A Review of Artificial Intelligence (AI) and Machine Learning (ML) for Supply Chain Resilience: Preliminary Findings

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Abstract - Global events (i.e., war in Ukraine, Covid-19) have highlighted the importance of developing resilient supply chains to deal with the increased frequency of interruptions. In response, organizations are increasingly seeking innovate ways to leverage AI and machine learning to enhance supply chain resilience (SCR). Anecdotal evidence suggests that AI and ML have potential to significantly enhance the resilience of supply chains. Despite its potential benefit, research on AI and ML is fragmented across academic disciplines due to the technical and managerial aspects of supply chains. This study aims to synthesize this fragmented body of knowledge to understand the link between AI, ML and how these technologies enhance the three dimensions of SCR, namely, readiness, responsiveness, and recovery. To achieve this aim, we conduct a systematic literature review of AI and ML research in the context of supply chain resilience that have been published between 2016 to 2022. The search strategy resulted in 153 studies, of which 24 primary studies form the basis of this study. The findings show that organizations that adopt AI and ML technologies enhance the resilience of their supply chains, as well as effective management of supply chains such as better decision-making, forecasting, supplier selection, and information processing. The study provides a roadmap for future researchers to advance understanding about the potential of these technologies.

Keywords - Artificial intelligence, machine learning, supply chain, resilience, systematic literature review

I. INTRODUCTION

Global events have highlighted the importance of developing resilient supply chains and the ability to respond to interruptions [1]. Organisations are increasingly seeking innovative ways to apply AI functions to enhance supply chain resilience (SCR) [39]. AI broadly refers to interlinked machines that create a system, which represents the human intelligence in its capability to predict, evaluate, and recommend information [3]. Use of AI in the supply chain and logistics market is expected to grow by 42.9% annually over the next two years, which considers a solution for supply chain crises [2]. Accordingly, Machine learning is considered as one of the vital technologies due to its high performance in forecasting a process through its algorithms in assisting stakeholders to deal with crises [5]. This paper aims to present a comprehensive framework of AI and ML in accomplishing SCR through a systematic literature review to analyse academic papers that have been published between 2016 and 2022 and stored in the Scopus and ProQuest databases.

The repeated disruptive events have pushed many companies to build resilient supply chains through improving their abilities [6]. In addition, reference [6] mentioned in his systematic literature review that capabilities and performance measurements of SCR depend on three dimensions, which are readiness, recovery, and responsiveness. Thus, the theoretical framework in this research will work on evaluating the SCR based on its capabilities and ability to achieve the three dimensions through applying AI technologies, specifically ML. As a result, the evaluation of SCR will identify the application of innovative strategies such as AI or ML techniques to create a responsive, flexible, and agile performance. The aim of this literature review is to aggregate the dispersed body of knowledge on how AI applications, specifically ML, can contribute to accomplishing SCR. This aim is achieved by answering four interrelated research questions:

1. What is the current state of AI and ML on supply chains?
1.1. How are AI and ML being defined in the literature?
1.2. How is supply chain resilience (SCR) being defined?
2. What are the main capabilities that AI and ML enhance to achieve SCR?
3. How has the Covid-19 pandemic impacted the resilience of supply chain that use AI or ML techniques?
4. How can AI/ML-based SCR enable innovations to achieve readiness, responsiveness, and recovery?

BACKGROUND

A. Supply chain resilience

The importance of supply chain resilience has appeared after diverse disruptions have affected supply chains globally, which reveals the vulnerabilities in the performance and risks. Reference [7] mentioned a survey, which was conducted by McKinsey showed that 93% of supply chain managers are planning to redesign their supply chains to become more resilient. Another statistic revealed that the top two strategies of enhancing SCR are dual sourcing of raw materials and increasing the inventory of critical products, leading by 53% and 47%, respectively, as showed in figure 1 [8]. SCR plays a crucial role in facilitating and accelerating product delivery, especially during interruptions. Reference [3] interpreted the SCR as the ability of resistance and recovering after getting influenced by any disruptions or risky events. In addition, reference [9] has defined the SCR as the strength that supply chains have to face the unpredicted disruptions to keep the stability and continuity in case of market variation. Reference [10] have mentioned the main principles needed for achieving SCR, which supply chain reengineering, collaborating within supply chain, agility, and applying risk management process through proactive and reactive activities. Also, this flexibility will be achieved by the firm's identifying and evaluating the coming risks through different strategies such as relying on

