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Review

AI-driven resilience in revolutionizing supply chain management: A systematic literature review

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Abstract: In today's fast-moving, disrupted business environment, supply chain risk management is crucial. More critically, Industry 4.0 has conferred competitive advantages on supply chains through the integration of digital technologies into manufacturing and logistics, but it also implies several challenges and opportunities regarding the management of these risks. This paper looks at some ways emerging technologies, especially Artificial Intelligence (AI), help address pressing concerns about the management of risk and sustainability in logistics and supply chains. The study, using a systemic literature review (SLR) backed by a mapping study based on the Scopus database, reveals the main themes and gaps of prior studies. The findings indicate that AI can substantially enhance resilience through early risk identification, optimizing operations, enriching decision-making, and ensuring transparency throughout the value chain. The key message from the study is to bring out what technology contributes to rendering supply chains resilient against today's uncertainties.

Keywords: artificial intelligence; Industry 4.0; resilience; risk management; supply chain management

1. Introduction

Due to the problems faced by companies regarding managing the supply chain, Supply chain management (SCM) becomes a very complex area to work on. However, this SLR explains the importance of AI in Industry 4.0 Revolution for reducing such challenges. With the incorporation of this technology through AI and other associated digital technologies, the supply chain is able to be resilient, efficient, and sustainable from the impacts of both traditional and modern-day challenges. This paper aims at discussing how AI, considering other Industry 4.0 technologies, may provide responses to problems related to supply chain risk management (SCRM), including those on supply chain resilience (SCR) and the effects of digital technologies on supply chain sustainability. In particular, the following research question is addressed: How do artificial intelligence (AI) and other Industry 4.0 technologies address key challenges in supply chain risk management (SCRM) and supply chain sustainability? This article aims to critically discuss how AI could revolutionize supply chain management, with the help of a systematic literature review, in relation to how AI amplifies resilience. The review discusses in detail how AI technologies, like predictive analytics and machine learning, add value to proactive risk mitigation and decision-making. Also, the synergies of AI with other Industry 4.0 technologies, such as Blockchain, big data analytics, and enterprise resource planning (ERP) systems, facilitate insight, transparency, and operational efficiency that are crucial for creating resilient supply chains. The topic is even more relevant considering the increased complexity of today's supply chains and their heightened exposure to disruption. According to Panetto et al. (2019), the 'Industry of the Future' is fully burdened with great challenges that include "the complexity of manufacturing systems, advanced methods for control, and increased cyber security threats." Baryannis et al. (2018) continue to establish that the importance of SCRM will further keep on growing because of the complexity and interdependence of contemporary global supply chains, and also the role of AI in enhancing the processes of risk management supported by decisions. The integration of AI into SCM is rather critical for solving contemporary challenges that were further exacerbated by such events as the COVID-19 pandemic, geopolitical tensions, and natural disasters (Eisinger et al., 2024; Raja and Muthuswamy, 2022). The present pandemic has identified how frail supply chains exist throughout the world; hence a chain must be resilient and flexible. AI-driven technologies are used to act as a sound framework for the prediction of disruptions that would allow continuity with efficiency. This review has drawn insights from diverse ranges of studies. As an example, Fagundes et al. (2020) provide the complete background concerning decision-making models and support systems for SCRM by examining vital research clusters and areas of future investigation. Aljabhan (2023) stipulates that strategic economic plans are important to SCRM; indeed, economic strategies can be deployed to enhance the growth and development aspects of organizations. Ivanov and Dolgui (2019) add to the discussion issues of ripple effect and resilience in managing supply chain disruption risks and the issues of digital supply chain twin for improved risk analytics. Ivanov et al. (2018) also discuss new drivers of flexibility in manufacturing and supply chain operations, emphasizing the role of digitalization and smart operations. Another critical contribution considers the role of cybersecurity in Supply Chain 4.0, as presented by Sobb et al. (2020), "The integration between manufacturing operations and telecommunication and IT processes opens completely new challenges from a cyber security point of view, calling for strong solutions and future research directions." Singh and Chaddah (2021) explored the use of blockchain technology in online pharmacy networks. According to their research, this technology can control counterfeit drugs, data privacy, and efficiency in distribution. This work has greater implications for how blockchain technology could be used to ensure supply chain security and integrity. In conclusion, integrating AI and Industry 4.0 technologies into supply chain management is very likely to enhance resilience, efficiency, and sustainability in supply chains. Meeting the challenges highlighted by the literature, therefore, in terms of complexity and cybersecurity, along with skilled work, will more effectively provide companies with supply chains that are more robust and adaptive. This review underlines how relevant strategic foresight and innovation are in braving the complexities of modern supply chains and coming out stronger from any disruptions.

