mining-based framework for supply chain risk management. *Computers & Industrial Engineering*, 139, 105570.

Katsaliaki, K., Galetsi, P., & Kumar, S. (2021). Supply chain disruptions and resilience: a major review and future research agenda. *Annals of Operations Research*, 1-38.

Kersten, W., Blecker, T., & Ringle, C. M. (2019). Artificial intelligence and digital transformation in supply chain management: innovative approaches for supply chains. Berlin: epubli GmbH. http://dx.doi.org/10.15480/882.2460

Kim, Y., Chen, Y. S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of operations Management*, 33, 43-59.

Koch, J., & Schermuly, C. C. (2021). Managing the Crisis: How COVID- 19 Demands Interact with Agile Project Management in Predicting Employee Exhaustion. *British Journal of Management*. Vol. 0, 1–19. https://doi.org/10.1111/1467-8551.12536

Koonin, L. M. (2020). Novel coronavirus disease (COVID-19) outbreak: Now is the time to refresh pandemic plans. *Journal of business continuity & emergency planning*, 13(4), 1-15.

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, 231, 107831.

Kuei, C. H., Madu, C. N., & Lin, C. (2001). The relationship between supply chain quality management practices and organizational performance. *International Journal of Quality & Reliability Management*, 18(8), 864-872.

Kuei, C. H., Madu, C. N., Lin, C., & Chow, W. S. (2002). Developing supply chain strategies based on the survey of supply chain quality and technology management. *International Journal of Quality & Reliability Management*. 19(7), 889-901.

Kuhn, K. D. (2018). Using structural topic modeling to identify latent topics and trends in aviation incident reports. Transportation Research Part C: *Emerging Technologies*, 87, 105-122.

Kumar, P. S., & Anbanandam, R. (2020). Theory building on supply chain resilience: a SAP–LAP analysis. *Global Journal of Flexible Systems Management*, 21(2), 113-133.

Kuo, T. C., Chen, K. J., Shiang, W. J., Huang, P. B., Otieno, W., & Chiu, M. C. (2021). A collaborative data-driven analytics of material resource management in smart supply chain by using a hybrid Industry 3.5 strategy. *Resources, Conservation and Recycling*, 164, 105160.

Kwak, D. W., Seo, Y. J., & Mason, R. (2018). Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains. *International Journal of Operations & Production Management*, 38(1), 2-21. https://doi.org/10.1108/IJOPM-06-2015-0390

Kwon, O., Lee, N., & Shin, B. (2014). Data quality management, data usage experience and acquisition intention of big data analytics. *International journal of information management*, 34(3), 387-394.

Lahri, V., Shaw, K., & Ishizaka, A. (2021). Sustainable supply chain network design problem: Using the integrated BWM, TOPSIS, possibilistic programming, and ε-constrained methods. *Expert Systems with Applications*, 168, 114373.

Lalmi, A., Fernandes, G., & Souad, S. B. (2021). A conceptual hybrid project management model for construction projects. *Procedia Computer Science*, 181, 921-930.

Lechler, S., Canzaniello, A., Roßmann, B., Heiko, A., & Hartmann, E. (2019). Real-time data processing in supply chain management: revealing the uncertainty dilemma. *International Journal of Physical Distribution & Logistics Management*. 49(10), 1003-1019.

Lee, J., Kang, J. H., Jun, S., Lim, H., Jang, D., & Park, S. (2018). Ensemble modeling for sustainable technology transfer. *Sustainability*, 10(7), 2278.

Majumdar, A., Shaw, M., & Sinha, S. K. (2020). COVID-19 debunks the myth of socially sustainable supply chain: A case of the clothing industry in South Asian countries. *Sustainable Production and Consumption*, 24, 150-155.

Mehrotra, S., Rahimian, H., Barah, M., Luo, F., & Schantz, K. (2020). A model of supply- chain decisions for resource sharing with an application to ventilator allocation to combat COVID-19. *Naval Research Logistics* (NRL), 67(5), 303-320.