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multiple source suppliers and limited inventory [3]. In contrast, the organisations that depend on single-source suppliers and minimise inventory were found to be in problematic situation due to the shortage of materials supply. Therefore, ML contributes to supporting companies to build a resilient supply chain that mitigates the implications of disruptions.

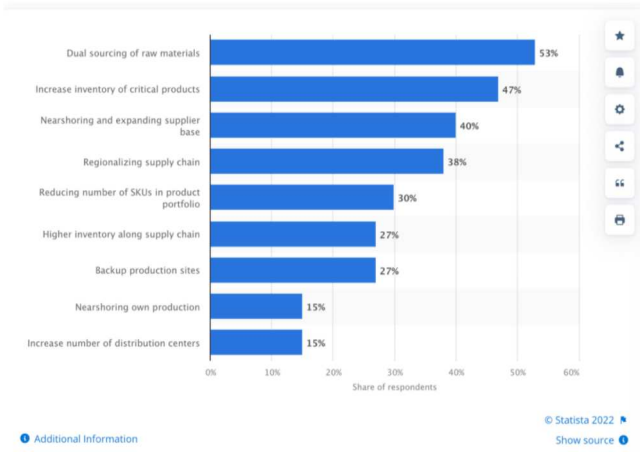

Figure 1: Strategies to enhance SCR [8].

B. *Artificial intelligence:*

AI was approved at the Dartmouth conference in 1956 as an academic major and got the academic's attention in different sectors [1]. Two main features of AI from general analytics are: (1) selection abilities of different actions based on specific goals to succeed, and (2) dealing with an unknown environment to predict future possibilities through adaptive and learning capabilities [11]. AI applications empower organisations to make-decision accurately and professionally based on the proactive forecasting of future risks [4]. Also, reference [3] confirmed that organisations who does not adopt AI activities could not accomplish SCR, which will become a needed feature for supply chain ever since Covid 19 period. For example, employed AI-driven robot to develop their production process and supply chain performance [12]. Another example of a vital sector that is expected to achieve great improvement in digital transformation through AI implementation is agriculture as annual profit can grow by 22.5% internationally [13].

C. *Machine Learning*

In this study, we focus on ML due to its ability to read and analyse the data, especially in decision-making, decreasing errors and enhancing computer training to interact with user at high quality by giving notes and feedback [14]. ML has been defined as a technical study for algorithms and calculation models to enhance the performance of machines and increase the quality of their prediction capabilities [1]. ML can be also defined as a wide range of algorithms that create outputs depending on accessible data without programmed results [16]. Additionally, many of the ML contributions have been linked to discover complexity, help in performance expectations and in dealing with unstructured data to improve decision making in the supply chain [15]. Data availability enables ML techniques to address information, which increases the firms' demand for applying ML techniques instead of other traditional methods [17]. Similarly, reference [16] mentioned that the flow of increasing data that supply chains have generated reached to over 1.6 billion data, which will be as inputs to the ML processing system. interest of investigating and clarifying the importance of AI technology including ML techniques in supply chains has increased in literature as a solution for weak supply chains. Most importantly, ML, which has an essential role in evaluating the decision-making and forecasting process especially in the logistical issues and in demand management [1]. Reference [18] assured that ML plays a vital role in manufacturing and improving the forecasting abilities, which keep ML applicable in resilient supply chains. Further, ML has been considered as one of the advanced AI functions that applies computer algorithms and reflects learning outcomes from human experiments [15].