2. Materials and methods

As seen on **Figure 1** the current study has done a review of the literature to test how opportunities for applying AI and other Industry 4.0 technologies have been carried out in practicality. This review tried to address issues like SCRM, supply chain risk, and the influence of digital technologies (DTs) on supply chain sustainability. A systematic literature review would identify and select those studies relevant to a clearly defined research question and critically evaluate them. It is explicit, detailed, and systematic in its processes to avoid bias and ensure the reliability of conclusions. This article review is limited to articles retrieved from Scopus, using narrow search strategies, selected limited databases, and timeframes that have constrained the retrieval process. The list of keywords chosen was then categorized into the PEO format, widely used in medical literature, for better results. The selected keywords include Artificial intelligence, Industry 4.0, Resilience, Risk management, and Supply chain Management. The research question to be answered is:

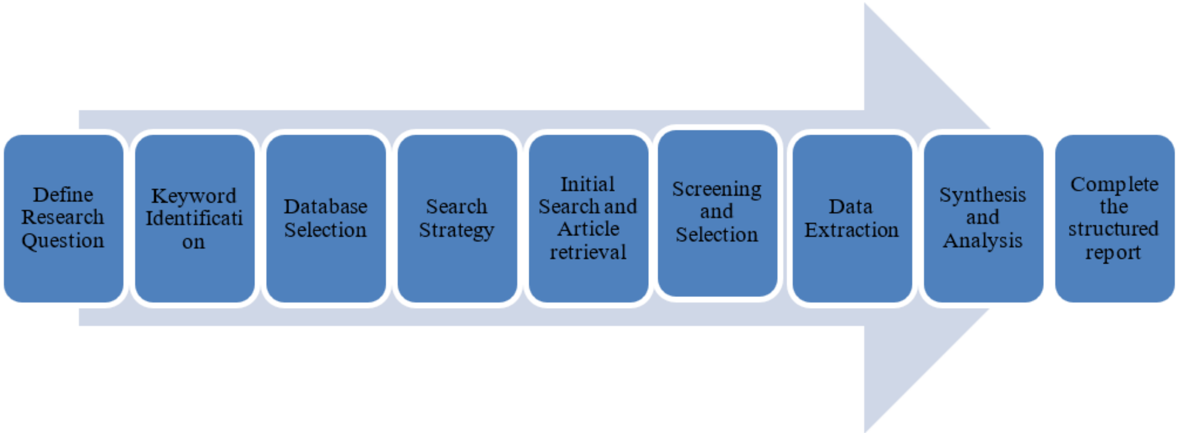

Figure 1. Literature review process steps.
Source: Author's own creation.

RQ: How do artificial intelligence (AI) and other Industry 4.0 technologies address key challenges in supply chain risk management (SCRM) and supply chain sustainability? Specifically, how does AI facilitate Supply Chain Resilience (SCR), enhance decision-making processes, proactively mitigate risks, and foster operational efficiency and transparency?

To answer the research question, a systematic literature review was conducted using the Scopus database to collect and categorize relevant articles. During the keyword identification phase, the study considered the most common synonyms and alternatives for artificial intelligence and Industry 4.0 technologies. The identified keywords included: pharmaceutical supply chain, supply chain management, artificial intelligence, Industry 4.0, Block Chain, Big Data, ERP, resilience, risk managements, demand risks, supply risks.