Mollenkopf, D. A., Ozanne, L. K., & Stolze, H. J. (2020). A transformative supply chain response to COVID-19. *Journal of Service Management*, 68, 143-149

Mousavi, S. M., Bahreininejad, A., Musa, S. N., & Yusof, F. (2017). A modified particle swarm optimization for solving the integrated location and inventory control problems in a two-echelon supply chain network. *Journal of intelligent manufacturing*, 28(1), 191-206. Doi: 10.1007/s10845-014-0970-z

Nagar, D., Raghav, S., Bhardwaj, A., Kumar, R., Singh, P. L., & Sindhwani, R. (2021). Machine learning: Best way to sustain the supply chain in the era of industry 4.0. *Materials Today: Proceedings*. (In Press). https://doi.org/10.1016/j.matpr.2021.01.267

Nayal, K., Raut, R. D., Queiroz, M. M., Yadav, V. S., & Narkhede, B. E. (2021). Are artificial intelligence and machine learning suitable to tackle the COVID-19 impacts? An agriculture supply chain perspective. *The International Journal of Logistics Management*. Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJLM-01-2021-0002

Neto, J. Q. F., Bloemhof-Ruwaard, J. M., van Nunen, J. A., & van Heck, E. (2008). Designing and evaluating sustainable logistics networks. *International journal of production economics*, 111(2), 195-208.

Nitsche, A. M., Schumann, C. A., & Franczyk, B. (2021). A Conceptual Reference Framework for Data-driven Supply Chain Collaboration. In Proceedings of the 23rd International Conference on Enterprise Information Systems (ICEIS 2021) - Vol 2, pp 751-758.

Ojha, R., Ghadge, A., Tiwari, M. K., & Bititci, U. S. (2018). Bayesian network modelling for supply chain risk propagation. *International Journal of Production Research*, 56(17), 5795-5819.

Pamucar, D., Yazdani, M., Obradovic, R., Kumar, A., & Torres- Jiménez, M. (2020). A novel fuzzy hybrid neutrosophic decision- making approach for the resilient supplier selection problem. *International Journal of Intelligent Systems*, 35(12), 1934-1986.

Papadopoulos, T., Gunasekaran, A., Dubey, R., Altay, N., Childe, S. J., & Fosso-Wamba, S. (2017). The role of Big Data in explaining disaster resilience in supply chains for sustainability. *Journal of Cleaner Production*, 142, 1108-1118.

Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution & Logistics Management*. 51(2), 104-125.

Pazhani, S., Ventura, J. A., & Mendoza, A. (2016). A serial inventory system with supplier selection and order quantity allocation considering transportation costs. *Applied Mathematical Modelling*, 40(1), 612-634.

Pishvaee, M. S., & Razmi, J. (2012). Environmental supply chain network design using multi-objective fuzzy mathematical programming. *Applied Mathematical Modelling*, 36(8), 3433-3446.

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. The international journal of logistics management. 20(1), 124-143.

Rahman, T., Taghikhah, F., Paul, S. K., Shukla, N., & Agarwal, R. (2021). An Agent-Based Model for Supply Chain Recovery in the Wake of the COVID-19 Pandemic. *Computers & Industrial Engineering*, 158, 107401.

Rajesh, R. (2020). A grey-layered ANP based decision support model for analyzing strategies of resilience in electronic supply chains. *Engineering Applications of Artificial Intelligence*, 87, 103338.

Reeves, M., & Whitaker, K. (2020). A guide to building a more resilient business. Harvard Business Review, 2-8.

Render, B., & Stair Jr, R. M. (2017). Quantitative Analysis for Management, 13e. Pearson Education.

Riahi, R., Li, K., Robertson, I., Jenkinson, I., Bonsall, S., & Wang, J. (2014). A proposed decision-making model for evaluating a container's security score. Proceedings of the Institution of Mechanical Engineers, Part M: *Journal of engineering for the maritime environment*, 228(1), 81-104.

Roberts, M. E., Stewart, B. M., & Tingley, D. (2019). Stm: An R package for structural topic models. *Journal of Statistical Software*, 91(1), 1-40.

Rowe, W. D. (1980). Risk assessment approaches and methods. In Conrad, J. (Ed.), Society, Technology and Risk Assessment, Academic Press, London, 343.

Sabbaghi, M. M. (2020). A Supplier Selection Model Emphasizing the Project Risk Management in Drug Production in Pharmaceutical Industry. *Tehnički glasnik*, 14(2), 111-120.