II. Methodology

We adopt a systematic literature review as it is a repeatable process that draws accurate findings [1] and it provides transparency and accuracy to recognise research trends and gaps in the literature [20].

The main steps of the data collection in this systematic literature review are based on guidelines provided by Okoli (2015) that consist of four steps: planning, selection, extraction, and execution. The planning step contains two sub-steps: clarifying the main objectives of conducting the systematic review and building the protocol of searching in this SLR. Then the selection process will depend on starting to research the literature through the search string and inclusion criteria. After that, the extraction phase will include screening, extracting the relevant information and evaluating the quality of studies. Lastly, the execution stage is the final process, which analyses the findings based on answering the research questions and reporting the review.

A. *Search String*

Scopus was chosen for as it is the largest database for management and engineering journal articles [22]. In addition, both Scopus and Proquest databases have been used by many researchers who conducted SLRs in similar fields [e.g., 39:40]. All selected articles are peer-reviewed, and the search strategy took place from 1 June 2022 until the end of August 2022. The search string applied is: "Artificial intelligence" and "Supply chain" and "resilien*", the star has been used instead of (resilience) word due to finding variances in the word such as (resilient, resilience, resiliency). The same search technique was reused; however, this time with "Machine learning" instead of "Artificial intelligence" due to the nature of ML as a function of AI.

B. *Inclusion & exclusion criteria*

The inclusion criteria: the literature should be published in English and in a specific date range, from 2016 to 2022. This duration was chosen due to time constraints of completing a master's dissertation. On the contrary, the exclusion criteria included short papers, the non-English, duplicated papers, papers that are not peer-reviewed (books, conference papers, and newspapers) and any studies that do not relate to the AI technologies and SCR. The scope of research has been limited to the valid academic publications through the quality evaluation process in the two electronic databases. This study aims to recognise as many studies as possible to answer the research questions and identify the recent AI and ML contributions to SCR. Furthermore, all studies must be relevant to SCR either explicitly or by pertinence to the supply chain performance that achieves the three dimensions of SCR, which were stated in the introduction. Based on Figure 2, the

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titles of (153) papers were screened. Papers were excluded if they were out of the scope of this study. The remaining (46) papers were read and the relevant papers have been retrieved by mainly focusing on the abstract, discussion and conclusion sections to then exclude any study that was out of the scope of this study. Duplicate papers in both databases were also removed.

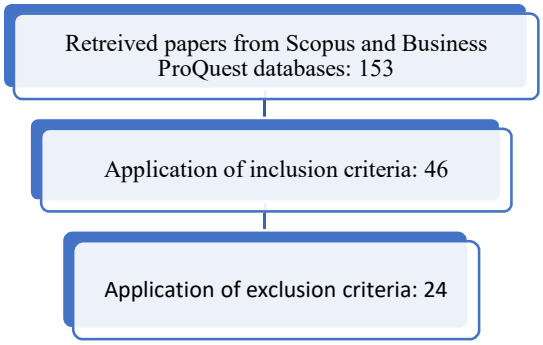

Figure 2: Distillation of papers

Due to the research topic resemblance and popularity in the business and engineering journals, the selected papers were highly reliable being from trusted databases. In addition, reducing the number of studies in terms of their quality is not necessarily due to the inclusion criteria but to trust the reliability of the final findings [21]. Thus, the results of a systematic literature review should be comprehensive, systematic, explicit, and repeatable [21].

III. ANALYSIS OF THE STUDIES

This section presents the analysis of AI and ML research in the Context of SCR based on the four research questions.