To organize these keywords and achieve more relevant research results, the PEO (population, exposure, outcome) framework was applied. This framework, commonly used in medical literature but less so in other fields, helps manage and break down a research question, organizing keywords for database searches. The PICO framework is typically used for quantitative searches, whereas PEO is more suitable for qualitative searches, aligning better with this research focus (Bettany-Saltikov, 2012; Mammun et al., 2021; Metzler and Metz, 2010).

The PEO framework categorizes keywords into three major questions: Population (P): Who are you studying? (Pharmaceutical Supply chain, Supply chain Management); Exposure (E): What is your population exposed to? (Artificial intelligence, Industry 4.0, Blockchain, Big Data, ERP); and Outcome (O): What is the result of the exposure on your population? (Resilience, risk management, demand risks, supply risks).

Keywords were combined using Boolean operators to generate complex search queries, enhancing the effectiveness of the literature search.

A combination of three, four and five keywords were applied for Scopus searches. Population refers to the main focus of the research question, which in this case is Pharmaceutical Supply chain, Supply chain Management. Exposure encompasses factors that influence the population, such as AI and Industry 4.0 technologies. Outcome defines the effects of these exposures on the population. To enhance the search for relevant literature, combinations of two, three, four and five keywords were used during database searches with Boolean operators to create complex keyword combinations. The following inclusion and exclusion conditions were established for the systematic literature review:

1) The articles have to be related to the engineering and management science fields.
2) The article has to be freely accessible.
3) The article has to be written in English.
4) The article has to be published between 2013 and 2023.
5) The article should not be duplicated any duplication will be removed.
6) The article should be related to the research question.

3. Results and discussion

3.1. Results

The review was performed according to the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA).

As only one search database was used in this study, no duplication was found, 1356 records were retrieved and then we applied the inclusion and exclusion criterions. The total number of included reports was 125 which represent 9.2% from the total search results. The complete flow of records including reasons for exclusion is illustrated in the PRISMA flow chart (**Figure 2**).

When we first applied the keyword combination in the Scopus Database, we obtained an initial result of 1356 articles. After applying all five inclusion and exclusion criteria, we ended up with 125 articles included in this study. Most of these articles were published between 2021 and 2023 as follows: 30% were published in 2023, 23% in 2022, and 17% in 2021. Most of the studied articles were published in Q1 journals such as Sustainability (6 articles), International Journal of Production Research (5 articles), International Journal of Production Economics (5 articles), and Annals of Operations Research (4 articles).