Sadeghi, A., Doumari, S. A., Dehghani, M., Montazeri, Z., Trojovský, P., & Ashtiani, H. J. (2021). A New "Good and Bad Groups-Based Optimizer" for Solving Various Optimization Problems. *Applied Sciences*, *11*(10), 4382.

Sayyadi, R., & Awasthi, A. (2020). An integrated approach based on system dynamics and ANP for evaluating sustainable transportation policies. *International Journal of Systems Science: Operations & Logistics*, 7(2), 182-191.

Shahed, K. S., Azeem, A., Ali, S. M., & Moktadir, M. A. (2021). A supply chain disruption risk mitigation model to manage COVID-19 pandemic risk. *Environmental Science and Pollution Research*, 1-16. https://doi.org/10.1007/s11356-020-12289-4

Shamsuzzoha, A., Ndzibah, E., & Kettunen, K. (2020). Data-driven sustainable supply chain through centralized logistics network: Case study in a Finnish pharmaceutical distributor company. *Current Research in Environmental Sustainability*, *2*, 100013. https://doi.org/10.1016/j.crsust.2020.100013.

Sharma, A., Rana, N. P., & Nunkoo, R. (2021). Fifty years of information management research: A conceptual structure analysis using structural topic modeling. *International Journal of Information Management*, 58, 102316.

Shih, W. C. (2020). Global supply chains in a post-pandemic world. Harvard Business Review, 98(5), 82-89.

Shishodia, A., Verma, P., & Dixit, V. (2019). Supplier evaluation for resilient project driven supply chain. Computers & Industrial Engineering, 129, 465-478.

Siderska, J., & Jadaan, K. S. (2018). Cloud manufacturing: a service-oriented manufacturing paradigm. A review paper. *Engineering Management in Production and Services*, 10(1), 22-31.

Sindhwani, R., Mittal, V. K., Singh, P. L., Aggarwal, A., & Gautam, N. (2019). Modelling and analysis of barriers affecting the implementation of lean green agile manufacturing system (LGAMS). *Benchmarking: An International Journal*. 26(2), 498-529.

Singh, S., Ghosh, S., Jayaram, J., & Tiwari, M. K. (2019). Enhancing supply chain resilience using ontology-based decision support system. *International Journal of Computer Integrated Manufacturing*, 32(7), 642-657.

Song, D. P., Dong, J. X., & Xu, J. (2014). Integrated inventory management and supplier base reduction in a supply chain with multiple uncertainties. *European Journal of Operational Research*, 232(3), 522-536.

Spieske, A., & Birkel, H. (2021). Improving supply chain resilience through industry 4.0: a systematic literature review under the impressions of the COVID-19 pandemic. *Computers & Industrial Engineering*, 158, 107452.

Sun, J., Matsui, M., & Yin, Y. (2012). Supplier risk management: An economic model of P-chart considered due-date and quality risks. *International Journal of Production Economics*, 139(1), 58-64.

Tang, C. S. (2006). Perspectives in supply chain risk management. *International journal of production economics*, 103(2), 451-488.

Tang, O., & Musa, S. N. (2011). Identifying risk issues and research advancements in supply chain risk management. *International journal of production economics*, 133(1), 25-34.

Taqi, H. M., Ahmed, H. N., Paul, S., Garshasbi, M., Ali, S. M., Kabir, G., & Paul, S. K. (2020). Strategies to manage the impacts of the COVID-19 pandemic in the supply chain: implications for improving economic and social sustainability. *Sustainability*, 12(22), 9483.

Tasleem, M., Khan, N., & Nisar, A. (2019). Impact of technology management on corporate sustainability performance. *International Journal of Quality & Reliability Management*. 36(9), 1574-1599.

Tchanche, B. (2021). Dynamics of Greenhouse Gas (GHG) Emissions in the Transportation Sector of Senegal. *Earth*, 2(1), 1-15.

Thunberg, M., Rudberg, M., & Gustavsson, T. K. (2017). Categorising on-site problems: A supply chain management perspective on construction projects. *Construction Innovation*. 17(1), 90–111. doi:10.1108/ci-10-2015-0059

Tjahjono, B., Esplugues, C., Ares, E., & Pelaez, G. (2017). What does industry 4.0 mean to supply chain? *Procedia manufacturing*, 13, 1175-1182.