RQ1.1 RQ1.2 The definitions of AI and ML

Of the twenty-four reviewed academic studies, only six papers have defined AI, which indicates that there is a lack of clear definition of AI. Although AI applications or technologies have been stated in most of selected studies, the authors avoided inferring definitions of AI to safeguard the accuracy of their studies. Even though AI and ML represent a huge part of these studies and several articles even *categories* the AI functions and provide through explanations yet of these articles did not present any definitions. Reference [13] mentioned that research of AI usually concentrated on ways of improving AI calculating, thinking, and learning skills to be human-like especially in crucial industries such as the medical sector, aviation, stock trading market, etc. Another relevant study conducted by reference [23] clarified how AI has the significant role in identifying the risks, enhance resilience and sustainability in disruptions specifically in Covid 19 period but without any defining of AI throughout the study. Similarly, reference [4] focused on AI based impacts on SCR through listing the main AI capabilities that provide different features to strengthen supply chain's performance without mentioning AI definition. As a result, the academics could fill the knowledge gap of AI definitions and *authorize* the main factors of applying AI related to SCR. Likewise, the literature has shortage in ML definitions and only four studies among the twenty-four *analyzed* papers defined ML and discussed its relation to the SCR through clarifying the concept of ML. Although several studies have stated ML as function of AI, explained the differences of applications, and features of each technology, which assists the reader to *recognize* their values. In addition, five research papers discussed ML techniques, models and applications in the supply chains and related the high-quality performance of ML to the data availability especially in risk and event prediction. Also, some of relevant studies (six papers) stated the types of ML such as supervised, non-supervised, and ML-based simulation; however, other research papers (four studies) mentioned ML as a general AI function without any classifications. Therefore, ML remains a poorly defined term in the literature to elucidate its features could added to the supply chains.

A. RQ1.2 Definitions of SCR

Sixteen research papers have defined SCR based on the recovery abilities and how the organizations could identify and evaluate the level of risks in early stage through activating risk management. Other five studies linked the definitions of SCR to adaptive abilities and one research paper mentioned that beside adaptative skills the organizations could measure the resilience level in the supply chain through readiness and responsiveness abilities. In addition, four papers related the resilient supply chains to their capabilities of return to their normal or even better performance level after the occurrence of a disruption. The definitions of SCR vary, as the effectiveness of the entire system of supply chain (one paper), the applicability of proactive and reactive strategies through contingency plans (one paper), the dependence on share risk level and top management support (one paper), SCR linking to the sustainability (one paper), and its basis on agility and ability to redundancy (two papers). A more detailed research paper defined SCR as the capability of organizations to deal with multi-suppliers especially during the disruptions. It is evident that SCR has broad definitions in the literature where many factors from different perspectives are included. However, some studies specify the definition for a specific sector or aspect such as health care SCR, disaster resilience, and vaccine SCR. In contrary, eight papers do not contain any definition for SCR even though they have stated 'resilience'.

B. RQ2 The main capabilities of AI and ML

Several studies mentioned different types of capabilities where AI and ML enhanced the SCR in different aspects. This section will focus on two types of capabilities that have been most analysed in the literature which are: 1) Information processing, 2) Prediction Process and Decision-Making.

From the twenty-four studies, only four studies have mentioned that the information processing could affect SCR and all these studies come to an agreement that most companies started processing the information through AI or ML technologies [24]. For instance, reference [24] provided an understanding of how AI-based information processing enhance the SCR through building robust supply chain performance. Reference [4] mentioned that the sensing abilities, multidirectional information, and reorganizing the supply chain have been improved by applying AI technologies to determine and analyze the directions in processing information. Additionally, reference [3] mentioned that the information processing abilities has a significant role in strengthening the SCR through professional dealing with uncertainty and facilitating the recovery stage after disruptions. Also, the same study focused on four stages to measure the abilities of AI technologies to accomplish SCR, which are: recognize, analyze, reconfigure, and activate.