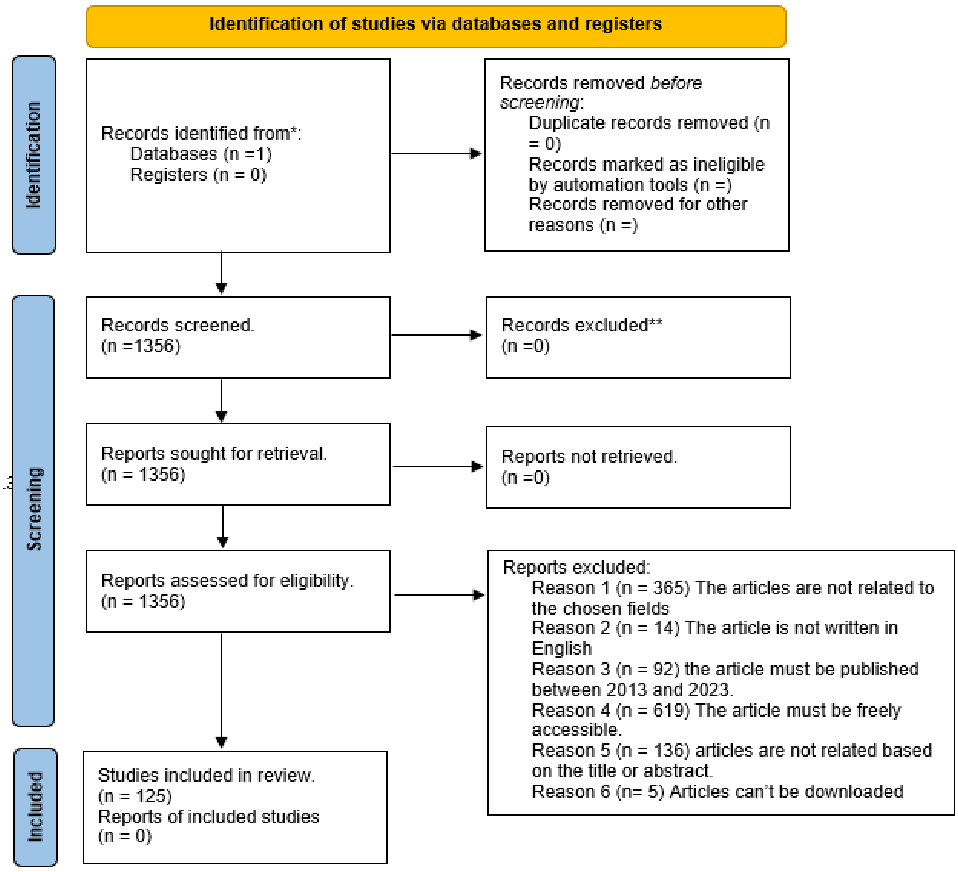

Figure 2. PRISMA chart for the systematic review.

Source: Author's own creation.

3.2. Discussion

In the context of Industry 4.0, supply chain management faces numerous challenges, including increased complexity, interconnectedness, and reliance on technology. This Systematic Literature Review (SLR) investigates the role of Artificial Intelligence (AI) and other digital technologies in addressing these challenges and enhancing supply chain resilience, risk management, and sustainability. The Discussion of finding will be presented here in categories based on the mutual topics that were discussed in the literatures starting with the blockchain technology.

3.2.1. Blockchain technology in supply chain management

It is now primed to revolutionize supply chain risk management thanks to a number of functionalities that will enable much-increased levels of transparency, traceability, and security. Naturally decentralized and immutable, blockchain promises to solve key pain points, such as data tampering and problems pertaining to trusting from the other participants in the chain. Still, there are binding reasons to suggest that full-scale adoption will be a long way in coming: chief among these, lack of standardization and clear regulation. Hu and Ghadimi (2022) also declared that blockchain technology automates the risk management processes, gains transparency as well as minimizes fraud and errors of a supply chain, which in turn contributes to being more resilient. On the other hand, according to Lohmer et al. (2020), blockchain enhances more visibility, transparency, and collaboration in supply chains for improved resilience by sharing information and relational competencies effectively. Amentae and Gebresenbet (2021) discussed how digitalization, through blockchain as one of the key enablers, could empower food systems to be sustainable and resilient. Their work also emphasized how blockchain would act to promote traceability and reduction of food loss. Wong et al. (2023) presented a digital platform where he embeds big data analytics and blockchain with the purpose of limiting potential risk in the pharmaceutical supply chains due to situations like unanticipated demand or drug shortages. Sim et al. (2022) investigated blockchain technology with the idea of how it may strengthen the traceability and resilience of the pharmaceutical supply chain by leveraging its transparency and consistency to prevent data fragmentation and counterfeiting.