Tranfield, D., Denyer, D. and Smart, P. (2003), "Towards a methodology for developing evidenceinformed management knowledge by means of systematic review", *British Journal of Management*, 14(3), 207-22.

Vinodh, S., Antony, J., Agrawal, R., & Douglas, J. A. (2020). Integration of continuous improvement strategies with Industry 4.0: a systematic review and agenda for further research. *The TQM Journal*, 33(2), 441-472.

Wang, C. N., Nguyen, N. A. T., Dang, T. T., & Lu, C. M. (2021). A compromised decision-making approach to third-party logistics selection in sustainable supply chain using fuzzy AHP and fuzzy VIKOR methods. *Mathematics*, 9(8), 886. https://doi.org/10.3390/math9080886

Wang, X., Wong, T. N., & Fan, Z. P. (2013). Ontology-based supply chain decision support for steel manufacturers in China. *Expert Systems with Applications*, 40(18), 7519-7533.

Wanke, P., Alvarenga, H., Correa, H., Hadi-Vencheh, A., & Azad, M. A. K. (2017). Fuzzy inference systems and inventory allocation decisions: Exploring the impact of priority rules on total costs and service levels. *Expert Systems with Applications*, 85, 182-193.

Wei, X., Prybutok, V., & Sauser, B. (2021). Review of supply chain management within project management. *Project Leadership and Society*, 2, 100013.

Wichmann, P., Brintrup, A., Baker, S., Woodall, P., & McFarlane, D. (2020). Extracting supply chain maps from news articles using deep neural networks. *International Journal of Production Research*, 58(17), 5320-5336.

Wong, C. W., Lirn, T. C., Yang, C. C., & Shang, K. C. (2020). Supply chain and external conditions under which supply chain resilience pays: An organizational information processing theorization. *International Journal of Production Economics*, 226, 107610.

Wu, D. D., Zhang, Y., Wu, D., & Olson, D. L. (2010). Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach. *European journal of operational research*, 200(3), 774-787.

Wu, L., Yue, X., Jin, A., & Yen, D. C. (2016). Smart supply chain management: a review and implications for future research. *The International Journal of Logistics Management*, 27(2), 395-417.

Wu, Y., Lu, R., Yang, J., & Xu, F. (2021). Low-carbon decision-making model of online shopping supply chain considering the O2O model. *Journal of Retailing and Consumer Services*, 59, 102388.

Xie, H., Zhang, Y., Wu, Z., & Lv, T. (2020). A bibliometric analysis on land degradation: Current status, development, and future directions. *Land*, 9(1), 28.

Yoon, J., Talluri, S., Yildiz, H., & Ho, W. (2018). Models for supplier selection and risk mitigation: a holistic approach. *International Journal of Production Research*, 56(10), 3636-3661.

Yu, W., Chavez, R., Jacobs, M. A., & Feng, M. (2018). Data-driven supply chain capabilities and performance: A resource-based view. *Transportation Research Part E: logistics and transportation review*, 114, 371-385. https://doi.org/10.1016/j.tre.2017.04.002

Zahedi, A., Salehi-Amiri, A., Smith, N. R., & Hajiaghaei-Keshteli, M. (2021). Utilizing IoT to design a relief supply chain network for the SARS-COV-2 pandemic. *Applied Soft Computing*, 104, 107210.

Zhang, F., Wu, X., Tang, C. S., Feng, T., & Dai, Y. (2020). Evolution of Operations Management Research: from Managing Flows to Building Capabilities. *Production and Operations Management*, 29(10), 2219-2229.

Zuo, K., Potangaroa, R., Wilkinson, S., & Rotimi, J. O. (2009). A project management prospective in achieving a sustainable supply chain for timber procurement in Banda Aceh, Indonesia. *International Journal of Managing Projects in Business*, 2(3), 386-400.

Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research

Operations Management Research

Manuscript ID: OMRA-D-21-00222

Dear Editor,

Please find attached our revised version of the manuscript (OMRA-D-21-00222R1). We thank you and anonymous reviewers of the first version of this paper, for your constructive suggestions and critical remarks to improve the quality of the paper and undoubtedly increase the understanding of the authors on the subject. The corrections incorporated are being highlighted in the paper (yellow highlighted in the paper). We have made major corrections in the paper strictly following your suggestions. The main changes and corrections are listed below point by point.

Once again thank you for highlighting the key improvement/changes needed to give us a clear direction. We are looking forward to hearing from you with high spirit.

Yours sincerely,

Corresponding Author

Response to Editorial Comments

GE's Comment:

Besides the reviewers' comments below, I would request authors to enhance the literature regarding Project Management in the context of supply chains/resilience, for a more robust theoretical background.

Response: Authors are extremely thankful to the Editor for taking the time to review our paper and constructive comments to improve it. As per given valuable suggestion, the following paragraphs are added in the manuscript to enhance the literature regarding Project management and Supply chain (Please see page no.: 2-3).

Likewise, Shishodia et al. (2019) in their study emphasized a project-driven supply chain which is a combination of both project management and supply chain and requires coordination among on-site project activities and off-site supply chain processes.

Integration of advanced technologies makes the supply chain resemble large-scale projects to coordinate and manage several activities, that enables smooth project management (Gaudenzi and Christoper, 2016). Wei et al. (2021) clarified that the increasing complexity of project management and SCM inclusion in it makes it critical for project managers to manage and coordinate requirements by adopting the best approach. For instance, it is advantageous in the ship building industry to integrate project management information systems along with SCM, where time-phased requirements are managed by project management and supply chain issues are tackled by SCM (Braglia and Frosolini, 2014).

Similarly, for successful projects, AI was applied in several sectors to improve flexibility, communication, and reducing unnecessary fluctuations (Lalmi et al., 2021).

Similarly, Zuo et al., (2009) asserted that the availability of international sources is not beneficial anymore because of the lack of communication between project management and procurement teams and because of lack of management in the entire supply chain.

Response to Reviewers' Comments

Reviewer # 1

Thank you very much for sending this paper to review. I have read the whole paper; it is a good piece of work and well structured. The following points might help the authors to improve the quality of the paper.

Response: Authors are extremely thankful to the esteemed reviewer for taking the time to review our paper and constructive comments to improve it. We are pleased with the feedback and sincerely hope that our revised version satisfies your queries/concerns. We have highlighted the modifications with yellow colour. We have also provided point-wise answers to the raised queries below.

Comments:

Query 1. The abstract is well written, but the authors can add 2-3 lines about how this work would help all involved stakeholders.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the following lines are added in the abstract for this purpose (Please see page no.: 1).

The study will be also helpful for future researchers and practitioners to identify research directions based on existing literature covered in this paper in the field of SCR.

Query 2. The introduction section of the paper is fine, the flow is missing therefore the author/s must read it and try to give more strength about study motivation etc.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the introduction part is checked and following paragraphs were added to enable a proper flow in the introduction. For this several changes were done and highlighted. To give strength about study motivation a paragraph is added (Please see page no.: 2-4).

Likewise, Shishodia et al. (2019) in their study emphasized a project-driven supply chain which is a combination of both project management and supply chain and requires coordination among on-site project activities and off-site supply chain processes.

Integration of advanced technologies makes the supply chain resemble large-scale projects to coordinate and manage several activities, that enables smooth project management (Gaudenzi and Christoper, 2016). Wei et al. (2021) clarified that the increasing complexity of project management

and SCM inclusion in it makes it critical for project managers to manage and coordinate requirements by adopting the best approach. For instance, it is advantageous in the ship building industry to integrate project management information systems along with SCM, where time-phased requirements are managed by project management and supply chain issues are tackled by SCM (Braglia and Frosolini, 2014).

Similarly, for successful projects, AI was applied in several sectors to improve flexibility, communication, and reducing unnecessary fluctuations (Lalmi et al., 2021).

For this purpose, the current study was conducted to analyse the significance of AI in SCR post COVID-19. The disruptions caused by the COVID-19 pandemic in the entire supply chain and project management created a need for a robust literature review in the related field to analyse the existing problems and solutions. The studies involved in this paper were conducted before and during the COVID-19 pandemic, hence it provides relevant evidence of AI in SCR. It is crucial to better understand the relevance and practical implication of existing AI-based models to solve issues concerning SCR that exists during or post COVID-19 disruptions. To the best of the authors' knowledge, this study is the first attempt to show the role of AI in SCR during or post COVID-19 pandemic.