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Another two research papers assured that the organizational information processing theory (OIPT) had a supportive role in data analysis. Reference [24] mentioned the integration of OIPT and AI implementations to mitigate risks and complexity in supply chain especially during the disruptions. However, the other twenty papers focus on information tracking, sharing, information system and information availability in supply chain without discussing the information processing. Another study conducted by reference [4] discussed the dynamic capability's role of AI to establishing resiliency in facing the disruptions through two factors: improving the cooperation with suppliers and contractors to maintain the stock level safe and affordable for any increasing demand. Also, AI developments contribute to increasing the calculating power of ML and big data, which makes researchers reconsider AI capabilities in determining, forecasting, and responding to sudden disruptions [23]. Therefore, AI technologies have the vital impact to enhance the information processing capabilities to achieve SCR.

Much of the current literature on ML applications largely focus on the role of data availability. Reference [16] concluded that ML has the abilities of addressing structured and unstructured data due to the data availability. Out of the twenty-four studies only a single research paper analysed the effects of AI implementations on supply chain finances. Reference [25] mentioned that AI can be a solution for relating financial operations to material flows and enabling suppliers to share information about financial sources. The same paper confirmed that AI technologies assist in supervising and improving the financial transactions to achieve a higher quality in reaching resources and observing the performance measurements to create a competitive advantage through minimising the operations' costs in the supply chain and a more efficient demand prediction. Further, the same study categorizes the suppliers based on four variables: type, financial requirements, the share among other suppliers, and the degree of investment risks [25]. These variables could facilitate the decision-making for a supplier selection with AI assistance to achieve SCR. Hence, utilizing AI technology supports evaluating the efficiency of the whole project through modelling the finance for supply chain and enhance the information exchanging process [25].

In relation to decision-making process ten research papers confirmed that the decision making, and risk prediction process are considered as significant factors of SCR and have been improved through the support of AI and ML techniques in taking proactive actions to deal with disruptions. Traditional methods in decision-making such as non-linear modelling and multi-criteria decision-making (MCDM) are one of the complicated approaches of decision-making [26]. The daily decision-making processes become more efficient if it is based on advanced technologies instead of humans which increase the opportunities for accurate information sharing and collaboration in supply chains [10]. Another study analysed the role of applying ML and simulation in improving supplier selection resilience [18] and showed that combining supervised ML and simulation will encourage supplier opportunities to be selected and enhance the delivery process.

Another study confirmed that applying ML has supported the decision-making process especially if the collaboration approach among supply chain stakeholders already exists [26]. Also, reference [18] referred that most of production planning processes relied on the accurate forecasting for lead time and cycle time, which ML can provide through analyzing the performance indicators and based on regression algorithm. Reference [27] have studied an integrated predicting framework that relies on temporal aggregation tool and ML techniques to develop the demand management, which result in enabling SCR, supporting decision makers, and meeting customer's needs, which increased the forecasting accuracy. Further reference [28] stated that the digital twins' approach has spread widely, which supported operations mapping, innovations, and delivery time minimization. One of the most effective digital twins are ML and simulation, which assist organizations in decision making. Also, Various firms attempt to leverage from the emergent technologies and digital twins such as simulation and reinforced ML for analyzing many production systems that add a competitive value and increase the resilience. level in supply chains [28]. Three research papers discussed the features of digital twins or combining technologies in supply chain. For instance, reference [28] assured that ML algorithm contribute to develop a decision support system through empowering logistical services and analyzing forecasts to achieve sustainability and resilience. Reference [9] mentioned that AI as one of the emergent techniques has several benefits for the organizations, which keep the supply chains more sustainable. Additionally, AI technologies contribute to succeeding inventory management, improving transportation and logistical tools, improving suppliers' relations, and planning for demand and supply processes [9]. Therefore, ML as an AI function plays a vital role in recognizing the pattern of sustainable supply chain data through improving management and support other AI functions to create accurate forecasting [9]. Moreover, one of the relevant studies references [29] proposed Bayesian network as a suitable tool for supply chain risk measuring through integrated process with ML techniques. this study assured that supervised and unsupervised ML techniques have a significant role in modelling and examining SCR through collaboration with Bayesian network. However, the other twenty-three studies did not investigate in Bayesian network and in its impact on supply chain, which could motivate the researchers to fill the knowledge gap about Bayesian network. Nevertheless, this identified gap can be filled by motivated researchers in the future. In addition, reference [26] confirmed also ML could enhance the adaptive abilities by sharing information to strengthening the accurate prediction especially in logistics cluster. As a result, applying ML for long term led the machine to learn and adapt with volatile demand, which result in more resilience and sustainability in the supply chain [26]. Alternatively, the enhancement in capabilities of SCR that AI and ML provide are becoming necessity especially in risk identification and prediction to mitigate the implications of any disruption. ML techniques contribute to support production planning as a main factor to building SCR and sustainability based on collaborating scenarios and data availability [30].