3.2.2. Industry 4.0 (I4.0) technologies in supply chain management

In this section we review some of the research works involving different Industry 4.0 (I4.0) technologies and their respective impacts on supply chain resilience, risk management, and process enhancement. Al-Banna et al. (2023) introduces a plan for developing Digital Supply Chain Resilience in the context of investment constraints. This roadmap shows the real path to the balance of SCR and supply chain vulnerabilities (SCV), using I4.0 technologies such as internet of things (IoT), cloud computing, and AI. It highlights strategic utilization of I4.0 enablers for enhancing resilience while controlling budgetary constraints. Their work presents a framework for companies to balance resilience and visibility with investment restrictions. The search of Zimmermann et al. (2019) deals with the effect of technologies I4.0 on supply chain risks. Their work examines the role and extent of I4.0 technologies in risk mitigation and determines the important context-specific factors for their appropriate adoption. Spieske et al. (2023) studied how I4.0 technologies could help and provide more supply chain resilience in a post-COVID-19 era. Their work has identified how the I4.0 technologies can be leveraged to build resilience against future disruptions, providing methods using data and digital capabilities for long-term supply chain enhancements. Huang et al. (2023) reviews how incremental enhancement in information technology (IT) and dynamic capabilities driven by I4.0 technologies can affect SCRM practices. This study instills a framework to understand the influences of I4.0 technologies on supply chain risk management through IT advancement and dynamic capabilities. Benešová et al. (2019) discusses changes in process management practices in supply chains brought about by technologies in Industry 4.0. These are underlined to put the spotlight on how automation, real-time data analytics, and flexibility can be applied to optimize supply chain management processes. This work looks at how changes in supply chain processes are propelled by I4.0 technologies, underlining the advantages of automation and real-time data in process optimization. Hsu et al. (2022) discusses I4.0 enablers and their impact on supply chain resilience. It applies the House of Quality (HOQ) and Multi-Criteria Decision-Making (MCDM) to evaluate the efficiency of big data enablers in resilience amplification.

3.2.3. Big data analytics (BDA) in supply chain risk management

Big data analytics encompasses a revolutionary tool for improved supply chain risk management by way of advanced risk monitoring, assessing, and responding. Big data analytics (BDA) enables an organization to make use of large data from diversified sources for the identification of patterns and trends; it also identifies potential risks, which in turn aids in better decision-making and proactive mitigation of risks. However, for BDA to realize its full potential, it faces challenges relating to data quality, security, and integration with emergent technologies. De Assis and Marques (2022) discuss how BDA can bring SCRM to the next level. They highlight that conventional approaches of SCRM are not suitable anymore to deal with modern business intricacies, in contrast to BDA which allows for far more sophisticated means of analysis, and seamless integration with SCRM processes. They mentioned several benefits come from the BDA, like enhanced risk monitoring, assessment, and response; meanwhile, there are many obstacles concerning data quality, security, and integration for successful implementation. Zhou et al. (2020) suggested a big data mining method to detect supply chain (SC) financial fraud through a Convolutional Neural Network (CNN) within big data infrastructures. They proved that their model has high accuracy in fraud detection. Zamani et al. (2022) introduced a systematic review regarding AI and BDA applications for supply chain resilience. They also stated that such technologies improve response, recovery, and adaptability. They also point out many challenges regarding data availability and the costs of implementation. Hsu et al. (2022), using the MCDM and HOQ methods, search to identify big data enablers that strengthen supply chain resilience. Their approach has given a method through which BDA could be implemented in order to enhance supply chains resilience. Tanaka et al. (2016) suggested a global supply chain systems simulation using big time series data for improving accuracy within simulations. This highlighted the implications of BDA in developing global supply chain models that are more accurate and realistic. Meriton et al. (2020) studied value-generating mechanisms of big data for supply chain management and emphasized a method to enhance capabilities such as resilience and agility.