Query 3. In many places, the author/s are missed to cite a single author to support their arguments the author/s must check this issue throughout the manuscript.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, it is now checked, and citations are provided at many places. The following arguments are supported with a citation throughout the manuscript.

To achieve effective leadership in the market, managing and launching innovation projects become crucial, which make supply chain management (SCM) further complicated (Kwak et al., 2018).

This can be done by deploying emerging technologies in the entire supply chain network (Ivanov et al., 2019)

Also, the risks associated with poorly handled project management reflects in the entire supply chain because the project risks are not well communicated all through the supply chain (Thunberg et al., 2017).

Recent economic and business risks that occurred due to the outbreak of the COVID-19 pandemic have shifted the focus of the practitioners and researchers to develop a resilient supply chain network (Spieske and Birkel, 2021).

Although resilience is regarded as a broad concept, core concern involves measurement of the effectiveness and performance of the entire system which comprises production line, supply chain network, telecommunication network, etc (Singh et al., 2019).

In this regard, the disruptions caused by the COVID-19 pandemic are probably the most severe in the last decade to the global supply chain (Araz et al., 2020).

A data-driven supply chain is a supply chain that employs big data as the core of qualitative and quantitative techniques to improve supply chain competitiveness (Shamsuzzoha et al., 2020).

However, a resilient network of the supply chain must operate effectively in both situations, either normally or during disruptions (Hasani et al., 2021).

Machine learning is considered one of the best tools in the present scenario as it focuses on resource optimization in the supply chain (Nagar et al., 2021).

An optimization algorithm is a method to compare various solutions until an effective and optimum solution for a problem is generated (Sadeghi et al., 2021).

Query 4. The analysis is done well but in many places, there are small issues, like Figure 6 is not very much clear, these are maybe small but impact the readability of the paper.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, figure 6 has been re-drawn and other issues also have been checked.

Query 5. The author/s used Structural Topic Modeling, they must check all the related equations carefully.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, all the equations have been checked.

Query 6. After using STM, the authors identified 10 emerging themes and proposed propositions for future research, all the proposed propositions are good but the author/s must check these, are define well or not if possible they can read more papers, find gaps and develop more propositions based on identified themes.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the propositions are checked, and some more are added.

Query 7. The author/s must check all the references carefully like page numbers, volume etc.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the references are checked, and changes are made in yellow highlighted part.

Query 8. There are few grammatical errors I observed therefore the authors must read the paper after incorporating all the suggestions and remove this issue.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, we tried our best to remove all grammatical mistakes in the entire paper after incorporating all the changes.

Query 9. The authors must check all cited references carefully

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, all the references have been checked for completeness.

Query 10. There are many grammatical issues the author/s must check these issues carefully

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the paper has been proofread.

Overall, the paper is written well and it is related to the themes of the journal.

Response: We thanks the esteemed reviewer for reviewing the paper very carefully and for positive feedback.

Reviewer # 2

I have read the entire paper. It is a good piece of work but requires serious revision.

Response: Authors are extremely thankful to the esteemed reviewer for taking the time to review our paper and constructive comments to improve it. We are pleased with the feedback and sincerely hope that our revised version satisfies your queries/concerns. We have highlighted the modifications with yellow colour. We have also provided point-wise answers to the raised queries below.

Comments:

Query 1. In the paper, the authors proposed many propositions for the future but did not mention anything in the abstract of the paper.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the proposition part is now mentioned in the abstract with the following statement (Please see page no.: 1).

This study will also provide several implications for supply chain managers to achieve the required resilience in their supply chains post COVID-19 by focusing on the elements of the proposed research framework.

Query 2. The authors must carefully check the alignment of project management with Supply Chain Resiliency in the entire paper. I would suggest please check the entire paper.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the alignment of the project management with Supply chain was checked. And following paragraphs are added at different places for better understanding (Please see page no.: 2-3).