C) RQ3 Impact of Covid-19 on the AI/ML-based SC

From the relevant literature, eight studies discussed the effects of the pandemic period and how that disruption has motivated many companies to adopt the SCR, including two research papers focused on the medical and Pharmacal sectors. Reference [23] mentioned that Covid 19 is one of the main reasons which attracted organisations to think of SCR and enhance agile project management. Further, one of the research papers discussed the SCR for vaccines by optimising the production and distribution systems. In addition, another

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study has discussed the major problematic issues relevant to supply chains before and during the pandemic: inventory, logistics, purchasing process, demand and production planning, top management support, and traceability [9]. However, reference [9] found a research gap in identifying the differences in supply chain challenges before and throughout Covid 19 period. Also, reference [31] indicates in their study that most medical companies preferred efficiency instead of resilience and recovery to deal with any disruptions to vaccine supply chains. However, the complicated network and unsteady increasing demand during the pandemic led the supply chains to suffer to find the best operational performance, especially during the interruptions [31]. Additionally, the same research paper confirmed that the pandemic revealed the essential need to improve the current vaccine supply chain through focusing on resilience, adaptation, and recovery from risky disruptions. Thus, reference [31] assured that modelling the vaccine supply chain process became necessary through implementing emergent technologies such as AI innovations, which are appreciated by many pharmaceutical participants in the supply chains.

[32] focused on the pharmaceutical sector, which works on covering the high demand of medical needs by presenting a comparison study between measuring the performance of forecasting the time for shipping the medical products in the e-pharmacy supply chains pre and post covid-19. E-pharmacy supply chains played a vital role in dealing with the pandemic challenges by benefiting from ML technology. As a result, [32] concluded that increasing restrictions among different countries during the pandemic forced many Pharmacal companies to shift to digitalization and invest in building SCR through AI innovations to keep production continue in that difficult time [32]. In addition, reference [32] found through the empirical experiment that utilising ML technologies could support e-pharmacy supply chains to predict shipping times for vaccines and drugs before and after the pandemic and the ML solutions offer an enhancement of 49%. Reference [4] relied on the experimental side in their paper by interviewing (35) experts from the e-commerce supply chain who confirmed that adopting AI innovations. enhanced their SCR during the pandemic. Also, as companies were looking for resilience and efficiency, most of them worked on redesigning their supply chain to develop their responsiveness during the challenges of Covid 19 [3]. Due to the pandemic effects and global restrictions, the companies concentrated on local supply chains to enhance their resilience through AI applications, which facilitate sensing the coming risks and understanding the data trends [3]. Further, reference [23] mentioned that the pandemic revealed the vulnerable supply chains around the world that stopped production based on different logistical disruptions, labour shortage, and lockdown circumstances. The same paper stated that the literature confirms that effective AI tools contributed to dealing with disruptions, such as using ML in agricultural supply chains to minimise the pandemic effects in this sector. Also, reference [9] focused on the electronics and automotive sector, which has been considered the most highly damaged sector in the pandemic. The study stated that demand planning had become one of the most challenging areas due to the threat of uncertain situations and inaccurate information for predicting future demands, which led to difficulties in production. As a result, the experts' recommendations stated that ML and neural network applications are the most effective AI technologies, which enhance zero errors in planning for demand [9].