3.2.4. Decision support systems (DSS) in supply chain management

Applications of decision support systems (DSS) use leading-edge technologies and analytical methods in order to support the decision-maker in response to complex issues arising from supply chains. This section reviews the Cardinal studies on development and application aspects of DSS for different aspects of supply chain management, namely risk management, sustainability, and public health. Oger et al. (2019) present an experiment of a risk-aware DSS for strategic supply chain planning in the cosmetic industry. Their work contributes to demonstrating exactly how a structured approach to decision making can integrate the principles of risk management at the level of strategic planning. The results show limitations within the state of the art in DSS technologies and request further research on advanced concepts, like hyperconnectivity, that would enable improvements in the supply chain management. They emphasize that the evolving frameworks of DSS should focus on the emerging challenges. Vieira et al. (2023) present a multi-objective Simulation-Based Decision Support System (SBDSS) for wine supply chains that aims at achieving sustainability goals. The SBDSS addresses the balance of economic, environmental, and social objectives with simultaneous management of risks related to disruptions in transport and price fluctuations. SBDSS applied to a Portuguese wine supply chain illustrates the fact that integrating sustainability with risk management is highly useful for designing an effective and resilient supply chain configuration. First, Fakhry et al. (2022) proposed the new DSS for sales and operations planning (S&OP) under very uncertain conditions. In their work, the authors present a certain number of limitations regarding classical S&OP approaches and demonstrate how AI-powered tools can be used in order to overcome some drawbacks. The DSS focuses on enhancing the accuracy of predictions and optimally allocating scarce resources in such dynamic and uncertain environments. Atek et al. (2023) present the Earth Cognitive System for Coronavirus Disease 2019, ECO4CO-a predictive DSS to support public health authorities during the COVID-19 pandemic. The core of ECO4CO is the integration of the analysis of social media data, satellite imagery, and machine learning techniques to predict cases and hospitalizations, further providing recommendations. The system enhances monitoring, forecasting, and resource allocation capabilities that could be potentially utilized in future public health emergencies. Khan et al. (2023) develops a supplier selection system for the pharmaceutical industry using the Supply Chain Operation Reference (SCOR) model and gradient boosting techniques. The DSS developed here will focus on traditional supply chain management frameworks integrated with state-of-the-art machine learning techniques in order to provide an efficient supplier selection process that will enhance resilience and sustainability.

3.2.5. Digital twins in supply chain management

This section discusses some recent research on how digital twins and other associated technologies influence the area of supply chain management, Alvarenga et al. (2023) investigate the use of digital technologies in improving supply chain resilience, with a focus on the concept of supply chain memory. On one side, their findings show how digital technologies can reinforce resilience significantly through the application of experience from prior disruptions. On the other side, this pandemic revealed that memory alone cannot completely address entirely new types of disruptions. Ivanov and Dolgui (2020) have presented out digital twins as one of the transformative technologies in Industry 4.0. They identify a digital twin as the computerized version of real-time physical components in a supply chain that can serve as a very encouraging tool for improving activities like visibility, disruption scenarios, and stakeholder collaboration. Fertier et al. (2021) develop an event-driven architecture in the field of crisis management, using digital twins and crisis management information systems to empower situational awareness and supply chain resilience. They provide a framework for the effective management of crises, integrating digital twin technology with robust supply chain operations.

3.2.6. Artificial intelligence (AI) and machine learning (ML) in supply chain management

AI and machine learning (ML) have surfaced as the revolutionary technologies in recent times in supply chain management, bringing innovative solutions for different challenges. Wang et al. (2022) go ahead to provide a high-level, advanced supplier selection using AI in searching suppliers, web scraping for data collection, and distributed ledger technologies (DLTs) for the provision of secure and transparent record keeping. In essence, this will help address challenges such as long selection procedures and also lack of transparency, hence providing small and medium enterprises (SMEs) with means of reducing costs while increasing the level of operational transparency. According to El Khayyam et al. (2018), Collaborative and Clustering Analytic Hierarchy Process (CCAHP) embeds human expertise in AI for better group decision-making in supply chain design. CCAHP employed k-means clustering for dealing with inconsistency in expert judgments and building consensus and filled the gap for a structured approach to deal with complex decision scenarios. Hsu et al. (2022) suggest a comprehensive framework that captures the integration of House of Quality, HOQ, with Multi-Criteria Decision-Making, MCDM, approaches like TOPSIS and Analytical Hierarchy Process (AHP) in order to identify and prioritize big data enablers that can enhance the supply chain's resilience. This framework allows for the selection of the most effective big data technologies according to their impact on the sustainable supply chain practices. Tanaka et al. (2016) introduce a new method for the design of global supply chains multi-agent simulation. They combine big time series data and agent-based modeling with machine learning in order to develop more realistic and precise supply chain simulations that can be used for both strategic planning and risk assessment. Wu and Zuo (2023), investigate the use of machine learning for green supply chain transformation. This will optimize the use of resources by improving the logistics with the help of proper dissemination of information to its participants, hence reducing carbon emissions in response to the goal of a green supply chain.