Likewise, Shishodia et al. (2019) in their study emphasized a project-driven supply chain which is a combination of both project management and supply chain and requires coordination among on-site project activities and off-site supply chain processes.

Integration of advanced technologies makes the supply chain resemble large-scale projects to coordinate and manage several activities, that enables smooth project management (Gaudenzi and Christoper, 2016). Wei et al. (2021) clarified that the increasing complexity of project management and SCM inclusion in it makes it critical for project managers to manage and coordinate requirements by adopting the best approach. For instance, it is advantageous in the ship building industry to integrate project management information systems along with SCM, where time-phased requirements are managed by project management and supply chain issues are tackled by SCM (Braglia and Frosolini, 2014).

Similarly, for successful projects, AI was applied in several sectors to improve flexibility, communication, and reducing unnecessary fluctuations (Lalmi et al., 2021).

Similarly, Zuo et al., (2009) asserted that the availability of international sources is not beneficial anymore because of the lack of communication between project management and procurement teams and because of lack of management in the entire supply chain.

Query 3. The author/s tried to show the study's motivation, but they must give more attention to make it clear.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the study's motivation is now further elaborated in the introduction part. For this the following paragraph is added (Please see page no.: 3-4).

For this purpose, the current study was conducted to analyse the significance of AI in SCR post COVID-19. The disruptions caused by the COVID-19 pandemic in the entire supply chain and project management created a need for a robust literature review in the related field to analyse the existing problems and solutions. The studies involved in this paper were conducted before and during the COVID-19 pandemic, hence it provides relevant evidence of AI in SCR. It is crucial to better understand the relevance and practical implication of existing AI-based models to solve issues concerning SCR that exists during or post COVID-19 disruptions. To the best of the authors'

knowledge, this study is the first attempt to show the role of AI in SCR during or post COVID-19 pandemic.

Query 4. The author/s also check the description of each table and figure.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the descriptions of each tables and figures have been checked.

Query 5. Emerging research themes of AI and supply chain resiliency, the authors did a very good job in this section, after reading this section, I would say that the author/ must read it carefully and check all proposed they must be aligned with identified themes clearly.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the propositions are checked, and some more are added.

Query 6. Above proposition 4, the authors mentioned "by employing fuzzy AHP and fuzzy VIKOR methods" it is required, if what AHP and VIKOR, I did not understand or remove this sentence. The author/s must take care of types of issues.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the full forms of above-mentioned methods are added in the explanation (Please see page no.: 20).

Nonetheless, a hybrid multi-criteria method is used to examine economic, social, environmental and risk aspects, by employing fuzzy analytic hierarchy process (AHP) and fuzzy vlsekriterijumska optimizacija i kompromisno resenje (VIKOR) methods for creating sustainable supply chain and logistics (Wang et al., 2021).

Query 7. After reading the entire paper, I would say that the topic of this paper would be "Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID 19? An Exploratory State-of-the-Art Review for Future Research" because project management, the authors already covered in the text, it would help the author to make it short.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the title of the paper is now changed as per the recommendation.

Is Artificial Intelligence an Enabler of Supply Chain Resiliency Post COVID-19? An Exploratory State-of-the-Art Review for Future Research

Query 8. The author/s must enhance the implications section of the paper.

Response: We are extremely thankful to the esteemed reviewer for this insightful suggestion. As per given valuable suggestion, the implication section is enhanced by adding following paragraphs (Please see page no.: 31).

This study contributes to the literature by providing a review of existing studies in the field of AI, project management, supply chain, and SCR. The current study provides a review of the studies conducted before and during the COVID-19 pandemic related to SCR. It adds to the literature by providing a systematic literature review along with the application of bibliometric technique and network analysis to identify the most influential works in this field of study.

This study will also help firms and practitioners by providing future research propositions. The implementation of AI techniques will enable firms and managers to mitigate sudden disruptions caused by any virus outbreak and to recover the supply chain instantly. The technological innovations and AI applications will help in creating a resilient supply chain and further facilitate risk mitigation, supplier selection, decision modeling, technology management, network design, data-driven and optimization algorithm in the supply chain.

The revised manuscript as per reviewers' feedback and Journal requirement is submitted for your kind consideration.

We look forward to your positive response.

With Warm Regards

Corresponding author