D) RQ4 Achieveing Readiness, Responsiveness, and Recovery

This section will clarify how AI and ML innovations contributed in succussed the procedures of readiness, responsiveness, and recovery as dimensions of SCR. Three research papers discussed these dimensions explicitly; however, the twenty-one remaining papers mentioned some factors relevant to readiness, responsiveness, and recoveries implicitly, such as high-quality forecasting, risk identification, demand management, and decision-making strategies. Reference [3] stated that AI functions could support several responsiveness systems that collect the risk's point and "what-if" scenarios as an emergent plan for interruptions through information processing capabilities. Further, the same paper confirmed that AI functions could build robust and secure supply chains in the recovery stage besides to the need to predict and evaluate the risks level, especially when the demand is uncertain in the sudden disruptions. In addition, reference [16] referred that ML implementation encouraged the proactive approach toward supply chain risk management, which achieved high responsiveness and improved resilience by reducing the lead time for analysing data traditionally. Additionally, one of the relevant research papers focused on resilient strategies, which could mitigate the risks and develop the entire system's flexibility of supply chains, which results in increasing responsiveness, effectiveness, and efficiency [33]. Therefore, implementing AI functions will improve organisations' responsiveness, enhance their visibility, and build innovative abilities, which strengthen supply chain performance.

Reference [3] assured that information processing plays a strategic role in facilitating recovery after disruptions. Another study in reference [24] mentioned that in terms of AI learning from the data and adapting abilities, the supply chain would be more responsive to any interruptions, and the recovery process becomes faster. However, some challenges have appeared, such as a lack of training workers to be more professional in analyzing uncertain demand, measuring the responsiveness level, and achieving a balance between supply and demand to survive in difficult situations [3]. As a result, AI techniques could become necessary for many companies in different sectors to build SCR and face risky disruptions [3]. Reference [23] ensured that ML is one of the significant AI functions that measure potential risks, enhance decision-making, and facilitate resilient supplier selecting. Also, reference [33] confirmed in his study that applying the resilient strategies of risk minimizing will improve the general resilience and focus on the organization's resources, such as capabilities, knowledge, and attributes, which are considered assets that will attain high responsiveness and efficiency.

On the other hand, a different approach has been adopted in reference [34] which is the data-mining approach in their study to extract the information via continuous monitoring of Twitter as a social media platform to identify any sudden risks. In terms of improving evaluation tools that depend on data mining, text analyzing, and ML algorithm, as stated in the same paper, a lot of information related to potential risks has been collected, which could enhance the readiness process and result in an accurate process of decision-making. Reference [34] confirmed that controlling the related information from Twitter or news articles to discover the redundancy of occurring risks could enhance

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proactive risk management activities. For instance, the most popular terms in their collected tweets, "semiconductor shortage, "port congestion", and "climate change", as results of determining risk indicators, which assist the managers in looking for alternative solutions for mitigating the implications of these issues [34]. However, the appearance of these modern techniques based on AI or ML algorithms has not been invested by practitioners in supply chain risk management [34].

IV. Discussion

Based on the four research questions, we found that the lack of AI and ML definitions could be a research gap for the future researchers. In addition, the capabilities of AI and ML have impacted different supply chains especially through information processing and forecasting ability which enhance readiness, responsiveness, and recovery. Similarly, the literature concur that AI and ML had a vital role in the pandemic to improve supply chain performance specifically in vaccine supply chain and pharmacal sector.