3.2.7. Sustainability and risk management in supply chains

The current key aspects of modern supply chain management entail sustainability and risk management in relationship to long-term viability-resilience against disruptions. Such a critical review of recent studies and frameworks was necessary regarding the integration of sustainable practices and strategies for risk management, showing their influence on quality performance and the resilience of supply chains. Trabucco and De Giovanni (2021) discusses how lean practices in the supply chain and digital technologies contribute towards sustainability in the COVID-19 pandemic. As a result, it finds that although lean practices have been good at maintaining production costs and inventories, the effect of digital technologies on resilience is mixed; while the adoption of mobile apps had a negative impact, the adoption of AI/Big Data did not show any significant effect. Therefore, the authors propose that integration of digital technologies with lean practices for better resilience must be done in a nuanced method. The two-stage decision framework developed by Mogre et al. aims at risk mitigation in the offshore wind industry. It integrates expert judgment and a decision-tree analysis into the examination of strategies for mitigating risks, demonstrating that the engineering, procurement, and construction (EPC) governance structure is one of the most efficient. This therefore serves as a starting point for further research to establish the efficiency of such an application in a wide range of industries and contexts. Burger et al. (2021) discusses the following risks caused by different levels of digitalization maturity in buyer-supplier relationships in the context of Industry 4.0: cybersecurity risks, risk of IT system compatibility, and technical mismatch. They recommend an integrated approach to carry out the risk assessment and IT-standardization to be able to respond to these challenges. Debnath et al. (2023)

highlighted 16 critical success factors that facilitate the implementation of Industry 4.0 in the pharmaceutical industry, which they have further categorized into technological, organizational, and environmental factors. It deals with unique challenges concerning Industry 4.0 adoption in the context of emerging economies and presents the benefits offered by Industry 4.0 in enhancing supply chain sustainability due to increased efficiencies and improved transparency. Blom and Niemann (2022) pointed out the importance of reputational risk management within the recovery from supply chain disruptions. Pre-emptive action and the enforcement of ethical practices would, as a result, avoid the disruption of business activities. The paper calls for the embedding of good risk management into addressing both environmental and social factors. Mubarik et al. (2021) reviews supply chain mapping and visibility as a means of attaining greater resilience and cleaner production within Industry 4.0. Such practices, the literature states, allow the companies an opportunity to realize areas of potential risks and devise realistic methods of mitigating them. Belhadi et al. (2021) have addressed impacts exaggerated by the COVID-19 pandemic on supply chains, emphasizing that only diversification, digitalization, and collaboration will make supply chains resilient, able to adapt easily to disruptions. Christy and R (2016) presented a framework for Risk Assessment and Management (RAM) in ERP systems. The proposed framework cited here gives an overall structured approach for managing the risks associated with ERP implementations. Chari et al. (2022) explores dynamic capabilities in the development of circular and resilient manufacturing supply chains. The core capabilities that are critical in identifying risks effectively are opportunity sensing, resource mobilization, and adaptation of the business model. Radanliev and De Roure (2023) propose a conceptual view of AI-powered solutions for risk prediction and dynamic coordination to secure vaccine production and supply chains during pandemics. The research by Kurdi et al. (2023) takes a closer look at the impact of SC4.0 on performance within the United Arabs Emirates (UAE's) food manufacturing industry, emphasizing that proper and safe risk handling heightens overall performance. Ghobakhloo et al. (2023) discusses how Industry 4.0 has the potential to make the supply chain more resilient by automating and sharing information, as well as through the capacity for innovation; they provide a proposed four-stage roadmap for implementing processes. Spieske and Birkel (2021) develop a model of Industry 4.0 enablers based on greater supply chain visibility, agility, and collaboration. Peng et al. (2021) prioritize the conceptual framework of the resilient manufacturing strategy in view of the Industrial Internet, covering continuous improvement by data acquisition, big data analysis, and intelligent service. Tortorella et al. (2023) give insights into the role of Industry 4.0 in developing health care supply chain performance during COVID-19 and how it was adapted and restored through advanced technologies. Sathiya et al. (2023) proposes a Chain-of-Things-based technology that helps strengthen the visibility, traceability, and security of the supply chain in the health sector by mitigating the vulnerabilities exposed to this pandemic.

4. Conclusion

The whole study on how AI, in tandem with other Industry 4.0 technologies, addresses issues to do with SCRM, SCR, and the effect of digital technologies on supply chain sustainability concludes with an answer to the research question: How does AI, potentially, and any other Industry 4.0 technologies address key challenges in SCRM and the sustainability of supply chains? The study is concluded with the emphasis on how crucial AI and all other Industry 4.0 technologies are in making supply chains disruptor-resistant, efficient, and green. At the same time, it underlines that the ability to take actual advantage of such development is directly related to the high business awareness and an innovative approach in overcoming current complex supply chain challenges. It has been underlined that the most important benefits from such technologies are related to some crucial issues of SCRM and SCR. The key takeaways of this research project are summarized below: AI-driven Predictive Analytics and Machine Learning: AI techniques impel SCM by granting them active identification and mitigation of risks, thereby driving much more decision-making. The integration of AI with Blockchain will move supply chain transparency, traceability, and security to an interoperable format. Meanwhile, Big data analytics provides significant information and data-driven strategies for more resourceful and greener supply chains. AI-driven data-mining frameworks can help identify, evaluate, and reduce environmentally related risks by enhancing sustainability among supply chains. In a nutshell, the reviewed papers clearly prove that, in the middle of all challenges of implementation and optimization, artificial intelligence coupled with other Industry 4.0 technologies contributes to the addressing of the most important challenges to SCRM and supply chain sustainability by: enhancing resilience: using predictive analytics and machine learning, supply chains are usually swift and quick in dealing with dislocations for enhanced resilience. Smarter Efficiency: Integrating AI with big data analytics and blockchain will lead to better operational efficiency by offering real-time insights and ensuring that transactions are secure and transparent. Greener sustainability: AI technologies allow for better environmental risk management thanks to advanced data mining techniques that create more sustainable supply chain practices.

This work contributes to the current existing body of knowledge by exhibiting the significant potential of AI and Industry 4.0 technologies in enhancing supply chain resilience, efficiency, and sustainability. The findings highlight the specific ways in which AI-driven techniques can be applied to address critical challenges in supply chain management.

The practical implications of this article are far-reaching. Organizations can be benefited from AI-powered predictive analytics and machine learning to proactively identify and mitigate risks, improve decision-making, and optimize operations. By integrating AI with big data analytics and blockchain technology, businesses can enhance transparency, traceability, and security, ultimately leading to more efficient and resilient supply chains. In addition, AI-driven data mining techniques can help organizations identify and reduce environmental impacts, promoting sustainable practices.

While this study offers valuable insights into the potential of AI and Industry 4.0 technologies, it is important to acknowledge certain limitations. The reliance on existing literature may limit the depth of analysis, and the rapid evolution of technology may render some findings outdated.

Future research could delve deeper into the specific applications of AI in different supply chain contexts, such as healthcare, manufacturing, and retail. Additionally, exploring the ethical implications of AI in supply chain management, including issues of privacy, bias, and job displacement, is essential. Furthermore, investigating the impact of other types of emerging technologies, such as 5G telecommunication technology, on supply chain resilience and sustainability could provide valuable insights.

Data availability statement: The data presented in this study are available on request from the corresponding author.

Conflict of interest: The authors declare no conflict of interest.

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