This systematic review concluded a great variety of methodologies used in the literature, which helped to get holistic results from different perspectives. In addition, the new research approaches build additional knowledge by using statistical tools and adopting specific frameworks based on real case studies or experimental examples. These research approaches will demonstrate a broad understanding of how AI applications contribute to improving supply chains to be more resilient. For instance, reference [10]. implemented an AI-powered multi-criteria decision-making (MCDM) methodology in their study. It presents several features, such as mapping skills, effective simulation, and the ability to self-adapting and update. Another example of a new research approach comes from reference [34] were used AI-based data analytical approaches as a research methodology for data extraction and analysis from social media. The authors justified choosing their methodology depending on the risk identification framework and ontology by using digital libraries that provide recent trends on the research topic. In contrast, reference [33] justified combining grey theory with layered analytic network process (ANP) as a specific research design in his paper to address a large amount of data; it has been utilised to facilitate converting any information to values through computing operations. Although these hybrid methodologies offer rich and in-depth information, these methodologies might present a complicated research design that should have a clear explanation and strong background. From the analysed literature, it can be noted that the research designs become updated by variating the research methods instead of limiting the research papers based on quantitative and qualitative methods. Due to the shortage of conducting qualitative research, it could indicate a noticeable gap in applying qualitative methods through interviewing the supply chain stakeholders to benefit from the practical experiment of using AI technologies in the supply chain.

Furthermore, many relevant research papers discussed employing AI innovations and ML techniques in different aspects of supply chains. However, reference [1] argued that adopting ML faced several obstacles, which the researchers did not mention in their analysis of the relevant studies and focused only on the bright side of applying emergent technologies such as AI and ML. For instance, the lack of skilled employees, high financial costs, and lack of reliable data make the managers reconsider before applying ML technologies in their supply chains [1]. Also, reference [36] confirmed that without top management supervision and an obvious strategy to plan for applying AI in the supply chain will conclude to disappointing results. Likewise, Reference [14] stated in his study some concerns about using AI in the supply chains, such as wrong programming, lack of free volition to AI unless human supervision, and difficulties in implementation. However, all twenty-four studies did not highlight these concerns and contribute to proposing supportive solutions. As a result, studying the main challenges or obstacles that face the firms in applying AI and ML in SCR could be a knowledge gap in the literature due to the shortage of focus on this research domain.

V. Conclusion

This paper provides synthesis knowledge about the linkage between the SCR and AI including ML applications through different parts of supply chains. A key finding is the lack of a clear definition for AI and ML technologies related to supply chains in the literature, which encourage the researchers in the future to explore more obvious definitions. In contrast, the SCR has defined widely through variety of relevant factors such as the abilities to recovery, forecast upcoming risks, and the abilities to adapt. In addition, this systematic review has found that generally AI and ML innovations provide different features, which will benefit the supply chain managers to enhance their capabilities through applying SCR. Also, the research findings conclude to the increasing disruptions such as Covid 19 have encouraged different organizations to build SCR and improve its performance. Most of organizations realize that applying AI and ML mitigate the effect of disruptions and remain the business situation stable based on accurate forecasting and managing demand. In addition, the present research explores that AI and ML applications could achieve readiness through employing accurate forecasting tools, responsiveness through handling the uncertain demand, and recovery based on deal with any disruptions professionally. A limitation of this study is that the search was confined to seven years. For the future studies, we recommend focusing on the impact of other AI functions, such as robotics, natural language processing, and deep learning, will discover the directions of different AI abilities in supply chain through achieving readiness, responsiveness, and recovery.

APPENDIX: RESEARCH PAPERS (R)

R1. Modgil, S., Singh, R. K., & Hannibal, C. (2021a). Artificial intelligence for supply chain resilience: learning from Covid-19. The International Journal of Logistics Management.

R2. Modgil, S., Gupta, S., Stekelorum, R., & Laguir, I. (2021b). AI technologies and their impact on supply chain resilience during COVID-19. International Journal of Physical Distribution & Logistics Management, 52(2), 130-149.

R3. 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.

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R4. Trabucco, M., & De Giovanni, P. (2021). Achieving Resilience and Business Sustainability during COVID-19: The Role of Lean Supply Chain Practices and Digitalization. Sustainability, 13(22).

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